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# A balanced scorecard analysis of performance metrics

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## Abstract

Many organizations have invested substantial resources in recent years to implement a balanced scorecard of performance metrics. From a historical focus exclusively on financial metrics of performance, the emphasis has shifted recently to a consideration of a portfolio of nonfinancial performance metrics related to customers, business process and technology. In this paper, we investigate the best practice frontier relationship between a financial performance metric (return on assets—ROA) and three nonfinancial performance metrics (number of access lines per employee, percentage of digital access lines and percentage of business access lines) reported and used in the US telecommunications industry. Analyzing detailed data from over fifty local exchange carriers for a period of five years (from 1993 to 1997), we find that managers must tradeoff contemporaneous ROA when increasing the percentage of business access lines. We also find that managers do not have to trade off ROA with the other two nonfinancial performance metrics because these metrics are contemporaneously congruent.

*Keywords:* Data envelopment analysis; Balanced scorecard; Performance metrics; Telecommunications

## 1. Introduction

In recent years, both practitioners and researchers have emphasized the need to move beyond financial measures of operations and to incorporate a much wider variety of nonfinancial metrics in an organization's performance reporting and reward systems (Kaplan, 1983). In today's complex competitive environment, firms need to be agile and flexible. As a result, availability of the right information at the right time for both decision making and performance evaluation has become critical. A popular performance measurement scheme suggested by Kaplan and Norton (1992) is the *balanced scorecard* that employs performance metrics from financial, customer, business process, and technology perspectives. By combining these different perspectives, the balanced scorecard helps managers understand the interrelationships and tradeoffs between alternative performance dimensions and leads to improved decision making and problem solving. With this objective, many firms have developed new performance measurement systems, but the nature and type of nonfinancial metrics used and the extent to which they are related to financial metrics vary widely across industries (Kaplan and Norton, 1996). It is an empirical question to

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determine whether there exist tradeoffs between financial and nonfinancial performance metrics in a given industry. In this paper, we present a method based on data envelopment analysis (DEA) to evaluate tradeoffs between alternative performance metrics.

Overemphasis on financial measures of corporate performance has been criticized as the root cause for many problems in US industries. Comparing investments made by US corporations and those made in Japan and Germany, Porter (1992) observes:

- The US system is less supportive of long-term corporate investment because of the emphasis on improving short-term returns to influence current share prices.
- The US system leads to underinvestment in intangible assets—product or process innovation, employee skills, customer satisfaction—whose short-term returns are more difficult to measure.
- The US system leads to overinvestment in assets that can be easily valued (such as mergers and acquisitions) and to underinvestment in internal development projects whose returns are more difficult to value.

Financial metrics are thus seen to be inadequate for evaluating corporate performance.

To survive and prosper competing in the information age, companies must use measurement systems derived from their strategies and capabilities (Kaplan and Norton, 1996). As managers get excessively focused on and pressured to deliver on short-term financial performance metrics, they will have a tendency to trade off actions that bring in long-term benefits for current profitability, and limit the search for investments in future growth opportunities. Larry D. Brady (Kaplan, 1993), the executive vice president of FMC Corporation stated:

> ... (T)he return on capital employed measure was especially important to us. At year end, we rewarded division managers who delivered predictable financial performance. We had run the company tightly for the past 20 years and had been successful. But it was becoming less clear where future growth would come from and where the company should look for breakthroughs into new areas. We had become a high return-on-investment company but had less potential for future growth.

The pressure for short-term financial performance can also cause a company to reduce spending on new product development, process improvements, human resource development, information technology and customer and market development. The accounting system reports such cutbacks as improved financial performance, but in reality, the firm's ability to create future economic value has been compromised (Kaplan and Norton, 1996). Such myopic actions by managers are a consequence of a poorly designed performance measurement system that focuses only on short-term financial performance. It is to avoid such distorted incentives that Kaplan and Norton (1992) suggest the deployment of the balanced scorecard.

The multiplicity of performance metrics in a balanced scorecard scheme, however, can potentially be very confusing, and lead to a lack of focus. While performance metrics that balance potentially conflicting short-term and long-term objectives are required, a good performance measurement system should be parsimonious and contain only the metrics that truly must be traded off against each other including the short term financial metrics.

In this paper, we present a DEA based method to assess whether such tradeoffs exist, and illustrate it with an application to the US local exchange carriers industry. Nonfinancial information plays a key role in industries such as telecommunications, biotechnology, and software development (Amir and Lev, 1996). With substantial reduction in regulatory constraints, firms in the US telecommunications industry have adopted a variety of competitive strategies (Banker et al., 1996). Hence it is an ideal industry to evaluate the role of alternative performance metrics and to see which of these performance metrics must be traded off for each other.

The remainder of this paper is structured as follows. The next section presents the theoretical basis of our proposed method. Section 3 describes the US local exchange carriers industry and common performance metrics in this industry. This section also contains the empirical results of the application of our method to the performance data collected for the five year period 1993–1997 from local exchange carriers. Section 4 concludes the paper.

## 2. Evaluating tradeoffs between different performance metrics

The balanced scorecard seeks to include nonfinancial metrics that are strategically important for a firm's long-term performance. If managerial actions to improve a performance metric do not imply a corresponding decline in short term financial performance, managers do not need to trade off one metric for the other. We refer to such metrics as *contemporaneously congruent*. If a nonfinancial metric is contemporaneously congruent with the financial metric, then there is no motivational distortion induced by a managerial reward system based on financial performance metrics. However, if a metric is not contemporaneous congruent with short-term financial performance, then it is important to include such a metric in addition, or else the incentives induced by a financial performance based reward system will lead to under-investment in effort to improve that nonfinancial metric.

To be concrete, consider the case of the two performance metrics illustrated in Fig. 1. The feasible set $\mathscr{S}$ is the set of all possible pairs $(y_1, y_2)$ of the values of performance metric 1 $(y_1)$ and performance metric 2 $(y_2)$ that a firm can attain. The North–East boundary of the feasible set indicates whether tradeoffs are required between $y_1$ and $y_2$. If performance for a metric $y_r$ can be improved only at the cost of a decline in the performance for the other metric $y_s$, $r \neq s$, then clearly, tradeoffs are required between the metrics $r$ and $s$. On the other hand, if performance for a metric $y_r$ can be improved without affecting the performance for the other metric $y_s$, then they are contemporaneously congruent because no tradeoffs are required between the two metrics.

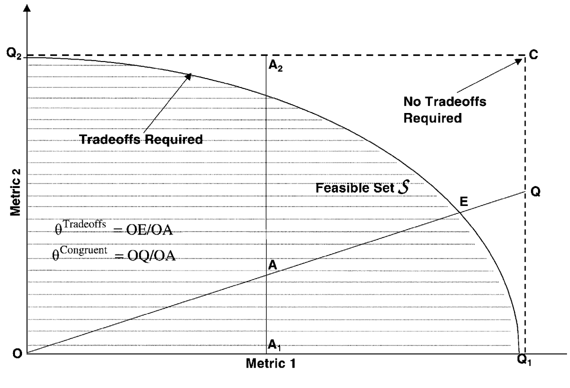

Fig. 1. Feasible set for two performance metrics.

Returning to Fig. 1, we observe that if the slope of the boundary of the feasible set $\mathscr{S}$ is either 0 or $\infty$, then there are no tradeoffs between the metrics $y_1$ and $y_2$ because improvements in one do not come at the sacrifice of the other. This is the case for the boundary $Q_1QCA_2Q_2$ represented by a broken line. In contrast, if the slope is not 0 or $\infty$, then there exist tradeoffs between the metrics $y_1$ and $y_2$ because an increase in the value of $y_1$ requires a decrease in the value of $y_2$, and vice versa. This corresponds to the case of the boundary given by $Q_1EQ_2$ of the set $\mathscr{S}$ represented by the shaded region. Thus, the test of whether no tradeoffs are required corresponds to a test of whether the boundary of the set $\mathscr{S}$ is given by $Q_1QCA_2Q_2$ rather than $Q_1EQ_2$. Observe that under the null hypothesis that the feasible set $\mathscr{S}$ is bounded by $Q_1QCA_2Q_2$, a consistent estimator of the radial inefficiency measure of observation A is given by $\hat{\theta}^{\text{TRADEOFFS}} = \text{OE/OA}$ relative to a feasible set for which we do not impose a contemporaneous congruence condition. When the true feasible set $\mathscr{S}$ does not require tradeoffs, $\hat{\theta}^{\text{TRADEOFFS}}$ will also converge to a consistent estimator of the radial inefficiency measure $\hat{\theta}^{\text{CONGRUENT}} = \text{OQ/OA}$ relative to a feasible set for which we do impose the no tradeoffs condition.

DEA has been widely used to estimate the production function relating the inputs consumed to the outputs produced. In this paper, we are interested in evaluating whether there are tradeoffs between various performance metrics. We do not have a production correspondence in this context. Instead, we model the feasible set of performance metrics, a set that contains all vectors of performance metrics that can be achieved by a firm. Let $Y_j = (y_{1j}, \ldots, y_{rj}, \ldots, y_{Rj}) \geqslant 0,\ j = 1, \ldots, N$, be $N$ observed vectors of performance metrics $y_r$, $r = 1, \ldots, R$, generated from the underlying feasible set $\mathscr{S}$ defined as

$$\mathscr{S} = \{Y | \text{performance metrics } Y \equiv (y_1, \ldots, y_r, \ldots, y_R) \text{ are feasible}\}. \tag{1}$$

For specificity, all performance metrics $y_r$ are oriented such that a higher value of $y_r$ denotes a better performance. The inefficiency $\theta_j \geqslant 1$ of an observation $Y_j \in \mathscr{S}$, measured radially by the reciprocal of Shephard's (1970) distance function, is given by

$$\theta_j \equiv \theta(Y_j) = \sup\{\theta | \theta Y_j \in \mathscr{S}\}. \tag{2}$$

Following Banker (1993), we maintain the assumptions embodied in the following four postulates about the feasible set $\mathscr{S}$ and the probability density function $f(\theta)$ for the inefficiency $\theta$:

*Postulate 1:* Convexity

$Y_j, Y_k \in \mathscr{S} \Rightarrow \lambda Y_j + (1 - \lambda) Y_k \in \mathscr{S}$ for all $\lambda \geqslant 0$.

*Postulate 2:* Monotonicity

$Y_j \in \mathscr{S}, \quad 0 \leqslant Y_k \leqslant Y_j \Rightarrow Y_k \in \mathscr{S}$.

*Postulate 3:* Envelopment

$f(\theta) = 0$ if $\quad \theta < 1$.

*Postulate 4:* Probability of efficient performance

$\int_1^{1+\delta} f(\theta)\,\mathrm{d}\theta > 0$ for $\quad \delta > 0$.

An estimator of $\theta$ is obtained as $\hat{\theta}_j^{\text{TRADEOFFS}}$ by solving the following BCC model of DEA (Banker et al., 1984):

$$\hat{\theta}_j^{\text{TRADEOFFS}} = \operatorname{Max} \theta \tag{3.1}$$

subject to

$$\sum_{k=1}^{N} \lambda_k y_{rk} \geqslant \theta y_{rj} \quad \forall r = 1, \ldots, R, \tag{3.2}$$

$$\sum_{k=1}^{N} \lambda_k = 1, \tag{3.3}$$

$$\theta,\ \lambda_k \geqslant 0, \quad \forall k = 1, \ldots, N. \tag{3.4}$$

The above model is different from the conventional DEA model in that it does not include any constraints corresponding to inputs. An alternative interpretation of this model is as a CCR model (Charnes et al., 1978) where all observations have the same level of a single input, say $x_j = x > 0\ \forall j = 1, \ldots, N$, so that the input convexity constraint $\sum_{k=1}^{N} \lambda_k x_k = x_j$ reduces to $x \sum_{k=1}^{N} \lambda_k = x$ or $\sum_{k=1}^{N} \lambda_k = 1$ as in constraint (3.3).

Under the maintained assumptions of postulates 1–4, the DEA estimator $\hat{\theta}_j^{\text{TRADEOFFS}}$ is a consistent estimator of the inefficiency of observation $j$. Observe that these four postulates do not impose any additional structure, such as whether tradeoffs are required or not required between any subsets of performance metrics. Therefore, the feasible set $\mathscr{S}$ in (1) and the estimator $\hat{\theta}_j^{\text{TRADEOFFS}}$ are consistent with both tradeoffs as well as contemporaneous congruence between performance metrics.

Consider next the feasible set expressed as follows that does not allow tradeoffs between any performance metrics:

$$\mathscr{S}^{\text{CONGRUENT}} \equiv \{Y | y_r \in \mathscr{S}^r,\ r = 1, \ldots, R\} \tag{4}$$

where

$$\mathscr{S}^r \equiv \{y_r | \text{performance metric } y_r \text{ is feasible}\}. \tag{5}$$

Here in (5), by construction, the level of a performance metric does not depend on the level of any other metric. Further, if each $\mathscr{S}^r$ and the corresponding probability density function $f_r(\theta_r)$ for performance metric $r = 1, \ldots, R$ satisfy the same postulates as those of $\mathscr{S}$ and $f(\theta)$ with $Y$ modified to read as $y_r$, then it can be shown that $\mathscr{S}^{\text{CONGRUENT}}$ and $f(\theta^{\text{CONGRUENT}})$ also satisfy the above four postulates, where $\theta^{\text{CONGRUENT}}$ is the inefficiency measure (Shephard's distance measure) relative to the feasible set $\mathscr{S}^{\text{CONGRUENT}}$.

An estimator of $\theta^{\text{CONGRUENT}}$ is obtained as $\hat{\theta}^{\text{CONGRUENT}}$ as described below:

$$\hat{\theta}_j^{\text{CONGRUENT}} \equiv \min\{\hat{\theta}_j^r | r = 1, \ldots, R\} \tag{6}$$

where

$$\hat{\theta}_j^r = \operatorname{Max} \theta \tag{7.1}$$

subject to

$$\sum_{k=1}^{N} \lambda_k y_{rk} \geqslant \theta y_{rk}, \tag{7.2}$$

$$\sum_{k=1}^{N} \lambda_k = 1, \tag{7.3}$$

$$\theta,\ \lambda_k \geqslant 0, \quad \forall k = 1, \ldots, N. \tag{7.4}$$

Note that the above linear program is similar to that in (3) except that the $R$ constraints in (3.2) are replaced by an appropriate single constraint only for the metric $r$. Since $\hat{\theta}_j^{\text{CONGRUENT}}$ is estimated from a less constrained program, $\hat{\theta}_j^{\text{CONGRUENT}} \geqslant \hat{\theta}_j^{\text{TRADEOFFS}}$ for all $j = 1, \ldots, N$. Because of the single constraint in (7.2), the linear program in (7) reduces to the simple program given below:

$$\hat{\theta}_j^r \equiv \max\{y_{rk}/y_{rj} | k = 1, \ldots, N\}. \tag{8}$$

Under the null hypothesis that there is no tradeoff between various performance metrics in the feasible set, the asymptotic empirical distribution of $\hat{\theta}^{\text{CONGRUENT}}$ is identical to that of $\hat{\theta}^{\text{TRADEOFFS}}$, with both $\hat{\theta}^{\text{CONGRUENT}}$ and $\hat{\theta}^{\text{TRADEOFFS}}$ retrieving the true distribution of $\theta$ (Banker, 1992, 1993, 1996). Based on the asymptotic correspondence between the empirical distributions of $\hat{\theta}^{\text{TRADEOFFS}}$ and $\hat{\theta}^{\text{CONGRUENT}}$, we can employ the following three tests to evaluate the null hypothesis of no tradeoffs between any performance metrics:

(i) *Banker's Sum Ratio Test*: If $\theta$ is exponentially distributed over $[1, \infty)$, then the test statistic

$$T_{\text{EX}} \equiv \sum_{j=1}^{N} \left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right) \Bigg/ \sum_{j=1}^{N} \left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right) \tag{9}$$

is evaluated relative to the Half-$F$ distribution $|F_{2N,2N}|$ with ($2N$, $2N$) degrees of freedom.

(ii) *Banker's Sum of Squares Ratio Test*: If $\theta$ is half-normally distributed over $[1, \infty)$, then the test statistic

$$T_{\text{HN}} \equiv \sum_{j=1}^{N} \left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right)^2 \Bigg/ \sum_{j=1}^{N} \left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right)^2 \tag{10}$$

is evaluated relative to the Half-$F$ distribution $|F_{N,N}|$ with ($N$, $N$) degrees of freedom.

(iii) *Kolmogorov–Smirnov Test*: If no such assumption is maintained about the distribution of $\theta$, then the Kolmogorov–Smirnov test statistic is employed to compare the distributions of $\hat{\theta}^{\text{CONGRUENT}}$ and $\hat{\theta}^{\text{TRADEOFFS}}$:

$$T_{\text{KS}} \equiv \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right) - F\left(\hat{\theta}_j^{\text{CONGRUENT}}\right) \middle| j = 1, \ldots, N\right\}. \tag{11}$$

Consider Fig. 1 again to examine the estimation of inefficiency relative to the feasible set that allows tradeoffs as well as the feasible set that does not allow tradeoffs. The estimated inefficiency $\hat{\theta}_j^{\text{TRADEOFFS}}$ relative to the surface $Q_1EQ_2$ is the ratio OE/OA and the estimated inefficiency $\hat{\theta}_j^{\text{CONGRUENT}}$ relative to the surface $Q_1QCA_2Q_2$ is the ratio OQ/OA, so that $\hat{\theta}_j^{\text{TRADEOFFS}} \leqslant \hat{\theta}_j^{\text{CONGRUENT}}$. If the true underlying feasible set does not require tradeoffs between the two performance metrics $y_1$ and $y_2$, then the estimated surface $Q_1EQ_2$ will converge to the estimated surface $Q_1QCA_2Q_2$ for large samples and consequently the two inefficiency estimators $\hat{\theta}_j^{\text{TRADEOFFS}}$ and $\hat{\theta}_j^{\text{CONGRUENT}}$ will converge to each other as well. Our test procedures are based, therefore, on a comparison of these two estimators.

We have so far evaluated the null hypothesis of a feasible set $\mathscr{S}^{\text{CONGRUENT}}$ as described in (4) that does not allow tradeoffs between any pairs of metrics. To evaluate whether there exist tradeoffs within subsets of metrics, but no tradeoffs between such subsets, we seek a more parsimonious feasible set to capture such a relation between metrics. For this purpose, we consider a set $I$ whose elements are subsets of the index set $M \equiv \{1, \ldots, r, \ldots, R\}$ for the performance metrics. That is, every element $i \in I$ is a set of the indexes for the performance metrics; $i \in M$. Let $I$ be a partition of $M$, that is $\bigcup_{i \in I} i = M$ and $i \cap m = \varnothing$ for all $i, m \in I$. Next, we define a feasible set $\mathscr{S}^i$ for each $i \in I$, such that $\mathscr{S}^i$

contains vectors $Y^i$ of performance metrics included in the set $i$:

$$\mathscr{S}^i \equiv \{Y^i | \text{performance metrics } Y^i \text{ are feasible}\}. \tag{12}$$

Proceeding as before, we write the following:

$$\mathscr{S}^I \equiv \{Y | Y_i \in \mathscr{S}^i, i \in I\} \tag{13}$$

and

$$\hat{\theta}^I_j \equiv \min\{\hat{\theta}^i_j | i \in I\} \tag{14}$$

where

$$\hat{\theta}^i_j = \operatorname{Max} \theta \tag{15.1}$$

subject to

$$\sum_{k=1}^{N} \lambda_k y_{rk} \geqslant \theta y_{rj} \ \forall r \in i, \tag{15.2}$$

$$\sum_{k=1}^{N} \lambda_k = 1, \tag{15.3}$$

$$\theta,\ \lambda_k \geqslant 0, \quad \forall k = 1, \ldots, N. \tag{15.4}$$

Tests of whether the parsimonious representation of $\mathscr{S}$ as in $\mathscr{S}^I$ is an adequate representation are constructed as described before in (9)–(11) except that $\hat{\theta}^{\text{CONGRUENT}}_j$ is replaced in each case by $\hat{\theta}^I_j$.

## 3. Empirical analysis and results

### 3.1. Industry background and performance metrics

We employ our proposed method to evaluate alternative financial and nonfinancial performance measures for over 50 local exchange carriers operating in the US, based on operating data collected for the period 1993–1997. Local exchange carriers own and operate the transmission lines running from the customers' premises to their central offices and the lines from the central offices to the point of presence of interexchange carriers. The divestiture agreement between the Justice department and AT&T in 1984 provided the local exchange carriers a monopoly right to carry calls within local access transport area (LATA). Local exchange carriers started out providing basic services such as local and long distance calls within LATA. From March 1988 onward, local exchange carriers were allowed to offer enhanced services such as voice mail, audiotext and electronic mail services and, in return, they were required to open up more than 100 network features to competition. In 1996, the local exchange carriers were exposed to further competition from long distance vendors, cable companies, local access providers and utility companies (Dodd, 1998). The 1996 legislation regulating the US telecommunications industry rewrote the rules governing competition for telephone service, telecommunication equipment manufacturing, cable TV, radio, and TV broadcasting, as well as the internet and online computer services.

The local exchange carriers' revenues in the US totaled about \$82 billion in 1997. The regional Bell operating companies controlled about 85% of the US telephone access lines. Most of the rest belonged to GTE and various independent franchise holders (Grover and Vaswani, 2000). Competitive access providers owned about 2% of the access lines but have been moving aggressively to become full-service providers by offering access to the internet and to long-distance markets.

For the past ten years, the US local telephone market has been experiencing major structural changes brought about by sharply falling telecommunications costs, deregulation, the internet and related technologies. The era of competition since 1988 has required the local exchange carriers to develop technical competencies and rethink their competitive strategies. If their managerial reward systems, however, rely primarily on short-term financial measures and ignore long-term performance, then they are likely to invest less in programs that will benefit them in the long run but cost them in the short run.

Based on analysis by industry experts and discussions with senior executives at a major local exchange carrier, four performance metrics were identified as being important in designing a balanced scorecard for the local exchange carrier. The first metric is *return on assets* (*ROA*). Historically, this has been an important indicator of the financial well being of the firm. In fact, during the era of regulation, the rates that the customers paid for their telephone services were set based on the target ROA for the local exchange carriers. This measure now reflects short-term financial performance. The second metric is *number of access lines per employee*. Access lines serviced is a key measure of activity volume. Therefore, the number of access lines per employee is an employee productivity measure. A high value of access lines per employee may indicate a higher productive efficiency, but it may also indicate a potential problem of under-staffing and deterioration in quality of the service. The third metric is *percentage of business access lines*. The long-term revenue potential from business customers is higher than that from residential customers because local exchange carriers have more opportunities to offer value-enhanced services to business customers. In the short term, however, local exchange carriers have to compete hard with other access providers for business customers. Cultivating, acquiring and maintaining a new business customer is costly for the local exchange carriers, who have to sacrifice financial profitability in the short run to acquire more business customers in the interest of long term performance. The fourth metric is *percentage of digital access lines*. Technological advances have enabled communication of large quantities of data at fast speeds. Digitization has played a key role in this technological development. Many newer services like video conferencing require that the access line be digital. Moreover, digital access lines also reduce the error rate in transmission. Installation and maintenance of digital access lines may require a greater investment, but the payback is in the form of the ability to offer value-enhanced services with a higher revenue potential and higher customer satisfaction due to error-free transmission of information.

As depicted in Fig. 2, the four performance metrics fit the template of four different perspectives of a balanced scorecard (Kaplan and Norton, 1992). ROA represents the financial perspective. Most local exchange carriers are subsidiaries that are not themselves listed on any stock exchange. Therefore, share price data are not available and ROA is the most important financial metric for the owners of these companies. The number of access lines per employee is a process efficiency measure that provides the internal business process perspective. Since both service demands and revenue potential of business customers differ from those of residential customers, and because of the strategic importance of acquiring business customers, the *percentage of business access lines* captures the customer perspective. Digital technology makes use of time-division switching and provides greater flexibility in the use of access lines and network resources (Flamm, 1989). Digital access lines also provide firms with faster, more flexible and higher quality of service delivery capabilities (Banker et al., 1998). Therefore, the percentage of digital access lines captures the technology perspective of the balanced scorecard.

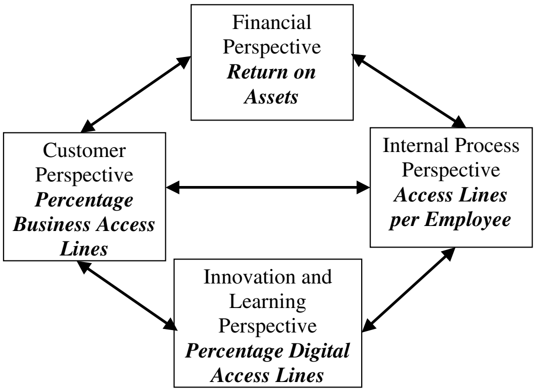

Fig. 2. Balanced scorecard for a local exchange carrier.

Inclusion of all four metrics in the reward system is necessary if each of them requires a tradeoff with the other metrics. However, if any of the nonfinancial metrics is contemporaneously congruent with the financial metric, then we can leave it out from the reward system and concentrate on the remaining metrics.

### 3.2. Empirical results

Table 1 presents the descriptive statistics of our sample. During the period of analysis, an average firm earned ROA of about 14.4%. The average number of access lines per employee increased from 313 in 1993 to 470 in 1997 indicating a

Table 1
Descriptive statistics of performance metrics US local exchange carriers

| Year | Variable | Mean | Standard deviation | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|
| 1993 ($N = 53$) | Return on assets | 0.1328 | 0.0375 | 0.1045 | 0.1352 | 0.1556 |
| | Access lines per employee | 313 | 134 | 237 | 281 | 351 |
| | Percentage of digital access lines | 0.0368 | 0.0484 | 0.0001 | 0.0131 | 0.0554 |
| | Percentage of business access lines | 0.2642 | 0.0798 | 0.2134 | 0.2638 | 0.3010 |
| 1994 ($N = 51$) | Return on assets | 0.1280 | 0.0331 | 0.1050 | 0.1311 | 0.1515 |
| | Access lines per employee | 351 | 150 | 272 | 320 | 391 |
| | Percentage of digital access lines | 0.0544 | 0.0527 | 0.0093 | 0.0354 | 0.0707 |
| | Percentage of business access lines | 0.2725 | 0.0777 | 0.2159 | 0.2760 | 0.3123 |
| 1995 ($N = 53$) | Return on assets | 0.1429 | 0.0411 | 0.1163 | 0.1466 | 0.1656 |
| | Access lines per employee | 382 | 134 | 305 | 366 | 422 |
| | Percentage of digital access lines | 0.0584 | 0.0532 | 0.0130 | 0.0454 | 0.0835 |
| | Percentage of business access lines | 0.2831 | 0.0728 | 0.2263 | 0.2783 | 0.3237 |
| 1996 ($N = 51$) | Return on assets | 0.1548 | 0.0390 | 0.1407 | 0.1524 | 0.1721 |
| | Access lines per employee | 427 | 154 | 332 | 417 | 514 |
| | Percentage of digital access lines | 0.0876 | 0.0662 | 0.0403 | 0.0862 | 0.1244 |
| | Percentage of business access lines | 0.2915 | 0.0803 | 0.2316 | 0.2885 | 0.3322 |
| 1997 ($N = 51$) | Return on assets | 0.1622 | 0.0468 | 0.1371 | 0.1675 | 0.1864 |
| | Access lines per employee | 470 | 161 | 351 | 461 | 556 |
| | Percentage of digital access lines | 0.1142 | 0.0726 | 0.0650 | 0.1115 | 0.1503 |
| | Percentage of business access lines | 0.2966 | 0.0719 | 0.2438 | 0.2940 | 0.3389 |

substantial improvement in the average productivity per employee in the local exchange carrier industry. Percentage of digital access lines has increased threefold during the sample period of five years. On average about one in four access lines provides service to business customers.

Our first null hypothesis is that there is no tradeoff between the metrics. We employ Banker's (1993) sum ratio and sum of squares ratio semi-parametric tests, and the Kolmogorov–Smirnov nonparametric test. Table 2 presents the results of tests of the null hypothesis that there is no tradeoff between any of the four metrics. The denominator of Banker's test statistic is based on the estimated deviations obtained by solving programs (3) corresponding to a feasible set that permits tradeoffs. The numerator of the test statistic is based on the estimated deviations obtained by solving programs (7) corresponding to a feasible set that assumes that no tradeoffs are required between metrics. If the null hypothesis of no tradeoffs between performance metrics is true, then the test statistic should be very close to one, and a high value of the test statistic leads to the rejection of the null hypothesis. Values of the test statistic for Banker's sum ratio and sum of squares ratio tests are presented in the first two columns respectively, for each year. The Kolmogorov–Smirnov test results are presented in the last column of Table 2. All three tests indicate the rejection of the null

Table 2
Results of testing hypothesis of no tradeoffs between any metrics

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 2.042 (0.001) | 3.826 (0.001) | 0.255 (0.001) |
| 1994 | 2.034 (0.001) | 3.251 (0.001) | 0.206 (0.001) |
| 1995 | 2.012 (0.001) | 3.568 (0.001) | 0.226 (0.001) |
| 1996 | 1.836 (0.002) | 2.815 (0.001) | 0.235 (0.001) |
| 1997 | 1.853 (0.002) | 3.026 (0.001) | 0.274 (0.001) |

*Testable hypotheses*: Null: no tradeoffs between any metrics; alternative: tradeoffs are required between some metrics.
Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right) \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right)^2 \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right) - F\left(\hat{\theta}_j^{\text{CONGRUENT}}\right)\Big| j = 1,\ldots,N\right\}.$$

$\hat{\theta}_j^{\text{CONGRUENT}}$: $\hat{\theta}_j$ estimated using model (6) with the maintained assumption of feasible set $S^{\text{CONGRUENT}}$ disallowing tradeoffs.
$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

hypothesis of no tradeoff between the performance measures for all five years.

The rejection of the null hypothesis of no tradeoff between four metrics does not preclude the possibility of no tradeoff between any two or more performance metrics. Our objective is to identify the most parsimonious set of performance metrics that must be traded off against each other. Therefore, we next proceed to form subgroups of metrics from the original set of four metrics and test the null hypothesis of no tradeoff between such subgroups that partition the original set. These results are presented in Tables 3–6.

In Table 3, the partition comprises two subgroups of metrics. The first subgroup consists of ROA ($y_1$), number of access lines per employee ($y_2$), percentage of digital access lines ($y_3$) and we allow for the possibility of tradeoffs between them. The second subgroup is singleton set consisting of the metric percentage business access lines ($y_4$). Under the null hypothesis, we do not allow tradeoff between this measure and any one of the metrics in the first subgroup. Although the results are mixed, we observe that the null hypothesis of no tradeoff between the percentage business access lines and any of the remaining three metrics is rejected in most cases.

In Table 4, we group ROA, number of access lines per employee and percentage business access lines together and consider the measure percentage digital access lines as the second subgroup. In every year, we do not reject the null hypothesis of no tradeoff.

Next, in Table 5, we allow tradeoffs between ROA, percentage digital access lines and percentage business access lines in one subgroup but preclude any tradeoffs with the number of access lines per employee in the other subgroup. Once again, in every year, we do not reject the null hypothesis of no tradeoff.

Finally, we combine all three nonfinancial metrics in one subgroup allowing tradeoffs between them, but do not allow any tradeoff with the financial metric ROA. The results presented in Table 6 indicate that the null hypothesis of no tradeoff between ROA and any of the nonfinancial measures is rejected in every year.

Combining together the results of Tables 3–6, it is clear that as long as we allow tradeoff between ROA ($y_1$) and percentage business access lines ($y_4$)

Table 3

Results of testing hypotheses of no tradeoffs between subgroups of performance metrics: Hypothesis of no tradeoffs between {ROA ($y_1$), access lines per employee ($y_2$), percentage of digital access lines ($y_3$)} and {percentage of business access lines ($y_4$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.583 (0.018) | 2.608 (0.001) | 0.151 (0.016) |
| 1994 | 1.288 (0.202) | 1.824 (0.031) | 0.128 (0.055) |
| 1995 | 1.552 (0.023) | 2.264 (0.004) | 0.132 (0.050) |
| 1996 | 1.257 (0.248) | 1.608 (0.092) | 0.137 (0.043) |
| 1997 | 1.302 (0.183) | 1.813 (0.034) | 0.470 (0.001) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{123,4}-1\right)\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{123,4}-1\right)^2\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right)-F\left(\hat{\theta}_j^{123,4}\right)\Big|j=1,\ldots,N\right\}.$$

$\hat{\theta}_j^{123,4}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{123,4}$ that allows tradeoffs between the three metrics {ROA ($y_1$), access lines per employee ($y_2$), and percentage of digital access lines ($y_3$)} but does not allow tradeoffs between any of them and {percentage of business access lines ($y_4$)}.

$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

by including them in the same subgroup, we do not reject the null hypothesis of no tradeoff between the subgroups. Whenever, we placed these two metrics in different subgroups, the null hypothesis of no tradeoffs between subgroups was rejected. This suggests that tradeoffs exist only between $y_1$ and $y_4$, but not between other metrics.

The results presented in Table 7 confirm this. Here, we form three subgroups of metrics. The first subgroup consists of ROA and percentage business access lines. The second and third subgroups are both singleton sets consisting of number of access lines per employee and percentage of digital access lines respectively. Similar to the analysis in Tables 3–6, in our null hypothesis, we allow tradeoffs between measures within the same subgroup but do not allow any tradeoff between metrics across subgroups. Results presented in Table 7 do not reject the null hypothesis of no tradeoff between the groups of metrics.

Our final test compares the three subgroup partition described above for Table 7, but compares it with the partition in which we treat each individual metric as a separate subgroup. The results corresponding to this test are presented in Table 8. As expected, we reject the null hypothesis because the null hypothesis does not allow tradeoff between ROA and percentage business access lines. Thus, these results lead to the conclusion that the most parsimonious representation requires tradeoffs between ROA and percentage business access lines, but that no tradeoff is necessary between other pairs of metrics.

The managerial significance of these results is on the design of the reward system. Since there is no tradeoff between ROA and number of access lines per employee or percentage of digital access lines, a reward system based on ROA is not likely to distort investors to invest in improving these two performance metrics. While we can omit these two metrics, we cannot exclude percentage of business access lines, because of the tradeoffs that exist between this metric and ROA. Thus, a parsimonious design of the reward system must be based on ROA and percentage of business access lines.

Table 4
Results of testing hypotheses of no tradeoffs between subgroups of performance metrics: Hypothesis of no tradeoffs between {ROA ($y_1$), access lines per employee ($y_2$), percentage of business access lines ($y_4$)} and {percentage of digital access lines ($y_3$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.047 (0.810) | 1.049 (0.861) | 0.047 (0.972) |
| 1994 | 1.141 (0.504) | 1.086 (0.768) | 0.078 (0.557) |
| 1995 | 1.023 (0.905) | 1.055 (0.954) | 0.038 (0.992) |
| 1996 | 1.047 (0.812) | 1.076 (0.792) | 0.022 (0.998) |
| 1997 | 1.072 (0.724) | 1.123 (0.677) | 0.049 (0.967) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{124,3} - 1\right) \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{124,3} - 1\right)^2 \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right) - F\left(\hat{\theta}_j^{124,3}\right)\Big|j = 1,\ldots,N\right\}.$$

$\hat{\theta}_j^{124,3}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{124,3}$ that allows tradeoffs between the three metrics {ROA ($y_1$), access lines per employee ($y_2$), and percentage of business access lines ($y_4$)} but does not allow tradeoffs between any of them and {percentage of digital access lines ($y_3$)}.
$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

Table 5
Results of testing hypotheses of no tradeoffs between subgroups of performance metrics: Hypothesis of no tradeoffs between {ROA ($y_1$), percentage of digital access lines ($y_3$), percentage of business access lines ($y_4$)} and {access lines per employee ($y_2$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.157 (0.452) | 1.334 (0.296) | 0.057 (0.886) |
| 1994 | 1.276 (0.218) | 1.622 (0.086) | 0.088 (0.405) |
| 1995 | 1.028 (0.884) | 1.052 (0.846) | 0.028 (0.999) |
| 1996 | 1.077 (0.707) | 1.146 (0.626) | 0.029 (0.999) |
| 1997 | 1.080 (0.696) | 1.125 (0.672) | 0.049 (0.967) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{134,2} - 1\right) \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{134,2} - 1\right)^2 \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}} - 1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right) - F\left(\hat{\theta}_j^{134,2}\right)\Big|j = 1,\ldots,N\right\}.$$

$\hat{\theta}_j^{134,2}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{134,2}$ that allows tradeoffs between the three metrics {ROA ($y_1$), percentage of digital access lines ($y_3$), and percentage of business access lines ($y_4$)} but does not allow tradeoffs between any of them and {access lines per employee ($y_2$)}.
$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

Table 6
Results of testing hypotheses of no tradeoffs between subgroups of performance metrics: Hypothesis of no tradeoffs between {ROA ($y_1$)} and {access lines per employee ($y_2$), percentage of digital access lines ($y_3$), percentage of business access lines ($y_4$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.543 (0.025) | 2.168 (0.005) | 0.151 (0.016) |
| 1994 | 1.601 (0.019) | 1.923 (0.020) | 0.176 (0.004) |
| 1995 | 1.719 (0.006) | 2.556 (0.001) | 0.198 (0.001) |
| 1996 | 1.713 (0.007) | 2.476 (0.001) | 0.235 (0.001) |
| 1997 | 1.668 (0.009) | 2.552 (0.001) | 0.216 (0.001) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{1,234}-1\right)\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{1,234}-1\right)^2\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right)-F\left(\hat{\theta}_j^{1,234}\right)\Big|j=1,\ldots,N\right\}.$$

$\hat{\theta}_j^{1,234}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{1,234}$ that allows tradeoffs between the three metrics {access lines per employee ($y_2$), percentage of digital access lines ($y_3$), and percentage of business access lines ($y_4$)} but does not allow tradeoffs between any of them and {ROA ($y_1$)}.
$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

Table 7
Results of testing hypothesis of no tradeoffs between {ROA ($y_1$), percentage of business access lines ($y_4$)}, {access lines per employee ($y_2$)}, and {percentage of digital access lines ($y_3$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.225 (0.296) | 1.414 (0.210) | 0.085 (0.429) |
| 1994 | 1.425 (0.074) | 1.740 (0.051) | 0.137 (0.043) |
| 1995 | 1.051 (0.794) | 1.067 (0.812) | 0.057 (0.886) |
| 1996 | 1.111 (0.594) | 1.226 (0.467) | 0.049 (0.967) |
| 1997 | 1.162 (0.448) | 1.275 (0.388) | 0.088 (0.405) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{14,2,3}-1\right)\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{14,2,3}-1\right)^2\Big/\sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{TRADEOFFS}}-1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{\text{TRADEOFFS}}\right)-F\left(\hat{\theta}_j^{14,2,3}\right)\Big|j=1,\ldots,N\right\}.$$

$\hat{\theta}_j^{14,2,3}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{14,2,3}$ that allows tradeoffs between {ROA ($y_1$) and percentage of business access lines ($y_4$)}, but does not allow tradeoffs between either of them and either of {access lines per employee ($y_2$)} and {percentage of digital access lines ($y_3$)}.
$\hat{\theta}_j^{\text{TRADEOFFS}}$: $\hat{\theta}_j$ estimated using model (3) with the maintained assumption of feasible set $S^{\text{TRADEOFFS}}$ allowing tradeoffs.

Table 8
Results of testing hypothesis of no tradeoffs between {ROA ($y_1$)} and {percentage of business access lines ($y_4$)} and either of {access lines per employee ($y_2$)} and {percentage of digital access lines ($y_3$)}

| Year | Test statistics (significance level in parentheses) | | |
|---|---|---|---|
| | Banker's sum ratio test | Banker's sum of squares ratio test | Kolmogorov–Smirnov test |
| 1993 | 1.704 (0.037) | 2.746 (0.008) | 0.207 (0.001) |
| 1994 | 1.509 (0.001) | 2.148 (0.001) | 0.127 (0.073) |
| 1995 | 1.939 (0.001) | 3.376 (0.001) | 0.198 (0.001) |
| 1996 | 1.696 (0.008) | 2.354 (0.001) | 0.235 (0.001) |
| 1997 | 1.742 (0.006) | 3.038 (0.001) | 0.225 (0.01) |

Test statistics:

$$\text{Banker's sum ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right) \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{14,2,3} - 1\right),$$

$$\text{Banker's sum of squares ratio test} = \sum_{j=1}^{N}\left(\hat{\theta}_j^{\text{CONGRUENT}} - 1\right)^2 \Big/ \sum_{j=1}^{N}\left(\hat{\theta}_j^{14,2,3} - 1\right)^2,$$

$$\text{Kolmogorov–Smirnov test} = \text{Max}\left\{F\left(\hat{\theta}_j^{14,2,3}\right) - F\left(\hat{\theta}_j^{\text{CONGRUENT}}\right)\Big| j = 1,\ldots,N\right\}.$$

$\hat{\theta}_j^{\text{CONGRUENT}}$: $\hat{\theta}_j$ estimated using model (7) with the maintained assumption of no tradeoff feasible set $S^{\text{CONGRUENT}}$.

$\hat{\theta}_j^{14,2,3}$: $\hat{\theta}_j$ estimated using model (14) with the maintained assumption of feasible set $S^{14,2,3}$ that allows tradeoffs between {ROA ($y_1$) and percentage of business access lines ($y_4$)}, but does not allow tradeoffs between either of them and either of {access lines per employee ($y_2$)} and {percentage of digital access lines ($y_3$)}.

## 4. Conclusion

To avoid the myopic incentives induced by the use of only financial performance metrics, many firms now include nonfinancial performance metrics in addition, in order to motivate their employees (Banker et al., 2000). Focusing on financial metrics alone motivate managers to cut back on investments that may provide long term benefits at the cost of a lower financial performance in the short term. Inclusion of a nonfinancial metric together with the financial metrics in the performance evaluation system, dissuade managers from taking actions solely to optimize short term profitability goals, if this metric reflects long term value but requires tradeoffs with financial metrics in the short run. However, if a nonfinancial metric does not require tradeoffs with financial metrics, but instead moves congruently with the financial metrics, then such a metric does not provide balanced incentives. Ceteris paribus, firms want to identify a parsimonious set of key performance metrics in designing their performance evaluation system that provides balanced incentives. It is important, therefore, to be able to identify tradeoffs between different performance measures.

In this paper, we presented a DEA based method that allows us to identify which performance metrics require tradeoffs between them. We illustrated the application of this method using data gathered from firms in the local exchange carrier industry. Our empirical results indicate that two of the three nonfinancial metrics that were considered for a local exchange carrier (number of access lines per employee and percentage of digital access lines) did not require any tradeoff with the financial metric (ROA). However, the third nonfinancial metric (percentage of business access lines) required tradeoffs with the financial metric. It was important, therefore, for the local exchange carrier to include percentage of business access lines in addition to ROA in its performance measurement and evaluation system to properly motivate its managers.

## References

Amir, E., Lev, B., 1996. Value-relevance of nonfinancial information: The wireless communications industry. Journal of Accounting and Economics 22, 3–30.

Banker, R.D., 1992. Selection of efficiency evaluation models. Contemporary Accounting Research, Fall, 343–355.

Banker, R.D., 1993. Maximum likelihood, consistency and data envelopment analysis: A statistical foundation. Management Science, 1265–1273.

Banker, R.D., 1996. Hypothesis tests using data envelopment analysis. Journal of Productivity Analysis 7, 139–159.

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Models for the estimation of technical and scale inefficiencies in data envelopment analysis. Management Science 30, 1078–1092.

Banker, R.D., Chang, H., Majumdar, S.K., 1996. A framework for analyzing changes in strategic performance. Strategic Management Journal 17, 693–712.

Banker, R.D., Chang, H., Majumdar, S.K., 1998. Economies of scope in the US telecommunications industry. Information Economics and Policy 10, 253–272.

Banker, R.D., Potter, G., Srinivasan, D., 2000. An empirical investigation of an incentive plan that includes nonfinancial performance measures. The Accounting Review 75, 65–92.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research, 429–444.

Dodd, A.Z., 1998. The Essential Guide to Telecommunications. Prentice Hall PTR, Upper Saddle River, NJ.

Flamm, K., 1989. Technological advances and costs: Computers versus communications. In: Crandall, R.W., Flamm, K. (Eds.), Changing the Rules: Technological Change, International Competition and Regulation in Communications. The Brookings Institution, Washington, DC.

Grover, K., Vaswani, J., 2000. Partnerships in the US Telecommunications Industry. Communications of the ACM, February, 81–86.

Kaplan, R.S., 1983. Measuring manufacturing performance: A new challenge for managerial accounting research. The Accounting Review 58, 686–705.

Kaplan, R.S., 1993. Implementing the balanced scorecard at FMC corporation: An interview with Larry D. Brady. Harvard Business Review 71, 143–147.

Kaplan, R.S., Norton, D.P., 1992. The balanced scorecard—measures that drive performance. Harvard Business Review 70, 71–79.

Kaplan, R.S., Norton, D.P., 1996. The Balanced Scorecard: Translating Strategy into Action. Harvard Business School Press, Boston.

Porter, M.E., 1992. Capital disadvantage: America's failing capital investment system. Harvard Business Review 70, 65–82.

Shephard, R.W., 1970. Theory of Cost and Production Functions. Princeton University Press, Princeton, NJ.