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The Framework For Analyzing The Efficiency Of Global Arms-Producing And Military Services Companies based on DEA-AR and ANP

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Abstract

The importance of the defense industry has been increased for national security and synergy effects with other industries. This paper aims to propose a framework for analyzing the efficiency of global arms producing and military services companies. Generally, the DEA has been utilized for analysis of management efficiency but there have been some problems. This research applied the DEA-AR model to solve them and acquire more accurate analysis results. Based on the proposed framework, we did a case study to show the feasibility of it.

Keywords: ANP, Arms-producing and military services, DEA-AR, Defense industry, Efficiency

Introduction

The importance of the defense industry has been increased for national security and synergy effects with other industries. The improvement of management efficiency is an important issue in companies including arms-producing and military services companies. Generally, DEA (Data Envelopment Analysis) has been utilized for analysis of management efficiency. However, there have been some problems related with it [1]. The accuracy of assessment is reduced by the over-measurement and unreasonable weights, etc. [2, 3, 4]. So, various research have applied the DEA-AR model to solve them and improve the accuracy of results, but the research about global arms-producing and military services companies is a relatively insufficient research field. Hence, this paper aims to propose a framework for analyzing their efficiency. Additionally, based on the proposed framework, we did a case study to show the feasibility of it.

The proposed framework consists of extraction of variables, calculation of relative importance using ANP (Analytic Network Process) and assessment of efficiency based on DEA-AR model to analyze the accurate efficiency results. The DEA-AR model is to assign the Assurance Region about the weight range of input and output variables in DEA [2]. Each step was applied in real global arms producing and military services companies (45 companies among the SIPRI Top 100 arms-producing and military services companies in the world in 2013) over the period 2011~2013(3 years).

This research is organized as follows. First, we review previous researches related to the analysis of efficiency using DEA. Next, we propose a framework for analyzing the efficiency of global arms producing and military services companies. We also did a case study according to the proposed framework. The research finishes with concluding remarks.

Literature Review

The analysis of efficiency using DEA had been done mainly for public areas such as governments, but it has also been utilized for private areas such as manufacturers recently [5]. In other words, the utilization of DEA has been broadened due to the strengths of it, providing the measurement information about inefficient Decision Making Unit (DMU)[6].

There are various researches using DEA in military areas such as military hospitals, units and arms-producing and military services companies due to its strengths. However, the research related with the advanced DEA for solving the weakness of DEA or applying another tool is a relatively insufficient research field. So, this paper aims to propose the analysis framework for analyzing arms-producing and military services companies accurately based on DEA-AR and ANP.

[7] proposed the DEA-AR model using Assurance Region that indicates the accurate and discreet analysis results than the existing DEA model, which has shortcomings such as indiscreet analysis because of the over-measurement and unreasonable weights. The weight ratio of other variables' weights based on a specific variable's weight is used to determine all variables weights in DEA-AR [8]. Using the DEA-AR model, the superior analysis results are extracted due to the change of the frontier of DMUs by assigning weights [9].

There is a formula for setting the weights of input and output variables.

$$L_{1,i} \le \frac{v_i}{v_1} \le U_{1,i}, i = 2,3,...,m$$

$$L_{1,r} \le \frac{u_r}{u_1} \le U_{1,r}, r = 2,3,...,n$$

$$L_{1,i} : \min\left(\frac{input\,variable\ i}{input\,variable\ 1}\right) \qquad U_{1,i} : \max\left(\frac{input\,variable\ i}{input\,variable\ 1}\right)$$

$$L_{1,r} : \min\left(\frac{output\,variable\ r}{output\,variable\ 1}\right) \qquad U_{1,r} : \max\left(\frac{output\,variable\ r}{output\,variable\ 1}\right)$$

AHP (Analytic Hierarchy Process) is often used for calculating the relative weights but this research uses ANP, a more general method than AHP[10], considering dependency among variables.

Framework

The framework which can be used to derive the efficiency of global arms producing and military services companies is shown in [Fig. 1].

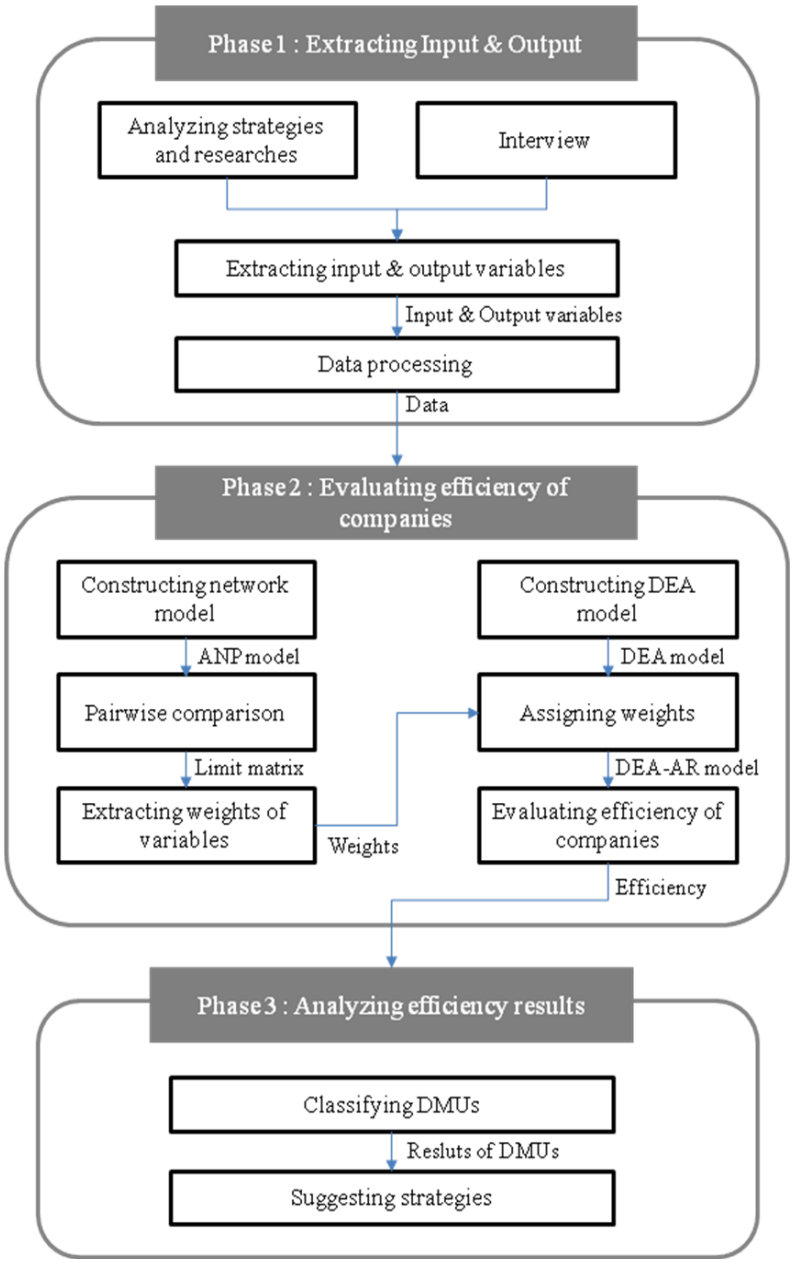

Figure 1: Framework

Variables (Input and Output) taking into account the multidimensional aspects are developed based on the procedure of phase 1. The purpose of this phase is to extract variables and relationships among them. The cause and effect relationship among variables is analyzed based on the results of interviews and studies.

The second phase in this framework is to derive how much each variable affects efficiency based on ANP. The purpose of this phase is to decide the weighted relative importance of variables using cause and effect relationships and ANP. This phase consists of three phases; constructing a hierarchical and dependence model (network model), extracting the limit matrix and estimating the weights.

Once this process has been completed, the next phase is constructing DEA-AR model. Based on the relative weighted importance and the data of variables, the next phase is to calculate the efficiency of global arms producing and military services companies. Their efficiency can be analyzed into TE (Technology Efficiency), PTE (Pure Technology Efficiency) and SE (Scale Efficiency). In the future, they can be utilized for extracting the improvement strategies about management efficiency.

Case Study

In this chapter, we apply the suggested framework to global arms producing and military services companies (45 companies among the SIPRI Top 100 arms-producing and military services companies in the world in 2013) over the period 2011~2013(3 years). We can validate the applicability and usefulness of it.

It is important to select the improvable and manageable variables for indicating not only the efficiency level but also improvement plan and goal [2, 11]. We suggest the input and output variables based on advanced research and experts' interviews. The input variables consist of total asset, employees and cost of revenue and the out variables are revenue and revenue profit. The data of global arms producing and military services companies was collected from Bloomberg DB and DART (Data Analysis, Retrieval and Transfer System). The statistical information of arms-producing and military services companies is presented in [Table 1].

Table 1. Statistical information

(Units : M$, Number)		Average	S.D	Min	Max
Input	Total asset	35,362	99,352	625	656,560
	Employees	59,649	76,834	2,674	317,500
	Cost of revenue	16,897	23,359	670	89,084
Output	Revenue	21,700	31,437	849	142,937
	Revenue profit	4,804	9,129	92	53,853

We derive the relative importance of variables using Super Decision Program ver. 2.2.6 for ANP. First, the pair-wise comparisons of variables are conducted based

on the network model and then we can get a limit matrix for this. The weights using ANP are presented in [Table 2].

Table 2. Weights

Experts		1	2	3	4	5
Input	Total asset	0.128	0.089	0.144	0.139	0.127
	Employees	0.117	0.133	0.136	0.115	0.117
	Cost of revenue	0.255	0.277	0.219	0.246	0.256
Output	Revenue	0.257	0.215	0.202	0.248	0.260
	Revenue profit	0.243	0.285	0.298	0.252	0.240

Finally, the efficiency for global arms producing and military services companies is presented in [Table 3, 4 and 5] based on DEA-AR model using EMS (Efficiency Measurement System) software ver. 1.3. [Tables 3, 4 and 5] indicate the comparison results between the existing DEA model and DEA-AR model using ANP. Generally, the efficiency can be analyzed into TE, PTE and SE. In the future, they can be utilized for extracting the improvement strategies about management efficiency. Consequently, we can also get the accurate efficiency results more than the existing DEA model considering the strategic relationship among variables and weights of experts as below.

Table 3. Efficiency (TE)

	2011		2012		2013			
	DEA	DEA-AR	DEA	DEA-AR	DEA		DEA-AR	
	Score	Score	Score	Score	Score	Rank	Score	Rank
DMU_1	0.769	0.389	0.765	0.364	0.767	14	0.405	26
DMU_2	0.712	0.441	0.743	0.419	0.763	16	0.492	10
DMU_3	0.735	0.420	0.732	0.326	0.737	21	0.435	25
DMU_4	0.768	0.443	0.748	0.321	0.743	19	0.438	23
DMU_5	0.716	0.399	0.705	0.439	0.691	31	0.374	21
DMU_6	0.752	0.444	0.739	0.356	0.767	14	0.452	18
DMU_7	0.728	0.385	0.610	0.397	0.646	37	0.374	27
DMU_8	0.595	0.332	0.606	0.286	0.612	39	0.340	33
DMU_9	0.748	0.468	0.745	0.407	0.745	18	0.440	12
DMU_10	0.709	0.357	0.723	0.199	0.706	28	0.390	36
DMU_11	0.681	0.395	0.729	0.453	0.722	23	0.408	16
DMU_12	0.914	0.318	0.846	0.381	0.742	20	0.210	38
DMU_13	0.890	0.431	0.864	0.340	0.869	4	0.419	24

DMU_14	0.614	0.185	0.690	0.477	0.721	24	0.229	43
DMU_15	0.747	0.458	0.750	0.315	0.768	13	0.488	19
DMU_16	0.974	0.397	0.999	0.429	0.956	2	0.377	22
DMU_17	0.669	0.379	0.695	0.239	0.694	30	0.346	34
DMU_18	0.746	0.461	0.807	0.090	0.823	8	0.504	39
DMU_19	0.646	0.312	0.667	0.182	0.651	36	0.338	44
DMU_20	0.759	0.450	0.798	0.339	0.771	12	0.434	20
DMU_21	0.607	0.256	0.619	0.311	0.598	41	0.263	40
DMU_22	0.871	0.142	0.818	0.591	0.821	9	0.079	45
DMU_23	0.732	0.245	0.783	0.369	0.831	7	0.229	42
DMU_24	0.725	0.340	0.739	0.326	0.700	29	0.343	31
DMU_25	0.896	0.379	0.837	0.416	0.808	10	0.346	28
DMU_26	1.000	0.532	1.000	0.382	1.000	1	0.642	6
DMU_27	0.710	0.397	0.666	0.224	0.651	35	0.376	32
DMU_28	0.745	0.416	0.704	0.312	0.721	25	0.352	29
DMU_29	0.659	0.382	0.705	0.689	0.781	11	0.500	5
DMU_30	0.659	0.390	0.668	0.482	0.680	32	0.389	15
DMU_31	0.620	0.265	0.491	0.409	0.569	42	0.282	35
DMU_32	0.738	0.341	0.657	0.221	0.667	33	0.357	37
DMU_33	1.000	0.752	1.000	0.477	1.000	1	0.704	2
DMU_34	0.806	0.491	0.832	0.318	0.839	6	0.467	17
DMU_35	0.698	0.437	0.688	0.475	0.658	34	0.363	14
DMU_36	0.573	0.246	0.613	0.335	0.714	26	0.252	41
DMU_37	0.718	0.450	0.777	0.661	0.766	15	0.466	4
DMU_38	0.643	0.357	0.597	1.000	0.600	40	0.322	7
DMU_39	0.750	0.488	0.754	0.337	0.758	17	0.482	13
DMU_40	0.587	0.339	0.624	0.382	0.622	38	0.351	30
DMU_41	0.916	0.717	0.883	0.366	0.897	3	0.684	3
DMU_42	1.000	1.000	1.000	0.491	1.000	1	1.000	1
DMU_43	0.742	0.357	0.702	0.668	0.713	27	0.374	11
DMU_44	0.834	0.385	0.854	0.667	0.856	5	0.391	8
DMU_45	0.768	0.399	0.762	0.619	0.727	22	0.377	9

Table 4. Efficiency (PTE)

	2011		2012		2013			
	DEA	DEA-AR	DEA	DEA-AR	DEA		DEA-AR	
	Score	Score	Score	Score	Score	Rank	Score	Rank
DMU_1	0.930	0.845	0.894	0.792	0.910	12	0.755	13
DMU_2	0.982	0.970	1.000	1.000	1.000	1	1.000	3
DMU_3	0.904	0.827	0.900	0.769	0.942	8	0.745	14
DMU_4	0.931	0.874	0.913	0.798	0.946	7	0.755	11
DMU_5	0.888	0.810	0.855	0.711	0.884	15	0.666	19
DMU_6	1.000	1.000	1.000	0.972	1.000	1	0.955	4

DMU_7	1.000	0.809	0.975	0.705	1.000	1	0.748	15
DMU_8	0.874	0.632	0.871	0.584	0.886	14	0.570	26
DMU_9	0.959	0.921	0.945	0.840	0.959	5	0.796	9
DMU_10	0.913	0.723	0.947	0.716	0.987	3	0.733	20
DMU_11	0.841	0.678	0.850	0.646	0.866	20	0.606	24
DMU_12	0.949	0.531	0.879	0.413	0.775	27	0.240	37
DMU_13	1.000	1.000	1.000	1.000	1.000	1	1.000	1
DMU_14	0.630	0.196	0.690	0.211	0.721	30	0.237	41
DMU_15	0.989	0.980	0.982	0.952	0.994	2	0.920	6
DMU_16	0.990	0.408	1.000	0.400	0.970	4	0.399	33
DMU_17	0.695	0.388	0.695	0.366	0.694	31	0.374	35
DMU_18	0.854	0.636	0.872	0.585	0.878	16	0.571	25
DMU_19	0.652	0.359	0.672	0.372	0.656	33	0.397	36
DMU_20	1.000	1.000	1.000	1.000	1.000	1	1.000	1
DMU_21	0.608	0.285	0.619	0.283	0.599	35	0.301	40
DMU_22	0.895	0.206	0.822	0.105	0.825	24	0.090	42
DMU_23	0.878	0.451	0.847	0.284	0.933	10	0.345	39
DMU_24	0.790	0.417	0.780	0.362	0.740	29	0.348	38
DMU_25	0.930	0.460	0.862	0.419	0.844	21	0.494	31
DMU_26	1.000	1.000	1.000	1.000	1.000	1	1.000	1
DMU_27	0.714	0.435	0.675	0.435	0.659	32	0.443	32
DMU_28	0.941	0.902	0.831	0.685	0.871	17	0.671	16
DMU_29	0.919	0.832	0.936	0.863	0.933	9	0.870	8
DMU_30	0.782	0.524	0.790	0.487	0.798	26	0.473	30
DMU_31	0.820	0.600	0.936	0.552	0.832	23	0.574	28
DMU_32	1.000	0.965	0.995	0.953	0.955	6	0.900	7
DMU_33	1.000	0.767	1.000	0.725	1.000	1	0.739	17
DMU_34	1.000	1.000	1.000	1.000	1.000	1	0.891	5
DMU_35	0.843	0.634	0.845	0.589	0.866	19	0.531	27
DMU_36	1.000	1.000	1.000	0.843	0.821	25	0.676	10
DMU_37	0.909	0.830	0.943	0.844	0.930	11	0.740	12
DMU_38	0.673	0.422	0.611	0.378	0.616	34	0.383	34
DMU_39	0.810	0.639	0.821	0.642	0.835	22	0.655	23
DMU_40	0.771	0.628	0.814	0.682	1.000	1	0.784	22
DMU_41	0.920	0.733	0.891	0.721	0.905	13	0.740	18
DMU_42	1.000	1.000	1.000	1.000	1.000	1	1.000	1
DMU_43	0.788	0.551	0.738	0.506	0.761	28	0.552	29
DMU_44	1.000	0.985	1.000	1.000	1.000	1	1.000	2
DMU_45	0.851	0.733	0.833	0.692	0.867	18	0.726	21

Table 5. Efficiency (SE)

	2011		2012		2013			
	DEA	DEA-AR	DEA	DEA-AR	DEA		DEA-AR	
	Score	Score	Score	Score	Score	Rank	Score	Rank
DMU_1	0.826	0.461	0.855	0.460	0.843	22	0.536	33
DMU_2	0.725	0.455	0.743	0.419	0.763	36	0.492	37
DMU_3	0.813	0.508	0.814	0.424	0.782	30	0.583	31
DMU_4	0.825	0.507	0.819	0.403	0.786	29	0.579	32
DMU_5	0.806	0.493	0.825	0.618	0.781	31	0.561	24
DMU_6	0.752	0.444	0.739	0.366	0.767	35	0.473	40
DMU_7	0.728	0.476	0.626	0.564	0.646	42	0.500	29
DMU_8	0.681	0.526	0.696	0.490	0.691	40	0.598	26
DMU_9	0.780	0.508	0.788	0.484	0.777	32	0.553	27
DMU_10	0.777	0.494	0.764	0.278	0.715	38	0.532	41
DMU_11	0.810	0.583	0.858	0.701	0.834	26	0.672	20
DMU_12	0.963	0.600	0.962	0.923	0.957	12	0.873	13
DMU_13	0.890	0.431	0.864	0.340	0.869	19	0.419	43
DMU_14	0.974	0.941	1.000	2.264	1.000	2	0.965	2
DMU_15	0.755	0.467	0.764	0.331	0.772	33	0.531	38
DMU_16	0.984	0.975	0.999	1.074	0.986	9	0.944	4
DMU_17	0.963	0.977	1.000	0.652	0.999	3	0.924	9
DMU_18	0.873	0.726	0.925	0.154	0.938	14	0.882	36
DMU_19	0.992	0.868	0.993	0.490	0.991	7	0.851	18
DMU_20	0.759	0.450	0.798	0.339	0.771	34	0.434	42
DMU_21	1.000	0.898	0.999	1.102	0.998	4	0.874	5
DMU_22	0.973	0.688	0.994	5.647	0.995	5	0.870	1
DMU_23	0.834	0.543	0.924	1.298	0.891	17	0.663	14
DMU_24	0.917	0.815	0.948	0.898	0.946	13	0.988	6
DMU_25	0.963	0.824	0.972	0.995	0.957	11	0.701	11
DMU_26	1.000	0.532	1.000	0.382	1.000	1	0.642	30
DMU_27	0.994	0.912	0.987	0.515	0.988	8	0.848	16
DMU_28	0.792	0.461	0.847	0.456	0.828	27	0.525	34
DMU_29	0.718	0.460	0.753	0.798	0.837	25	0.574	23
DMU_30	0.843	0.743	0.846	0.991	0.851	21	0.822	8
DMU_31	0.757	0.441	0.525	0.742	0.683	41	0.492	25
DMU_32	0.738	0.353	0.660	0.232	0.699	39	0.396	45
DMU_33	1.000	0.981	1.000	0.658	1.000	1	0.953	7
DMU_34	0.806	0.491	0.832	0.318	0.839	23	0.524	39
DMU_35	0.827	0.688	0.814	0.806	0.760	37	0.684	17
DMU_36	0.573	0.246	0.613	0.397	0.870	18	0.373	44
DMU_37	0.790	0.543	0.824	0.783	0.824	28	0.630	21
DMU_38	0.955	0.845	0.978	2.646	0.974	10	0.840	3
DMU_39	0.925	0.765	0.919	0.525	0.908	16	0.735	19

DMU_40	0.761	0.540	0.767	0.559	0.622	43	0.448	28
DMU_41	0.996	0.979	0.992	0.508	0.992	6	0.925	15
DMU_42	1.000	1.000	1.000	0.491	1.000	1	1.000	12
DMU_43	0.942	0.648	0.951	1.320	0.936	15	0.677	10
DMU_44	0.834	0.391	0.854	0.667	0.856	20	0.391	35
DMU_45	0.903	0.544	0.915	0.893	0.838	24	0.520	22

Conclusions

Many researchers have recognized the importance of the defense industry. Management efficiency is important to upgrade the competitiveness of companies including arms-producing and military services companies. Most researches have utilized DEA to analysis management efficiency but there have been some problems. The over-measurement and unreasonable weights assignment in DEA causes the reduction of accuracy. The DEA-AR model has been applied in solving it and improving the accuracy of results. However, the research about global arms producing and military services companies is a relatively insufficient research field. Hence, the purpose of this paper is to propose a framework to analyze their efficiency using DEA-AR model and ANP. We did case study to show its feasibility according to the proposed framework.

The proposed framework was organized as follows. First, input and output variables are extracted and then relative importance is calculated using ANP. Finally, we assess the relative efficiency by applying the DEA-AR model to analyze the accurate efficiency results. Each step was utilized in real global arms producing and military services companies.

However, the case study was limited for DMU (Decision Making Unit). China and Russia arms-producing and military services companies were excluded for lack of data. It is necessary to expand the period and other arms-producing and military services companies. Also, we would provide the detail strategies for global arms producing and military services companies in low level of efficiency.

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