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To cite this article: Fu-Chiang Yang (2016): Efficiency decomposition in dealers from the perspectives of demand forecasting, sales force, and inventory control: a case study, Production Planning & Control, DOI: 10.1080/09537287.2016.1220648

To link to this article: http://dx.doi.org/10.1080/09537287.2016.1220648

Published online: 10 Aug 2016.

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Efficiency decomposition in dealers from the perspectives of demand forecasting, sales force, and inventory control: a case study

Fu-Chiang Yang

Department of Business Administration, De Lin Institute of Technology, New Taipei City, Taiwan, ROC

ABSTRACT
Efficiency decomposition is being able to know the most effective way to improve a company's organisational efficiency. This study proposes a network performance evaluation model with non-controllable variables to evaluate dealers with an emphasis on their internal processes, including demand forecasting, sales force and inventory control. The proposed model decomposes the organisational efficiency into a weighted average of internal process efficiencies, where the weights associated with the internal processes are data-driven. This is applied to an empirical case consisting of 27 automobile parts dealers in Taiwan. Based on the analysis results, dealers know the relative contribution of each internal process to the organisational efficiency, and inefficient dealers are assigned targets for enhancing the organisational efficiency as well as the process efficiencies.

1. Introduction

Dealers help suppliers or manufacturers to share inventory, sell products and acquire any information of the consumers’ needs, so that a strong dealer network can increase one's competitiveness in the market. Dealers are firms or individuals who are engaged in buying and selling goods, and play an intermediary role between the suppliers (or manufacturers) and the retailers\(^1\) in a trade cycle. To satisfy consumers’ timely needs, dealers usually purchase goods by demand forecasting before receiving the orders from consumers. Unfortunately, to avoid any backorder cost and to be able to increase the consumer’s satisfaction, the goods purchased by demand forecasting are usually over and above the real demands of consumers, leading to a higher level of inventory. In a worst case scenario, inventory becomes dead stock if the goods are not sold after a limited amount of time, such as one to three years. In sum, the dealer is a complex organisation whose internal processes composed of demand forecasting (buying goods), sales force (selling goods) and inventory control (keeping goods) under a hierarchical structure. These internal processes widely exist in most dealers, e.g. furniture dealers, antique dealers, automobile parts dealers, used car dealers and used motorcycle dealers.

Efficiency evaluation is able to identify the benchmarks in a group of similar organisations that offer useful information for decision-making. The benchmarks typically represent the average performance, and thereby provide dealers with the opportunity to identify improvement areas by comparing their performance relative to that of similar companies (Gonzalez-Padron, Akdeniz, and Calantone 2014). Essentially, the efficiency is a ratio of output to input (Keh and Chu 2003). If any organisation has the same level of input, but a higher level of output, when compared to other organisations, then this one is recognised as efficient. In terms of this concept, the data envelopment analysis (DEA) proposed by Charnes, Cooper, and Rhodes (1978) has been recognised as a representative tool that can objectively evaluate the relative efficiencies of a set of homogeneous decision-making units (DMUs), i.e. organisations or individuals, with the consideration of multiple inputs and outputs. Through the determination of efficient DMUs, the DEA provides a reference set of the best practices recognised as the role model DMUs for the inefficient ones. Inefficient DMUs thus know what the extent is of reducing inputs and/or increasing outputs to improve their performance. Empirical applications of the DEA have been reported by Cook and Seiford (2009), Liu et al. (2013), and Seiford (1996).

In the traditional DEA framework, the DMU is viewed as a black box. However, in practice, the DMU is usually a complex organisation that consists of multiple internal processes. Let's take electric power companies as an example, where the internal processes include generation, transmission and distribution (see Tone and Tsutsui 2009). Being unable to consider the internal structure of a DMU may lead to a deceptive result for decision-making (Tone and Tsutsui 2009; Kao 2014a, 2014b). To exactly measure the efficiency of a DMU, the network DEA can decompose the organisational efficiency into internal process efficiencies. Efficiency decomposition discloses the impact of each internal process to organisational performance and indicates the most effective way to improve the efficiency of inefficient DMUs. Therefore, network DEA offers the evaluation results more realistically when compared to the black box DEA (Kao 2014a).
This is the first research that attempts to construct a network performance evaluation model to evaluate dealers with an emphasis on their internal processes, i.e. demand forecasting, sales force and inventory control. The proposed model decomposes the organisational efficiency into a weighted average of the internal process efficiencies, where the weights associated with the internal processes are data-driven. This is applied to an empirical case consisting of 27 automobile parts dealers in Taiwan. Based on the analysis results, dealers know the relative contribution of each internal process to their organisational efficiency, and inefficient dealers are assigned ways of enhancing their organisational efficiency as well as internal process efficiencies.

2. Literature review

2.1. Black box and network DEA

The DEA is able to rank the DMUs, identify sources of inefficiency and create a quantitative basis for reallocating resources (Golyan and Roll 1989). Technically, the DEA is a linear programming model to evaluate the relative efficiencies of the DMUs. The efficiency score of a DMU is determined by a comparison with the benchmark DMUs located on the efficient frontier representing the minimum resources necessary for a DMU to achieve at a given level of output (input oriented), or the maximum output expansion at a given level of input resources (output oriented) (see Hsieh and Lin 2010).

The CCR model (Charnes, Cooper, and Rhodes 1978), and the BCC model (Banker, Charnes, and Cooper 1984), are the two main DEA models. The CCR model is based on the assumption of the constant returns to scale. The BCC model extends the CCR model to take into account the assumption of variable returns to scale. The CCR model determines the overall efficiency, but the BCC model measures the pure technical efficiency. The scale efficiency can be obtained by the overall efficiency divided by the pure technical efficiency. Obtaining these efficiencies enables one to know whether the inefficiency comes from a technical problem or from a scale problem.

The CCR and BCC models use the radial measure of efficiency which has two major problems: (1) the inputs and outputs need to undergo proportional changes; and (2) the efficiency of a weakly efficient DMU cannot be appropriately measured (Charnes, Cooper, and Thrall 1986; Tone 2001; Tone and Tsutsui 2009; Kao 2014a). To solve these problems, Tone (2001) developed a slacks-based measure (SBM) approach to efficiency evaluation by dealing directly with the input excess and output shortfall. The SBM is a non-radial method and is suitable for measuring efficiencies when inputs and outputs may change non-proportionally. However, the CCR, BCC and SBM models treat the DMU as a ‘black box’, where the intermediate products or linking activities are ignored (Färe and Grosskopf 1996; Kao 2014b).

To open the black box, Färe and Grosskopf (1996, 2000) firstly introduced the network DEA models, which have been extended and applied by Lewis and Sexton (2004), Löthgren and Tambour (1999), Prieto and Zofío (2007) and Vaz, Camanho, and Guimarães (2010). However, those network DEA models are based on the CCR or the BCC model. Then, Tone and Tsutsui (2009) proposed the network SBM (NSBM) that utilises the SBM approach for evaluating the efficiency of the DMUs with the consideration of the internal processes of a DMU. Practical applications and/or extensions of NSBM can refer to Liu and Lu (2010), Lozano and Gutiérrez (2014) and Yu (2010). The NSBM is able to decompose the overall efficiency into the internal process efficiencies. One can employ the weighted SBM model (see Cooper, Seiford, and Tone 2007; Tsutsui and Goto 2009) to assign the weights of the internal processes. The overall efficiency is a weighted average of the internal process efficiencies. Importantly, the discriminating power of the NSBM is higher than the SBM (i.e. the black box approach). Recently, Kao (2014a) enhances Tone and Tsutsui’s NSBM. In Kao’s method, the weights associated with the internal processes are data-driven. The overall efficiency is also a weighted average of internal process efficiencies. According to Kao’s method, one can objectively know the relative contributions of internal processes to the organisational performance. A comprehensive review of the network DEA has been reported by Kao (2014b).

2.2. Performance assessment of dealers

As indicated by Liu et al. (2013), in terms of the DEA methodology, 67% of the DEA articles are presented in a real-world application (also see Gattoufi et al. 2004). Banking, education, health care and hospital efficiency were found to be the most popular application areas (Emrouznejad, Parker, and Tavares 2008). Additionally, the DEA literature includes several studies concerning the performance assessment of retail outlets (see Kamakura, Lenartowicz, and Ratchford 1996; Donthu and Yoo 1998; Keh and Chu 2003; Vaz, Camanho, and Guimarães 2010; Gauri 2013). Although a strong dealer network helps a supplier (or manufacturer) to increase its competitiveness in the market, the DEA literature includes a limited amount of studies concerning the performance assessment of dealers. Perhaps, it is because the empirical data-set of a dealer network is not easily accessed.

In terms of the applications of the DEA to evaluate dealers, Akdeniz, Gonzalez-Padron, and Calantone (2010) proposed an integrated benchmarking model (stochastic frontier and DEA) to investigate the performances of 45 furniture dealers over a period of time. Gonzalez-Padron, Akdeniz, and Calantone (2014) utilises the DEA for benchmarking sales staffing efficiency in dealerships, where manufactures obtain a comprehensive view of allocating sales staff to increase dealer efficiency. However, these studies use a black box DEA to evaluate the efficiency of dealers without considering the internal structure of a dealer. The black box DEA cannot explain the relationships between the efficiency of each internal process and the efficiency of the organisation, thereby missing the critical information for setting the targets of performance improvement.

In practice, manufacturers monitor independent dealer performance through industry benchmarks using operational ratios (e.g. total revenue per square feet) and financial ratios (e.g. net profit margin) to ensure a consistent and fiscally stable distribution channel (Gonzalez-Padron, Akdeniz, and Calantone 2014). By means of a private communication with a Senior Special Assistant in an automobile parts dealership, Lien (2015) indicates that suppliers usually adopt the average revenue per salesperson (the sales revenue divided by the number of salespeople) and the achievement rate (the sales revenue divided by the sales target)
to monitor dealer performance since top management believes that income depends on sales performance. However, as emphasised in this study, an internal structure of a dealer consists of demand forecasting, sales force and inventory control. Paying strict attention to the monitoring of the sales performance may boost sales revenue in the short term. Taking all three internal process performances into account could boost the organisational performance in the long term.

3. Methodology

3.1. Case background

In Taiwan, about 400,000 new cars are sold to consumers per year. In terms of the imported cars, Audi, BMW and Mercedes Benz are usually the most popular selection for Taiwanese consumers. The research target, Company XYZ, owns a strong dealer network consisting of 29 dealers that mainly sell the automobile parts of Audi, BMW and Mercedes Benz to large and middle-sized vehicle maintenance facilities in Taiwan. The sales revenue of Company XYZ is about NT$ 1.5 billion per year, and this company is one of the largest automobile parts suppliers in Taiwan.

Practical applications of several performance analysis tools have been reported in the literature, including analytic hierarchy process (Bhagwat and Sharma 2007), balanced scorecard (Folan and Browne 2005; Grando and Belvedere 2008) and DEA (Braglia, Zanoni, and Zavanella 2003). Currently, the case company utilises its key performance indicators (KPIs) to monitor the dealer performance. The dealer with the highest KPI score gets the highest bonus, and then the manager of the dealer assigns the bonus to each employee in terms of his/her contributions. The KPI score is useful for ranking dealer performance. However, the DEA methodology not only ranks dealers, it also assigns the targets of the performance indicators (i.e. the inputs and outputs in the DEA model) that the inefficient dealers should achieve.

Company XYZ faces a situation, where although the sales revenue is increased on a yearly basis, the stock quantity is also much higher. After a group meeting with their managers, it was found that the two main KPIs assigned to dealers are the achievement rate and the average revenue per salesperson. These two KPIs primarily monitor the sales performance. Dealers thus pay less attention to the inventory control as well as the demand forecasting. Other reasons for ignoring the inventory control and the demand forecasting made by the dealers in Company XYZ are also concluded as follows: (1) the performances of demand forecasting and inventory control do not directly affect the sales revenue; (2) purchasing an exact amount of goods before receipting the orders from consumers involves too many decision variables, e.g. consumers’ needs, suppliers’ inventory, competitors’ price, public policy and product life cycle; and (3) reducing the inventory may delay the goods supplied to the consumers, leading to a loss of sales. However, one should note that a high level of inventory brings about the following predicaments: (1) decreases the amount of cash available to run the company; (2) generates additional operating expenses for inventory management; and (3) yields a large amount of dead stock. To increase the competitiveness in the long term, companies should pay more attention to not only the sales force, but also the inventory control.

3.2. Network performance evaluation model

In this case study, the performance of a dealer is determined by the aggregated efforts of demand forecasting, sales force and inventory control under a hierarchical structure. Firstly, the managers are required to forecast the demands of the consumers and then buy the goods before receipting the orders from the consumers. Then, the salespeople endeavour to sell the goods in order to archive the sales target assigned by Company XYZ. Finally, stock quantity is increased when the purchased goods are not sold. In some worse case scenarios, the sold goods are returned by the consumers (i.e. returned goods) and the goods that are not sold after one year become dead stock. It is thus suggested that Company XYZ, in determining the bonus for dealers, should consider not only their achievement rate (the sales revenue divided by the sales target), but also stock quantity, returned goods and dead stock. Figure 1 depicts a network structure of the dealers in the current case study.

This study proposes a network performance evaluation model based on Kao’s NSBM (Kao 2014a). The proposed model evaluates the organisational efficiency as well as the internal process efficiencies of demand forecasting, sales force and inventory control. The efficiency of demand forecasting implies the purchase ability of managers who are in charge of buying goods, where the inputs are executive pay (X1), and operating expenses (X2), and a single output is purchase quantity (Z1). Note that purchase quantity (Z1) is an intermediate product between the demand forecasting and the sales force. Indeed, purchase quantity (Z1) is an intermediate output from the demand forecasting, but it is an intermediate input to the sales force. The efficiency of the sales force represents the sales performance of the salespeople, where the inputs are purchase quantity (Z1) and sales salary (X3), and the outputs are sales revenue (Y1), gross profit margin (Y2) and achievement rate (Z2). It can be seen that the achievement rate (Z2) serves as an intermediate output from the sales force, but it is an intermediate input to the inventory control. The efficiency of the inventory control measures the ability of keeping an appropriate stock quantity for managers and salespeople, where the inputs are achievement rate (Z2), dead stock (X4), returned goods (X5) and stock quantity (X6), and a single output is the bonus (Y3).

Notably, purchase quantity (Z1) is a ‘controllable’ variable in the process of the demand forecasting, but it is a ‘non-controllable’ variable in the process of the sales force. That is, the purchase quantity is determined by the managers, so that it is a fixed input to the process of the sales force. Additionally, the achievement rate (Z2) is a “controllable” variable in the process of the sales force, but it is a ‘non-controllable’ variable in the process of the inventory control. The achievement rate is decided by the salespeople, and therefore, it is a fixed input to the process of the inventory control. In Kao’s NSBN, all the intermediate products are treated as ‘controllable’ variables. Being able to fit the case of Company XYZ, Kao’s NSBN is modified. In the proposed model, the intermediate products (Z1 and Z2) between two internal processes are controllable outputs, but they are non-controllable inputs (Readers can refer to Banker and Morey (1986), for their details of the non-controllable variables in DEA).

Suppose that there are n dealers. The proposed model is described by the following linear fractional program:
\[ E_k = \min \left\{ \frac{1}{2} \left( 1 - \frac{t_1}{r_1} \right) + \frac{1}{2} \left( 1 - \frac{t_2}{r_2} \right) + \frac{1}{2} \left( 1 - \frac{t_3}{r_3} \right) \right\} \]

\[ \sum_{j=1}^{n} \lambda_j^{(1)} Y_{ij} - s_{k}^+ = Y_{sk} \quad (1.7) \]

\[ \sum_{j=1}^{n} \lambda_j^{(2)} Y_{ij} - s_{k}^+ = Y_{sk} \quad (1.8) \]

\[ \sum_{j=1}^{n} \lambda_j^{(3)} Y_{ij} - s_{k}^+ = Y_{sk} \quad (1.9) \]

\[ \sum_{j=1}^{n} \lambda_j^{(1)} X_{ij} + t_1 = X_{1k} \quad (1.1) \]

\[ \sum_{j=1}^{n} \lambda_j^{(1)} X_{ij} + t_2 = X_{2k} \quad (1.2) \]

\[ \sum_{j=1}^{n} \lambda_j^{(2)} X_{ij} + t_3 = X_{3k} \quad (1.3) \]

\[ \sum_{j=1}^{n} \lambda_j^{(3)} X_{ij} + t_4 = X_{4k} \quad (1.4) \]

\[ \sum_{j=1}^{n} \lambda_j^{(3)} X_{ij} + t_5 = X_{5k} \quad (1.5) \]

\[ \sum_{j=1}^{n} \lambda_j^{(3)} X_{ij} + t_6 = X_{6k} \quad (1.6) \]

\[ \sum_{j=1}^{n} \lambda_j^{(p)} = 1, \quad p = 1, 2, 3 \quad (1.14) \]
where $s_i^r$ ($i = 1, \ldots, 6$), $s_i^s$ ($i = 1, \ldots, 3$) and $l_i^r$ ($i = 1, 2$) are slack variables associated with the input, output and intermediate output. The $\lambda^{(1)}$, $\lambda^{(2)}$ and $\lambda^{(3)}$, respectively, represents the intensity vector for demand forecasting, sales force and inventory control, being larger or equal to zero. The intermediate inputs are non-controllable variables, so that they do not have slack variables, see Equations (1.11) and (1.13). This model is linearised in Appendix 1.

The $E_k$ represents the organisational efficiency for dealer $k$, lies in the range 0–1 and it is efficient if $E_k = 1$. Equations (1.1–1.2) and (1.10) evaluate the efficiency of the demand forecasting. Equations (1.3), (1.7–1.8) and (1.11–1.12) evaluate the efficiency of the sales force. Equations (1.4–1.6), (1.9) and (1.13) evaluate the efficiency of the inventory control. Adding Equation (1.14) allows the returns to scale being variable.

Let $E_k^{(1)}$, $E_k^{(2)}$ and $E_k^{(3)}$, respectively, denote the efficiency of demand forecasting, sales force and inventory control for dealer $k$. According to Kao (2014a), the efficiencies of internal processes are calculated as follows:

$$E_k^{(1)} = \frac{1 - \left( \frac{s_1^r}{x_{1r}} + \frac{s_1^s}{x_{1s}} \right)}{1 + \frac{l_1^r}{z_{1r}}}$$

$$E_k^{(2)} = \frac{1 - \frac{s_1^r}{x_{2r}}}{1 + \left( \frac{l_2^r}{x_{2r}} + \frac{l_3^r}{x_{3r}} + \frac{l_4^r}{x_{4r}} \right) / 3}$$

$$E_k^{(3)} = \frac{1 - \left( \frac{s_1^r}{x_{3r}} + \frac{s_2^r}{x_{4r}} + \frac{s_3^r}{x_{5r}} \right)}{1 + \frac{l_5^r}{z_{5r}}}$$

4. Case study results

Of the 29 dealers in Company XYZ, this study excludes two dealers that were launched in 2014. If the dealer is viewed as a black box, the organisational efficiency is evaluated by using the inputs $X_1$, $X_2$, $X_3$, $X_4$, $X_5$ and $X_6$, and the outputs $Y_1$, $Y_2$ and $Y_3$, with the SBM approach (see Appendix 2). The third column of Table 1 shows the SBM efficiency scores of the 27 dealers, of which 12 are efficient. However, the fourth column of Table 1 presents the organisational efficiency calculated by the proposed network performance evaluation model. In contrast to the high proportion of efficient dealers in the black box model, only three dealers are recognised as efficient. This is because a dealer is only efficient if all of its internal processes are efficient. In this case study, only D6, D8 and D18 are efficient for all the three internal processes. This property gives the proposed model a stronger discriminating power than the black box model.

The fifth to seventh columns of Table 1 show the internal process efficiencies, calculated by Equations (2.1–2.3). The last three columns of Table 1 display the weights associated with the internal processes determined by Equations (3.1–3.3). As expected, the organisational efficiency is a weighted average of the three process efficiencies. Taking D1 as an example, it has $0.742 = 0.633 \times 0.316 + 0.884 \times 0.358 + 0.693 \times 0.326$. Notably, the weights of the internal processes indicate the priority for performance improvement of a dealer. Again, taking D1 as an example, the weights of the demand forecasting, sales force and inventory control are 0.316, 0.358 and 0.326, respectively. The D1 should pay much more attention to the sales force because the efficiency of the sales force obviously influences the organisational performance the most. According to the average weights of the internal processes (shown in the last row in Table 1), the three internal processes that are arranged in effective order to the organisational performance are sales force (0.384), inventory control (0.322) and demand forecasting (0.294).

Figure 2 shows the averages of the efficiency scores of the organisation, and the internal processes related to three locations in Taiwan, i.e. north, central and south Taiwan. According to this figure, the averages of the efficiency scores of the organisation, demand forecasting and sales force seems not to be different from the three locations, but the average of the efficiency score of inventory control appears to differ in the three locations. This study then investigates whether the efficiency scores of the organisation and the three internal processes, on average, differ in terms of the locations by examining the following null hypotheses: ($H_1$) the dealers in north, central and south Taiwan do not differ in their organisational efficiency; ($H_2$) the dealers in north, central and south Taiwan do not differ in the efficiency of demand forecasting; ($H_3$) the dealers in north, central and south Taiwan do not differ in the efficiency of sales force; and ($H_4$) the dealers in north, central and south Taiwan do not differ in the efficiency of inventory control. A nonparametric statistical analysis, the Kruskal–Wallis test, is used for the unknown distribution scores.
Table 1. The black-box, organisational and internal process efficiencies of the 27 dealers, along with the weights of internal processes.

<table>
<thead>
<tr>
<th>Dealer</th>
<th>Location</th>
<th>Black box model</th>
<th>Organisation (rank)</th>
<th>Process 1: demand forecasting</th>
<th>Process 2: inventory control</th>
<th>Process 3: Weight on process 1</th>
<th>Weight on process 2</th>
<th>Weight on process 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.7423 (13)</td>
<td>0.6327</td>
<td>0.8835</td>
<td>0.6934</td>
<td>0.3164</td>
<td>0.3581</td>
</tr>
<tr>
<td>D2</td>
<td>Central Taiwan</td>
<td>0.6723</td>
<td>0.6455 (23)</td>
<td>0.8170</td>
<td>0.6712</td>
<td>0.4850</td>
<td>0.2634</td>
<td>0.3924</td>
</tr>
<tr>
<td>D3</td>
<td>North Taiwan</td>
<td>0.6713</td>
<td>0.5663 (27)</td>
<td>0.7935</td>
<td>0.5745</td>
<td>0.4161</td>
<td>0.2300</td>
<td>0.4004</td>
</tr>
<tr>
<td>D4</td>
<td>South Taiwan</td>
<td>1.0000</td>
<td>0.8564 (9)</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.5904</td>
<td>0.3248</td>
<td>0.3248</td>
</tr>
<tr>
<td>D5</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.8642 (8)</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.6225</td>
<td>0.3202</td>
<td>0.3202</td>
</tr>
<tr>
<td>D6</td>
<td>North Taiwan</td>
<td>0.7157</td>
<td>1.0000 (1)</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.3333</td>
<td>0.3333</td>
</tr>
<tr>
<td>D7</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.6908 (15)</td>
<td>0.6717</td>
<td>0.6274</td>
<td>0.8110</td>
<td>0.2782</td>
<td>0.4435</td>
</tr>
<tr>
<td>D8</td>
<td>Central Taiwan</td>
<td>1.0000</td>
<td>1.0000 (1)</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.3333</td>
<td>0.3333</td>
</tr>
<tr>
<td>D9</td>
<td>North Taiwan</td>
<td>0.8311</td>
<td>0.7511 (12)</td>
<td>0.7641</td>
<td>0.8408</td>
<td>0.6319</td>
<td>0.3131</td>
<td>0.3145</td>
</tr>
<tr>
<td>D10</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.8733 (7)</td>
<td>0.9177</td>
<td>0.8092</td>
<td>0.9006</td>
<td>0.3110</td>
<td>0.3565</td>
</tr>
<tr>
<td>D11</td>
<td>North Taiwan</td>
<td>0.8291</td>
<td>0.6820 (17)</td>
<td>0.9152</td>
<td>0.5433</td>
<td>0.7004</td>
<td>0.2480</td>
<td>0.4565</td>
</tr>
<tr>
<td>D12</td>
<td>North Taiwan</td>
<td>0.7716</td>
<td>0.6494 (21)</td>
<td>0.5719</td>
<td>0.6603</td>
<td>0.7095</td>
<td>0.2835</td>
<td>0.4294</td>
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<tr>
<td>D13</td>
<td>North Taiwan</td>
<td>0.6881</td>
<td>0.5807 (25)</td>
<td>0.7625</td>
<td>0.5622</td>
<td>0.4595</td>
<td>0.2494</td>
<td>0.4436</td>
</tr>
<tr>
<td>D14</td>
<td>Central Taiwan</td>
<td>0.7109</td>
<td>0.5682 (26)</td>
<td>0.7265</td>
<td>0.5000</td>
<td>0.5514</td>
<td>0.2319</td>
<td>0.4638</td>
</tr>
<tr>
<td>D15</td>
<td>Central Taiwan</td>
<td>1.0000</td>
<td>0.8914 (5)</td>
<td>0.7899</td>
<td>0.8987</td>
<td>1.0000</td>
<td>0.3527</td>
<td>0.3409</td>
</tr>
<tr>
<td>D16</td>
<td>North Taiwan</td>
<td>0.8974</td>
<td>0.7945 (11)</td>
<td>0.8099</td>
<td>0.7867</td>
<td>0.7890</td>
<td>0.3057</td>
<td>0.3868</td>
</tr>
<tr>
<td>D17</td>
<td>North Taiwan</td>
<td>0.6608</td>
<td>0.6765 (18)</td>
<td>0.8202</td>
<td>0.7118</td>
<td>0.5397</td>
<td>0.2620</td>
<td>0.3681</td>
</tr>
<tr>
<td>D18</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>1.0000 (1)</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.3333</td>
<td>0.3333</td>
</tr>
<tr>
<td>D19</td>
<td>South Taiwan</td>
<td>0.8008</td>
<td>0.6731 (19)</td>
<td>0.6288</td>
<td>0.6666</td>
<td>0.7194</td>
<td>0.2728</td>
<td>0.4093</td>
</tr>
<tr>
<td>D20</td>
<td>Central Taiwan</td>
<td>1.0000</td>
<td>0.8287 (10)</td>
<td>0.7552</td>
<td>0.7521</td>
<td>1.0000</td>
<td>0.3054</td>
<td>0.3893</td>
</tr>
<tr>
<td>D21</td>
<td>South Taiwan</td>
<td>1.0000</td>
<td>0.9591 (4)</td>
<td>0.8773</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.3333</td>
<td>0.3333</td>
</tr>
<tr>
<td>D22</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.6967 (14)</td>
<td>0.5503</td>
<td>0.6208</td>
<td>1.0000</td>
<td>0.3216</td>
<td>0.4186</td>
</tr>
<tr>
<td>D23</td>
<td>North Taiwan</td>
<td>1.0000</td>
<td>0.8911 (5)</td>
<td>0.8846</td>
<td>0.8854</td>
<td>0.9042</td>
<td>0.3301</td>
<td>0.3541</td>
</tr>
<tr>
<td>D24</td>
<td>South Taiwan</td>
<td>0.6569</td>
<td>0.5889 (24)</td>
<td>0.6485</td>
<td>0.6237</td>
<td>0.5044</td>
<td>0.2519</td>
<td>0.4039</td>
</tr>
<tr>
<td>D25</td>
<td>South Taiwan</td>
<td>0.7639</td>
<td>0.6875 (16)</td>
<td>0.7554</td>
<td>0.6952</td>
<td>0.6197</td>
<td>0.2777</td>
<td>0.3994</td>
</tr>
<tr>
<td>D26</td>
<td>South Taiwan</td>
<td>0.6312</td>
<td>0.6475 (22)</td>
<td>0.6735</td>
<td>0.7438</td>
<td>0.4918</td>
<td>0.2990</td>
<td>0.4020</td>
</tr>
<tr>
<td>D27</td>
<td>Central Taiwan</td>
<td>0.7560</td>
<td>0.6577 (20)</td>
<td>0.7124</td>
<td>0.6585</td>
<td>0.6167</td>
<td>0.2575</td>
<td>0.3911</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.8540</td>
<td>0.7579</td>
<td>0.7955</td>
<td>0.7673</td>
<td>0.7317</td>
<td>0.2941</td>
<td>0.3837</td>
</tr>
</tbody>
</table>

(Hollander and Wolfe (1999) provide further details on how to apply the Kruskal–Wallis test.). The Kruskal–Wallis test statistic is $H$.

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1),$$

where $k$ is the number of samples, i.e. the number of locations ($k = 3$), $N$ is the total number of observations, i.e. the number of dealers ($N = 27$), $n_i$ is the number of observations in sample $i$ and $R_i$ is the sum of the ranks for sample $i$.

Table 2 documents the rank of each dealer in terms of its efficiency score of organisation, demand forecasting, sales force and inventory control. Equation 4 obtains the Kruskal–Wallis test statistic based on the ranking scores in Table 2. Taking the hypothesis ($H_a$) for example, the Kruskal–Wallis test statistic ($H$) is obtained by the following computational process:

$$H = \left[\frac{12}{27(27+1)} \times \left(\frac{22^2}{15} + \frac{82^2}{6} + \frac{74^2}{6}\right)\right] - 3(27 + 1) = 0.4275.$$
Efficiency scores are useful for ranking dealers, so that managers can realise their relative competitiveness in the peer group. However, inefficient dealers desire to know the targets associated with inputs and outputs that they should achieve in order to improve their performance. Table 3 reports the potential improvement of the 27 dealers, in percentage terms, calculated by the slack value divided by the initial value for each input and output. Note that the intermediate products, Z1 and Z2, have slack values when they are treated as outputs. These values indicate the inputs should decrease to what extent and the outputs should increase to what extent. Take D1 as an example, its X1, X2, X3, X4, X5 and X6 should, respectively, decrease 41.63, 31.82, 0.00, 8.40, 68.49 and 9.11%, and its Y1, Y2, Y3, Z1 and Z2 should, respectively, increase 3.45, 11.44, 2.88, 0.00 and 41.63%.

Figure 3 shows the averages of the potential improvement of inputs, indicating that inefficient dealers should, on average, decrease their inputs to what extent. The inputs arranged in improved order are returned goods, operating expenses, dead stock, executive pay and stock quantity. In terms of the inputs, the three major factors of inefficient dealers are returned goods, operating expenses and dead stock, and those have, on average, to be reduced by over 20%. Figure 4 displays the averages of the potential improvement of outputs, indicating that inefficient dealers should, on average, increase their outputs to what extent. The outputs arranged in improved order are gross profit margin, bonus, sales revenue and purchase quantity. In terms of the outputs, gross profit margin (over 50%) is the first priority to improve the performance of inefficient dealers. Such results offer Company XYZ a new direction to monitor the performances of their dealers.
of all inputs and outputs that they should achieve.

for their dealers. The inefficient dealers are assigned the targets

primary, secondary and tertiary goals of improving performance

ing, sales force and inventory control, Company XYZ can set the

results give Company XYZ a new direction for managing dealers.

A strong dealer network is helpful to increase the competitiveness of the suppliers and/or manufacturers. However, compared to retailers, a limited amount of DEA studies have investigated the evaluation of dealers. This study is the first to construct a network performance evaluation model with non-controllable variables based on the NSBM proposed by Kao (2014a) for evaluating automobile parts dealers in Taiwan. Importantly, this study outlines a general internal structure of dealers that comprises demand forecasting, sales force and inventory control. Evaluating the efficiency of a dealer should take all the internal processes into account. This is a novel perspective for evaluating dealers. Additionally, the proposed model explains why dealers recognised as efficient by the black box model are actually considered inefficient when taking the internal processes into account. Efficiency decomposition is more realistic in reflecting the organisational performance of a dealer.

Technically, the only background required for executing the proposed model is to know how to solve linear programming models via the commercial software like LINGO. In Company XYZ, the Senior Special Assistant is in charge of the development and maintenance of the LINGO code and data mining for the required measures, i.e. the inputs and outputs in the proposed model. Model building (by LINGO), data mining and computation are not time-consuming works for Company XYZ. The analysis results give Company XYZ a new direction for managing dealers. By referencing to the weights associated with demand forecasting, sales force and inventory control, Company XYZ can set the primary, secondary and tertiary goals of improving performance for their dealers. The inefficient dealers are assigned the targets of all inputs and outputs that they should achieve.

Initially, the Senior Special Assistant was the only one who completely understood the meaning of the proposed method for the purpose of evaluating dealers. Since the analysis results provide a new and effective method of managing the dealer network, the managers of all dealers were invited to attend a demonstration of the proposed method. Most managers endorsed the proposed method. However, one major difficulty faced by Company XYZ was that some managers were resistant to incorporating the dead stock, returned goods and stock quantity into the calculation of their bonus. After several meetings with the managers, the Senior Special Assistant convinced them of the importance of cutting inventory since the current inventory of the dealer network approximates NT$ 170 million. To encourage the dealers to cut inventory, especially for some particular items not sold over 12 months, the case company now offers the special bonus.

Future studies can apply the proposed network structure (comprising demand forecasting, sales force and inventory control) to decompose the organisational efficiency in different dealers. For example, pharmaceutical dealers are mainly concerned with demand forecasting and inventory control, but few DEA studies attempt to decompose the organisational efficiency of a pharmaceutical dealer and discuss its internal process efficiencies in a real-world case. In practice, the achievement rate (the sales revenue divided by the sales target) majorly depends on consumer needs, the number of competitors and the business cycle. Because the achievement rate (Z2) (%)

Buy (Y1) (%)

Gross profit margin (Y2) (%)

Purchase quantity (Z1) (%)

Achievement rate (Z2) (%)
rate is driven by a wide range of factors, Company XYZ always sets reasonably achievable sales targets for each dealer. Thus, from the business point of view, the case company believes that the achievement rate should be considered as a controllable variable in the process of sales force.

3. As requested by Company XYZ, this study cannot disclose any information about the raw data in the case study. Therefore, the slack values of the inputs and outputs are transformed into the percentage terms.

Acknowledgements

We are grateful to Dr. William W.H. Lien who is a Senior Special Assistant in the case company and generously offers the data-set to accomplish this research. We also thank the anonymous reviewers for their constructive suggestions, which improved this paper significantly.

Notes on contributor

Fu-Chiang Yang received the PhD degree in business administration from the National Central University, Taoyuan City, Taiwan, in 2010. He is currently an assistant professor at the Department of Business Administration, De Lin Institute of Technology, New Taipei City, Taiwan. Previously, he was an associate research fellow at the Research Division V, Taipei Institute of Economic Research, Taipei City, Taiwan. His main areas of scholarly interest include performance evaluation, operations management and inventory control. He has written papers which have been published in peer reviewed journals including INFOR, Energy Policy, Quality & Quantity, Computers and Mathematics with Applications, Journal of Medical Systems and Expert Systems with Applications.

References


Appendix 1.

Linearised network performance evaluation model

The proposed network performance evaluation model is linearised by letting \[ \frac{1}{1 + \frac{s_1}{X_{ik}}} + \frac{1}{1 + \left( \frac{s_1}{Y_{rk}} + \frac{s_2}{X_{ik}} + \frac{s_3}{Y_{rk}} \right)} + \frac{1}{1 + \frac{s_4}{X_{ik}}} = \frac{1}{Q}, \]
substituting the variables appropriately to obtain the following model:

\[
E_k = \min \left[ Q - \left( \frac{s_4}{X_{ik}} + \frac{s_5}{X_{ik}} \right) / 2 \right] + \left[ Q - \left( \frac{s_4}{X_{ik}} + \frac{s_5}{X_{ik}} \right) / 3 \right] + \left[ Q - \left( \frac{s_4}{X_{ik}} + \frac{s_5}{X_{ik}} \right) / 3 \right]
\]

s.t.

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

where \( \hat{s}_1 = Qs_1^*, \hat{s}_2 = Qs_2^*, \hat{s}_3 = Qs_3^* \), and \( \hat{s}_4 = Qs_4^* \).

If \( E_k = 1 \), dealer \( k \) is efficient. Otherwise, dealer \( k \) needs to decrease \( X_{ik}, Y_{rk}, Z_{rk} \), and by \( s_1, s_2, s_3, s_4, s_5, s_6 \) respectively; and increase \( Y_{rk}, Y_{rk}, Z_{rk}, Z_{rk} \), and \( Z_{rk}, Z_{rk}, Z_{rk}, Z_{rk} \), respectively, to be efficient.

Appendix 2.

SBM approach

Denote \( X_i \) as the 4th input, \( i = 1, \ldots, m \), and \( Y_r \) as the 4th output, \( r = 1, \ldots, s \), of the \( j \)th DMU, \( j = 1, \ldots, n \). The SBM approach proposed by Tone (2001) is as follows:

\[
E_k = \min \frac{1 - (1/m) \sum_{i=1}^{m} s_i / X_{ik}}{1 + (1/s) \sum_{r=1}^{s} y_r / Y_{rk}}
\]

s.t.

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}, \quad i = 1, \ldots, m
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

\[
\sum_{j=1}^{n} x_{ik} + x_i = Qx_{ik}
\]

where \( s_i \) is the excessive inputs utilised and \( s_i^* \) is the insufficient outputs produced. This approach is based on the relative insufficiency of the inputs produced and excessiveness of the inputs utilised by a DMU compared to what the outputs and inputs would be if it were efficient (Kao 2014a). The efficiency of DMU \( k \), \( E_k \), lies in the range 0–1, and it is efficient if \( E_k = 1 \).