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Examining the Impact of Logistics on Military Strength among European Nations Using Data Envelopment Analysis

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EXAMINING THE IMPACT OF LOGISTICS ON MILITARY STRENGTH AMONG EUROPEAN NATIONS USING DATA ENVELOPMENT ANALYSIS

THESIS

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Abstract

The purpose of this study is to evaluate if logistics and economic factors affect how a country achieves its military power. Countries have focused on material factors such as nuclear weapons or massive military presence for far too long. What has not been discussed is, do other factors play a role in achieving military power.

This study applied Data Envelopment Analysis (DEA) and linear regression to a series of United States European Command (EUCOM) countries and the United States to understand how efficient each country was at achieving its military power. Additionally, the overall relationship between military power and each variable chosen in the study was examined.

This research shows that countries are not efficient at achieving their current military power. Moreover, showing the relationship between the variables and military power provided what variables carried the most weight. Both results provided a way for countries to improve on efficiency and where to begin.

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EXAMINING THE IMPACT OF LOGISTICS ON MILITARY STRENGTH AMONG EUROPEAN NATIONS USING DATA ENVELOPMENT ANALYSIS

I. Introduction

Background/Problem Statement

For many years, countries have used military power to garner new territory, punish their adversary, and show a force that appears unstoppable. History provides a great outlook of countries using their military power. Alexander the Great, who was known for his amazing military mind, took over and ruled the largest empire to be seen at that time. He used his military forces to overpower his enemies by sure mass alone and applied advanced military tactics the world had not seen up to that point. As technology advanced, countries used their military power to deter and defend their homeland. This advancement started with the buildup of nuclear arsenals starting in World War II and has even stretched into modern military strategies. North Korea is a prime example of a country, though hurting economically, has deterred enemies from attacking them due to the nuclear arsenal they have produced over the years. In the end, many other countries over the years have used some form of defense to show their overall military power capabilities.

In recent years, the United States Air Force has heard the phrase "do more with less." The United States Air Force is expected to provide the same amount of service at any given time no matter how many resources the Air Force has. This is the ongoing battle that is fought at many different levels within the Department of Defense (DOD). The United States Air Force needs to learn to be more efficient with the resources given to achieve a more effective military power. Ideally, it is great to have the biggest military or the most nuclear weapons, but how good is it if the military is not efficiently using them and inefficiently wasting money trying to achieve it?

Stephen Biddle (2004) stated that military power is not just about gross national strength but non-material factors such as force employment. These nonmaterial factors play a role in how powerful a country’s military is. Additionally, Risa Brooks (2007) said military effectiveness could depend on social, political, and global environments. Additionally, they suggested that military effectiveness is dependent on a country's material and human resources such as wealth, technology, and human capital.

Military power and effectiveness are discussed in modern times but lacked quantitative research in combining many different factors to show how efficient countries are at achieving their military power. This study will fill this gap by incorporating multiple factors to provide a more concise and clearer picture of how efficient countries are at achieving their military power and what factors affect it the most.

Purpose Statement

The purpose of this study was to evaluate how efficient each country, within the United States European Command (EUCOM), was at achieving their current military power given the variables selected. Additionally, this paper addressed how much each variable affected military power. This paper used Data Envelopment Analysis (DEA) to address each country's overall efficiency, and linear regression was used to determine the overall weight each variable had on military power. Hopefully, this study's importance and contribution will show which variables are the most efficient and provide a framework to address them. This would lead to countries achieving their military power more efficiently and knowing what variables to improve on first.

Research Questions

This study answered two research questions.

RQ1: How efficient is each country at achieving its current military power?

RQ2: How much effect does logistics have on military power?

To answer the first question, this study employed data envelopment analysis within the framework of production theories. Additionally, this study used linear regression to answer the second question.

Research Focus

First, production theory was examined to understand the inputs and outputs selected for the Data Envelopment Analysis (DEA) assessment. The literature review focused on key factors or variables that have been used within DEA studies when trying to compare or rank countries. Finally, once all variables were selected, Data Envelopment Analysis and linear regression models were developed to determine how efficiently each country achieved its current military power and how much each factor affects it.

Methodology

This study used three unique DEA models. Each provided different insight to answer the first research question. Additionally, linear regression was used to answer the second research question. DEA models are known to be a good approach for measuring relative performance measurements and benchmarking for entities. Linear regression helps understand the relationships between independent and dependent variables and how much each independent variable can affect the dependent variable.

Assumptions/Limitations

The major limitation of this study was the use of subjective measurements. The military power indices published by Global Fire Power, mainly focused on the quantitative aspects of military power, such as weapon systems, military personnel, etc. These indices cannot address intangible sides of military power, for example, doctrines, strategies, willingness to fight, etc. Additionally, the logistics performance measures are survey-oriented, though completed by the experts in their fields, are still subjective in nature. The logistics performance index measurements have been used in many studies to provide efficiency numbers, so the application was deemed useful in this study.

II. Literature Review

Chapter Overview

This section aimed to support the need to focus on efficiency, on top of many other variables. This section started with a foundational look at production theory. This theory provided an excellent framework for understanding the selection of inputs and outputs for any given model.

Next, the literature review focused on Data Envelopment Analysis models that compare countries on multiple different types of topics. This showed how many different industries use DEA for analysis. Additionally, this section looked at studies specifically focused on the economic and logistics factors used when running DEA models. This provided a starting framework to show that many factors or variables are considered when comparing countries. Finally, this literature review showed no attempt to run a DEA model that uses economic and logistics variables to measure how efficiently a country achieves its current military power.

Production Theory

Production theory helped drive a better understanding of how variables are categorized in a Data Envelopment Analysis. Production theory derives from the world of economics. The idea of this theory was used to find out how much output to sell to their consumers. The companies would align this with how much of the materials they are willing to put into the system to produce this product, also known as their inputs. Production theory focused on balancing the price of the goods and the price to make them useful (that is, wages, supplies, facilities, etc.) (Dorfman, 2016). Dorfman (2016) classified productive activities. The first layer he mentioned was the method to produce the output selected. Next, he discussed how to determine the most profitable quantity of the products. Finally, he mentioned the best size and equipment to maximize profits. He painted the picture to select your inputs to optimize your output.

Cobb and Douglas (1928) proposed a production theory that measured the input and output changes and determined what relationships existed between them. Furthermore, they attempted to find the relative influence upon production of the outputs due to the inputs such as labor and capital. This "relative influence" has been modeled in DEA as efficiency. They not only helped shape the theory of production, but they also invented their production function, labeled as the Cobb-Douglas production function. This function was the first attempt to represent a relationship between inputs and the output produced by those inputs. This is an important piece to remember when working with DEA models because knowing what inputs are needed and the corresponding outputs make for a better overall assessment. This study looked through the lens of production theory and applied these concepts to determine what mix of inputs and outputs to measure.

DEA and Efficiency

Efficiency evaluation using Data Envelopment Analysis has been used in many streams of other literature in the past. According to Rashidi & Cullinane (2019), it has been used in many different transportation types like air (Cui & Li, 2017a, 2017b, 2017c; Oum et al., 2005) and freight (Chakhtoura & Pojani, 2016; Lovold Rodseth, 2017). Kim et al. (2020) used DEA to measure the efficiency of healthcare investment and health competitiveness of 34 developing countries in Asia. The energy field has also used Data

Envelopment Analysis. Biresselioglu et al. (2018) used DEA to measure how energy efficient the European Union was and used those measures to hit climate targets. Gomez-Calvet et al. (2014) used DEA to measure how energy efficient the European Union was and used that to derive heat generation. Wang et al. (2019) used DEA to look at energy use efficiency to improve national economic competitiveness and sustainability. Salas-Velasco (2019) and Fifekova (2019) used DEA to look at the competitiveness efficiency between countries. Now that there has been a wide variety of topics shown in this section, it is time to focus on the literature streams that have used the inputs and outputs this study analyzed.

Logistics Performance Index

The logistics performance index is one of the inputs that will be used in this study. So, it is essential to provide background information as well as studies that have used the logistics performance index to validate its use in this model. The Logistics Performance Index (LPI) is published by the World Bank every two years. It looks at approximately 160 countries over many different years. It is a global survey where individuals, who are experts in the logistics arena, are asked to rate the performance of the countries on a scale from 1 to 5, where 1 is the worst and 5 the best for six criteria which are listed below (Rashidi & Cullinane, 2019):

Customs: This element measured the efficiency of clearing through customs based on speed, simplicity, and predictability.

Infrastructure: This looked at the quality of the infrastructure in ports, railroads, highways, and roads.

Arranging Shipments: This looked at how easy it was to arrange shipments compared to the market.

Logistics Quality and Competence: This metric showed the overall competence and quality of services provided by operators, shippers, drivers, etc.

Tracking and Tracing: This is the ability to track and trace shipments through the entire supply chain.

Timeliness: This measured how "on-time" the product is when reaching the destination.

Overall, these metrics are critical for countries to monitor because they provide insight into how customers view their logistics performance. Rashidi & Cullinane (2019) stated logistics performance indices are a great benchmarking tool to help show the issues and challenges each country faces. Marti et al. (2014) stated it allowed countries to focus on those areas and improve their LPI number. A handful of studies have looked at LPI and used DEA to determine an overall efficiency score relative to each LPI metric. Rashidi & Cullinane (2019) performed a DEA on all the listed LPI's above on ten countries in the Organization for Economic Co-operation and Development or OECD. Additionally, they ran a second DEA model on sustainable operational logistics performance factors, also known as SOLP. These factors included energy and green-house gas emissions or GHGE for the logistics industry in each country. Finally, they combined the outputs to form an SLPI score, a combination of the LPI and SOLP. They concluded that the SOLP approach provided useful information when accompanied by LPI metrics and allowed countries to efficiently identify improvement areas.

Luisa Marti, et.al. (2014) used a gravity model to see if countries used their rankings to improve their processes over time. Results showed that over the five-year period of data, the countries chosen did improve their overall LPI scores. This means that from a logistical sense, countries are improving over this five-year period. This shows countries are paying attention to these metrics, making it even more of a reason to include them as a variable in this study.

Markovits-Somogyi & Bokor (2014) looked at 29 European countries that were tested with the new DEA-PC or pairwise comparison. The new DEA method results were compared to the traditional DEA Method or Charnes, Cooper, and Rhodes model (CCR). Finally, those results were compared to the single number attached to the LPI known as logistics quality and competence index. This study showed that traditional DEA models and DEA-PC could assess one performance dimension known as efficiency very well. Furthermore, since they can assess logistic efficiency, it can be seen as a complementary method to other performance and efficiency measurement techniques such as logistics performance indicator surveys. Additionally, another PCA-DEA study agreed with the outcome of Rita Markovits and Zoltan Boker’s study. Andrejić & Kilibarda (2016) echoes Markovits-Somogyi by stating, "provides useful information about the benchmarks, as well as potential improvements of inefficient countries.” This is just another example of a study using DEA and LPI factors to help countries realize their current logistics standing.

Furthermore, Andrejic & Kilibarda (2016) referenced a study done by Kim & Min (2011) where they combined LPI factors and environmental performance indexes (EPI) to form a Green Logistics Performance Index (GLPI) to show countries how their logistics competitiveness affects the environment. The study concluded that GLPI is a great way to judge a country's green logistics efficiency. Not all studies just include LPI factors. Marti et al. (2017) performed a study to see if income and geographical area accompanying LPI factors influence countries' overall efficiency. The study concluded that logistics performance highly depends on the country's income and geographical location.

Economic Growth Measures

Competitiveness is at the core of every country. Countries try to compete with military, goods, and services, or even the supply chain. One area that is discussed when talking about competitiveness is economic growth. Efficiency is the primary analysis when looking at the economic growth of a country. Melecky et al. (2019) said efficiency comes from action taken with the resources at hand. The goal is to compare these economic inputs and outputs to gauge which one provided the best overall efficiency, and what areas need to be worked on to improve them. DEA models will output these efficiencies. Melecky et al. (2019) study is not the first study to attempt to add economic measures in DEA models to capture how economic factors played a role in the country's efficiency regarding the economy. There are many ways to evaluate economic growth in a country.

The first way is transportation, specifically inland transport in European Countries. Baran & Górecka (2019) used DEA to look at the economic and environmental aspects of inland transport. Specifically, they captured that ineffective roads and rail transportation sectors led to economic and environmental concerns. This led to those country's being ranked towards the bottom. Knox Lovell et al. (1995) studied

19 OECD countries' macroeconomic performance over 20 years from 1970-1990. They focused on the performance in 4 services: real GDP per capita, low rate of inflation, low rate of unemployment, and a fair-trade balance. They used a DEA model to perform the analysis, then compared those results when adding environmental factors into the mix. The results showed most European (EU) countries did worse when the environmental factors were added, indicating that environmental factors play a factor in macroeconomic performance.

Economic growth factors have also been applied to the creation of a knowledge-based economy. Knowledge-based economy focused less on the traditional inputs such as land, labor, or capital but more on knowledge and technology inputs such as telecommunications, the number of PC, and scientists and engineers in the country. Tan & Hooy (2007) used DEA to perform an efficiency analysis on developing countries in East Asia using this new knowledge-based economy theory. They found that smaller countries were more efficient at providing better knowledge-based outputs than the United States and Japan.

There has been literature suggesting that economic measures can play a huge role in military effectiveness. Michael Beckley (2010) looked at ways some countries are more militarily powerful than others. The research suggested that 'non-material' factors such as democracy can play a huge role in military effectiveness. Michael Beckley (2010) states that military effectiveness is the ability to transfer given resources into military force. He suggested that economic development and a country’s resources provided the best basis for defense planning. He also stated that militaries are mostly embedded within a country's overall economic system; thus, countries that produced civilian goods would also excel in producing military goods. He summarized a study done by Biddle and Long (2004) that showed the determinants of military effectiveness. They used variables such as human capital, culture, democracy, and economic development. The results showed that the primary determinant of military effectiveness was economic development. It also showed that economic development and defense spending move in the same direction. In the end, Michael Beckley concluded that economic development is the primary function of military effectiveness and needed to be considered when judging how well a country can be militarily effective. When resources and effectiveness are combined, it will lead to a more accurate measure of military power.

Sometimes it is not about how big your military arsenal is when power and national security are determined. Lloyd Dumas (1990) stated that national security is almost always thought of as purely military defense, in a time when weapons of mass destruction, if used, could provide more damage rather than good results. He argued there is a way to integrate economic measures into the equation to provide a more effective and useful route to achieve national security. He stated that countries need first to settle their differences in a non-violent manner. This would provide an effective way to help generator security instead of solely on military power. The model he proposed considered contributive and non-contributive goods as the total economic output. Contributive goods provide the material standard of living that has an overall economic impact. Whereas non-contributive goods did not add to the material standard of living. This could be churches that provide goods and services, but sadly that does not add to the material standard of living. His results concluded that when economic strength is added into the equation, he found a more positive outlook on national security that is not solely based on the number of destructive weapons a country has, but how well a country can settle their conflicts economically.

Summary

First, production theory provided an excellent framework to explain the relationship between how inputs and outputs react with each other and their results. Since the theory is grounded in an analysis of inputs and outputs, it is a grand theory to base this study on. This literature review attempted to show that certain variables, both inputs and outputs, have been used with a Data Envelopment Analysis to provide efficiency numbers to countries. The literature identified a major gap. No study was performed using all these variables (economic, LPI, military) with DEA that tackled how efficient these selected countries are at achieving their military power. Additionally, linear regression was used to answer what inputs have the greatest impact on achieving a country's military power. The next chapter, methodology, will show how the data was collected and implemented through the lens of production theory and the use of DEA and linear regression models.

III. Methodology

Chapter Overview

The purpose of this section was to discuss, in detail, the two methods performed in this study and outlined the reasons for the use of these methods. Additionally, this section discussed the sources used to obtain the variables, and two tables are presented that focus on the variable's descriptive statistics and correlations.

Research Methodology

Since this study's main objective was to understand how efficient countries were at achieving their military power based on the inputs selected, Data Envelopment Analysis (DEA) was the primary method used. DEA is a linear programming application that was discovered by Farrell (1957). He proposed the first known framework of DEA in 1957 when he studied production analysis. Though he was unable to solve the equation that he discovered, it was a step toward discovery. Charnes et al. (1978) picked up Farrell’s work and used linear programming to solve the model that Farrell was unable to solve at the time. This led to the creation of the Charnes-Cooper-Rhodes (CCR) model. The next model used in DEA was discovered by Banker et al. (1984). They decided to edit the constant-return-to-scale (RTS) measurements in CCR to a more variable RTS and called it the Banker-Charnes-Cooper (BCC) model. Tone (2001) created the third of the most common three models used in DEA, known as the slack-based measure of efficiency (SBM) model. This model measured the slacks that are caused when the variables are completely efficient. DEA's main goal is to take inputs and outputs of a specific decision-making unit (DMU) and produce the overall efficiency related to its benchmarked DMU. A "benchmark" DMU is one that is efficient in a model. To understand the mathematics of DEA, we review a CCR model (Cooper et al., 2007: p.23). E_0 will be the efficiency score for DMU *0:*

Maximize
$$E_0 = \frac{\left\{\sum_{r=1}^{R} u_{r0} y_{r0}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{i0}\right\}}$$

subject to

$$\frac{\left\{\sum_{r=1}^{R} u_{r0} y_{rk}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{ik}\right\}} \leq 1$$
for all *k*

u_{r0}, $v_{i0} \geq$ δ™ for all *r*, *i*,

where

y_{rk}: the observed quantity of output *r* generated by unit *k* = 1, 2, …, *N*,

x_{ik}: the observed quantity of input *i* consumed by unit *k* = 1, 2, …, *N*,

u_{r0}: the weight to be computed given to output *r* by the base unit *0*,

v_{i0}: the weight to be computed given to input *i* by the base unit *0*,

™δ: a very small positive number.

This fractional programing model can be converted to a linear programing model by moving the denominator of the objective function to side constraints and multiplying the denominator to both sides of the original side constraint. In this study, to make sure all bases were covered, three different DEA models were used. This study first measured the efficiency of the decision-making units with a CCR and BCC model. To look at projections where countries could better perform to increase military power, this study used an SBM model. Finally, the study broke down the efficiency across all three models in comparison to their benchmark country.

Specification of Data and Variables

After an in-depth literature review that saw many different inputs and outputs being used to measure a vast amount of DMU efficiencies, this study decided on 34 overall DMUs. These DMUs focused on countries, except for one country (United States), within the EUCOM region. The goal was to understand what factors affect military power. This study retrieved 5 variables to measure how each country efficiently achieved its military power. These are:

(1) Logistics Infrastructure, (2) Gross Domestic Product (GDP), (3) Labor Force (4) Land Area, and (5) Military Power Index.

The first two variables listed were pulled from World Bank (2020). Logistics Infrastructure was used as an input in this model because this measure focused on the infrastructure's quality in ports, railroads, highways, and roads, which will factor into a country's overall ability to support or move their military assets when needed. GDP was used as an input in this model because it represented goods and services produced in 2019 within a given country; thus the higher your GDP, the better opportunities a country has to invest it in other areas such as the military. Additionally, studies have linked the status of a country's economy to overall military effectiveness or power in this case. The next input used in this study was labor force. The labor force of a country can directly affect wartime material output, such as bullets, bombs, or uniforms (Global Fire Power, 2020). Land area was the last input used in this study. The greater your land area, the more opportunities a country will have to produce goods and have access to a great labor force, but the greater your land area, the more a country must defend itself (Global Fire Power, 2020). Therefore, this measure was perfect for this study. The only output used in this study was the military power index. The military power index showed a country's overall military strength. For this study, the reverse military power index was used because DEA assumed that the larger the military power index, the better the country is. With the original measure, the smaller the military index the better. Once reversed, the smallest indices from the original measure became the largest, which satisfied the DEA assumption. When combined, these inputs were able to show how efficient countries were at achieving their military power index when DEA was performed. Table 1 summarizes the descriptive statistics of these variables.

Table 1: Descriptive Statistics for Variables

	Labor Force	Land Area	GDP	LPI Infrastructure	R_Power-Index
Maximum	160,400,000.00	17,098,242.00	21,374,418,877,706.70	4.37	16.50
Minimum	931,200.00	20,273.00	11,955,435,456.80	2.02	0.47
Mean	16,242,094.12	984,412.38	1,288,259,921,395.59	3.37	2.81
Standard Deviation	29,716,878.27	3,247,660.72	3,611,230,420,835.89	0.64	3.53
Variable Type	Input	Input	Input	Input	Output

It is important to note that land area is measured in kilometers per the Global Fire Power database, and GDP is measured in dollars. The next table shows the correlations between input and output variables to ensure no closely related inputs or outputs.

Table 2: Correlation Matrix for Variables

	Labor Force	Land Area	GDP	LPI Infrastructure
Labor Force				
Land Area	0.7489			
GDP	0.9190	0.5085		
LPI Infrastructure	0.2319	-0.0421	0.3115	
R_Power-Index	0.9430	0.8686	0.7695	0.2042

The correlation between the inputs and our one output is high for many of our inputs, which is desirable based on production theory. Additionally, when the inputs' correlations were looked at, there is a strong correlation at .9190 between labor force and GDP. This was taken as a note when linear regression was performed to measure the overall percentage, based on R^2, each input had on the military power index.

Post Ad Hoc Analysis Using Linear Regression

To tackle the next research question, how much does logistics effect a country's military power, this study applied simple and multiple linear regression. Sir Francis Galton discovered linear regression in 1885 (Kumari & Yadav, 2018). The linear regression's overall goal is to show the relationship between the dependent and independent (s) variables quantitatively. Mathematically, linear regression in its simplest form can be modeled as:

$y= mx+c+e.$

Kumari & Yadav (2018) explained that this equation represented the best fit line and explained the relationship between the independent (x) and the dependent variable (y). Additionally, another important piece of information used from this model is the coefficient of determination or R^2. It measured the total variation in the dependent variable that is explained by the independent variable. The closer to 1 this number is, the stronger the linear relationship between x and y is. Kumari & Yadav (2018) stated that if the number is 1, then 100% of the variation in y is explained by the variation in x. Linear regression is important in many ways, but one in particular helped this study the most. Linear regression helped analyze the weight each input (x) had on the military power index (y), thus helping target what inputs to adjust to help achieve a better military power. This study implemented both DEA and linear regression to answer the two research questions discussed in the introduction.

Summary

The methodology of both DEA and linear regression and variables chosen provided an avenue to tackle the research question presented in this study's introduction. The next chapter of this study, analysis and results, provides the outcome of using these methods. The results provide insight on how efficiently countries achieve their military power and what inputs have the biggest impact on military power.

IV. Analysis and Results

Chapter Overview

This chapter aimed to show the results from the two methods applied from the methodology section. After this section has been discussed and examined, it will lead to the recommendation on what inputs need improvement to achieve military power more efficiently. Additionally, it will bring insight into which inputs have the greatest impact on the military power index.

DEA Models and Results

This study performed three input-oriented DEA models (CCR, BCC, and SBM). The main focus was to see how efficient each country was at achieving its military power index, given its resources or inputs. Table 3 shows the results of running these models on the next page.

Table 3: Efficiency Scores by Three DEA Models

Countries	BCC-I Score (PTE)	CCR-I Score (TE)	SBM-I-C Score	Scale Efficiency*	MIX Efficiency**
Russia	1.00	1.00	1.00	1.00	1.00
United Kingdom	1.00	1.00	1.00	1.00	1.00
Sweden	0.62	0.46	0.34	0.73	0.75
Switzerland	0.67	0.49	0.40	0.72	0.81
Turkey	1.00	1.00	1.00	1.00	1.00
Portugal	0.71	0.49	0.33	0.70	0.67
Netherlands	0.65	0.40	0.29	0.62	0.73
Finland	0.69	0.55	0.35	0.79	0.65
France	1.00	1.00	1.00	1.00	1.00
Germany	0.80	0.71	0.42	0.90	0.58
Greece	0.86	0.86	0.64	0.99	0.75
Italy	0.94	0.92	0.77	0.98	0.84
Israel	1.00	1.00	1.00	1.00	1.00
Ukraine	1.00	1.00	1.00	1.00	1.00
Spain	0.72	0.59	0.31	0.82	0.53
Poland	0.90	0.78	0.46	0.87	0.59
Romania	0.82	0.64	0.41	0.79	0.64
Denmark	0.67	0.53	0.38	0.79	0.71
Norway	0.90	0.85	0.50	0.94	0.59
Czechia (Czech Republic)	0.77	0.74	0.50	0.97	0.68
Belarus	1.00	1.00	1.00	1.00	1.00
Hungary	0.71	0.64	0.43	0.90	0.68
Bulgaria	1.00	1.00	0.90	1.00	0.91
Austria	0.55	0.33	0.24	0.60	0.73
Serbia	1.00	1.00	1.00	1.00	1.00
Croatia	1.00	1.00	1.00	1.00	1.00
Belgium	0.76	0.25	0.22	0.32	0.91
Lithuania	0.93	0.76	0.68	0.82	0.90
Georgia	1.00	0.99	0.87	0.99	0.87
Ireland	0.62	0.29	0.16	0.47	0.57
Slovenia	1.00	0.85	0.64	0.85	0.75
Latvia	1.00	0.85	0.66	0.85	0.78
Moldova	1.00	1.00	1.00	1.00	1.00
United States	1.00	1.00	1.00	1.00	1.00
Mean	0.86	0.76	0.64	0.86	0.81

*: Scale Efficiency = CCR-I/BCC-I; **: MIX Efficiency = SBM-I-C/CCR-I

11 out of the 34 countries outputted a 1.00 or 100 percent efficiency across all three DEA models and can be used as benchmarks discussed later in this study. Three scores are important to note and require further discussion. First, the BCC input-oriented model measured pure technical efficiency (PTE). This score focused on the local factors that are controlled by the country themselves. The CCR input-oriented model measured technical efficiency. The next score calculated was the SBM input-oriented model. The SBM model score is a combination score based off multiplying PTE, SCALE, and MIX scores. The next score computed was the scale efficiency score (SCALE). This score is the division of TE by PTE. The SCALE score is represented by the operating conditions or external factors affecting the country. Finally, the MIX score is obtained by the division of SBM by TE. This score represented the mix of inputs used to achieve the desired output (military power). Table 3 showed that the mean score for PTE and SCALE are both 0.86, whereas the lowest score is the MIX score 0.81. MIX efficiency is the lowest of the three scores meaning the mix of inputs that achieve the output might need to be evaluated. Now that an overview was provided to explain what each score means and how it is calculated, it is time to go in-depth with explanations.

Looking at the first column of all the BCC or PTE, it is important to note 4 countries are above 0.90. This means that they might not be 100 percent efficient internally, but overall, they are very close and could focus on another area that makes up their overall score or SBMIC score since this is a combination of all the three scores talked about previously. Additionally, going down the column, Austria has the worst PTE score among the 34 countries at 0.55. This means that internally they need to become more efficient with the resources held within their country. This same method can be applied to the remaining two scores previously talked about to look at the individual area of improvements.

Next, it is important to address the three scores in combination as this provides the overall efficiency number or SBM explained early. Using Germany as an example, their PTE is .80, SCALE is 0.90, and MIX is 0.58, leading to an overall efficiency score in the SBM column of 0.42. It appeared that the mix of resources or inputs used to achieve their military power index was being used inefficiently as that is the lowest score and most likely contributed the most to a low overall SBM score. Another example from the table was Ireland. Ireland has a PTE of 0.62, SCALE of 0.47 and a MIX of 0.57. This led to an overall score of 0.16. It can be said that Ireland needs to address all their areas to achieve its current military power more efficiently. Since SCALE is the lowest of the three, it can be said that a focus first on external conditions would be advised first. Providing those examples helps to interpret the rest of the table easier as this technique can be applied to every country.

Table 3 provided a great way for countries to see where they are not very efficient in achieving their military power. Next, this study wanted to provide relative projections in percentages of how much each country could improve its inputs to achieve its current military power more efficiently using an SBM model. Table 4 below provides that data.

Table 4: Projections by the SBMIC Model

Countries	Score	(I) Labor Force	(I) Land Area	(I) GDP	(I) LPI Infrastructure	Benchmark
Russia	1.00	0.00	0.00	0.00	0.00	N/A
United Kingdom	1.00	0.00	0.00	0.00	0.00	N/A
Sweden	0.34	-56.01	-97.30	-56.34	-53.93	Israel
Switzerland	0.40	-53.89	-70.23	-66.76	-51.00	Israel
Turkey	1.00	0.00	0.00	0.00	0.00	N/A
Portugal	0.33	-72.24	-91.85	-39.95	-62.99	Israel
Netherlands	0.29	-73.48	-73.72	-77.16	-58.43	Israel
Finland	0.35	-45.38	-97.75	-46.18	-69.52	Israel
France	1.00	0.00	0.00	0.00	0.00	N/A
Germany	0.42	-77.00	-81.08	-75.25	0.00	Israel
Greece	0.64	-41.36	-76.01	0.00	-25.36	Israel
Italy	0.77	-23.75	-53.72	-15.15	0.00	United Kingdom
Israel	1.00	0.00	0.00	0.00	0.00	N/A
Ukraine	1.00	0.00	0.00	0.00	0.00	N/A
Spain	0.31	-83.77	-96.23	-73.98	-20.37	Israel
Poland	0.46	-79.08	-93.92	-38.90	-5.00	Israel
Romania	0.41	-77.38	-95.61	-20.43	-42.37	Israel
Denmark	0.38	-47.04	-80.97	-55.18	-66.79	Israel
Norway	0.50	-15.25	-96.22	-42.25	-46.80	Israel
Czechia (Czech Republic)	0.50	-58.33	-85.19	-9.84	-45.87	Israel
Belarus	1.00	0.00	0.00	0.00	0.00	N/A
Hungary	0.43	-66.89	-92.36	-7.05	-61.44	Israel
Bulgaria	0.90	-0.89	-37.66	0.00	0.00	Israel
Austria	0.24	-67.29	-91.95	-71.22	-74.10	Israel
Serbia	1.00	0.00	0.00	0.00	0.00	N/A
Croatia	1.00	0.00	0.00	0.00	0.00	N/A
Belgium	0.22	-77.62	-79.84	-77.89	-75.21	Israel
Lithuania	0.68	-31.55	-56.15	0.00	-39.04	Israel
Georgia	0.87	-16.74	-36.22	0.00	0.00	Belarus
Ireland	0.16	-71.15	-95.28	-83.77	-83.84	Israel
Slovenia	0.64	-25.73	-45.40	0.00	-74.27	Israel
Latvia	0.66	-22.70	-60.33	0.00	-52.91	Israel
Moldova	1.00	0.00	0.00	0.00	0.00	N/A
United States	1.00	0.00	0.00	0.00	0.00	N/A
Mean	0.64	-34.84	-52.50	-25.21	-29.68	N/A

This study's SBM model was input-oriented because this study cared about how countries efficiently used their resources to achieve their current military power. Table 4 expands on table 3 by showing, relatively, how much each country can improve its inputs by percentage to achieve its current military power more efficiently. The percentages presented are relative in nature. Negative percentages indicated underutilization of that resource. For example, Spain has -73.98 percent in GDP. The number is relative, but the negative number showed they needed to utilize their GDP more efficiently (i.e., invest more of it into their military) to achieve their current military power. Another example from the table was Greece. Greece's LPI infrastructure is currently being underutilized by -25.36 percent relatively. Meaning to achieve their current military power more efficiently, they need to improve their infrastructure.

Notice the score column is the numbers from the SMBIC section of table 3. This score represents the total efficiency after combining local factors, external factors, and a mix of inputs to produce the output. The following columns in table 4 show all the inputs tested in the models and the last column is the benchmark. These benchmark countries are already at 100 percent efficiency and can be used as a model for inefficient countries closely related to them. Of the benchmark countries, Israel appeared the most at 21 out of 23 times. Looking at Israel in the table, they are truly 100 percent efficient as no improvements are needed to achieve their current military power index. That does not mean they can sit back and be on cruise control. This world is constantly evolving, but at their current military strength index, they are achieving it efficiently at 100 percent.

The mean numbers in the table showed that their efficiency score was about 0.64 percent on average across all countries. Additionally, on average, all input resources were underutilized when trying to achieve their current military power index. Specifically, land area has the highest underutilization numbers in the chart. It is important to note this input can be misleading if not interpreted correctly. This input does not tell the country to cut off their land or increase their land by attacking another country to gain land mass. Land area is given to a country so a country cannot change that; however, they can utilize the resources, assuming they have it, to achieve a better military power.

The last column to explain in more detail would be the benchmark column. The benchmark column refers to the lambda value that is found in the SBM output results. To qualify as a benchmark country, the country must be 100 percent efficient. Among the 100 percent efficient countries located on the efficiency curve, the closest one to the inefficient country is that country's benchmark. An example will help clear the technical explanation of this relationship. If you look at Italy in table 4, you can see that its benchmark country is the United Kingdom. Diving further into the data, most of their inputs are very close in reference. Compared to the United Kingdom, which is 100 percent efficient, Italy needs to utilize all its inputs better to achieve its current military power index more efficiently. A benchmark provided a comparison between the two countries.

Linear Regression Analysis and Results

To determine how strong a relationship each input had with a country's military power index, this study utilized linear regression. It is important to note that this study decided to drop one of the variables due to the 0.90 correlation between GDP and labor force. Additionally, when the original data was assessed, Russia and the United States appeared to be outliers due to their extremely high military power index compared to other countries. The graphs forthcoming later in the study will show this. To reduce the influence these outliers could cause, this study transformed the reverse military strength index variable by taking the square root of the original reverse military power index. Table 5 provides a summary of the results for all the models that were tested in this study.

Table 5: Regression Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Labor Force	.894***			.873***		.623***
LPI Infrastructure		.292*		.090*	.325***	.161**
Land Area			.771***		.785***	.310***
F-Statistic Significance	.001	.093	.001	.001	.001	.001
Adjusted R^2	.792	.057	.582	.794	.681	.829

*: significant at α=.1; **: significant at α=.05; ***: significant at α=.01

In model 1, this study used only one independent variable, labor force and the dependent variable or the square root reverse military index. The first number shown in Table 5 is 0.894. This number represents the standardized beta coefficient. The closer to 1 this number is, the more effect it has on the dependent variable. The next piece of information presented in this model is the asterisk next to that number. Below the chart, the reader will notice it is correlated to a significant level of that variable. Following down the column in Model 1, the F-statistic significance is 0.001. This number represents the overall significance of the model or the probability of an error in the model. Finally, Adjusted R^2 is the last row to explain, and for model 1 that is 0.792. Adjusted R^2 is the percentage of variation in Y that is explained by X. In this model then, 79 percent of the variation in the military power index is explained by changes in the labor force of that country. This same explanation can be carried throughout the rest of the table. It is worth noting the best model produced in this study was model 6. This included all logistic inputs, minus GDP as exampled before, used in this study. The model suggested, based on the standardized beta coefficients, that labor force had the strongest effect on the military power index at 0.623, followed by land area and LPI infrastructure. Additionally, all the variables and the overall model were significant. Finally, the overall Adjusted R square was 0.829, suggesting that this model with these three variables can explain 82.9 percent of the variation in a country's military power index. Overall, these results showed that logistics factors play a huge role in a country's military power, and should be looked at more in detail when assessing how to improve its military power.

Next, presented below, is a graphical representation of each input in relation to our single output. It is important to remind the reader that the United States and Russia could be potential outliers. To lower the influence they have on the overall dataset, this study took the square root of the reverse military power index. The first figure will be the square root reversed power index and labor force.

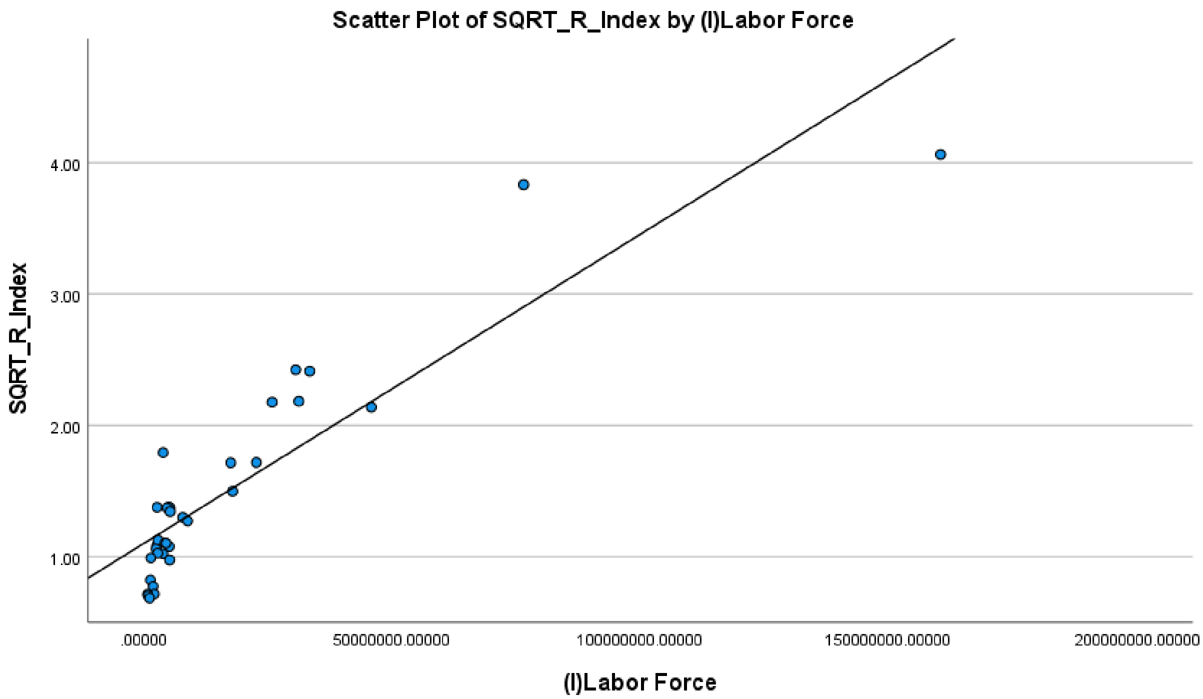

Figure 1: Scatter Plot for Square Root Reversed Power Index and Labor Force

Figure 1 showed that the relationship between labor force and military power index moved in a positive linear trend relationship. A positive linear trend relationship indicated that, on average, as a country increased its labor force numbers, their military power index rose as well on average. It is important to note the two possible outliers in this figure. Since this study decided to keep the outliers in and take the square root to lessen the outliers' impact, the best fit line does not appear to fit the data well, but Table 5 clearly shows the importance of this variable. Figure 2 below showed the relationship between square root reversed power index and logistics infrastructure.

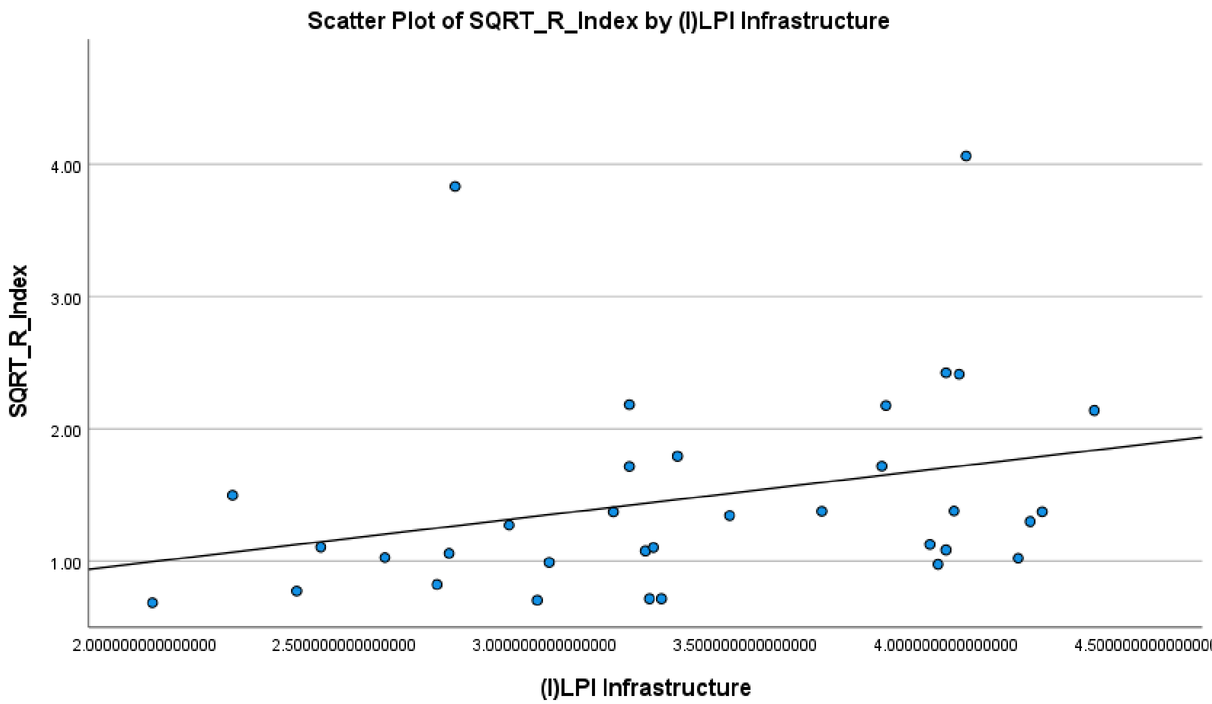

Figure 2: Scatter Plot for Square Root Reversed Power Index and LPI Infrastructure

Figure 2 showed the relationship between the LPI infrastructure and the military power index moved in a positive linear trend relationship. Generally speaking, as a country's infrastructure is improved, so is their military power index. Also, this data fits the linear trend line a little better besides the two outliers (United States and Russia). Finally, figure 3 showed the relationship between land area and military power index.

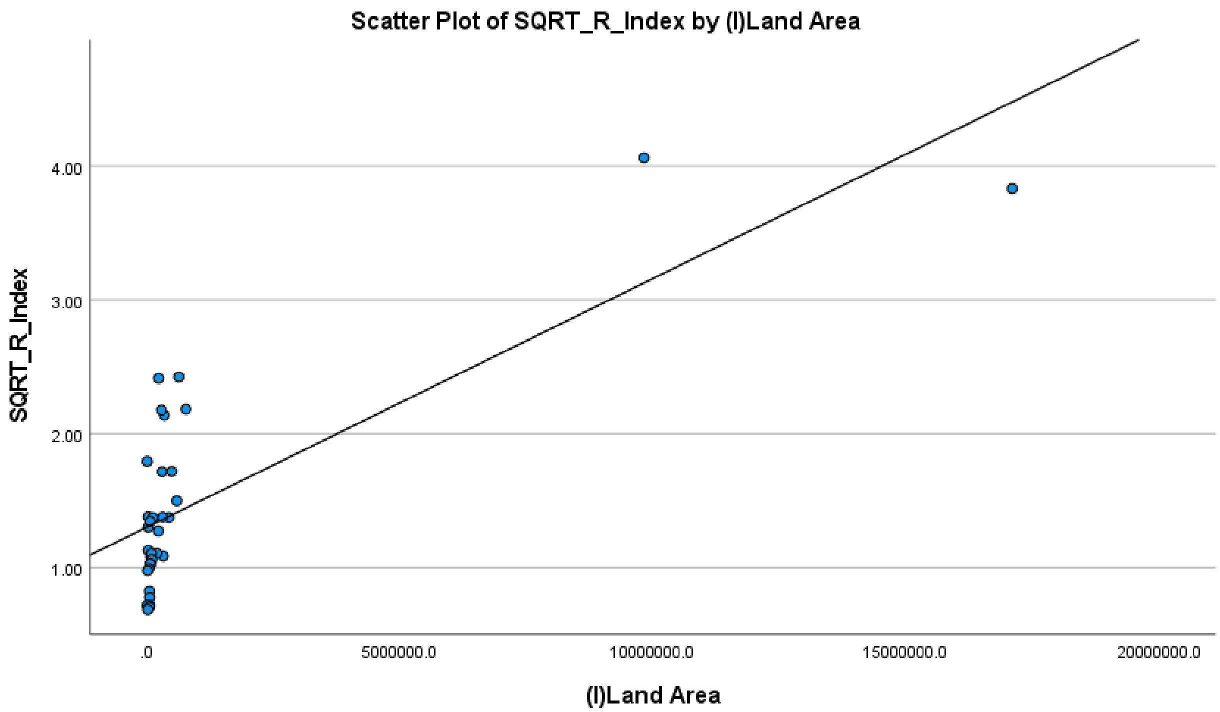

Figure 3: Scatter Plot for Square Root Reversed Power Index and Land Area

Figure 3 also showed a positive linear relationship between land area and military power index. Again due to the outliers of the United States and Russia, the line's fit is skewed. Due to this positive linear relationship shown by the fit line, generally speaking, bigger countries (greater land mass) have a higher military strength index.

Summary

This analysis and results chapter provided the results of this study. Presented first was how efficient each country was at achieving its current military power index. This study found that some countries were efficient at achieving their military power index with the inputs given and others needed to improve a lot. Out of all the scores presented, the MIX efficiency had the lowest mean between the three scores looked at. This means that, on average, countries need to look at how they are using their inputs to achieve their current output or military power index. Further on in this chapter, this study used projections from the SBM model to show, relatively, how much they need to improve these inputs to achieve their current military power index more efficiently. Since all these numbers are negative in nature, this means they are underutilizing their resources. The input with the highest mean score was land area with -52.50 percent. Since a country cannot improve its true land area, this interpretation means given their current land area; they are under-utilizing the space given.

Linear regression was used to understand what logistic inputs had the strongest influence on the military power index and either a positive or negative linear relationship. Table 5 showed six different model combinations tested. Overall, model 6, which included all logistic input variables, had the best overall fit based on R^2. It also highlighted that labor force has the biggest effect on a country's military power index, followed by land area and LPI infrastructure. Finally, this study showed three figures that provided a graphical representation of the individual inputs related to the military strength index. This study showed that each tested input variable has a positive relationship with the military power index; thus it is safe to say that countries that increase any or all of these inputs will improve their military power index.

V. Conclusion and Future Research

Conclusion

Countries military power for many years was built on sure military forces, nuclear weapons, and equipment. Though these are great assets to have, this study showed logistics factors (land area, LPI infrastructure, and labor force) play a huge role in the overall military strength index of a country. It goes without saying there were some limitations in this study. LPI infrastructure and the military strength index are considered subjective in nature. For this study, it provided a great starting framework to show just how important other factors are to military power. It answered both research questions by showing that some countries need to improve how they efficiently achieve their military power index and what inputs provided the greatest weight in relation to the military power index. Additionally, this study showed that each logistic factor had a positive linear relationship between each input and output. As a country improves its inputs, it can achieve a higher military power index. Countries need to look at these models and determine how they can improve efficiencies and what inputs to start with and not just rely on their nuclear arsenal to show or improve military power.

Future Research

Since this study only encompassed one economic factor and three logistics factors, future research would be warranted to include other inputs that could be a factor in military power. Additionally, with the military power index and LPI infrastructure both being subjective measures in nature, it would be ideal to perform a study with more objective inputs that provide a sound number that would not introduce bias in the models.

Expanding these models and providing more inputs can provide a deeper understanding of how a country's military is boosted. For now, this study provided the first initial framework to understand better what factors drive a country's military power and how efficient they are at achieving it.

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14. ABSTRACT
The purpose of this study is to evaluate if logistics and economic factors affect how a country achieves its military power. Countries have focused on material factors such as nuclear weapons or massive military presence for far too long. What has not been discussed is, do other factors play a role in achieving military power. This study applied Data Envelopment Analysis (DEA) and linear regression to a series of United States European Command (EUCOM) countries and the United States to understand how efficient each country was at achieving its military power. Additionally, the overall relationship between military power and each variable chosen in the study was examined. This research shows that countries are not efficient at achieving their current military power. Moreover, showing the relationship between the variables and military power provided what variables carried the most weight. Both results provided a way for countries to improve on efficiency and where to begin.

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