Discussion Papers in Management

The Path to Efficiency in DEA. Multidimensional Scaling as a Tool for Post-Optimality Analysis

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Number M01-1
October 2001 **ISSN 1356-3548**

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This version: September 2001

Cecilio Mar Molinero was a Professor on Sabbatical leave at the University of Zaragoza with a grant from the programme "Ayudas para estancias de profesores, investigadores, doctores y tecnólogos en España" funded by the Secretaría de Estado de Educación y Universidades.

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ABSTRACT

DEA measures efficiency by means of a mere score. This is clearly useful, but there is a need to look further away into the context in which efficiency is achieved. It is argued that Scaling techniques provide a framework for the interpretation of DEA efficiency scores. A methodology is proposed and illustrated by means of a case study: the dot com business. This methodology has the advantage of visualising the main characteristics of the situation under investigation, and revealing aspects that would otherwise have remained hidden. It is shown that DEA model selection can greatly benefit from its inclusion in a scaling framework. It is also shown how the methodology proposed can highlight various strategic behaviours that firms follow in the path to efficiency.

KEY WORDS

Internet, Dot Com, intangible assets, financial ratios, non-financial indicators, strategic groups, multidimensional scaling, multivariate statistics, DEA.

THE PATH TO EFFICIENCY IN DEA. MULTIDIMENSIONAL SCALING AS A TOOL FOR POST-OPTIMALITY ANALYSIS

1. INTRODUCTION

Data Envelopment Analysis (DEA) is now well established as a tool for the study of efficiency. The standard way of proceeding in a DEA study is to obtain data on inputs and outputs for a set of homogeneous decision-making units (DMU), to solve a mathematical programming problem that is basically an exercise in multiple comparisons, and to obtain a score between zero and one; Norman and Stocker (1991), Ganley and Cubbin (1992), Fare et al (1994), and Seiford (1996). This score, comparative efficiency, needs to be interpreted. DEA assumes that DMUs are interested in efficiency maximisation, but this may not necessarily be the case. DMUs may have other objectives that are not readily apparent. Is it possible to place the results of DEA in context so that we can distinguish between DMUs whose aim is (should be) to maximise efficiency, and DMUs that pursue different objectives even if they operate in the same area of business using the same inputs and the same outputs? Furthermore, efficiency is just a number. There are many ways of achieving the same level of efficiency when various inputs and outputs are involved. Different DMUs may have different strategic behaviour, something that is not reflected in the score. Is it possible to place the efficiency score in context so that the strategic behaviour of the DMU is revealed? This paper attempts to answer the above questions by means of a synthesis of DEA efficiency analysis and multivariate statistics tools.

Multiple comparisons have long been performed within a statistical context. Some of the tools used for this purpose are mathematical, such as cluster analysis, multiple discriminant analysis, logistic regression, principal components analysis, etc. Other tools, such as Self-organising neural networks (SONN) -Kohonen (2001)- and multidimensional scaling (MDS) attempt to visualise the characteristics of the data and have proven particularly productive in specific situations; Serrano Cinca (1996 and 1998), Mar Molinero et al (1996 and 2001). There is much in common between SONN and MDS as they both attempt to represent the main characteristics of the data in the form of a statistical map that is generated using non-linear algorithms. Here, MDS has been chosen in preference to SONN because the tools to interpret an MDS map (configuration) are well developed and available in standard statistical packages such as SPSS.

Rather than develop a mathematical argument and illustrate it by means of a case study, this paper proceeds in the opposite direction: a case study, the dot com sector, is used to illustrate how

DEA results can be interpreted within a MDS context.

This paper attempts to go beyond the pure measurement of efficiency. It is concerned with placing efficiency into context. This is done with the help of scaling tools, in particular MDS and its associated multivariate statistical techniques.

Section 2 describes the case study, the sample and the variables used. DEA analysis is reported in section 3. This is followed by an account of MDS results and their interpretation. The paper ends with a conclusion section.

2. THE CASE STUDY

The object of the case study is Internet dot com companies. This is a particularly interesting group of DMUs, since it is an area of business in which traditional management performance measurement tools do not work well. There are two main reasons for this to be the case. First, it is a new industrial sector, and time series of accounting information are not available, so that financial ratio analysis is often not even feasible; Lev and Zarowin (1999). Second, intangible assets- such as ideas, trade names, management efficiency, human resources, customer image- take a particular relevance in this sector; Trueman et al (2000). This lack of data could explain the paradoxical situation of firms that make losses but their shares are highly valued in the stock markets. Take, for example, Terra Networks, (http://www.terra.com), the company that took over the well-known Internet portal Lycos. During the first semester 2001, the most recent period for which information is available, Terra Networks made losses before taxes of 490,178,000 €. Any financial analyst would have described it as being on the verge of failure. But, despite the downturn taken by the new technology sector during the years 2000 and 2001, this company is highly valued by investors. On the 6th September 2001 its 621,266,000 shares were valued at 7 € each, a total market value of 4,348,862,000 €. Markets are clearly expecting this present negative stream of earnings to become positive in the future.

The usual way of explaining that a loss making company has high market capitalisation is to make reference to intangible assets and intellectual capital; Copeland et al (1995), Aboody and Lev (1998), Brooking (1997). A well-managed company with a good image, with high quality staff, that has achieved the loyalty of many customers -all of these being intangible assets- is expected to bring high profits in the future. But, how do we measure such intangible assets? Intangible assets cannot be directly measured, but some measurable performance indicators may be related to their

importance. For this reason, a set of performance indicators specific to the dot com business, known as web metrics, have been developed, and companies have been ranked according to such indicators; Demers and Lev (2000). But achieving high values of web metrics indicators, which can be considered to be the outputs of a production process, does not reveal the complete story since a high value of output can always be achieved by using inputs inefficiently. Thus, management efficiency has to be taken into account, and this is precisely the object of DEA analysis.

Web metric indicators are collected, processed and published by independent rating agents, such as Media Metrix, Netscoreonline, and Nielsen/Netratings. This study uses data collected by Netscoreonline (http://www.netscoreonline.com). This company uses panel samples to collect the data, and claims that its panels include over 1.5 million people. From all the information available, only reach, page hits, unique visitors, and time spent were included in the model.

"Reach" (y_1) gives a measure of market share, since it is defined as the proportion of all the Internet-using machines visiting a particular site as a proportion of all the machines that visit Internet sites during a specific time period. Achieving a high market share is clearly a management objective, and could be considered an output in a DEA study.

Once a user has accessed an Internet site, the company is interested in this user to visit as many pages as possible, since each page would typically contain some publicity, and the income generated by this concept depends on the number of times the page is visited. Publicity is an important source of revenue for many dot com companies. Following this reasoning, "page hits" (y_2), was also considered to be an output of the production process.

Some companies focus on electronic commerce. The number of times a page is visited is of less relevance than the number of users who visit the page, as a user can visit a page several times during an Internet session. This would measure the number of potential customers. Thus, "unique visitors" (y_3) was also included as a measure of output.

The last measure of output in the model was "time spent" (y_4). This is a statistic that gives information on the amount of time that a user spends visiting an Internet site. Long visits are more desirable than short visits, as they may indicate a higher level of interest in the product on offer.

In summary, a dot com company is interested in receiving many visitors, in such visitors surfing through many pages within the web site, in their staying connected for long periods of time, and on such customers being a high proportion of the total Internet users. These measures are clearly not independent, as a high level of reach cannot be obtained with a small number of unique

users when the market is potentially large but, different firms may have different strategies with respect to such variables, and this is a subject worthy of investigation.

Rating agencies merely publish web metrics data and rank firms according to such indicators, but this is a limited view of the world. It is important to take into account how a level of an indicator is achieved, the resources that go into obtaining the metrics, the inputs of the production process.

The classical inputs into the production process are often described as the four m's: men, machines, materials, and money. These have guided the selection of inputs as number of employees (x_1), total assets (x_2), total operating expenses (x_3), and total liabilities (x_4). Again, these are not independent, but they can be used in different proportions to achieve the same objective, and different ways of organising a firm can reflect different management strategies. Information on x_1 to x_4 was obtained from financial statements, which are published in the net by Edgaronline.com. This website collects its information from the Securities and Exchange Commission (SEC). Figure 1 summarises the inputs and outputs of the production process.

Figure 1 about here

Data was obtained for 74 dot com firms. All these firms are listed in the Internet Stock List (http://www.internetstocklist.com). Some firms, "Pure-Plays", operate solely in the Internet. Many, however, are known as "Brick and Click" since they operate only partially in the Internet. Information for all the variables included in the model, and in the post-optimality analysis was available for all the firms for the years 1999 and 2000. The 31st of March was chosen as the date for data collection, as accounting data is often made public around this date. Stock share prices were available for all the companies for the two successive years. The list of companies can be seen in Table 1.

Table 1 about here

Table 2 shows the values of the four inputs and the four outputs for each of the firms in the sample for the year 1999.

Table 2 about here

3. DEA EFFICIENCY

The first step in the analysis was to calculate DEA efficiency scores for all the dot com companies in the sample for the year 1999. This section will describe the DEA modelling process.

It has already been argued that the inputs in the model are not independent, and that the same is true of outputs. It follows that the information provided by an input (output) may have already been conveyed by another input (output), or by a combination of several inputs (outputs). Clearly, all inputs and outputs could be included in the model, but an attempt was made to engage in model selection in order to obtain a parsimonious representation of the dot com world. There are several approaches to model selection in DEA. For example, Norman and Stocker (1991) correlate efficiency measures with the value of a variable not included in the model. The model selection procedure implemented in this study was developed by Ruiz et al (2001). This methodology tries to establish up to what point a variable not included in a DEA study (either an input or an output) improves efficiency estimates when included in it. DEA efficiencies are estimated twice, once with the reduced model -which does not include the variable-, and once with the total model -which includes the variable.

Results of the selection process are reported in detail in Table 3. The table shows, for each model, the variables included. The last row of Table 3 shows the percentage of DMUs whose efficiency changed by more than 10% after the addition of an input or an output.

Table 3 about here

The first model estimated contained employees as an input and reach as an output and was estimated using constant returns to scale (CRS). This is the first basic model in the first step of Table 3. This model was next estimated with variable returns to scale (model 2), resulting in a change of 25%. The basic model was next incremented with total operating expenses (model 3) resulting in a change of 32%. The procedure was repeated with total assets as an extra variable (model 4), the change being 28%. Next, total liabilities was treated as an additional input (model 5) and the resulting change was 14%. The addition to the basic model of unique users (model 6) left the results unchanged. Page hits (model 7) changed only 3% of DMUs by more than the threshold value. Finally, the last model estimated in this step included time spent as an extra output with a change of 3%. The best results were, therefore obtained with employees and total operating expenses as inputs and reach as an output. This became the basic model in step 2 and the procedure

was repeated. The second step found the "best" model, which contained employees (x_1) and total operating expenses (x_3) as inputs, and reach (y_1) as output. It was estimated under VRS. This was found to be optimal in the sense that no great improvements were found by adding extra inputs or outputs, and no simplifications were found to be possible.

Nine firms were found to be 100% efficient. Efficiency ratings were found to vary greatly. Eleven firms returned efficiency values that were smaller than 1%. See Table 4 for the full results.

Table 4 about here

It is important to realise that variables are excluded because their presence does not result in great changes in efficiency scores. Thus, if some variables discarded by the model selection process are included, efficiency scores will not be greatly affected. Of course, one has to be sensitive to the relationship between DMUs and number of inputs plus outputs, and one has to remember that the number of fully efficient DMUs depends on the number of variables in the model, Pedraja et al (1999). Taking into account that there are 76 DMUs in the study, and only four inputs and four outputs, efficiency scores of the model selected using Ruiz et al (2001) procedures should not be very different from the efficiency scores obtained from the full model. Following this philosophy, efficiency scores were also estimated for the model that includes all four inputs and all four outputs, under constant returns to scale. Also, as firms differ in their strategic behaviour in the sense that some firms may be more interested in obtaining high values for page hits, while others may be interested in obtaining high values for time spent, efficiency scores were also estimated, under constant returns to scale, for four models that contained all four inputs and only one output. The relevance of this exercise in the interpretation of the results will be seen below.

Some thoughts are now in place. The model selection procedure applied has been based on the philosophy that if two models are roughly equivalent, the most parsimonious version is to be preferred. But two models are rarely equivalent. Efficiency does change, and the changes may important for some of the firms. These changes may or may not be indicative of important features of the production process. Before selecting a reduced model in preference to an extended model, one should start by establishing how influential the firm whose change is considered to be ignorable is in the overall understanding of the production process. This is a subject that will be taken up below.

Table 4 shows efficiency scores for a series of models. The variables included in the model are given in the first row of the table. The models are as follows: the most

parsimonious model obtained applying the model selection procedure; the full model with all inputs and all outputs under CRS; and models with only one output but all four inputs under CRS.

About (BOUT), Adobe (ADBE), Cybergold (CGLD), Drkoop (KOOP), Ebay (EBAY), Infospace (INSP), Lifeminders (LFMN), Uproar (UPRO) and Yahoo (YHOO) appear as 100% efficient in most models. Other firms, such as Fashionmall (FASH), and Homestead (HSTD) are efficient only in some of the models.

Examples of inefficient firms are: American Express (AXP), Bell Electric (BELL), Bellsouth (BLS), Dell Computer (DELL), Gateway (GTW), Gte. Corp (GTE), Southwest Airlines (LUV), Sprint (FON), Staples (SPLS), and Verisign (VRSN). All these firms are "Brick and Click". Brick and Click firms operate only partially in the Internet, and it should not be surprising to discover that they appear to be inefficient when judged only on the limited view of their performance in the Web.

Given a particular firm, efficiency depends on the model estimated. This is natural, as firms have various objectives, and if an input (output) that is particularly relevant to a firm is included (excluded), its efficiency rating will be affected. Some firms, that value a particular input (output) more than any other become efficient only when such an input (output) is in the model. Visual inspection of Table 4 reveals that many firms are efficient or inefficient according to the choice of inputs and outputs in the model. An example is ADOBE, which is always fully efficient except when the model contains only page hits as an output. This is consistent with the strategic behaviour of this company in the Internet, which is principally based on the distribution of a single product, Acrobat Reader®. Millions of users access the ADOBE website in order to download this product, but do not visit many of the pages available in the site.

It is hard to obtain a full view of the way firms aim at achieving efficiency just by looking at a mere score. This is a subject that will be further discussed within a MDS context.

4. MDS CONFIGURATION

Up to now we have been concerned with DEA efficiency analysis. This is obtained by means of a Linear Programming algorithm that performs multiple comparisons between the inputs and outputs of the production process for individual firms. In what follows, an attempt will be made to place DEA results into the context of the universe of firms. For this purpose, a statistical representation of the universe of firms, or configuration, will be created using Ordinal Multidimensional Scaling (MDS). Examples of uses of MDS for the analysis of

management problems are: Green and Maheshwary (1969), Moriarity and Barron (1976), Belkaoui and Cousineau (1977), Rockness and Nikolai (1977), Frank (1979), Libby (1979), Belkaoui (1980), Brown (1981), Emery et al (1982), Bailey et al (1983), Day et al (1987), Mar-Molinero and Ezzamel (1991), Mar-Molinero et al (1996), Hodgkinson et al (1996), and Mar-Molinero and Serrano-Cinca (2001).

Creating a MDS configuration involves a process of multiple comparisons but, when using MDS, there is no need to limit the amount of data available for each firm, as the technique engages in data reduction. This section will contain several subsections. First, the extra data included in the MDS analysis will be described. A summary account of the technique will be given next. This will be followed by an interpretation of the results.

4.1 Data for MDS analysis

To figure out the world of the dot com firms, the approach followed has been to obtain data on each company and to represent this company on a statistical map, or configuration. If two companies, on the basis of available data, are similar, they will be placed next to each other in the configuration. If the companies are different, they will be placed far from each other in the configuration. Using a metaphor, the configuration will place apples next to apples, pears next to pears, and apples far from pears. The technique will decide what is an apple, what is a pear, on which basis should the comparison take place, and where apples and pears should be located.

What data should we use to perform comparisons? This is not an easy question to answer. Dot com companies aim at making an impact on the net. They follow various strategies in order to achieve good results, and achieve them with various degrees of efficiency. The information required is of two different kinds: variables that measure the impact that a firm has on the web, and variables that measure the resources devoted to, or obtained from, making such an impact. These variables will be used in the form of ratios in order to control for size and in order to relate resources to results. If we do not work with ratios, comparisons between firms will be overwhelmed by size.

Impact on the web is measured by web metrics, as published by Netscoreonline. The resources employed are of a financial nature, and can be gathered from the balance sheet and from the profit and loss account. In total, values on 34 ratios were computed for each firm. Ratios 1 to 4 are related only to web metrics. They include reach (V1), already a ratio; page hits per visitor (V2); average number of seconds spent in a web site by a visitor (V3); and, since a visitor can visit a site

several times during the data collection period, average number of seconds spent in a web site per visit (V4). The full definitions can be obtained from the Netscoreonline website.

The next set of variables, V5 to V34, combines an accounting item with a web metrics measurement. The particular accounting items for which data was collected were revenues, selling and marketing expenses, gross profit, cash flow, number of employees, total assets, total operating expenses, total liabilities, and R&D expenses. These ratios are of two different kinds. Some ratios measure the amount of financial inputs per web metrics. This measures the amount of effort devoted to obtaining an impact. The other set of ratios attempt to measure the financial success of such an impact. An example of the first kind of ratio would be unique visitors per total operating expenses (V21). An example of a ratio of the second kind would be revenues per unique visitors (V15). Since our concern is to place efficiency in the context of strategy, the inclusion of financial ratios, where both the numerator and denominator of the ratio are accounting items, is not advisable. This is a standard way of proceeding in the study of strategic groups; Nayyar (1989). Table 5 gives a complete list of variables and definitions.

Table 5 about here

The sample of 76 companies is very mixed; it includes many different types of firms. For example, Yahoo (YHOO) is an Internet portal; EBAY conducts auctions in the web; DELL is a computer manufacturer that sells through the Internet; American Express (APX) is a financial services company; Bell Atlantic (BEL) is in the telecommunications business. This points towards a standard problem in management research: the presence of discordant observations. It is usual to start by identifying and removing from the data those companies whose behaviour does not conform to standard patterns of behaviour, but such a procedure has not been followed in this case. The reasons are twofold. First, the technique used in the analysis: MDS is robust to the presence of outliers. Second, discordant observations may have a story to tell and it is possible that more can be learned by leaving them in the sample than by removing them. Stolarski et al (1986) give a famous example of the importance of extreme observations. They relate the case of NASA computers, which were programmed to delete satellite observations of ozone concentrations below a specified level, thus failing to discover the existence of the so-called "ozone hole" over the South Pole.

4.2 MDS analysis

A measure of how different two companies are needs to be computed. This is known as a measure of dissimilarity. The measure of dissimilarity between any two companies is based on the 34 variables available for each company on which data is available. Before proceeding any further, it has to be noted that each variable is measured in different units. It does not make sense to do arithmetic with variables measured in different units. To overcome this problem, variables were transformed to zero mean and unit variance. The measure of dissimilarity was the Euclidean distance between two companies on the basis of standardised variables. This procedure resulted in a symmetric table of dissimilarities. Dissimilarities obtained in this way are transformations of correlation coefficients; Coxon (1982).

A decision has to be made on the number of dimensions on which the map is to be plotted. There are various ways in which this can be done. It is possible to exploit the mathematical links between Principal Components Analysis (PCA) and MDS; Chatfield and Collins (1980). Following this, the dissimilarity matrix was used as input in a PCA exercise. The number of eigenvalues taking values higher than 1.0 was found to be six, indicating that the map is to be constructed in a six-dimensional space. The percentage of the total variance explained by the first six eigenvalues was 89%, a very high value in this type of study. A different way of assessing dimensionality is to use the "elbow test", which attempts to measure the extra contribution that each additional dimension makes to a measure of goodness of fit, stress; Kruskal and Wish (1978). Again, a representation on to a six dimensional space was found to be appropriate.

The MDS configuration was calculated on a six dimensional space using the computer package SPSS. In this configuration, each dot com company is a point in the space, its position being given by a set of six coordinates. MDS implicitly performs PCA analysis, and the different coordinates are uncorrelated. Stress 1, a standardised measure of goodness of fit was found to be 0.056, this is described as "good" in Kruskal´s (1964) verbal classification.

Obviously, a point on a six dimensional space is impossible to represent other than mathematically by means of a vector. But it is possible to project the six dimensional cloud of companies on to pairs of two dimensions. The fact that coordinates on different dimensions are uncorrelated means that each dimension can be interpreted separately, and that projections on to specific pairs of dimensions may reveal important features of the problem. It has long been observed that even when a data set contains many dimensions, the aspects of the data that are relevant to the problem at hand can be revealed on a low dimensional representation; Thom (1989). The first dimension is always the most important from a statistical point of view in the sense that it explains the highest proportion of variance in the data. Dimension 1 is often found to be related to

some important feature of the case study. Figure 2 shows the projection of the configuration on to Dimension 1 and Dimension 2, and Figure 3 shows the projection of the configuration on to Dimension 1 and Dimension 3.

Figure 2 about here

Figure 3 about here

Most companies in Figures 2 and 3 appear cluttered in a small area of the map. A few companies, the ones that would normally have been classified as "discordant observations", are clearly visible. In Figure 2, "Pure Plays" such as YHOO, EBAY, UPRO, and LFMN, appear on the right hand side of the configuration. All these firms were found to be 100% efficient by the DEA algorithm. "Brick and Click" firms, such as GTE, FON, AXP and BEL appear on the lower left hand side quadrant of the same figure. These firms were found to be highly inefficient by the DEA algorithm. It appears to be the case, using visual inspection, that both the degree of involvement of the company in Internet business, and the efficiency with which this business is conducted, are related to the position of the company in the configuration. This will be further explored in the next section.

4.3 MDS interpretation and superimposition of DEA results

Visual inspection is always useful, but it is desirable to use more formal analytical approaches. In particular, we have used property fitting (Pro-Fit).

Property fitting is a regression-based technique. Its rationale is as follows. If the value taken by a characteristic (property) of the firm is related to its position in the configuration, a function exists that relates the value of the property to the coordinates of the firm in the space. In the absence of any information, this relationship is considered to be linear. This results in a multiple regression in which the dependent variable is the value of the property, and the explanatory variables are the coordinates of the firm in the space. The results of the regression can be represented graphically by means of a directional vector in the same way in which North-South directions are represented in a geographical map. A full discussion of property fitting techniques can be found in Schiffman et al (1981). The analysis can be internal or external. Internal analysis

represents as vectors variables that were used to create the configuration. External analysis represents as vectors variables that were not used in the estimation of the configuration, but that might be related to the position of the points in the map. After the regressions were estimated, directional vectors were standardised to unit length. In this way, if a vector appears to be long in a particular projection, it indicates a strong relationship between the property and the dimensions on which the vector is represented. In other words, a long vector in a particular projection indicates that there is a story that relates the position of the points in the projection and the value of the variable.

Internal analysis was carried out by representing as vectors all 34 ratios, V1 to V34. Regression results are given in Table 6. As can be seen in this table, R^2 were high, most of them higher than 0.8. Only when the regression results are good enough are the vectors represented in the configuration. In this case, only vectors with associated R^2 higher than 0.6 were drawn. The projections of these directional vectors on dimensions 1 and 2 can be seen in Figure 4. The projections of the same directional vectors in dimensions 1 and 3 can be seen in Figure 5.

Table 6 about here

Figure 4 about here

Figure 5 about here

Besides the 34 variables, V1 to V34, efficiency ratings were also treated as properties. These are the values listed in Table 3. The DEA results treated as properties were as follows: the most parsimonious model (DEA Opt) obtained using the procedure suggested by Ruiz (2001); the full model with four inputs and four outputs under CRS (DEA Full); a model with four inputs and Users as an output (DEA Users) under CRS; a model with four inputs and Page Hits as an output (DEA Hits) under CRS; a model with four inputs and Time Spent as an output (DEA Time) under CRS; and a model with four inputs and Reach as an output (DEA Reach) under CRS. Regression results can be seen in Table 6. R^2 varied from 0.759 to 0.847, with the exception of the "optimal" model, that achieved only 0.539. DEA Opt is not shown in Figures 4 and 5 because the value of R^2 is lower than 0.6, although when represented, the vector appears to overlap DEA Full.

Figure 4 is the wind rose that helps to interpret the MDS configuration in Figure 2, and

Figure 5 is the wind rose that helps to interpret the MDS configuration in Figure 3.

The most striking feature of Figures 4 and 5 is that DEA related vectors are the longest ones amongst all the pro-fit lines, and that they all point towards the right hand side of the map, very close to the horizontal, indicating a strong relationship between Dimension 1 and efficiency in its various definitions. It is usual to attach labels to dimensions in a MDS exercise. Dimension 1 can thus be interpreted as "web management efficiency", an intangible management asset. Here we have a procedure to measure this intangible asset: it is just the value of the first coordinate of the point that represents the firm in the configuration. But we must remember that this efficiency has to be interpreted as efficiency in using resources in order to obtain results in the Internet. Firms whose position in Figures 2 and 3 are situated on the far right are associated with high levels of web efficiency, while firms whose position in these figures is situated on the far left are associated with low levels of web efficiency. A ranking of firms in terms of efficiency in the use of resources in the Internet is simply a ranking of firms on the first dimension of the MDS configuration.

To further explore this idea, the name of the companies in Figures 2 and 3 was replaced with the various measures of efficiency. As an example, Figure 6 shows DEA User efficiency in Dimensions 1 and 3 (Figure 3). The directional vector associated with DEA User has also been plotted in the configuration. It can be clearly seen how firms with high values of DEA Users plot towards the right of the map, in the direction of growth of the oriented vector, while firms with low values of DEA User efficiency plot towards the left of the figure. Clearly, a firm that targets the Unique Users web metric as one of its objectives would be interested to know both its position on the configuration and its efficiency rating.

Figure 6 about here

Figures 4 and 5 show the directional vectors associated with variables V1 to V34. These form a fan, with most vectors pointing in the positive direction of Dimension 1. In Figure 4, vectors that point towards the positive side of Dimension 2 are, from top to bottom: V3 (avg. time spent per user), V2 (page hits per user), V23 (page hits/number of employees), V29 (page hits/R&D expenses), V31 (page hits/total liabilities), V30 (page hits/total operating expenses), V25 (page hits/selling & marketing expenses), and V34 (time spent/total operating expenses). All these variables have measures of page hits or time spent in their definition. Vectors that point towards the

positive side of Dimension 1 but the negative side of Dimension 2 are, from bottom to top: V18 (unique visitors/cash flow), V19 (unique visitors/total assets), V10 (reach/total assets), V22 (unique visitors/total liabilities), V16 (unique visitors/selling & marketing expenses), V13 (reach/total liabities), V12 (reach/total operating expenses), V7 (reach/selling & marketing expenses), V21 (unique visitors/total operating expenses), V11 (reach/R&D expenses), and V20 (unique visitors/R&D expenses). These variables contain either reach or unique visitors in their definitions. Dimension 2 appears to be discriminating between two different strategic modes of behaviour: the firms that aim at attracting unique visitors, and the firms that focus on having their visitors surfing through many web pages and spending long periods of time in the web site. It is to be noticed that DEA vectors that contain in their definition time spent or page hits point further up than vectors that contain visitors or reach. When efficiency calculation includes time spent or page hits, achieving high values in ratios that contain these web metrics becomes relevant. When DEA efficiency is calculated on the basis of unique visitors or reach, the achievement of high values in variables that contain in their definition reach or unique visitors becomes important. Thus, it can be concluded that there are two paths to efficiency. Each firm that sails in the turbulent waters of electronic commerce needs to find its best wind in the compass. Some will aim for unique visitors and some will aim for high values of page hits.

Vectors V8 (gross profit/reach), V17 (gross profit/unique visitors), V24 (revenues/page hits), V26 (gross profit/page hits), V32 (revenues/time spent), and V33 (gross profit/time spent) point in the negative direction of Dimension 2, and in the positive direction of Dimension 3. The variables associated with these vectors have profit or revenues in their numerator. Their projections on Dimension 1, the dimension associated with efficiency, are very small. This indicates that, on the whole, achieving high profitability in the sense defined by these variables, and using resources efficiently are two independent aspects of the dot com firms. There is a widespread belief that a high web impact is achieved at the expense of profitability. This view is partially supported by the results of Pro-Fit analysis. In Figure 4 DEA associated directional vectors lean towards the top of Dimension 2, and project on the positive side of this dimension, while web profitability measures (V8, V17, V32, V33) project on the negative side of this dimension. This can be interpreted to mean that firms that achieve, say, a high value of V32, tend to have low values of DEA-Full efficiency. This effect is much more pronounced when Figure 5 is examined, as most DEA associated vectors point quite far down in Dimension 3, while web profitability measure vectors point towards the top of Dimension 3. We must emphasise the fact that web profitability ratios are not the same thing as financial profitability for the firm; they are only measures that relate income to web impact. A full profitability analysis would require knowledge of how profit is

achieved by the firm, since it is not the same thing to obtain income from publicity in the web, than from selling a product. The information required to perform such a study is not available.

Having interpreted how different areas of the configuration are related to the variables in the study, we are in a situation to comment on the strategic behaviour of individual firms. We will start with Figure 3. This figure highlights efficiency versus web profitability as defined in this study. We can see the case of "Brick and Click" companies such as the telephone communications companies GTE, FON, BEL, and BLS; the financial services company AXP (American Express); and the microprocessors manufacturer INTC (Intel). The area of Figure 3 in which they appear is characterised by high web profitability measures and low web efficiency. Also in Figure 3, towards the top of Dimension 2 but towards the right of Dimension 1 we find companies with high web efficiency and high web profitability measures. Two firms appear clearly in this region: ADBE and EBAY. ADBE is the only "Brick and Click" company that is also having impact in the web, and whose web metrics can be compared with the best in the Internet. EBAY, the leader in Internet auctions, is also atypical in the sense that it is a profitable "Pure Play".

The relationship between efficiency and strategy can be seen in Figure 2. Efficiency increases from left to right in this figure. Companies that plot at the top of this figure focus on page hits and time spent. Companies that plot at the bottom of this figure focus on reach and unique visitors. YHOO, EBAY, and UPRO plot in the top right hand quadrant indicating both web efficiency and high values of page hits. This is certainly the case. Visitors to EBAY spend long periods of time connected while they place their bids in the auctions. YHOO, the leading Internet portal and directory, is visited in order to conduct searchers or obtain information on the most diverse subjects. UPRO is a popular games destination. Companies that plot at the bottom of Dimension 2 focus on unique visitors. The salient example is LFMN (Life Minders), which provides specialised information to communities of subscribers.

5. CONCLUSIONS

DEA has long been established as a tool for the analysis of efficiency in cases when traditional measures of profitability are not appropriate. But DEA results in a mere score between zero and one. There are many ways in which this score can be obtained. Decision Making Units may follow different strategies in the path to efficiency. There may be several possible DEA models competing for implementation. It has been argued that Multidimensional Scaling provides

the framework to put efficiency into context, to allow us to look beyond efficiency scores. A case study, Dot Com companies, has been used to illustrate the methodology.

The proposed combination of both DEA and MDS goes beyond traditional analysis and provides a graphical visualisation of the context in which efficiency is achieved. It reveals the strategic behaviour of firms in relation to efficiency. In the specific example discussed, the methodology has shown the different strategic behaviours that exist in the dot com business.

MDS produces statistical maps that are supplemented with oriented vectors in the way geographical maps are supplemented with North-South directions. DEA efficiency has been plotted as a vector in a MDS configuration.

A question that arises in any practical study is what inputs and outputs should be included in a DEA model. Various model selection procedures have been proposed, all of them with the common characteristic of being more or less automatic in the way they are implemented. Model selection in DEA normally relies on the assumption that simplified and extended specifications are roughly equivalent. If this were the case, the different DEA associated vectors would overlap in the projection. But we have seen that this is not necessarily the case. Adding or removing an output to the specification results in a different DEA related vector. Any DEA model selection methodology compares efficiencies obtained from a simplified specification with efficiencies obtained from an extended specification. Clearly, there will be differences between the two sets of efficiencies for any given Decision Making Unit (DMU). The choice of a specification over the alternative rests in a judgement that these differences are not important. If the differences are not important, the two vectors will overlap. If the differences are important, the two vectors will plot differently in the configuration. Model selection in DEA should not be totally automatic, but supplemented with the tools of multivariate analysis and the knowledge of the area under investigation.

MDS maps are very useful: a simple picture can convey statistical and DEA results in a way that can be understood by a person not trained in statistical techniques. Decision makers can set objectives, segment markets, study their competitors, and understand the time evolution of their firm. MDS offers a tool that allows us to look beyond efficiency.

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No	Name	Ticker	Web address	SICCODE
1	ABOUT COM INC	BOUT	http://www.about.com	SIC-7370 Services-Computer Programming, Data Processing
2	ADOBE SYSTEMS INC	ADBE	http://www.adobe.com	SIC-7372 Prepackaged Software
3	ALLOY ONLINE INC.	ALOY	http://www.alloy.com	SIC-5961 Catalog & Mail-Order Houses
4	AMAZON COM INC	AMZN	http://www.amazon.com	SIC-5961 Catalog & Mail-Order Houses
5	AMERICAN EXPRESS	AXP	http://www.americanexpress.com	SIC-6199 Finance Services
6	AMERITRADE HOLDING CORP	AMTD	http://www.ameritrade.com	SIC-6211 Security Brokers
7	ASK JEEVES INC	ASKJ	http://www.ask.com	SIC-7389 Business Services
8	AUDIBLE INC	ADBL	http://www.audible.com	SIC-7389 Business Services
9	AUDIOHIGHWAY	AHWYQ	http://www.audiohighway.com	SIC-7374 Computer Processing
10	AUTOBYTEL COM INC.	ABTL	http://www.autobytel.com	SIC-5900 Retail
11	AUTOWEB COM	AWEB	http://www.autoweb.com	SIC-7500 Auto repair, services and garages
12	BARNESANDNOBLE COM INC	BNBN	http://www.barnesandnoble.com	SIC-5735 Retail-Record & Prerecorded Tape Stores
13	BELL ATLANTIC CORP	BEL	http://www.bell.com	SIC-4813 Telephone Communications
14	BELLSOUTH	BLS	http://www.bellsouth.com	SIC-4813 Telephone Communications
15	BIGSTAR ENTERT INC	BGST	http://www.bigstar.com	SIC-5961 Catalog & Mail-Order Houses
16	BUY COM INC	BUYX	http://www.buy.com	SIC-5734 Computer & Computer Software Stores
17	CDNOW INC/PA	CDNW	http://www.cdnow.com	SIC-5735 Record & Prerecorded Tape Stores
18	CISCO SYSTEMS INC	CSCO	http://www.cisco.com	SIC-3576 Computer Communications Equipment
19	CNET NETWORKS INC	CNET	http://www.cnet.com	SIC-7812 Motion Picture and Video Tape Production
20	COOLSAVINGS COM INC	CSAV	http://www.coolsavings.com	SIC-7389 Business Services
21	CROSSWALK	AMEN	http://www.crosswalk.com	SIC-7371 Computer Programming Services
22	CYBERGOLD INC	CGLD	http://www.cybergold.com	SIC-7311 Advertising Agencies
23	DELL COMPUTER CORP	DELL	http://www.dell.com	SIC-3571 Electronic Computers
24	DOUBLECLICK INC	DCLK	http://www.doubleclick.com	SIC-7310 Services-Advertising
25	DRKOOP CPM INC	KOOP	http://www.drkoop.com	SIC-8090 Miscellaneous Health and Allied Services
26	EARTHLINK INC	ELNK	http://www.earthlink.com	SIC-7370 Services-Computer Programming, Data Processing
27	EBAY INC	EBAY	http://www.ebay.com	SIC-7389 Business Services
28	EDGAR ONLINE	EDGR	http://www.edgaronline.com	SIC-7389 Business Services
29	EFAX	EFAX	http://www.efax.com	SIC-3577 Computer Peripheral Equipment, NEC Plotter Controll
30	EGGHEAD COM INC/DE	EGGS	http://www.egghead.com	SIC-5961 Catalog & Mail-Order Houses
31	EGREETINGS NETWORK INC	EGRT	http://www.egreetings.com	SIC-7389 Business Services

32	FASHIONMALL	FASH	http://www.fashionmall.com	SIC-5949 Sewing, Needlework, and Piece Goods Stores
33	FATBRAIN	FATB	http://www.fatbrain.com	SIC-5990 Retail Stores
34	FREESHOP COM INC	APTM	http://www.freeshop.com	SIC-7389 Business Services
35	GATEWAY INC	GTW	http://www.gateway.com	SIC-3571 Electronic Computers
36	GOTO COM INC	GOTO	http://www.goto.com	SIC-7389 Business Services
37	GTE CORP	GTE	http://www.gte.com	SIC-4813 Telephone Communications, Except Radiotelephone
38	HEADHUNTER NET INC	HHNT	http://www.headhunter.net	SIC-7389 Business Services
39	HOMESTEAD COM INC	HSTD	http://www.homesteadbank.com	SIC-6035 Savings and loan associations
40	HOTJOBS COM LTD	HOTJ	http://www.hotjobs.com	SIC-7389 Business Services
41	INFOSPACE INC	INSP	http://www.infospace.com	SIC-7374 Computer Processing and Data Preparation
42	INSWEB CORPORATION	INSW	http://www.insweb.com	SIC-7389 Business Services
43	INTEL	INTC	http://www.intel.com	SIC-3674 Semiconductors and Related Devices
44	IPRINT COM INC	IPRT	http://www.iprint.com	SIC-7389 Services-Business Services
45	IVILLAGE	IVIL	http://www.ivillage.com	SIC-2721 Periodicals, Paper
46	JFAX COM INC	JCOM	http://www.j2.com	SIC-4822 Telegraph & Other Message Communications
47	LIFEMINDERS INC	LFMN	http://www.lifeminders.com	SIC-7389 Services-Business Services
48	LOOKSMART LTD	LOOK	http://www.looksmart.com	SIC-7374 Computer Processing and Data Preparation
49	MAPQUEST COM INC	MQST	http://www.mapquest.com	SIC-7374 Computer Processing and Data Preparation
50	MARKETWATCH COM INC	MKTW	http://www.marketwatch.com	SIC-7374 Computer Processing and Data Preparation
51	MCAFEE COM CORP	MCAF	http://www.mcafee.com	SIC-7389 Business Services
52	MEDICONSULT COM INC.	MCNS	http://www.mediconsult.com	SIC-7310 Services-Advertising
53	MEDSCAPE INC	MDLI	http://www.medscape.com	SIC-7374 Computer Processing and Data Preparation and
54	MOTHERNATURE COM INC	MTHR	http://www.mothernature.com	SIC-5412 Retail-Convenience Stores
55	MUSICMAKER COM	HITS	http://www.musicmaker.com	SIC-5961 Retail-Catalog & Mail-Order Houses
56	MYPOINTS COM INC	MYPT	http://www.mypoints.com	SIC-7370 Services-Computer Programming, Data Processing
57	NBC INTERNET INC	NBCI	http://www.nbci.com	SIC-7389 Business Services
58	NEXTCARD INC	NXCD	http://www.nextcard.com	SIC-6141 Personal Credit Institutions
59	NEXTEL COMMUNIC INC	NXTL	http://www.nextel.com	SIC-4812 Radiotelephone Communications
60	NOVELL INC	NOVL	http://www.novell.com	SIC-7372 Services-Prepackaged Software
61	ONHEALTH NETWORK CO	ONHN	http://my.webmd.com	SIC-7372 Services-Prepackaged Software
62	PRODIGY COMMUNIC. CORP	PRGY	http://www.prodigy.com	SIC-7370 Services-Computer Programming, Data Processing, Etc.

63	SOUTHWEST AIRLINES CO	LUV	http://www.southwest.com	SIC-4512 Air Transportation, Scheduled
64	SPORTSLINE COM INC	SPLN	http://www.sportsline.com	SIC-7374 Services-Computer Processing & Data Preparation
65	SPRINT CORP	FON	http://www.sprint.com	SIC-4813 Telephone Communications (No Radiotelephone)
66	STAPLES INC	SPLS	http://www.staples.com	SIC-5940 Retail-Miscellaneous Shopping Goods Stores
67	SWITCHBOARD INC	SWBD	http://www.switchboard.com	SIC-7389 Services-Business Services
68	THE STREET COM	TSCM	http://www.thestreet.com	SIC-2711 Newspapers: Publishing or Publishing & Printing
69	THEGLOBE COM INC	TGLO	http://www.theglobe.com	SIC-7310 Services-Advertising
70	TICKETMASTER	TMCS	http://www.ticketmaster.com	SIC-7990 Services-Miscellaneous Amusement & Recreation
71	TRVELOCITY COM INC	TVLY	http://www.travelocity.com	SIC-6770 Blank Checks
72	UBID INC	UBID	http://www.ubid.com	SIC-5961 Retail-Catalog & Mail-Order Houses
73	UPROAR INC	UPRO	http://www.uproar.com	SIC-7374 Services-Computer Processing & Data Preparation
74	VERISIGN INC	VRSN	http://www.verisign.com	SIC-7371 Services-Computer Programming Services
75	WOMEN	WOMN	http://www.women.com	SIC-2741 Miscellaneous Publishing
76	YAHOO INC	YHOO	http://www.yahoo.com	SIC-7373 Services-Computer Integrated Systems Design

Table 1. Companies in the sample

DMU	*Expenses*	*Total Assets*	*Employees*	*Liabilities*	*Reach*	*Unique Users*	*Page Hits*	*Time Spent*
BOUT	14398	15658	113	40320	14.2	6357	133146	1067
ADBE	668	767331	2679	250966	4.4	1962	26874	434
ALOY	12007	7407	25	10453	1.1	508	10319	93
AMZN	242719	648460	2382	509715	16.4	7355	227385	1676
AXP	15208000	126933000	84979	116735000	1.3	583	7112	39
AMTD	134384	1290402	982	1205830	0.9	422	7657	62
ASKJ	6367	9933	200	1642	6.3	2838	95057	903
ADBL	6813	12147	24	31675	0.5	223	2091	19
AHWYQ	3750	13467	24	2660	0.4	175	2100	29
ABTL	44469	34207	177	8339	1.4	636	18245	164
AWEB	23624	7185	81	5877	1.1	482	6350	45
BNBN	98121	202144	654	32995	6.6	2972	47477	397
BEL	24939000	55144000	125692	42119000	0.9	403	10753	118
BLS	17219000	39410000	88419	23300000	2.0	888	106650	2041
BGST	3330	1338	50	1833	3.0	1326	26504	180
BUYX	19802	26837	196	20202	2.9	1312	35376	276
CDNW	57019	69044	211	17905	7.0	3133	185872	1279
CSCO	9900	7663	21000	19825	0.4	185	14452	302
CNET	23877	88357	491	11884	8.9	4013	121319	805
CSAV	6061	6371	121	1777	6.0	2688	64435	450
AMEN	4126	4903	37	723	0.3	128	15747	186
CGLD	5385	4040	56	1938	6.7	3005	67376	403
DELL	2060000	6877000	24398	4556000	3.1	1378	38683	344
DCLK	84503	260361	482	5359	1.2	521	1534	6
KOOP	9160	380	63	2968	4.2	1891	35296	265
ELNK	229540	266341	1343	68997	8.8	3969	169566	3051
EBAY	57270	149536	138	48998	15.3	6853	3634757	27694
EDGR	3292	785	16	3006	0.2	101	1767	14
EFAX	32019	16215	116	2378	1.5	665	9478	93
EGGS	94584	245611	200	54103	3.8	1710	28111	238
EGRT	8115	2968	171	4457	4.2	1870	64405	674
FASH	2044	508	16	650	1.0	446	3493	18
FATB	15685	39614	260	3118	0.4	199	2986	18
APTM	4387	3687	120	4905	5.6	2499	29811	213
GTW	918825	2890380	19301	1546005	1.8	790	31753	265
GOTO	13731	19969	75	3572	8.4	3781	95183	648
GTE	20137000	43615000	120000	34849000	0.3	1698	27967	388
HHNT	4916	2225	122	4193	1.6	739	71052	361
HSTD	3041	88819	20	72877	2.0	894	50980	950
HOTJ	5201	3654	89	6537	0.9	405	17082	88
INSP	42992	103005	76	8281	14.5	6509	230850	1519
INSW	26212	49357	158	29775	0.4	183	1006	16
INTC	5806000	31471000	1386	8094000	4.7	2093	23978	312
IPRT	2581	914	135	4569	0.8	365	25827	116
IVIL	54965	45721	229	13699	5.2	2335	73309	682
JCOM	11164	10513	80	23829	0.3	137	502	4
LFMN	1969	278	85	477	5.1	2287	30959	399
LOOK	19097	14090	184	15351	9.2	4114	101714	634
MQST	10524	11450	222	31218	5.7	2535	68866	733
MKTW	16444	4487	65	7617	2.4	1075	27594	349
MCAF	4580	2438	103	7569	3.1	1411	43583	491
MCNS	5940	1142	35	864	0.4	168	1892	9

MDLI	17539	24308	298	6965	0.6	280	9786	88
MTHR	7135	13462	190	882	0.5	219	9054	52
HITS	4069	3234	15	4889	0.2	85	1227	12
MYPT	8494	18306	79	9023	6.3	2817	154989	709
NBCI	12747	66874	500	6541	3.1	1393	21810	224
NXCD	17261	45542	122	5605	3.6	1612	12811	63
NXTL	2899000	11573000	9702	9736000	0.2	93	3018	31
NOVL	727546	1924112	4326	430614	0.3	152	10307	120
ONHN	12541	3894	34	4195	0.9	396	3863	45
PRGY	113270	78332	395	48540	2.7	1199	12652	170
LUV	3480369	4715996	27643	2318078	2.4	1056	46572	351
SPLN	53157	137655	303	18692	5.3	2355	304756	2443
FON	8141000	33257000	64882	20809000	1.4	637	4894	45
SPLS	1420005	3179266	21576	1451871	1.3	604	10261	45
SWBD	10190	3565	42	14984	4.5	2030	76579	470
TSCM	16799	27581	122	4057	1.6	712	14283	214
TGLO	20232	38130	210	7829	6.3	2804	56550	501
TMCS	42195	416725	608	13137	3.4	1522	41580	448
TVLY	23451	11169	84	59100	6.0	2701	85026	744
UBID	13974	34625	100	15992	5.0	2223	38405	474
UPRO	6957	9111	144	1384	8.1	3628	145974	3273
VRSN	42621	64295	315	23567	0.3	155	993	21
WOMN	20831	18062	264	40767	3.0	1356	30408	228
YHOO	207645	781019	803	104007	56.0	25103	7065879	71958

Table 2. Values of the four inputs and the four outputs for each of the firms in the sample for the year 1999

	Step 1								*Step 2*							*Step 3*		
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*	*Model 3*	*Model 9*	*Model 10*	*Model 11*	*Model 12*	*Model 13*	*Model 14*	*Model 9*	*Model 15*	*Model 16*
Employees	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Expenses			X						X	X	X	X	X	X	X	X	X	
Assets				X							X							
Liabilities					X							X						
Reach	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Users						X							X					
Page Hits							X							X				
Time								X							X			
VRS		X								X						X	X	X
CRS	X		X	X	X	X	X	X	X		X	X	X	X	X			
T	25.0%	31.6%	27.6%	14.5%	0.0%	2.6%	2.6%	2.6%	31.6%	26.3%	5.3%	1.3%	0.0%	5.3%	5.3%	26.3%	55.3%	27.6%

T = Percentage of firms whose efficiency changes by at least 10% in the new model

Table 3. Results of model selection procedure

Ticker	*DEA Optimal*	*Full model*	*DEA Reach*	*DEA Users*	*DEA Hits*	*DEA Time*	*Full model 2000*
BOUT	100.00%	100.00%	100.00%	100.00%	32.05%	26.33%	84.32%
ADBE	100.00%	100.00%	100.00%	100.00%	63.39%	100.00%	2.00%
ALOY	65.60%	33.85%	32.81%	33.83%	5.50%	5.87%	19.22%
AMZN	10.12%	5.86%	5.70%	5.70%	1.48%	1.43%	5.45%
AXP	0.02%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
AMTD	1.62%	0.76%	0.72%	0.76%	0.09%	0.10%	1.10%
ASKJ	56.61%	66.26%	48.21%	48.42%	60.21%	30.07%	100.00%
ADBL	64.06%	14.33%	14.33%	14.27%	0.70%	0.79%	6.33%
AHWYQ	65.80%	12.93%	12.92%	12.60%	1.04%	1.61%	34.27%
ABTL	9.94%	6.60%	6.26%	6.34%	2.74%	2.19%	7.09%
AWEB	20.25%	11.24%	11.24%	10.98%	3.09%	2.05%	21.04%
BNBN	7.99%	7.93%	7.89%	7.93%	1.81%	1.35%	7.92%
BEL	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
BLS	0.02%	0.03%	0.02%	0.02%	0.01%	0.03%	0.03%
BGST	79.04%	75.57%	74.07%	72.96%	54.86%	30.62%	27.84%
BUYX	15.58%	12.64%	12.27%	12.38%	5.00%	3.96%	15.43%
CDNW	23.30%	25.76%	24.75%	24.70%	13.49%	9.80%	31.72%
CSCO	9.85%	8.77%	1.56%	1.61%	5.22%	8.77%	4.96%
CNET	29.96%	23.95%	22.43%	22.55%	12.60%	7.08%	16.83%
CSAV	61.07%	66.56%	63.05%	62.98%	44.53%	19.04%	89.05%
AMEN	49.48%	24.43%	9.15%	8.70%	24.44%	17.82%	11.14%
CGLD	100.00%	100.00%	100.00%	100.00%	58.93%	29.64%	83.17%
DELL	0.15%	0.12%	0.12%	0.11%	0.03%	0.03%	0.20%
DCLK	3.49%	3.49%	3.49%	3.38%	0.28%	0.05%	11.93%
KOOP	56.55%	100.00%	100.00%	100.00%	100.00%	76.14%	37.80%
ELNK	4.99%	7.28%	5.17%	5.20%	3.10%	5.12%	4.56%
EBAY	71.23%	100.00%	65.84%	65.74%	100.00%	100.00%	100.00%
EDGR	96.50%	13.96%	12.36%	13.91%	6.95%	4.74%	9.59%
EFAX	15.52%	14.27%	14.27%	14.10%	4.51%	2.79%	15.49%
EGGS	14.03%	10.76%	10.73%	10.76%	0.70%	0.75%	7.76%
EGRT	33.72%	53.89%	33.86%	33.61%	52.06%	44.14%	49.11%
FASH	100.00%	71.76%	71.75%	71.23%	19.30%	8.49%	14.69%
FATB	12.91%	2.33%	2.10%	2.33%	0.97%	0.29%	2.50%
APTM	66.26%	65.78%	65.77%	65.45%	24.17%	13.71%	100.00%
GTW	0.22%	0.13%	0.12%	0.11%	0.05%	0.06%	0.54%
GOTO	84.22%	86.38%	85.88%	86.17%	33.39%	20.02%	50.67%
GTE	0.01%	0.02%	0.00%	0.02%	0.00%	0.00%	0.02%
HHNT	40.83%	79.07%	17.96%	18.50%	79.06%	32.19%	46.94%
HSTD	100.00%	95.03%	77.32%	77.19%	26.41%	64.58%	100.00%
HOTJ	38.91%	15.38%	11.38%	11.42%	14.82%	6.16%	12.87%
INSP	100.00%	100.00%	100.00%	100.00%	36.61%	25.58%	32.70%
INSW	9.95%	1.98%	1.94%	1.98%	0.08%	0.15%	15.66%
INTC	2.32%	1.78%	1.78%	1.76%	0.07%	0.11%	0.17%
IPRT	75.95%	50.44%	11.96%	12.17%	50.42%	17.87%	100.00%
IVIL	17.01%	18.33%	17.90%	17.92%	6.95%	6.40%	16.68%
JCOM	19.89%	3.06%	3.00%	3.06%	0.18%	0.14%	5.83%
LFMN	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
LOOK	43.11%	42.02%	41.65%	41.53%	25.30%	13.75%	35.44%
MQST	32.30%	34.68%	32.17%	31.90%	20.24%	17.18%	82.55%
MKTW	33.53%	39.38%	31.52%	31.47%	20.53%	22.62%	29.35%
MCAF	47.31%	53.24%	38.88%	39.46%	48.66%	44.03%	37.76%
MCNS	44.84%	13.27%	13.27%	12.42%	4.91%	1.90%	6.14%

MDLI	11.54%	2.59%	2.26%	2.35%	1.77%	1.14%	6.46%
MTHR	28.08%	9.73%	5.30%	5.18%	9.73%	2.49%	24.09%
HITS	100.00%	10.28%	10.28%	9.76%	1.47%	1.62%	9.75%
MYPT	66.34%	71.65%	65.54%	65.37%	33.49%	17.43%	100.00%
NBCI	15.51%	10.12%	10.01%	10.03%	4.14%	3.69%	3.42%
NXCD	25.84%	23.32%	23.32%	23.28%	2.86%	1.20%	12.23%
NXTL	0.15%	0.01%	0.01%	0.01%	0.00%	0.00%	0.03%
NOVL	0.36%	0.07%	0.05%	0.06%	0.03%	0.04%	0.08%
ONHN	46.69%	21.59%	21.59%	21.19%	3.60%	4.18%	100.00%
PRGY	5.86%	5.37%	5.37%	5.32%	0.62%	0.93%	23.39%
LUV	0.09%	0.07%	0.07%	0.07%	0.04%	0.03%	0.21%
SPLN	13.89%	22.52%	13.28%	13.15%	20.82%	15.58%	29.26%
FON	0.03%	0.02%	0.02%	0.02%	0.00%	0.00%	0.03%
SPLS	0.14%	0.07%	0.06%	0.07%	0.01%	0.01%	0.25%
SWBD	81.84%	100.00%	88.70%	89.24%	74.53%	42.23%	96.95%
TSCM	15.41%	12.56%	11.22%	11.13%	4.26%	4.90%	9.65%
TGLO	25.41%	25.69%	25.07%	24.88%	8.85%	6.39%	44.86%
TMCS	6.87%	6.41%	6.02%	6.01%	3.61%	2.50%	16.76%
TVLY	50.67%	59.04%	57.07%	57.38%	28.14%	25.39%	100.00%
UBID	41.49%	39.76%	39.46%	39.13%	4.51%	7.03%	25.31%
UPRO	87.14%	100.00%	82.45%	82.35%	100.00%	100.00%	100.00%
VRSN	5.06%	0.87%	0.76%	0.87%	0.06%	0.14%	3.50%
WOMN	13.66%	11.03%	10.77%	10.85%	5.86%	3.66%	38.72%
YHOO	100.00%	100.00%	48.25%	48.22%	89.75%	100.00%	100.00%

Table 4. DEA efficiency estimates.

V1 Reach	**V18** Unique visitors/cash flow
V2 Page hits per user	**V19** Unique visitors/total assets
V3 Avg. time spent per user	**V20** Unique visitors/R&D expenses
V4 Avg. time spent per page	**V21** Unique visitors/total operating expenses
V5 Reach/number of employees	**V22** Unique visitors/total liabilities
V6 Revenues/reach	**V23** Page hits/number of employees
V7 Reach/selling & marketing expenses	**V24** Revenues/page hits
V8 Gross profit/reach	**V25** Page hits/selling & marketing expenses
V9 Reach/cash flow	**V26** Gross profit/page hits
V10 Reach/total assets	**V27** Page hits/cash flow
V11 Reach/R&D expenses	**V28** Page hits/total assets
V12 Reach/total operating expenses	**V29** Page hits/R&D expenses
V13 Reach/total liabilities	**V30** Page hits/total operating expenses
V14 Unique visitors/number of employees	**V31** Page hits/total liabilities
V15 Revenues /unique visitors	**V32** Revenues/time spent
V16 Unique visitors/selling & marketing expenses	**V33** Gross profit/time spent
V17 Gross profit/unique visitors	**V34** Time spent/total operating expenses

Table 5. Variables in the MDS

	Directional cosines						F	Adj. R square
	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6		
V_1	0.28	0.63	-0.11	0.32	-0.63	0.00	17.31	0.566
	(3.990)**	(7.332)**	(-1.265)	(3.212)*	(-4.815)**	(1.658)		
V_2	0.35	0.66	0.34	0.50	0.27	-0.07	206.25	0.943
	(15.450)* *	(23.792)**	(11.882)**	(15.512)**	(6.378)**	(-1.525)		
V_3	0.32	0.67	0.41	0.41	0.00	-0.32	58.31	0.821
	(7.485)**	(12.773)**	(7.644)**	(6.735)**	(2.562)*	(-3.638)**		
V_4	0.00	-0.02	0.29	-0.30	0.04	-0.91	8.97	0.389
	(-0.070)	(-0.236)	(3.311)*	(-3.075)*	(0.309)	(-6.257)**		
V_5	0.36	0.30	-0.42	0.22	-0.56	0.49	23.54	0.643
	(6.585)**	(4.516)**	(-6.140)**	(2.861)*	(-5.443)**	(4.251)**		
V_6	-0.21	-0.29	0.66	0.12	0.04	-0.64	9.12	0.394
	(-2.325)	(-2.707)*	(5.957)**	(0.961)	(0.257)	(-3.486)**		
V_7	0.62	-0.29	0.14	-0.70	-0.02	0.13	123.27	0.914
	(20.104)**	(-7.098)**	(3.038)**	(-12.821)**	(-0.310)	(2.026)		
V_8	-0.13	-0.26	0.50	0.48	-0.34	-0.57	43.11	0.771
	(-2.940)*	(-4.936)**	(9.090)**	(7.773)**	(-4.250)**	(-6.263)**		
V_9	0.42	-0.40	-0.41	0.38	0.60	0.03	96.67	0.889
	(14.744)**	(-11.518)**	(-11.439)**	(9.476)**	(11.317)**	(0.470)		
V_{10}	0.54	-0.54	-0.43	0.27	0.16	-0.37	48.87	0.793
	(10.262)**	(-8.498)**	(-6.594)**	(3.735)**	(1.674)	(-3.393)*		
V_{11}	0.63	-0.12	-0.01	-0.73	-0.15	0.18	67.92	0.874
	(14.413)**	(-1.693)	(-0.117)	(-7.617)**	(-1.606)	(1.612)		
V_{12}	0.67	-0.30	0.12	-0.61	-0.23	0.11	59.50	0.824
	(14.164)**	(-5.241)**	(1.976)	(-9.106)**	(-2.605)*	(1.092)		
V_{13}	0.47	-0.22	-0.47	0.01	-0.56	-0.44	52.31	0.804
	(9.734)**	(-3.790)**	(-7.711)**	(0.168)	(-6.235)**	(-4.417)**		
V_{14}	0.36	0.30	-0.42	0.22	-0.56	0.49	23.49	0.643
	(6.579)**	(4.508)**	(-6.137)**	(2.865)*	(-5.434)**	(4.249)**		
V_{15}	-0.04	-0.47	0.70	0.18	0.01	0.50	13.39	0.498
	(-0.475)	(-4.565)**	(6.722)**	(1.548)	(0.084)	(2.897)*		
V_{16}	0.62	-0.29	0.14	-0.70	-0.02	0.13	122.45	0.914
	(20.057)**	(-7.085)**	(2.992)*	(-12.751)**	(-0.316)	(1.999)		
V_{17}	-0.04	-0.31	0.45	0.65	-0.52	0.00	30.95	0.706
	(-0.672)	(-4.572)**	(6.370)**	(8.212)**	(-4.944)**	(-1.166)		
V_{18}	0.42	-0.40	-0.41	0.38	0.60	0.03	99.30	0.891
	(14.952)**	(-11.668)**	(-11.577)**	(9.614)**	(11.485)**	(0.475)		
V_{19}	0.00	0.00	0.00	0.00	-1.00	0.00	48.74	0.792
	(10.247)**	(-8.485)**	(-6.583)**	(3.736)**	(1.682)	(-3.391)**		
V_{20}	0.63	-0.12	-0.01	-0.73	-0.16	0.18	68.05	0.874
	(14.433)**	(-1.698)	(-0.127)	(-7.603)**	(-1.630)	(1.598)		
V_{21}	0.68	-0.30	0.12	-0.61	-0.23	0.11	59.76	0.825
	(14.209)**	(-5.255)**	(1.953)	(-9.106)**	(-2.614)*	(1.086)		
V_{22}	0.47	-0.22	-0.47	0.01	-0.56	-0.44	52.35	0.804
	(9.741)**	(-3.791)**	(-7.711)**	(0.169)	(-6.238)**	(-4.417)**		
V_{23}	0.41	0.67	0.28	0.52	0.16	0.09	77.90	0.860
	(10.935)**	(14.465)**	(5.891)**	(9.754)**	(2.332)	(1.185)		
V_{24}	-0.06	-0.44	0.53	0.28	-0.10	0.66	23.04	0.638
	(-0.972)	(-6.078)**	(7.077)**	(3.309)**	(-0.947)	(5.345)**		

$\mathbf{V_{25}}$	0.86 (20.596)**	0.42 (7.605)**	0.29 (4.561)**	-0.02 (-0.262)	0.02 (0.222)	0.07 (0.761)	94.12	0.890
$\mathbf{V_{26}}$	-0.04 (-0.964)	-0.37 (-8.194)**	0.47 (10.275)**	0.63 (12.073)**	-0.48 (-7.054)**	0.10 (1.261)	72.08	0.850
$\mathbf{V_{27}}$	0.39 (9.147)**	-0.16 (-2.994)*	-0.23 (-4.377)**	0.45 (7.483)**	0.74 (9.268)**	0.14 (1.626)	32.80	0.726
$\mathbf{V_{28}}$	0.60 (12.139)**	-0.36 (-6.003)**	-0.39 (-6.336)**	0.42 (6.065)**	0.32 (3.551)**	-0.28 (-2.754)*	50.78	0.799
$\mathbf{V_{29}}$	0.51 (11.270)**	0.54 (7.407)**	0.49 (5.153)**	0.42 (4.234)**	0.13 (1.280)	-0.14 (-1.250)	67.10	0.872
$\mathbf{V_{30}}$	0.78 (21.865)**	0.52 (12.030)**	0.28 (6.172)**	0.17 (3.376)**	-0.02 (-0.370)	0.08 (1.014)	120.54	0.905
$\mathbf{V_{31}}$	0.49 (9.521)**	0.45 (7.125)**	-0.16 (-2.509)*	0.24 (3.347)**	-0.58 (-5.991)**	-0.37 (-3.431)**	41.17	0.763
$\mathbf{V_{32}}$	-0.04 (-0.728)	-0.41 (-6.123)**	0.44 (6.524)**	0.30 (3.944)**	-0.13 (-1.275)	0.73 (6.470)**	25.00	0.658
$\mathbf{V_{33}}$	-0.02 (-0.644)	-0.39 (-8.452)**	0.47 (9.787)**	0.64 (11.878)**	-0.47 (-6.561)**	0.00 (3.383)**	69.37	0.845
$\mathbf{V_{34}}$	0.80 (15.442)**	0.36 (5.677)**	0.35 (5.405)**	-0.19 (-2.645)*	-0.21 (-2.143)	-0.17 (-1.619)	61.16	0.828
DEA Full	0.73 (14.478)**	0.19 (3.178)*	-0.39 (-6.257)**	0.15 (2.061)	-0.37 (-3.972)**	0.35 (3.345)**	48.89	0.793
DEA Reach	0.64 (12.317)**	0.05 (0.781)	-0.43 (-6.695)**	-0.01 (-0.148)	-0.52 (-5.363)**	0.37 (3.447)**	40.33	0.759
DEA Users	0.64 (12.324)**	0.05 (0.781)	-0.43 (-6.695)**	-0.01 (-0.143)	-0.52 (-5.359)**	0.37 (3.450)**	40.35	0.759
DEA Hits	0.86 (15.876)**	0.19 (2.905)*	-0.29 (-4.298)**	0.37 (4.815)**	-0.05 (-0.449)	-0.01 (-0.132)	53.98	0.809
DEA Time	0.94 (18.740)**	0.22 (3.620)**	-0.04 (-0.596)	0.20 (2.816)*	-0.06 (-0.662)	-0.18 (-1.722)	70.42	0.847
DEA Opt	0,60 (7.319)**	0.20 (1.959)	-0.47 (-4.571)**	0.01 (0.062)	-0.51 (-3.347)**	0.34 (2.002)	15.62	0.539

** Significant at the 0.01 level.

* Significant at the 0.05 level

Table 6. Pro-Fit Analysis. Regression results

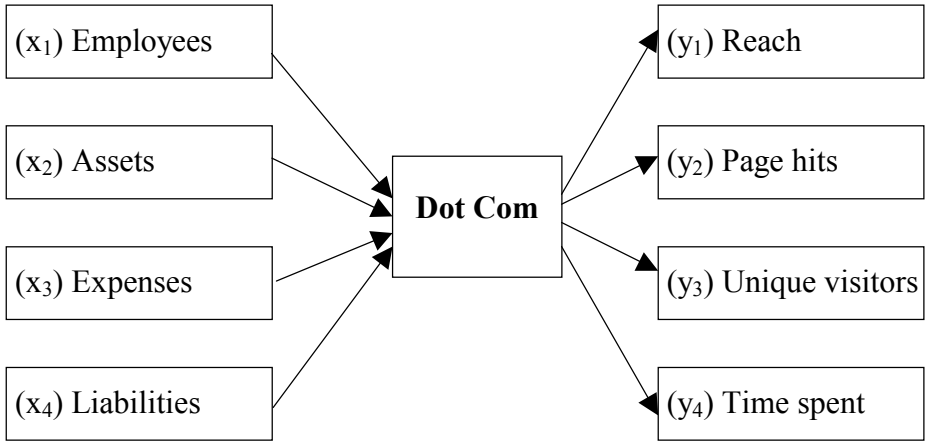

Figure 1. Input and Output in the Dot com industry

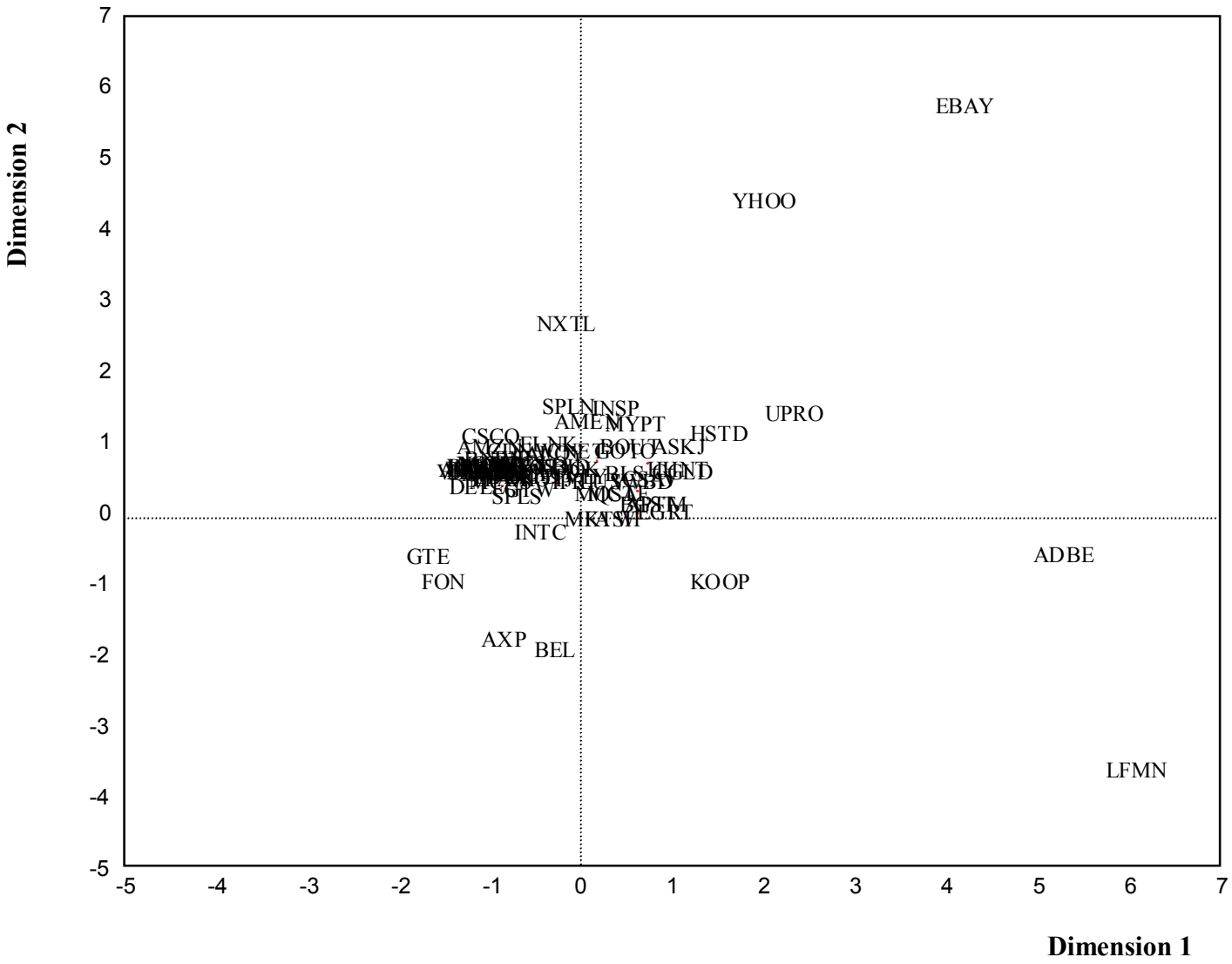

Figure 2. Multidimensional scaling results. Projection on Dimension 1 and Dimension 2. As argued in the text, most companies plot in a small area and their names overlap. The interesting companies are the ones whose name can be clearly read.

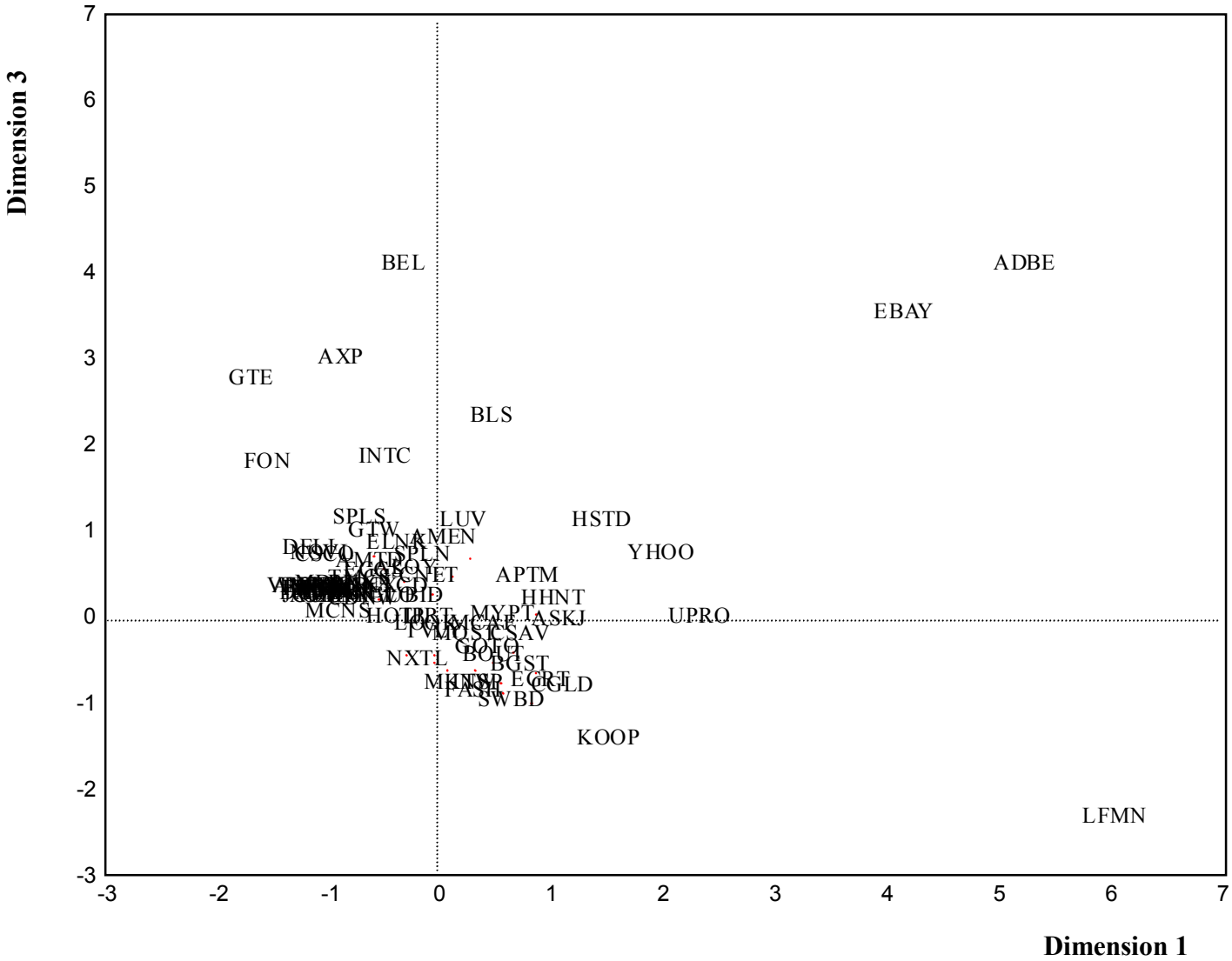

Figure 3. Multidimensional scaling results. Projection on Dimension 1 and Dimension 3. As argued in the text, most companies plot in a small area and their names overlap. The interesting companies are the ones whose name can be clearly read.

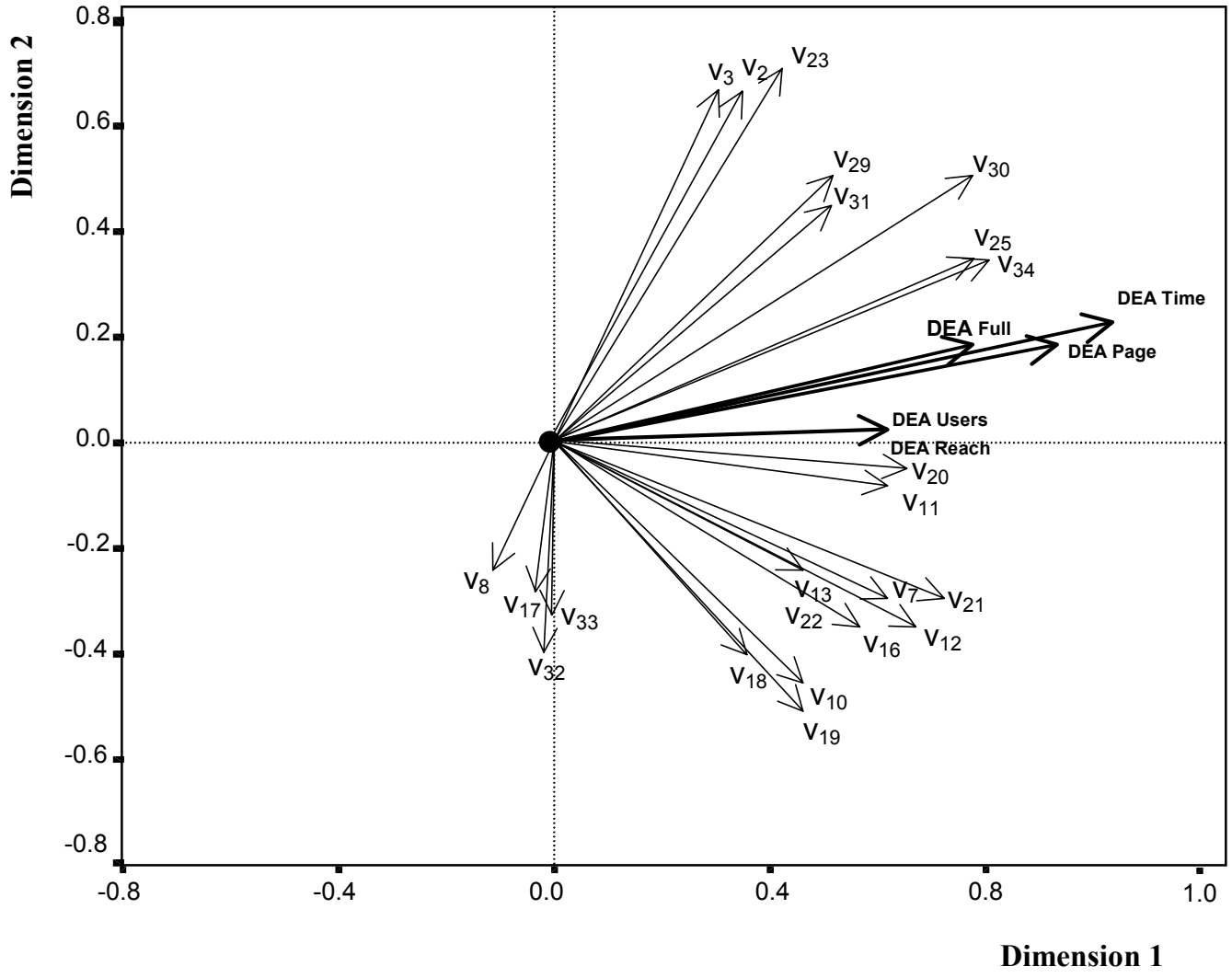

Figure 4. ProFit Analysis. Vectors for each variable. Dimension 1 and 2.

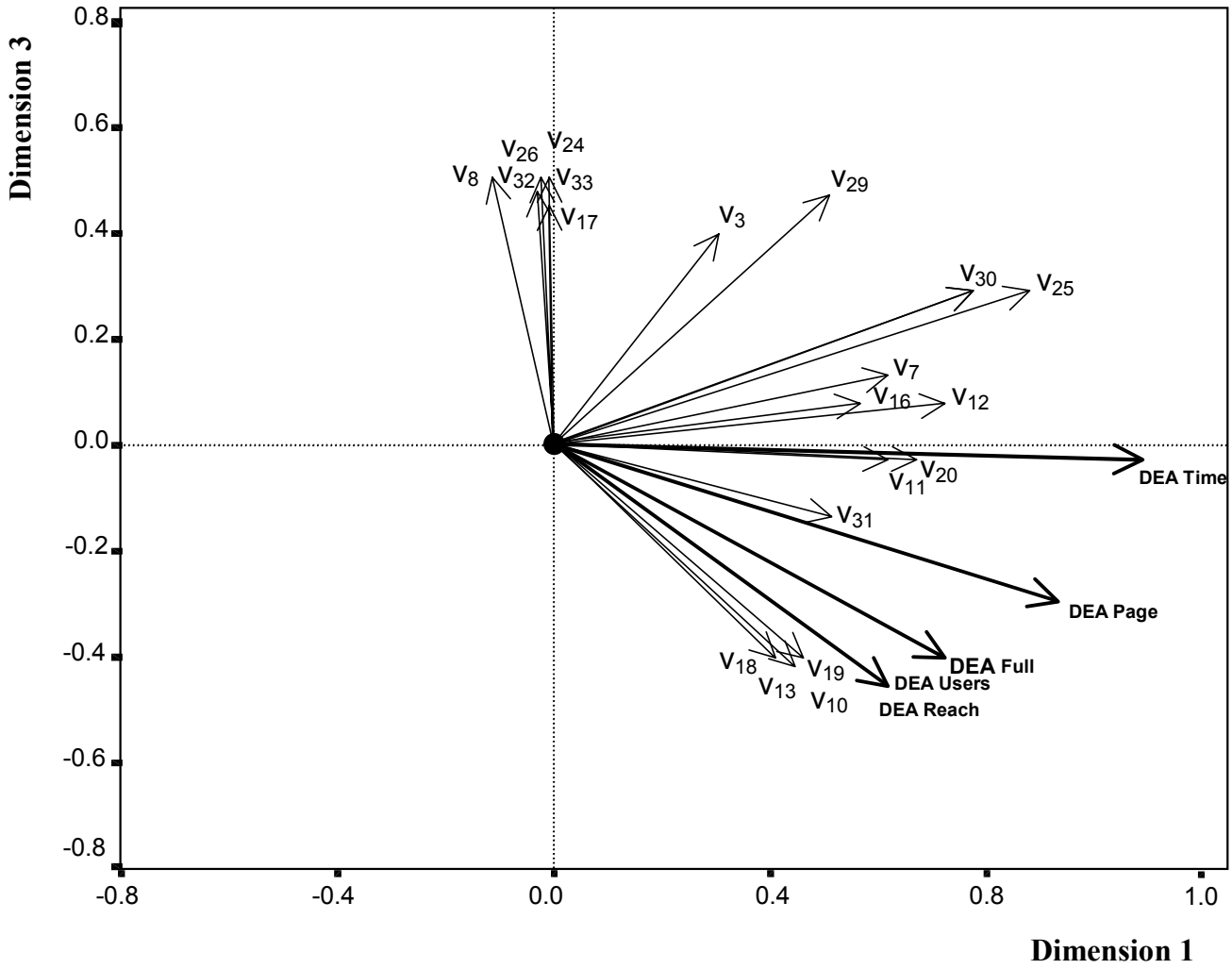

Figure 5. ProFit Analysis. Vectors for each variable. Dimension 1 and 3.

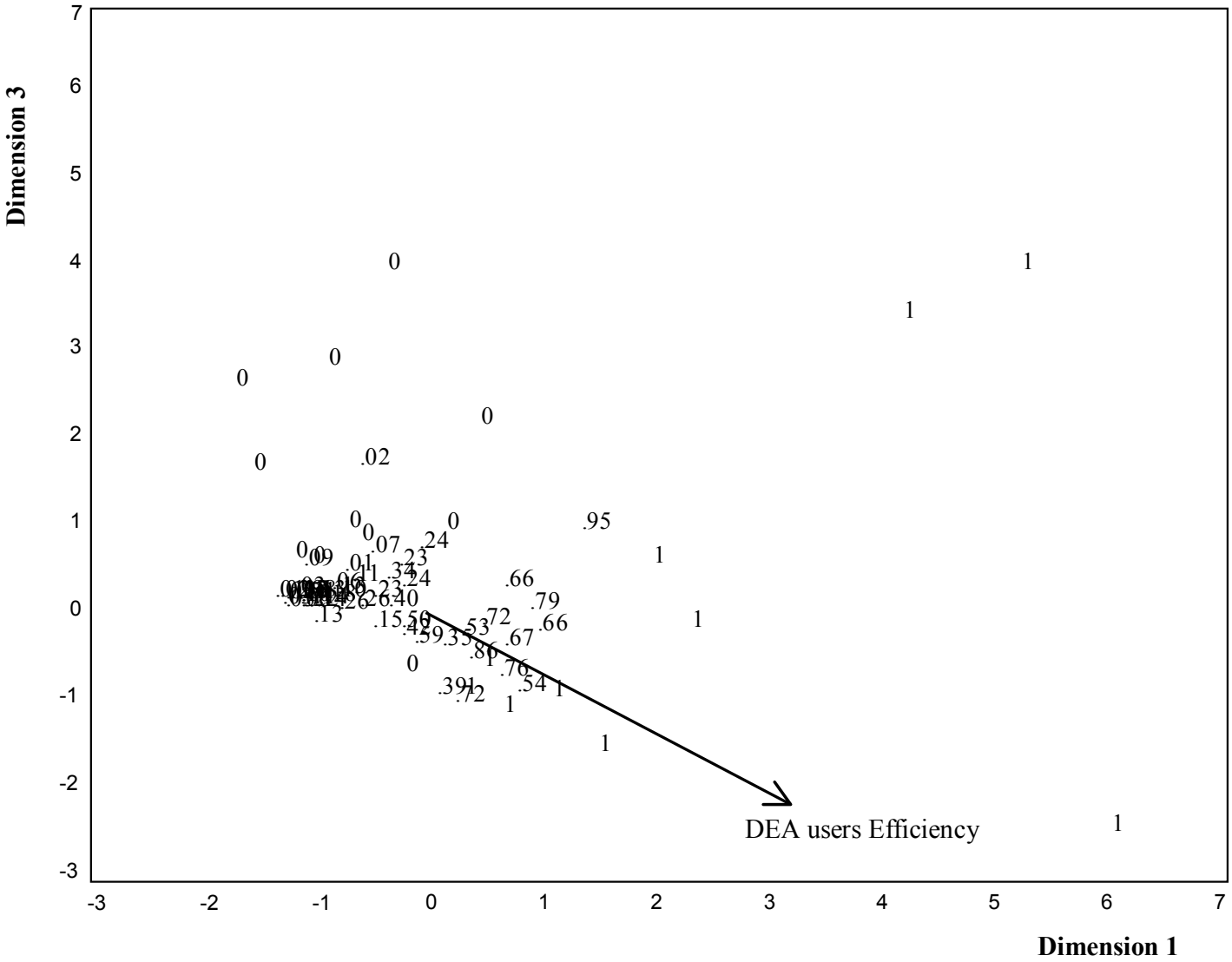

Figure 6. Superimposition of DEA efficiency on MDS Map. Dimension 1 and 3. As argued in the text, most companies plot in a small area and their observations overlap.