DATA ENVELOPMENT ANALYSIS (DEA) FOR EFFICIENCY ASSESSMENT OF THE BEST USE OF INFORMATION SYSTEMS IN GREEK STOCK-EXCHANGE BROKERAGES

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Abstract

In this paper we analyze data from Greek stock-exchange brokerage companies, with the method of Data Envelopment Analysis (DEA) so as to assess the utilization and the effect of the relevant ERP modules for the production of financial services. It is discussed both the appropriate conceptual models for the value of the IT systems, and also the managerial recommendations to the companies for improving the efficiency of the utilization.

Key words: Data Envelopment Analysis, ERP, Stock Exchange Brokerages.
JEL codes, C88, C67
Introduction
In this paper we focus among all Greek enterprises to Stock Exchange Brokerage companies. Such companies produce financial services of special type.
The research had 7 steps and was carried out with a time duration of several months
For the paper there were two favorable factors that contributed to its more meaningful realization.
1) The first of the authors was the designer, production manager and implementation specialist of the IT modules that were studied, for a significant percentage of the Greek stock Exchange brokerages
2) A research program, was financed by the Ministry of Education of Greece at TEI of Epirus, Greece, so as to study the best use practices of ERP software in Enterprises which included may different research methods for different functions of enterprises and a large spectrum of different companies in Greece.

§ 1 Information systems for production of financial services in Greek stock exchange brokerages.
Stock Exchange Brokerage companies produce specialized financial services. We will not be concerned for all the ERP of such companies. We focus only on the financial services produced for the customers. Such services include:
Front Office: 1) Receiving and submission of orders 2) Technical Analysis in real time or Fundamental Analysis on historic data, and production of customer recommendations for trading and investment. 3) Analysis of the risk of the traded financial instruments 4) Calculation of specialized trading parameters of financial derivatives like futures and options
Back Office: 1) Calculation of the daily clearance of the orders of the customers 2) Calculation of the daily reports of portfolios of investment of the customers 3) Calculation of history of trading and investments, for profits, orders, opened closed positions etc of the customers 4) Computation of the monthly accounting and feeding it with daily data so as to change the necessary taxes 5) Computation of Brokerage company volume of activity statistics that are useful for the customers. Etc
For the above services a number of interrelated software applications are used. E.g.
1) Order processing software, either from the dealing room or online from the web by the customers 2) Daily clearance software for orders of securities. 3) Daily clearance software for orders of derivatives. 4) Software that receives real time price data for all financial instruments of the Stock Exchanges and markets 5) Software that performs charts and technical analysis of all financial instruments 6) Software that calculates real time or daily historic risk analysis for all financial instruments. 7) Software that computes fundamental Analysis of the financial statements of all involved companies in the stock Exchanges and the markets 8) Software that performs like a robot automated trading of special financial instruments in the markets. Etc.
Although there is a uniformity, in the above financial services produced by the Brokerage companies, there is also, a significant diversity of different software applications utilized for such financial services. Among the listed financial services above, the clearance is done by software produced by a unique Software applications company in Greece specializing in applications for Greek Brokerages. This company has by far the largest market share among the Greek Brokerages. It is within this company that the first of the authors designed and produced software for clearance. And this helps somehow in analyzing and comparing the efficiency of the utilization of software applications for the production of financial services in the Greek Brokerages.

§ 2 Assessment of the value, utilization and efficiency of information systems. The conceptual model
In order to analyze conceptually the value of the utilization of the involved iT systems the Applications Layers Model is been used.
1) Organization 2) Process 3) Application 4) Information 5) Network
Due to the mentioned diversity of utilized software, an application-process only model would not be enough and convenient.
We choose to involve all the three layers and dimensions of hardware, software and organizations effects. This will be discussed in more details later when presenting the inputs and outputs of the analysis. As far as best utilization practices we will try an assessment of the relative efficiency in the utilization of such IT systems with Data Envelopment Analysis which we will discuss in detail in next paragraphs. But also an informal qualitative historic analysis of the utilization of such IT systems may be also relevant and interesting. By analyzing, with interviews, the evolution of the value and effects during the last 10 years of the utilization of software applications in the Greek Brokerages relevant to the production of the above financial services, we may summarize the next trends
1) The introduction of always better upgrades of the software has resulted in the raising of the employees working IQ.
2) There is a shifting of the customers investment decisions from higher rank managers to middle layer employees that are the users of technical analysis, risk analysis, and fundamental analysis software modules.
3) The boundaries of the business have changed, and the internet has been involved even in back office procedures.
4) There is a better perception of the statistics of the brokerages activities and customer’s activities.

§ 3 The methodology of DEA

3.1 What is expected from DEA
The methodology of Data Envelopment Analysis (DEA) allows for a calculation of the mutually relative efficiency from 0% to 100% of a number of Decision Making Units (DMU’s). (See e.g. [23] D. Sherman and J. Zhu, 2006 chpt 2) This gives not only a relative ordering of the units but also it permits the estimation of what has to happen to units that are not 100% efficient so as to become 100% efficient. The calculation is based on data of inputs and outputs, for each unit. Millions of dollars can be saved in this ways and there are real life examples in various and different industries. There are more than 3000 publications of papers utilizing the DEA methodology in various sciences and disciplines. This does not mean that DEA is an infallible methodology. It has of course as all methods both advantages and disadvantages that we discuss below.
It is well known that one of the main advantages of the DEA is that the input and output values of the units can be of radically different nature and units of measurement. They can be magnitudes and units of technological nature, human nature or economic nature.

3.2 The basic axioms behind the DEA method
DEA is based on the following logically working axioms. (see e.g. [24] S. Sagaroudi 2009 chapter 2)

Production Possibility Set
In productivity or efficiency measurement and analysis in general, when the DMUs consume s different inputs to produce m different outputs, the production possibility set (PPS) is the collection of all feasible DMUs that are capable of producing output \( y = (y_1, y_2, ..., y_m) \) consuming input \( x = (x_1, x_2, ..., x_s) \). The PPS is defined as the set:
\[
\Psi = \{ (x, y) \in \mathbb{R}^{m+s} / x \text{ can produce } y \}
\]

Disposability axiom: A fundamental assumption to form the PPS out of the available data is ‘disposability’. If \( x \) can produce \( y \) so does any \( x_i \_ x \) and if \( y \) could be produced by \( x \) so could be any \( y_j \_ y \). Formally each observed data \( X = (x_1, ..., x_m), Y = (y_1, ..., y_s) \) brings along part of the unobserved piece of the PPS which is defined as
\[
\{ (x, y) \in \mathbb{R}^{m+s} / x_i \geq X \text{ and } y_j \leq Y \}
\]
This is like saying if DMUi could be realized then any DMU that is doing worse is feasible, too. This assumption leads to the Free Disposal Hull (FDH) model, which shares its PPS with most of the other models.

Convexity: Any convex linear combination of realized DMUs is feasible. In other words if two DMUs are in the PPS so does the line connecting these two ones (any linear combination of them). This assumption leads to the BCC model, a variable return to scale model.

Ray Unboundedness: Scaling up or down of any realized DMU generates a new feasible DMU. This assumption added to the convexity assumption is the basis of CCR, a constant returns to scale model.

3.3 The mathematical formulation as LP
A fractional formulation for the case of \( s \) outputs, \( m \) inputs, and \( n \) DMUs where the \( y \) terms represent output levels, the \( x \) terms represent input levels, and the \( u \) and \( v \) terms represent the weights associated with outputs and inputs respectively, is shown below as Formulation1
The formulation is not linear [6] Charnes and Cooper (1978) demonstrate that this particular type of non-linear problem can be converted to linearity. Thus the DEA can be solved using linear methods. A linear version of the above formulation is shown below as Formulation 2.

Maximize \( \sum_{r=1}^{s} u_r y_{r1} - \sum_{i=1}^{m} v_i x_{i1} \)

subject to \( -\sum_{i=1}^{m} v_i x_{i1} \leq -1, \)

\( \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \) for \( j = 1, \ldots, n \), and

\( u_r, v_i \geq 0, \) for \( r = 1, \ldots, s \) and \( r = 1, \ldots, m. \)

DEA assumes the benefit of the doubt to each branch or service unit (see e.g [23] D. Sherman and J. Zhu, 2006 page 66) when calculating the efficiency value. All DMUs should convert the same set of inputs into the same set of outputs.
3.4 Efficiency frontier, constants and variable returns to scale
The two basic DEA models are named after the respective researchers who first introduced them: the [6] Charnes Cooper Rhodes (CCR) and the [1] Banker Charnes Cooper (BCC) models. (See e.g. [10] Kassim, et al. 2010 and [1] ) The two models are a constant-return-to-scale (CRS) or variable return-to-scale (VRS) represented in the CCR and the BCC models, respectively. An organization is said to exhibit CRS if an increase in inputs will result in a proportional increase in its outputs.

3.5 Input and output orientation
The models orientation is either input or output orientation. (see e.g. [24] S. Sigaroudi 2009 page 12) Input orientation is implying that an inefficient organization may be turned in to efficient by reducing the proportions or magnitudes of its inputs but keeping the output proportions constant; Output orientation is implying that an inefficient organization may be made efficient by increasing the proportions of its outputs while keeping the input proportions constant.

DMUs are represented by their inputs and outputs in the frontier diagram.. Efficiency scores depend on how far the DMU is located from the frontier. Depending on the problem, DMUs can reduce their inputs or increase their outputs or target improvement in inputs and outputs simultaneously in order to move to a point on the frontier. The CCR and BCC models are either focused on minimizing input (input oriented) or maximizing output (output oriented). An additive model by definition is the one that focus on decreasing input and increasing output simultaneously and therefore has no orientation. Additive model shares the same PPS with BCC model.

3.6 Types of efficiency
In the next we set some definitions between different concepts of efficiency. (See e.g. [20] R. S. Sale, M.L. Sale 2003) In DEA, the efficiency is relative. It is relative because we compare the DMU between them. But if all of them would be of equal efficiency this would be a 100%. In reality we do no know if the best of the DMU could be further improved by some internal technical management innovation or re-design.

Full Absolute Efficiency: Full absolute efficiency is attained by any DMU, in a isolated analysis , if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs irrespectively of the other comparing units. This is also called absolute Pareto optimality. (See e.g. [20] R. S. Sale, M.L. Sale 2003)

Full Relative or Technical efficiency: Full technical efficiency is attained by any DMU if and only if, compared to other observed DMUs, none of its inputs or outputs can be improved without worsening some of its other inputs or outputs. This is also called relative Pareto optimality.

Relative efficiency of the unit when compared to its peer groups is the amount of input that could be eliminated or the amount of output increased without worsening any other input or output. The peer groups might change over time or as the result of managerial decisions, because of changing the production technology or merging with other entities.

Scale efficiency: Is the difference between the “variable returns to scale” model, BCC, and the “constant return to scale” model, CCR, as a production scale effect. Scale efficiency represents the failure in achieving the most productive scale size and the score difference between CCR and BCC models reflects that. It is computed as the CCR efficiency score divided by the BCC efficiency score:

3.7 Formula relating input, output and number of production units
One rule of thumb is that there should be at least twice as many DMUs as there are inputs and outputs combined. (see e.g. [24] S. Sigaroudi 2009 chpt. 4 p.26 and [20] R. S. Sale, M.L. Sale 2003 ) and If this is not the case then the likelihood of most or all DMUs receiving efficiency scores at or near 1.0 is great. Again, this limits the interpretive power of the DEA.

More precisely the general rule for DEA models requires n >=max {3(m + s),m × s}.

3.8 Slack factors
(See e.g. [24] S. Sigaroudi 2009 page 11)

Input Slack factor: identifies the minimum value x for input m without changing other inputs or output y when (x, y) belongs to the PPS
Input substitution factor: identifies the smallest value x for input m that is possible for any x such that (x, y) belongs to the PPS
Output Slack factor: identifies the maximum value y for output s without changing other outputs or inputs when (x, y) belongs to the PPS
Output substitution factor: identifies the largest value y for output s that is possible for any y such that (x, y) belongs to the PPS

§ 4 The input and output factors of a pilot study.
The research was carried out with the design of a questionnaire, that was distributed in at least 10 of the about
15 functioning Stock Exchange Brokerages, in Greece after the economic Crisis. (10 years ago, there were more than 90 such brokerages!). Therefore the sample although seeming small is a quite representative of the totality of such enterprises. There were also interviews with the main software company that provides most of the back-office, and middle-office software for Brokerages, so as to chose the inputs and outputs, that would make most sense in assessing the relative efficiency of the best use of IT in the Greek Stock Exchange Brokerages. Then an interview was conducted for each company, to collect the data and discuss their reliability and meaning. It was given the promise not to reveal the identity of each Brokerages for obvious reasons. As the practical ruler followed here (see paragraph 3.7) was that the number of inputs plus the number of outputs are about half the number of companies and the companies were 10, the number of inputs + number of outputs = 5.

The inputs were three
INPUT1=Number of users of ERP modules systems in the Brokerage
INPUT2=Average monthly cost of maintaining the ERP modules systems
INPUT3=Total memory storage capacity
And the outputs two
OUTPUT1=Estimated percentage of business processes executed through the relevant ERP modules
OUTPUT2=Annual net profits of the company.

The collected data are in the next table 1

<table>
<thead>
<tr>
<th>DMU No.</th>
<th>INPUT1</th>
<th>INPUT2</th>
<th>INPUT3</th>
<th>OUTPUT2</th>
<th>OUTPUT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 1</td>
<td>8</td>
<td>2,500</td>
<td>12</td>
<td>95</td>
<td>30.50</td>
</tr>
<tr>
<td>DMU 2</td>
<td>50</td>
<td>3,000</td>
<td>25</td>
<td>94</td>
<td>389.00</td>
</tr>
<tr>
<td>DMU 3</td>
<td>7</td>
<td>1,200</td>
<td>6</td>
<td>75</td>
<td>51.00</td>
</tr>
<tr>
<td>DMU 4</td>
<td>9</td>
<td>2,000</td>
<td>9</td>
<td>85</td>
<td>482.00</td>
</tr>
<tr>
<td>DMU 5</td>
<td>8</td>
<td>500</td>
<td>10</td>
<td>80</td>
<td>578.00</td>
</tr>
<tr>
<td>DMU 6</td>
<td>9</td>
<td>5,000</td>
<td>11</td>
<td>95</td>
<td>315.00</td>
</tr>
<tr>
<td>DMU 7</td>
<td>120</td>
<td>10,000</td>
<td>50</td>
<td>87</td>
<td>3000.00</td>
</tr>
<tr>
<td>DMU 8</td>
<td>20</td>
<td>7,000</td>
<td>17</td>
<td>97</td>
<td>0.00</td>
</tr>
<tr>
<td>DMU 9</td>
<td>90</td>
<td>6,000</td>
<td>40</td>
<td>98</td>
<td>460.00</td>
</tr>
<tr>
<td>DMU 10</td>
<td>110</td>
<td>3,000</td>
<td>30</td>
<td>93</td>
<td>2000.00</td>
</tr>
</tbody>
</table>

§ 5 Efficiency analysis results
The results after running an input oriented constant returns (CRS) to scale and variable returns to scale (VRS) classification of relative efficiency are summarized in the next table. As expected the variable returns to scale model derives a larger number of efficient Brokerages. The results indicate that most of the Brokerages make a rather efficient use of their IT and front-office, middle-office and back-office software.

<table>
<thead>
<tr>
<th>DMU No.</th>
<th>DMU Name</th>
<th>CRS Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 1</td>
<td></td>
<td>1.00000</td>
</tr>
<tr>
<td>DMU 2</td>
<td></td>
<td>0.37670</td>
</tr>
<tr>
<td>DMU 3</td>
<td></td>
<td>1.00000</td>
</tr>
<tr>
<td>DMU 4</td>
<td></td>
<td>0.97952</td>
</tr>
<tr>
<td>DMU 5</td>
<td></td>
<td>1.00000</td>
</tr>
<tr>
<td>DMU 6</td>
<td></td>
<td>0.98364</td>
</tr>
</tbody>
</table>
Table 3

<table>
<thead>
<tr>
<th>DMU No.</th>
<th>DMU Name</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DMU 1</td>
<td>1.00000</td>
</tr>
<tr>
<td>2</td>
<td>DMU 2</td>
<td>0.81987</td>
</tr>
<tr>
<td>3</td>
<td>DMU 3</td>
<td>1.00000</td>
</tr>
<tr>
<td>4</td>
<td>DMU 4</td>
<td>1.00000</td>
</tr>
<tr>
<td>5</td>
<td>DMU 5</td>
<td>1.00000</td>
</tr>
<tr>
<td>6</td>
<td>DMU 6</td>
<td>1.00000</td>
</tr>
<tr>
<td>7</td>
<td>DMU 7</td>
<td>1.00000</td>
</tr>
<tr>
<td>8</td>
<td>DMU 8</td>
<td>1.00000</td>
</tr>
<tr>
<td>9</td>
<td>DMU 9</td>
<td>1.00000</td>
</tr>
<tr>
<td>10</td>
<td>DMU 10</td>
<td>0.92692</td>
</tr>
</tbody>
</table>

§ 6 Deduced suggestions to managers

Nevertheless two of the Brokerages are not relatively efficient compared to the other. The suggested increase in the inputs, so as to become relative efficient in using the ERP, that is in INPUT1=Number of users of ERP modules systems in the Brokerage, INPUT2=Average monthly cost of maintaining the ERP modules systems, INPUT3=Total memory storage capacity, in the constant returns to scale (CRS) model, for the non-efficient Brokerages are summarized in the next table 4.

Table 4

<table>
<thead>
<tr>
<th>DMU Name</th>
<th>INPUT1</th>
<th>INPUT2</th>
<th>INPUT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 2</td>
<td>9.27324</td>
<td>1130.08854</td>
<td>9.41740</td>
</tr>
<tr>
<td>DMU 4</td>
<td>8.81571</td>
<td>1022.48824</td>
<td>8.81571</td>
</tr>
<tr>
<td>DMU 6</td>
<td>8.85274</td>
<td>1447.409</td>
<td>10.82002</td>
</tr>
<tr>
<td>DMU 8</td>
<td>9.05333</td>
<td>1552.000</td>
<td>7.76000</td>
</tr>
</tbody>
</table>
And the resulting values for the outputs are summarized in the next table 5.

### Table 5

<table>
<thead>
<tr>
<th>DMU Name</th>
<th>OUTPUT2</th>
<th>OUTPUT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 2</td>
<td>94.00000</td>
<td>389.00000</td>
</tr>
<tr>
<td>DMU 4</td>
<td>85.00000</td>
<td>482.00000</td>
</tr>
<tr>
<td>DMU 6</td>
<td>95.00000</td>
<td>315.00000</td>
</tr>
<tr>
<td>DMU 8</td>
<td>97.00000</td>
<td>65.96000</td>
</tr>
<tr>
<td>DMU 9</td>
<td>98.00000</td>
<td>460.00000</td>
</tr>
<tr>
<td>DMU 10</td>
<td>93.00000</td>
<td>2000.00000</td>
</tr>
</tbody>
</table>

The suggested increase in the inputs, so as to become relative efficient in using the ERP, that is in INPUT1=Number of users of ERP modules systems in the Brokerage, INPUT2=Average monthly cost of maintaining the ERP modules systems, INPUT3=Total memory storage capacity, in the variable returns to scale (VRS) model, for the non-efficient Brokerages are summarized in the next table 6.

### Table 6

<table>
<thead>
<tr>
<th>DMU Name</th>
<th>INPUT1</th>
<th>INPUT2</th>
<th>INPUT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 2</td>
<td>9.21520</td>
<td>2459.61475</td>
<td>12.29054</td>
</tr>
<tr>
<td>DMU 10</td>
<td>15.15721</td>
<td>2780.77444</td>
<td>14.22984</td>
</tr>
</tbody>
</table>

And the resulting values for the outputs are summarized in the next table 7.

### Table 7

<table>
<thead>
<tr>
<th>DMU Name</th>
<th>OUTPUT2</th>
<th>OUTPUT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU 1</td>
<td>95.00000</td>
<td>30.50000</td>
</tr>
<tr>
<td>DMU 10</td>
<td>93.00000</td>
<td>2000.00000</td>
</tr>
</tbody>
</table>

§ 7 Concluding remarks
The simple conclusions of the preceding DEA analysis, is that in spite the economic crisis in Greece, most of the Brokerages are performing a relative efficient use of their ERP software, in producing financial services. This is natural due to the small size of the particular kind of enterprises, the high competition, and the efficiency of the information that each brokerage has for the other brokerages. The relatively small inefficiencies are correctable in the way suggested in the previous paragraphs.

Besides the above DEA analysis, interviews with personnel in the software companies that produce the software for the Stock exchange brokerages, revealed the next points of possible improvements, of the good use of the Information Systems

1) Greater use of the internet, in the interaction with the customer. E.g. not only systems that give the buy/sells etc orders of the customers through the internet but also free of charge technical analysis tools and risk analysis tools in real time.
2) The same as in 1) but using applications in mobile phones and smart phones.
3) Systematic weekly, communication and interaction of the Brokerages, with the data providers and the software production companies, so to redesign and upgrade the software systems in a consistent and continuous way. This will make the monthly cost of upgrade and utilization of the software systems.
4) Increase the number and kinds of middle-office software systems that calculate eg the risk of investment compared to the kind of software systems in the front-office and the back-office functions of the Brokerage.
5) Increase of the number and types that are utilized for automatic portfolio management and trading information systems.
6) Increase of the number and types of software systems that are utilized to compute by simulation the future profits and future loss of portfolios and trading.
7) Easier and universal free of charge for the customers virtual accounts (Demo accounts) for virtual or simulated transactions and trading.
8) Improvement of the security of the information systems for transactions in respect to personal data or trading data of the customers.

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