

# Retail Productivity Assessment Using Data Envelopment Analysis

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*Current approaches to retail productivity measurement have long been controversial because of difficulties in identifying the level of retail services. Data Envelopment Analysis, an operations research-based performance evaluation methodology, is introduced as one solution for resolving this problem and assessing managerially useful measure of store-level retail productivity. Data Envelopment Analysis measures relative-to-best performance efficiency of retail outlets characterized by multiple inputs and outputs. In an empirical illustration, using data collected over time from retail stores belonging to a restaurant chain, the potential applications and strengths of Data Envelopment Analysis in assessing retail productivity are highlighted.*

## INTRODUCTION

The purpose of this study is to suggest and illustrate Data Envelopment Analysis (DEA), an operations research-based methodology, to assess retail productivity. While still remaining in the output-to-input ratio measurement domain of retail productivity, DEA can measure retail productivity at the retail firm or store level using multiple inputs and outputs (both controllable and uncontrollable) simultaneously and provide a single relative (to best) productivity index.

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Retail productivity has been considered important for society and for the individual retail firm (Bucklin, 1978; Ingene, 1984). Despite a special issue of the *Journal of Retailing* (Fall, 1984) and subsequent research, there is still no single widely accepted definition and measurement methodology for retail productivity. Retail productivity is usually measured as ratios of outputs to inputs (Bucklin, 1978; Ratchford and Brown, 1985; Ratchford and Stoops, 1988). Bloom (1972) defined productivity as a ratio of output measured in specific units and any input factor also measured in specific units. A higher ratio of measured output to measured input factors can be directly interpreted as higher productivity.

For the most part such measures have been developed as macro tools, such as those created by the Bureau of Labor Statistics, and play an important role in assessing how efficiently a particular industry, or economy, is developing, absorbing technology, or offsetting rising wages. For these purposes, the existing techniques may be more appropriate. However, there is a need for such measures as micro tools (e.g., individual store level).

Despite its popularity in literature, the output-to-input ratio approach to retail productivity has several problems. First, retail productivity has been used interchangeably with labor or salesperson productivity simply because retailing is often a labor-intensive activity (Bush, Bush, Ortinau, and Hair, 1990; Ingene, 1982, 1984; Stern and El-Ansary, 1992; Thurik and Wijst, 1984), even though there is a large non-sales portion of labor force in retail industries. As a result, retail productivity has sometimes been treated as an issue of sales management. Focusing on an individual salesperson does not directly meet the measurement criteria of retail productivity because labor is simply one of the input factors (Good, 1984).

Second, traditional retail productivity studies have often focused on too micro units of analysis (e.g., salesperson evaluation; Bush, Bush, Ortinau, and Hair, 1990) or too macro units of analysis (e.g., retail industries or aggregation of stores; Goldman, 1992; Pilling, Henson, and Yoo, 1995; Yoo, Donthu, and Pilling, 1997). Previous research has ignored retail productivity with respect to individual stores and has not applied macro techniques to any extent as a managerial tool. Measuring productivity of individual stores would make the evaluation and control of managerial activities more feasible and objective. Retail managers need such store level productivity measurement tools.

Third, most previous measures have been absolute measures of productivity. These indexes are calculated by inserting numbers into the predetermined formulas or ratios. They do not take into account the performance of other retail outlets or other environmental circumstances. The productivity measurement of an individual retail outlet should be "relative" and incorporate the performances of other similar outlets.

We need a new approach to retail productivity measurement, that focuses on one outlet relative to the *best* performers rather than the *average* performers as done in the traditional absolute measures. There are two major advantages of relative-to-best measures. First, in contrast to relative-to-average measures, relative-to-best measures are consistent with quality control movements such as benchmarking. The best performing units need to be used as role models or the bases for evaluation (Farrell, 1957). Second, in contrast to absolute measures, relative-to-best measures show contingent productivity, which takes into account performances of other comparable units and environmental factors. The absolute

measures tend to focus only on controllable input factors such as labor and capital (Banker and Morley, 1986).

Finally, previous techniques of retail productivity such as cost function and total factor productivity indexes have a few drawbacks. Regression in the form of a cost function imposes a particular functional form. Total factor productivity, which refers to the measurement of efficiency of all employed inputs (Bucklin, 1978), and relates net output to the associated total factor input; that is, to the input of both labor and capital (Bloom, 1972). The weights employed in calculating indexes for total factor productivity (weighted sums of outputs divided by weighted sums of inputs) are often subjective.

In conclusion, to assess the productivity of outlets of a retail firm there is a need to develop an output-to-input ratio system which can handle multiple inputs and outputs in order to go beyond basic labor or capital productivity measurement. Ideally such a system would measure relative-to-best productivity or efficiency as opposed to absolute or relative-to-average values, and resolve problems in traditional measurement techniques (such as cost functions and total factor productivity discussed above).

In the next section Data Envelopment Analysis (DEA) is briefly introduced. Then, for an empirical illustration, the methodology is applied to 24 stores of a fast food restaurant chain using 4 inputs and 2 outputs. Also, the tracking of retail productivity over time and the sensitivity analysis of individual stores is performed. This technique provides a method for store-level productivity measurement and enhances retail management. The limitations of the technique are also discussed.

## **DATA ENVELOPMENT ANALYSIS**

Data envelopment analysis (DEA) is an operations research-based method for measuring the performance efficiency of decision units that are characterized by multiple inputs and outputs. DEA converts multiple inputs and outputs of a decision unit into a single measure of performance, generally referred to as relative efficiency. We suggest that DEA may be used to assess retail productivity/efficiency and to address some of the problems with existing retail productivity measures. While traditional approaches are more appropriate for macro-level analysis, DEA is a micro-level or store-level productivity measurement tool that may have more managerial relevance.

Charnes, Cooper, and Rhodes (1978) were the first to propose the DEA methodology as an evaluation tool for decision units. Since then, DEA has been applied successfully as a performance evaluation tool in many fields including manufacturing, schools, banks, pharmacies, small business development centers, nursing homes chains, maintenance units of the US Air Force, and hospitals, to name a few. Seiford (1990) provides an excellent bibliography of DEA applications.

In the marketing literature, Charnes et. al. (1985) first discussed potential applications of DEA. However, it has not been extensively applied in marketing. Kamakura, Ratchford, and Agrawal (1988) used DEA to measure market efficiency and welfare loss. Mahajan (1991) examined operations of insurance companies in a state. Parsons (1990) and Boles, Donthu, and Lohtia (1995) studied performance of salespersons using DEA.

In using DEA to measure retail outlet performance, the performance efficiency or productivity of a retail outlet is estimated by comparing its inputs and outputs with the inputs and outputs of all comparable outlets under consideration. The most distinguishing feature of DEA is that in computing the relative performance efficiency, the best performing outlets are used as the bases for comparison. Comparing a retail outlet's performance with that of the *best* performing outlets (often referred to as benchmarking) is an important step towards achieving a retailing operation oriented towards excellence. Retail firms can use internal (own retail outlets) or external (outside retail outlets) standards as their benchmark.

Productivity or efficiency in the context of DEA deals with producing the maximum quantity of outputs for any given amount of inputs or the minimum use of inputs for any given amount of outputs. The first task of DEA is to find the most efficient retail outlets, which produce a so-called efficient frontier, analogous to isoquants (equal-product curves) of production functions in microeconomics. The efficient frontier is a series of points, a line, or a surface connecting the most efficient outlets, which are determined from a comparison of inputs and outputs of all retail outlets under consideration. Thus DEA produces the relative efficiency boundaries, which are called envelopes.

Retail outlets lying on the efficient frontier are given the arbitrary efficiency score of one. Outlets whose efficiency is less than one are placed inside the frontier. A retail outlet is deemed efficient (efficiency = 1) if its output is optimal (maximum possible) for its inputs in comparison with the inputs and outputs of all comparable outlets.

Efficiency is the ratio of the weighted sum of outputs to the weighted sum of inputs. For example, if a retail outlet uses 2 input variables  $X_1$  and  $X_2$  and 2 output variables  $Y_1$  and  $Y_2$ , its efficiency

$$h_1 = \frac{U_1 Y_1 + U_2 Y_2}{V_1 X_1 + V_2 X_2}$$

In using DEA, the weights are estimated separately for each retail outlet such that its efficiency is the maximum attainable. DEA estimates the weights  $U_1$ ,  $U_2$ ,  $V_1$ , and  $V_2$  for outlet 1 such that its estimated efficiency  $h_1$  will be the maximum possible. However, the weights  $U_1$ ,  $U_2$ ,  $V_1$ , and  $V_2$  estimated for outlet 1 should be such that when they are applied to the inputs ( $X_s$ ) and outputs ( $Y_s$ ) of all other units in the analysis their ratio of weighted outputs to weighted inputs should be less than or equal to 1. Similarly, DEA will estimate a separate set of weights for each outlet such that the estimated weights will lead to a maximum attainable efficiency for that outlet. The estimated  $U$ 's and  $V$ 's for all outlets should be greater than zero. In contrast, regression estimates just one set of weights ( $U$ 's and  $V$ 's) for all outlets and forces one functional form relating inputs and outputs of all outlets under consideration.

In other words, the efficiency of any outlet is computed as the maximum of a ratio of weighted outputs to weighted inputs, subject to the condition that similar ratios, using the same weights, for all other outlets under consideration are less than or equal to one. Hence the maximum efficiency,  $h_o$ , for outlet  $o$  is:

$$\begin{aligned} \text{Max } h_o = & \frac{\sum_{r=1}^s U_r Y_{ro}}{m} \\ & \sum_{i=1}^m V_i X_{io} \\ \text{subject to} & \frac{\sum_{r=1}^s U_r Y_{rj}}{m} \leq 1 \text{ for all } j = 1, \dots, n \\ & \sum_{i=1}^m V_i X_{ij} \\ & u_r, V_i > 0; r = 1, \dots, s; i = 1, \dots, m; \end{aligned}$$

$Y_{rj}$  and  $X_{ij}$  are the  $r^{\text{th}}$  output and  $i^{\text{th}}$  input observations for the  $j^{\text{th}}$  outlet and  $U_r$  and  $V_i$  are the variable weights to be estimated by the data of all comparable outlets that are being used to arrive at the relative efficiency for the  $o^{\text{th}}$  outlet. The above formulation has  $s$  output variables,  $m$  input variables, and  $n$  retail outlets. In practice, the above formulation is first linearized and then solved using the methods of linear programming. The dual of the linear program is usually estimated as it is much easier to solve (Mahajan, 1991).

As seen above, DEA optimizes on each individual retail outlet's performance in relation to the performance of all other outlets. In comparison, regression methods perform just one optimization and obtain the average relationship across all retail outlets. Regression analysis estimates just one set of weights for all outlets. Recent advances in DEA allow for the estimated weights to be constrained so that no one input or output variable will dominate the efficiency estimation. It is also possible to set minimum limits for the estimated weights so that all inputs and outputs are forced to play a role in efficiency computation. Mathematically speaking, these just amount to additional constraints in the above optimization.

The efficiency computed by DEA assumes that 100% efficiency is attained for an outlet only when (1) none of the outputs can be increased without either increasing one or more inputs or decreasing some of its other outputs and (2) none of the inputs can be decreased without decreasing some of its outputs or increasing some of its other inputs. This is often referred to as Pareto Optimality. If there is no absolute standard of efficiency, as is the case in retail outlet performance evaluation, then we have to adopt a standard which refers to the levels of efficiency relative to known levels of attained efficiency by other retail outlets in similar conditions. Hence 100% efficiency is defined to have been attained by a retail outlet only when comparisons with other outlets do not provide evidence of inefficiency in the use of any inputs and in creation of any outputs.

DEA can accommodate, both, controllable and uncontrollable factors. Uncontrollable inputs / outputs are usually environmental or competitive factors which are beyond the control of management. Examples of uncontrollable factors are competitive conditions, location, demographics of clientele in the area, etc. In the case of DEA with both controllable and uncontrollable outputs, the formulation for efficiency ( $h_o$ ) for the  $o^{\text{th}}$  unit is:

$$\begin{aligned} \text{Max } h_o = & \frac{\sum_{r=1}^s U_r Y_{ro} - \sum_{k=1}^p W_k Z_{ko}}{\sum_{i=1}^m V_i X_{io}} \\ \text{subject to } & \frac{\sum_{r=1}^s U_r Y_{rj} - \sum_{k=1}^p W_k Z_{kj}}{\sum_{i=1}^m V_i X_{ij}} \leq 1 \text{ for all } j = 1, \dots, n \\ & U_r, V_i, W_k > 0; r = 1, \dots, s; i = 1, \dots, m; k = 1, \dots, p \end{aligned}$$

$Y_{rj}$ ,  $X_{ij}$ , and  $Z_{kj}$  are the  $r^{\text{th}}$  controllable output,  $i^{\text{th}}$  controllable input, and  $k^{\text{th}}$  uncontrollable output observations for the  $j^{\text{th}}$  outlet and  $U_r$ ,  $V_i$ , and  $W_k$  are the variable weights to be estimated by the data of all comparable outlets that are being used to arrive at the relative efficiency for the  $o^{\text{th}}$  outlet. The above formulation has  $s$  controllable output variables,  $m$  controllable input variables,  $p$  uncontrollable output variables, and  $n$  retail outlets. Because the uncontrollable variables cannot be controlled or manipulated by management, the basic idea behind this formulation is that the effect of the uncontrollable output is subtracted from the total output before computing the relative efficiency. Similar formulations can be incorporated for uncontrollable inputs also.

At the individual retail outlet level, DEA also provides rich diagnostic information through sensitivity analysis. For every retail unit not on the efficient frontier, DEA identifies a set of efficient reference outlets in the corresponding envelope. These efficient reference outlets (whose efficiency is 100%) help in identifying the inadequacies or slacks in the controllable inputs / outputs of the inefficient outlet. By comparing the controllable inputs and outputs of the inefficient outlet with the controllable inputs and outputs of a linear combination of the efficient reference outlets that comprise the frontier (a virtual outlet), the amount of slack in each of the variables can be computed. This helps the inefficient outlet identify how to allocate resources more efficiently and improve its productivity.

An inefficient outlet may become efficient by increasing all outputs by an amount equal to its corresponding slack (i.e., move towards the efficient frontier vertically in the case of a 2-dimensional plot) or by decreasing all controllable inputs by amounts equal to its corresponding slacks (i.e., move towards the efficient frontier horizontally in the case of a 2-dimensional plot). This is also referred to as decreasing the technical inefficiency (or  $x$ -inefficiency). Allocative inefficiency refers to moving on the efficient frontier to minimize cost and is not addressed by traditional DEA as the actual cost of the inputs are usually not known. Sensitivity analysis as explained above assumes that all inefficiencies are technical inefficiency and can be addressed by simply increasing output or decreasing input to move towards the frontier.

Input and output variables for DEA should be chosen such that they accurately reflect the retail firm's goals, objectives, and sales situation. The choice of the input and output vari-

ables is critical to the successful application of this technique. Factors that have a direct cost to the firm and tend to vary are a good choice for input variables. For example, if rent is a major cost to the firm that varies from store to store, then it should be included as an input variable. The choice of the output variables often reflect the goals or objectives of the company. For example, if customer satisfaction is an objective of the firm, it would make sense to include customer satisfaction as an output variable.

In summary, the main advantages of DEA-based retail outlet productivity evaluations are that:

1. DEA utilizes *both* output and input observations.
2. DEA accommodates *multiple* inputs and outputs.
3. DEA accommodates *both* controllable and uncontrollable factors.
4. DEA computes a *single index* of productivity.
5. DEA develops a *relative* measure of performance for each retail outlet using *best* performers as the bases.
6. DEA does not force *one* functional form relating the inputs and outputs of all observations.

From above it is clear that most of the limitations of the traditional productivity measurement techniques, such as output-input ratios, regressions, cost functions, and total factor productivity indexes discussed in the Introduction section can be addressed by DEA. Unlike regression, DEA does not impose any particular functional form on the data, creating a more flexible piecewise linear function. Also, unlike total factor productivity indexes, DEA gives each of the observations (i.e., individual stores) its own set of weights.

## EMPIRICAL ILLUSTRATION

Data for the empirical illustration was from a fast food restaurant chain. Data from a major metropolitan city with 24 outlets belonging to the chain were used in the analyses. Given that only data from the 24 stores, all belonging to this one chain, were used the analyses may be characterized as internal benchmarking.

Based on a literature review, the major input and output criteria that have been considered relevant for retail productivity assessment are summarized in Table 1. Input factors consist of controllable and uncontrollable factors, depending on whether a retail firm includes the factor in its management action plans. Uncontrollable inputs can be further divided into environmental factors and customer factors. Controllable factors can be divided into retail managerial factors and labor personal factors. Often, uncontrollable input factors are ignored in the assessment of retail productivity.

Profit as an output measure seems problematic. Profit includes both revenues, which are price times output quantity, and costs, which are factor prices times input quantity. Since it includes inputs as well as outputs, it would be desirable to avoid profit as an output measure. Service quality measurement issues have been well debated in retailing literature (see Parasuraman et al., 1994). Behavioral retail outputs should not be ignored because they are good indicators of the capability to make financial outcomes (Achabal, Heineke, and

TABLE 1

### Inputs and Outputs of Retail Productivity

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**Inputs**

1. Environmental conditions
  - Industry technology level/Retail & whole-sale structure Goldman 1992
  - Competitive conditions Goldman 1992; Ingene 1984; Piling, Henson, & Yoo 1995; Yoo, Donthu, & Piling 1997
  - National and regional economy (e.g., per capita income, population growth, and population density) Ingene 1982; Ortiz-Buonafina 1992; Piling et al. 1995
2. Customer factors
  - Socioeconomics and demographics/ Psychological wants and needs/Psychic energy expended/Shopping time invested Ingene 1984
3. Retail firm's managerial efforts
  - Size of firm (e.g., square feet of selling space) Bucklin 1978; Ingene 1982; Lusch & Moon 1984; Ratchford & Stoops 1988
  - Ownership type Douth 1984; Lusch & Moon 1984; Piling et al. 1995
  - Inventory investment Lusch & Serpkenci 1990
  - Current assets Bucklin 1978; Douth 1984
  - Labor control systems Oliver & Anderson 1994
  - Number of employees Bucklin 1978; Piling et al. 1995; Yoo et al. 1997
  - Labor intensity Good 1984; Ingene 1982
  - Capacity utilization/Firm's technology/ Labor turnover rate/Compensation method/Presence of unions Good 1984
  - Service capacity Douth 1984
  - Organizational culture Dunn, Norburn, & Birley 1994
  - Marketing mix strategies Cappel, Wright, Wyld, & Miller 1994; Conant, Smart, & Solano-Mendez 1993; Ingene 1984; Lusch & Moon 1984
  - Level of R&D Bucklin 1978
  - Overall wage rate Lusch & Moon 1984
4. Employees' personal factors
  - Hours worked Bucklin 1978; Douth 1984; Ratchford & Stoops 1988
  - Education Good 1984
  - Job training level & Motivation Bush et al. 1990; Lusch & Serpkenci 1990
  - Wage rate Bucklin 1978
  - Attitudes Bush et al. 1990; Meckenzie, Podsakoff, & Fetter 1993

**Outputs**

1. Financial or economic outcomes
    - Sales volume Bucklin 1978; Lusch & Serpkenci 1990; Ratchford & Stoops 1988
    - Profits & Value added Bucklin 1978; Douth 1984; Kendrick & Creamer 1965
    - Market share & Gross margin Ingene 1984; Lusch & Ingene 1979
  2. Behavioral outcomes
    - Service quality (e.g., SERVQUAL) Parasuraman, Zeithaml, & Berry 1994
    - Customer store loyalty/Customer & employee satisfaction Lusch & Serpkenci 1990
-

McIntyre, 1984). Also, Ingene (1984) emphasized the importance of understanding both the economic and behavioral views of output creation. It is important to consider outcomes beyond basic financial figures (Eccles, 1991).

The numerator and the denominator of an ideal output-to-input ratio formula for retail productivity would consist of a set of meaningful multiple output measures and a set of meaningful multiple input measures, respectively. If not, different productivity measures can be estimated for specific purposes by changing the elements of the numerator and/or the denominator of the ratio (Good, 1984).

For the illustrative example, the input and output variables were chosen in consultation with the retail chain management. In order to move away from complete reliance upon financial-based productivity measurement, we used both, financial and customer-based outputs. Sales (\$) and customer satisfaction were the 2 output variables included in the analyses. Sales and customer satisfaction data for three years were used. Customer satisfaction was measured at each store several times in a year. Each store had at least 600 random customer satisfaction surveys conducted each year. These surveys were conducted in all stores at various times of the day and on different days of the week to reduce respondent and situation bias. While several questions were used in the satisfaction survey, here we only use overall satisfaction measured on a 5 point scale.

Four types of input variables were used in the analyses. Store size (in square yards of serving area), store manager experience with the chain (in years), store location (inside a shopping mall versus free-standing) and promotion/give-away expenses (\$) were used as the input variables. They represented capital or capacity, personnel/labor or managerial, environmental (uncontrollable or fixed), and marketing variables, respectively. Labor costs such as employee wages were not included in this example because management felt that their labor cost did not vary from store to store. Once again, the main motivation was to use as many different kinds of major inputs as possible in this illustrative example. As discussed in the literature review, in the past studies tended to focus on just one kind of input or output and usually ignored uncontrollable inputs.

Sales and customer satisfaction may be considered as an approximate measure of the number of customers created and the store loyalty of these created customers, respectively. Store location (inside a shopping mall versus free-standing) may be considered a major environmental factor that influences demand. Store location represents unique competition and customer demographic characteristics of the very spot where the store is located. Management treats store location as a surrogate for traffic (or demand) and consumer characteristics. Restaurants within a shopping mall attract a very different amount and kind of customers. Hence, the store location variable indirectly captures customer demographics for each store. Because stores of the same restaurant chain operating in one city were analyzed, other environmental factors such as population demographics, store technology levels, and regional economy remained almost equal among the stores analyzed; therefore, they were not included as input factors in this illustration.

In the first analysis the data on the six variables (2 outputs and 4 inputs) from the first year only were used in DEA. The estimated efficiencies for the 24 stores, along with their rank orders, are shown in Table 2. As explained before, these efficiencies were computed for each store after taking into consideration the inputs and outputs of all 24 stores in the set. Hence these efficiencies are relative efficiencies. Moreover, the efficient stores (whose

TABLE 2

## Efficiency of Stores (DEA Versus Regression)

Store Number	DEA Efficiency	DEA Ranking	Regression 1 Ranking <sup>a</sup>	Regression 2 Ranking <sup>b</sup>
1	.73	21	23	21
2	.70	23	24	23
3	.88	12	1	7
4	1.0	1	2	5
5	1.0	1	12	8
6	.90	9	3	6
7	.72	22	22	18
8	.82	16	4	9
9	.97	8	11	17
10	1.0	1	13	12
11	1.0	1	15	19
12	.77	20	18	10
13	.70	23	19	24
14	.80	18	14	22
15	.88	12	8	15
16	.78	19	16	20
17	1.0	1	10	13
18	.87	14	17	16
19	1.0	1	7	2
20	.89	11	9	3
21	.81	17	20	14
22	.81	17	20	14
23	.90	9	5	11
24	1.0	1	6	4

Notes: a. using Sales as the dependent variable.

b. using Customer Satisfaction as the dependent variable.

efficiency = 1) were used as the benchmark. Therefore these efficiencies represent relative-to-best efficiencies. While standard optimization computer packages can be used for estimation, here we used a commercial DEA package called IDEAS (see Seiford (1990) for citations on DEA-related computer programs).

Stores 4, 5, 10, 11, 17, 19, and 24 had efficiency of 1 and hence lie on the efficient frontier. All other stores were inefficient (had efficiency less than 1) and hence lie inside the frontier. Given that we used 2 outputs and 4 inputs, a pictorial representation of the efficient frontier (which requires more than 3 dimensions) was not possible. In order to appreciate these concepts a hypothetical 2-dimensional efficient frontier is shown in Figure 1. This analyses could be from an DEA application using just 1 input and 1 output. The efficient stores are on the frontier, while other stores lie inside the frontier. The frontier basically connects the best performers under different input levels.

If we had relied on traditional output-to-input ratios, for example, sales per square foot of store space, then store 3 would have the highest productivity. However, in applying DEA, and using the 2 outputs and 4 inputs and performing relative-to-best analysis, we found that store 3 had an efficiency of only 0.88. Similarly if the company focused on max-

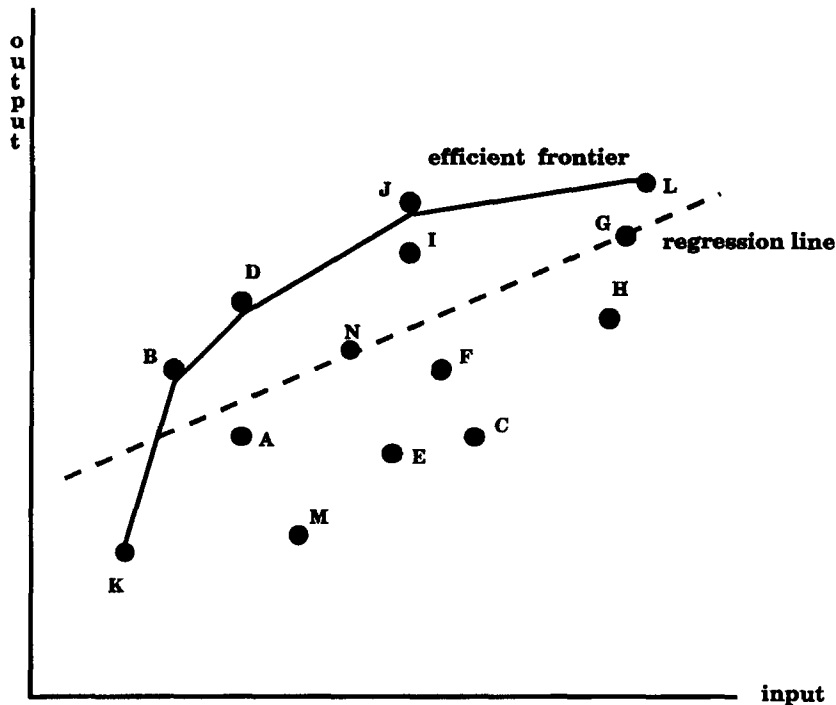


FIGURE 1

### DEA Versus Regression (Hypothetical Illustration)

imizing customer satisfaction only, then store 22 would be ranked number 1. However, in the DEA analyses its efficiency was only 0.86.

Regression has often been used to evaluate store productivity. The main drawback of such analysis is that we can only use one output variable at a time as the dependent variable. (It is possible to create an aggregate output variable by taking a weighted sum of the individual output variables using statistical techniques such as canonical analysis, for example.) Table 2 also has the store rankings by linear regression analysis using the 2 output variables at the dependent variables in 2 separate regression analyses. The last 2 columns of this table represent store rankings using the 4 input variables as the independent variables and sales and customer satisfaction as the dependent variables respectively. From this table it is clear that each of these regression-based rankings is different from the DEA-based rankings. The rank order Spearman correlations are in the range of .56 to .65 only. Theoretically one can argue that the DEA-based rankings provide a more complete picture as they include both output (dependent) variables in one analysis. The regression results are just 2 separate snapshots of store performance. Moreover, DEA analysis uses the best performers as the bases for efficiency computation, whereas regression uses the average performance as the bases for computations. Also, regression optimizes across all 24 stores

TABLE 3

## Sensitivity Analysis of Store 3

Variable Type	Variable Name	Estimated Weight	Value Measured	Value if Efficient	Slack
Output	Sales	.04	5400	6100	700
Output	Satisfaction	36.2	4.4	4.6	.2
Input	Store Size	3.1	42	40	2
Input	Manager Experience	15.5	7	5	2
Input	Promotions	.58	240	200	40

Note: Efficiency = .88  
Iterations = 10

and computes one model and the same coefficients for all stores. DEA optimizes over each store separately, and computes unique weights for each store.

A closer look at each of the inefficient stores can be taken by performing sensitivity analysis at each store level. For example, Table 3 has the sensitivity analysis results for store 3. This table shows the amount of slack in each of the controllable input and output observations for this store. This slack is computed by comparing the input and output of store 3 with the inputs and outputs of its efficient reference stores. These efficient reference stores are stores which operate under circumstances similar to that of store 3, but have 100% efficiency. Store 3 can become efficient (increase efficiency from 0.88 to 1.00) by increasing all outputs by the corresponding slack amounts or decreasing all controllable inputs by corresponding slacks (Traditional DEA analysis does not include uncontrollable variables in the sensitivity analysis because, by definition, management cannot manipulate (improve or change) these uncontrollable variables).

Practically speaking it may not always be possible for a store to ever become efficient because several of the inputs may not be under the full control of local management. For example, while store 3 management may be able to decrease its promotion budget or increase customer satisfaction, it may not be possible to increase store size (instantaneously) at this point in time (even though store size has been modeled as a controllable variable in this application in order to develop implications for future expansion of the franchise). Also, as explained before, here we are focusing on improving technical inefficiencies only.

Store 3's estimated weights for the 6 variables are also shown in Table 3. DEA estimates these weights such that the estimated efficiency of .88 for store 3 is the maximum attainable. No other combination of weights would have produced a higher efficiency estimate for Store 3 and yet satisfy all of the constraints (e.g., for any other store the same set of weights should produce efficiency less than or equal to 1) in the optimization. The weights estimated for the store show that all of the variables were important in estimating the efficiency. No one variable dominated the productivity estimation of this store. In the case of regression these weights are the same for all stores. In DEA these weights are uniquely estimated for each store, hence, allowing for each store to determine how they will become efficient. In other words, each store is given *its best shot* because the unique weights are estimated for each store so that the highest possible efficiency is estimated for that store.

TABLE 4

## DEA Rankings of Stores Over 3 Time Periods

Store Number	Rank (Year 1)	Rank (Year 2)	Rank (Year 3)
1	21	19	23
2	23	21	21
3	12	17	15
4	1	6	1
5	1	1	1
6	9	10	6
7	22	19	20
8	16	11	15
9	8	1	1
10	1	1	7
11	1	8	1
12	20	22	22
13	23	24	23
14	18	12	17
15	12	13	14
16	19	23	19
17	1	8	9
18	14	6	10
19	1	1	7
20	11	14	11
21	17	18	18
22	15	14	13
23	9	14	11
24	1	1	1

Another issue of managerial relevance is the tracking of productivity over time. Given that we had longitudinal data on the 24 stores over 3 years, such an analysis was possible. There are two ways of performing DEA analysis on data collected over time. First, three separate DEAs can be run for each of the time period. In such an analysis, the efficiency of any store may not be directly compared with efficiency of another store in different time periods, including itself. The efficiencies are relative and are computed by looking at performance data of stores included in that analysis (or time period) only. Hence, for example, it may not be valid to compare the efficiency of store 4 in 1990 with its efficiency in 1991 or the efficiency of store 5 in 1991. However, the comparison of rank orders of stores from different time periods may be meaningful. Hence we can compare the rank of store 4 in 1990 with its rank in 1991 or the rank of store 5 in 1991.

Second, the data from three years may be pooled to create 72 (24 stores X 3 time periods) observations and used in a DEA. In such an analysis, the store efficiency may be directly compared and tracked over time. Hence, now we can compare the efficiency of store 4 in 1990 with its efficiency in 1991 and the efficiency of store 5 in 1991. However, the efficiency values may be slightly misleading as the benchmark in this analysis is different. The benchmark in this analysis is not the best performers in any given year.

Both analyses were run from the restaurant chain data. Table 4 has the rank orders of the stores from the three individual DEA runs for the three years respectively. From this table we can see that stores 5 and 24 have been consistently ranked number 1.

TABLE 5

**Efficiency of Stores Over 3 Time Periods—Pooled Analysis**

<i>Store Number</i>	<i>Efficiency (Year 1)</i>	<i>Efficiency (Year 2)</i>	<i>Efficiency (Year 3)</i>
1	.76	.76	.80
2	.72	.74	.80
3	.90	.90	.96
4	.98	.99	1.0
5	1.0	1.0	1.0
6	.92	.90	.96
7	.70	.70	.74
8	.80	.80	.76
9	.90	.80	.91
10	.98	.89	.91
11	.90	.90	.80
12	.81	.68	.70
13	.68	.74	.77
14	.84	.88	.88
15	.85	.89	.84
16	.70	.71	.69
17	1.0	.96	1.0
18	.85	1.0	.88
19	1.0	1.0	.93
20	.81	.80	.82
21	.78	.72	.66
22	.90	.90	.84
23	.86	.86	.80
24	1.0	1.0	1.0

Table 5 has the efficiencies for the 24 stores using the pooled data. Here we see that once again stores 5 and 24 have efficiency of 100% in all three years. They performed well even when the benchmark was the best performers across all three years. Store 19 has an efficiency of 1 in year 1 and 2, but its efficiency dropped to 0.93 in year 3. The management may want to take a closer look at this store to investigate the reason behind such drop in efficiency in the third year. Such pooled analysis can also be used to determine overall productivity change, which could be measured as the increase in average efficiency over time.

The rank order Spearman correlations for the 3 years (in Table 4) were fairly high (ranged between .86 and .93). Similarly the correlations for the 3 year efficiencies (in Table 5) were also high (ranged between .82 and .85). This suggests that the analyses had some validity. The performance of the stores, as determined by DEA, was fairly consistent over time and may suggest that our choice of the inputs and outputs was meaningful.

## DISCUSSION

In a wide variety of retailing institutions, such as chain stores and franchise systems, the comparative performance of outlets is of strategic importance. Output-to-input

ratios are often used to measure retail performance or productivity. While retail productivity measurement is important, it is a difficult and challenging task. Retail productivity is a multidimensional concept. Several input and output factors may impact the productivity of a retail outlet. Moreover, productivity is a relative concept. The true performance of a retail outlet can not be appreciated unless performance of comparable stores is also taken into consideration. This makes the whole issue even more difficult and challenging.

In this paper we conceptualize retail productivity as the relative performance efficiency of a retail store characterized by multiple inputs and outputs and present an operations research-based methodology called Data Envelopment Analysis (DEA) that seems to address most of the concerns with current retail productivity measurement. This method accommodates multiple inputs and outputs and yet produces a single measure of efficiency that is relative in nature. Moreover, this relative efficiency computation uses the best performers as the bases.

In an empirical illustration the DEA methodology was applied to 24 stores of a fast food restaurant chain using 4 inputs (3 controllable and 1 uncontrollable) and 2 outputs (1 financial and 1 behavioral). Also the tracking of retail productivity over time and the sensitivity analysis of individual stores was performed using DEA. The use of customer satisfaction as an output variable in this example is new to retail productivity measurement. Past applications have tended to omit such behavioral output measures.

Several applications of DEA are possible in the retailing area. Beyond the basic efficiency measurement, DEA can be used to improve individual store performance using the diagnostic information provided in the sensitivity analysis. DEA may also be used to compensate individual store operators. This will motivate store operators to maximize operating efficiency as opposed to just increasing outputs. DEA-based evaluation will motivate employees to not only work hard, but also work smart. Tracking productivity over time is meaningful from a long term perspective.

The most important consideration in any DEA application is the selection of the input and output variables. Management must be very careful in this process and make sure that these variables represent their overall goals and policy. Also, considerable effort should be used in determining which stores to include in the analyses. For example, it may not be meaningful to include some stores which serve one kind of menu and other stores which have a very different menu.

While DEA may help address some of the limitations in traditional productivity measurement techniques, DEA is very sensitive to outliers, which makes the selection of stores even more critical. This over sensitivity to outliers is often cited as the main drawback of DEA. Outliers may greatly influence the shape of the efficient frontier and alter all efficiency estimates. There is also the possibility of including data from competing stores to perform external benchmarking. Some retailers may want to create dummy store data for inclusion in the analyses to represent their perception of ideal store performance. Finally, DEA is an operation research-based technique which is not stochastic in nature. Traditional DEA does not allow for an error structure. Hence, another drawback of DEA is that there is no goodness-of-fit information which is found in statistical analyses such as regression.

## REFERENCES

- Achabal, Dale D., John M. Heineke, and Shelby H. McIntyre. (1984). "Issues and Perspectives on Retail Productivity," *Journal of Retailing*, **60** (Fall).
- Anderson, Evan E. (1984). "The Growth and Performance of Franchise Systems: Company Versus Franchisee Ownership," *Journal of Economics and Business*, **36**: 421-431.
- Banker, Rajiv D. and Richard C. Morley. (1986). "Efficiency Analysis for Exogenously Fixed Inputs and Outputs," *Operations Research*, **4** (July/August): 513-521.
- Bloom, G. F. (1972). *Productivity in the Food Industry: Problems and Potential*. Cambridge, MA: MIT Press.
- Boles, James, Naveen Donthu, and Ritu Lohtia. (1995). "Salesperson Evaluation Using Relative Performance Efficiency: The Application of Data Envelopment Analysis," *Journal of Personnel Selling and Sales Management*, **15**(3): 31-49.
- Bracker, Jeffrey S. and John N. Pearson. (1986). "The Impact of Franchising on the Financial Performance of Small Firms," *Journal of the Academy of Marketing Science*, **14** (4): 10-17.
- Bucklin, Louis P. (1978). *Productivity in Marketing*. Chicago: AMA.
- Bush, Robert P., Alan J. Bush, David J. Ortinau, and Joseph F. Hair, Jr. (1990). "Developing A Behavior-Based Scale to Assess Retail Salesperson Performance," *Journal of Retailing*, **66** (Spring): 119-136.
- Cappel, Sam D., Peter Wright, David C. Wyld, and Joseph H. Miller, Jr. (1994). "Evaluating Strategic Effectiveness in the Retail Sector: A Conceptual Approach," *Journal of Business Research*, **31**: 209-212.
- Charnes, A.C., W.W. Cooper, and E. Rhodes. (1978). "Measuring Efficiency of Decision Making Units," *European Journal of Operations Research*, **2**: 429-449.
- Charnes, A. C., W. W. Cooper, D. B. Learner, and F. Y. Philips. (1985). "Management Science and Marketing Management," *Journal of Marketing*, **49** (Spring): 93-105.
- Conant, Jefferey S., Denise T. Smart, and Roberto Solano-Mendez. (1993). "Generic Retailing Types, Distinctive Marketing Competencies, and Competitive Advantage," *Journal of Retailing*, **69** (Fall): 254-279.
- Doutt, Jefferey T. (1984). "Comparative Productivity Performance in Fast-Food Retail Distribution," *Journal of Retailing*, **60** (Fall): 98-106.
- Dunn, Mark G., David Norburn, and Sue Birley. (1994). "The Impact of Organizational Values, Goals, and Climate on Marketing Effectiveness," *Journal of Business Research*, **30** (June): 131-141.
- Eccles, Robert G. (1991). "The Performance Measurement Manifesto," *Harvard Business Review*, **69** (January-February): 131-137.
- Ehrlich, Isaac and Lawrence Fisher. (1982). "The Derived Demand for Advertising: A Theoretical and Empirical Investigation," *American Economic Review*, **72** (June): 366-388.
- Farrell, M. (1957). "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society, Series A, General*, **120**, Part 3, 253-281.
- Goldman, Arie. (1992). "Evaluating the Performance of the Japanese Distribution System," *Journal of Retailing*, **68** (Spring), 11-39.
- Good, W. S. (1984). "Productivity in the Retail Grocery Trade," *Journal of Retailing*, **60** (Fall): 91-97.
- Ingene, Charles A. (1984). "Productivity and Functional Shifting in Spatial Retailing: Private and Social Perspectives," *Journal of Retailing*, **60** (Fall): 15-36.
- \_\_\_\_\_. (1982). "Labor Productivity in Retailing," *Journal of Marketing*, **46** (Fall): 75-90.

- Kamakura, Wagner A., Brian T. Ratchford, and Jagdish Agrawal. (1988). "Measuring Market Efficiency and Welfare Loss," *Journal of Consumer Research*, **15** (December): 289-302.
- Lusch, Robert F. and Ray R. Serpkeni. (1990). "Personal Differences, Job Tension, Job Outcomes, and Store Performance: A Study of Retail Store Managers," *Journal of Marketing*, **54** (January): 85-101.
- Lusch, Robert F. and Soo Young Moon. (1984). "An Exploratory Analysis of the Correlates of Labor Productivity in Retailing," *Journal of Retailing*, **60** (Fall): 37-61.
- Lusch, Robert F. and Charles A. Ingene. (1979). "The Predictive Validity of Alternative Measures of Inputs and Outputs in Retail Production Functions." Pp. 330-333 in *Proceedings of the 1979 Educators' Conference*, Neil Beckwith et al. (eds.). Chicago: American Marketing Association.
- Mahajan, Jayashree. (1991). "A Data Envelopment Analytic Model for Assessing the Relative Efficiency of the Selling Function," *European Journal of Operational Research*, **53**: 189-205.
- MecKenzie, Scott B., Philip M. Podsakoff, and Richard Fetter. (1993). "The Impact of Organizational Citizenship Behavior on Evaluations of Salesperson Performance," *Journal of Marketing*, **57** (January): 70-80.
- Nooteboom, Bart. (1983). "A New Theory of Retailing Costs," *European Economic Review*, **17**: 163-186.
- Oliver, Richard L. and Erin Anderson. (1994). "An Empirical Test of the Consequences of Behavior- and Outcome-Based Sales Control Systems," *Journal of Marketing*, **58** (October): 53-67.
- Ortiz-Buonafina, Marta. (1992). "The Evolution of Retail Institutions: A Case Study of the Guatemalan Retail Sector," *Journal of Macromarketing*, **12** (Fall): 16-27.
- Parasuraman, A., Valarie A. Zeithaml, and Leonard L. Berry. (1994). "Alternative Scales for Measuring Service Quality: A Comparative Assessment Based on Psychometric and Diagnostic Criteria," *Journal of Retailing*, **70** (Fall): 193-199.
- Parsons, L. J. (1990). "Assessing Salesforce Performance with Data Envelopment Analysis," paper presented at TIMS Marketing Science Conference, University of Illinois, Urbana.
- Pilling, Bruce K., Steve W. Henson, and Boonghee Yoo. (1995). "Competition Among Franchises, Company-Owned Units and Independent Operations: A Population Ecology Application," *Journal of Marketing Channels*, **4** (1): 177-195.
- Ratchford, Brian T. and Glenn T. Stoops. (1988). "A Model and Measurement Approach for Studying Retail Productivity," *Journal of Retailing*, **64** (Fall): 241-263.
- Ratchford, Brian T. and James R. Brown. (1985). "A Study of Productivity Changes in food Retailing," *Marketing Science*, **4** (Fall): 292-311.
- Seiford, Larry. (1990). "A Bibliography of Data Envelopment Analysis," University of Massachusetts, working paper.
- Stern, Louis W. and Adel I. El-Ansary. (1992). *Marketing Channels*, fourth ed. Englewood Cliffs, NJ: Prentice Hall.
- Thurik, Roy and Nico van der Wijst. (1984). "Part-Time Labor in Retailing," *Journal of Retailing*, **60** (Fall): 62-80.
- Yoo, Boonghee, Naveen Donthu, and Bruce K. Pilling. (1997). "Channel Efficiency: Franchise versus Non-Franchise Systems," *Journal of Marketing Channels*, forthcoming.