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Efficiency and productivity in the operational units of the armed forces: A Norwegian example ☆

Torbjørn Hanson

Norwegian Defence Research Establishment (FFI), Instituttveien 20, PO Box 25, NO-2027 Kjeller, Norway

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ABSTRACT

Most nations spend a considerable part of their gross domestic product (GDP) on defense. However, no previous study has addressed productivity and efficiency in the core area of the armed forces, operational units, using Data Envelopment Analysis (DEA). Introducing a model for the production process of an operational unit, productivity and efficiency are estimated by DEA for units of one branch of the Norwegian armed forces. Small samples are a characteristic of DEA studies in the military, and the public sector in general, resulting in nearly half of the units being estimated as fully efficient. We find that, by using the bootstrap technique to estimate confidence intervals, we can point to uncertainty in the estimates and reduce the number of candidates for best practice.

1. Introduction

Most nations spend a considerable part of their gross domestic product (GDP) on defense. NATO has set a target for its member countries to allocate at least 2% of GDP to defense objectives. The branches or services of the armed forces like army, navy and air force produce services which are classical examples of public goods not provided by markets. However, most resources are bought in the market place or have alternative cost set by markets.[1] The fact that services are not sold in markets leaves the armed forces without information from a price mechanism in evaluating efficient use of resources or effective mix of services. Despite the absence of price information on services, assessment of efficient resource allocations may still be carried out by other methods if physical information on the services is available.

In the efficiency literature, Data Envelopment Analysis (DEA) is a well established non-parametric method for efficiency studies which can be employed without any information on market prices.[2]

Previous studies of efficiency and productivity by DEA in the armed forces have solely been concentrated on various support functions like maintenance and recruitment, reviewed in Section 2 of the present paper. However, operational units, the core area of defense, have not been studied in the literature. In fact, the field has not developed towards military operational applications since the pioneering work by Lewin and Morey (1981) and Charnes et al. (1984). The purpose and main contribution of this paper is to show that studies of efficiency and productivity by DEA can be carried out also for operational units of the armed forces.

There are at least three possible reasons for the lack of studies: Difficulties in modeling and measuring output in the military; heterogeneity leading to small populations of military units; and restricted data on performance of operational units. The most important, but perhaps also the easiest problem to overcome, is difficulties in modeling the production process and output of the armed forces. Hartley (2010, 2012) implicitly defines military output as aircraft squadrons, submarine or tank forces by acknowledging that defense markets have no market prices for their outputs, referring to the lack of prices on such forces. Furthermore, Hartley acknowledges that few published studies have estimated military productions functions, and those which have are using a cost-effectiveness approach. In this manner the present paper represents a methodological contribution by its pioneer work on output measures for operational units of the armed forces.

What is the output of the armed forces, and where can the line between outputs and outcomes of defense be drawn? These questions are addressed in this paper by setting up a general model for the production process of an operational unit. In our model the emphasis is on production of troops and soldiers, and

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E-mail address: torbjorn.hanson@ffi.no

[1] The armed forces may have distinct legal rights to draw upon the resources of society, e.g. conscripted personnel are not paid according to market prices, but still have opportunity cost.

[2] DEA is a non-parametric method for the estimation of production frontiers by a piecewise linear surface enveloping the observations from above in the standard case. The initial DEA model presented in Charnes et al. (1978) built on the earlier work of Farrell (1957). Statistical interpretations and an overview of recent developments can be found in e.g. Fried et al. (2008).

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not outcomes of operations. In this way education and training activities are essential, resulting in the necessary proficiency levels (quality) for combat readiness being met for soldiers and units. A simple measure of number of soldiers, e.g. reported in The Military Balance, is of no value without adjusting for quality as measured by e.g. training level and available equipment.[3] The model is specified for units of one branch or service of the Norwegian Armed Forces, the Home Guard.[4] This is where the largest number of homogeneous units are found in Norway, and where we are given access to a quality index. Specified for land force units the model is, however, straight forward to apply also for navy and air force units.

The second reason for the lack of studies on operational units is the low number of observations generated. This is due to limited demand for homogeneous units in most armed forces. Very few nations have the need nor the resources necessary for large scale duplication of military units. Studies of efficiency in operational units is therefore limited to small populations of homogeneous units. Studies of productivity and efficiency are of interest to the armed forces for identifying potential benchmarks. However, low number of units in most studies limits interpretation of the results, as on average nearly half of the units appear fully efficient. From a review of the literature on DEA in the military we do have reasons to believe that small samples are a common phenomenon for studies of the sector. This is the case also in our empirical example of all the eleven operational Norwegian Home Guard districts during the period 2008–2011. Panel data from four successive years gives us the opportunity to pool the data and increase the number of observations to 44. In order to reduce the number of units estimated as fully efficient and thereby reducing the number of potential benchmarks, the estimation could also be supplemented by other methods.

Introducing state of the art methods (bootstrapping) enables a statistical interpretation of results and construction of confidence intervals around the estimates. Additional information provided by confidence intervals can reduce the number of potential benchmark candidates among the units significantly and contribute to the making of more informed decisions for picking benchmark units within the armed forces. Further, confidence intervals for the Malmquist index let us consider also the significance of changes in productivity. Resampling of efficiency scores and the Malmquist index is done by the bootstrap procedure developed in Simar and Wilson (1999). The convergence rate of the DEA estimator is sensitive to sample size and dimensionality (Simar and Wilson, 2000). The literature provides no rules of thumb for when the DEA-bootstrap is justified, but experiments in Simar and Wilson (2000) indicates that a sample size of $n=10$ is perhaps too small to obtain meaningful results in applied studies. However, increasing the sample size even from $n=10$ to $n=25$ more than halves the range of confidence intervals in the experiment. These findings lead us to focus only on the pooled sample of size $n=44$ when bootstrapping efficiency scores for the Home Guard. We argue that it is better to report standard errors for the DEA estimates rather than completely ignoring any uncertainty in the estimates.

Including several nations in the study could extend available data dramatically. However, data sources on performance of operational units are usually restricted and possibilities of collecting an extended data set consisting of data from several nations are few.[5] Additionally, heterogeneity in training standards and requirements between nations makes a wider study even more difficult. Restrictions on data and heterogeneity between nations represent a third possible reason for lack of studies. We have benefitted from close cooperation with the Armed Forces in access to data on military operational units. The scope of the paper is, however, limited to measuring the performance of operational military units and thereby offering a new tool for managers. Our results point to best practice candidates among the units, but explanations for the mechanisms behind any estimated differences in performance is outside the scope of the present paper.

The paper is structured as follows. In Section 2 a discussion on previous DEA studies in the defense sector is given. Section 3 of the paper presents concepts and data. First, military activity is linked to the concepts of public service activities, drawing a line between output and outcome in the sector, before we set up a general model for the output of an operational unit. The model is specified for operational units in the Home Guard, a branch of the Norwegian Armed Forces. Estimates from the 44 observations are presented in Section 4 of the paper, before we introduce the bootstrap procedure resampling the data, and additional pseudo observations are generated. Developments in productivity for the Home Guard and its units are presented in the last part of the section. Finally, Section 5 of the paper concludes and points at some topics for further research.

2. Data envelopment analysis in the military

Application of DEA in the defense sector started out in the early eighties with the studies by Lewin and Morey (1981) and Charnes et al. (1984) on recruitment and aircraft maintenance units respectively. While the military was introduced as a new and promising field for DEA studies at the time, it is somewhat striking that application to other areas and activities in the armed forces is still absent 30 years later. In fact, the approach in Charnes et al. (1984) constitutes the best example of measuring efficiency in operational units, the core activity of the armed forces, in the literature. An overview of DEA studies in the military, including the field of study and number of variables, is outlined in Table 1. Charnes et al. (1984) study 14 aircraft maintenance units in the U. S. Air Force over a period of seven months. The four outputs in the model include hours of mission capable aircraft, hours of non capable aircraft due to maintenance problems, number of sorties flown and the number of completed jobs of a specific type. By introducing hours of mission capable aircraft and number of sorties flown as outputs possible measures of operational outputs are included in the model. This is in contrast to solely measuring the number of completed maintenance jobs of various types. However, for the measure to fully cover the operational unit, in form of a squadron of aircraft in this case, at least some measure of personnel (e.g. pilots) has to be introduced.

A study of a similar production structure is done in Roll et al. (1989) for the efficiency of aircraft maintenance units in the Israeli Air Force. The original production model consisted of three inputs and six outputs. However, the model was modified after studies of

[3] The Military Balance is an annual assessment of global military capabilities including number of personnel and equipment for 171 different countries, published by the International Institute for Strategic Studies. Publicly available combat readiness and quality of forces is of course not found in such assessments.

[4] The principal task of the Home Guard is to protect important infrastructure, support national crisis management, strengthen the military presence throughout the country and provide support to the civil community (Norwegian Ministry of Defence, 2010). The Home Guard consists of one Home Guard Staff, two school departments, and a number of operational districts located in all geographical regions in Norway. The personnel in a Home Guard district are mostly conscripted personnel with a full time job outside the military (300–1000 officers and 1500–4500 soldiers), except for the personnel in the District Staff who are full time employed in the Armed Forces (around 50 people).

[5] However, Owen (1994) shows that international benchmarking of military manpower ratios is possible across 15 different countries.