A Framework for Analyzing Changes in Strategic Performance

Rajiv D. Banker; Hsi-Hui Chang; Sumit K. Majumdar


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A FRAMEWORK FOR ANALYZING CHANGES IN STRATEGIC PERFORMANCE

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In this paper we present a framework for analyzing changes in strategic performance. Traditional measures for comparing the strategic performance across firms or over time have been return on investment (ROI) and its component ratio, return on sales (ROS). We decompose the ROS ratio into four separate ratios that capture the impact of changes in a firm’s productivity, price recovery, product mix and capacity utilization on its profitability. These ratios help to highlight the micro sources of strategic success or failure. They can be used to assess changes in the performance of a firm compared to itself over time, or to other firms in its industry group. This framework can also be used to evaluate changes in the dynamic performance of an industry as a whole. We illustrate the use of these ratios with a 4-year analysis of the performance of a large manufacturing company. We also demonstrate how the technique can be applied to an industry with an evaluation of the performance of U.S. telecommunications firms between 1975 and 1987, a period during which the industry experienced a progressive increase in competitive pressure.

INTRODUCTION

Many strategy research studies have sought to measure differences in firm performance to support their propositions (e.g., Capon, Farley, and Hoenig, 1990; Cool and Diericks, 1993; Davis and Kay, 1990; Hansen and Wernerfelt, 1989; Lenz, 1981; Chakravarthy, 1986; Porter, 1985; Ramanujam and Venkatraman, 1986; Venkatraman and Prescott, 1990; Woo, Willard and Dahlenbach, 1992). The performance measures used in these studies have been typically highly aggregated, such as return on investment (ROI) or its component ratio, return on sales (ROS). Such aggregate measures often confound the impact of different strategic factors, such as product differentiation leading to higher price recovery and productivity improvement providing a cost advantage. For instance, on being deregulated, industry profits may decline due to increased competition, but the adverse impact of such decline on firm profits may be offset by improved productivity and capacity utilization exhibited by firms striving to be more efficient in the deregulated environment. As a result, analysis of aggregate measures such as ROI or ROS is likely to not reveal the detailed dynamics of the performance impacts of deregulation. In fact, even in computers and other industries that have experienced considerable productivity growth industry
prices have declined to partially offset gains in ROI and ROS. The objective of this paper, therefore, is to present a framework for analyzing financial performance along dimensions that reflect different factors affecting the strategic success of a business.

We present a methodology to disaggregate the ROS measure into four ratios that reflect changes in productivity, price recovery, product mix and capacity utilization. It can be used to compare the performance of one firm relative to its past performance, to compare the performance of a group of firms relative to each other, or to analyze the performance of all firms in an industry group over time. Such comparisons can help illuminate how changes in underlying components impact profitability, highlight the microfactors that drive strategic success, and develop ‘a coherent, company-wide grammar for performance measurement’ that is particularly important in the light of the ever-more stringent competitive environment’ (Eccles, 1991: 134).

In the remainder of this paper, we begin with a description of our methodology for analyzing financial measures of strategic performance. Next, we illustrate how the methodology is applied to evaluate the performance of a manufacturing firm over a four year period. We also apply the methodology to local exchange companies in the U.S. telecommunications industry to illustrate its use in isolating changes in their strategic performance along different key dimensions. We conclude with a summary of our findings.

MEASURES OF STRATEGIC PERFORMANCE

Return on investment (ROI) and return on sales (ROS) are commonly used as financial measures of a firm’s strategic performance. ROI and ROS are related by the algebraic identity:

\[
\text{ROI} = \text{ROS} \cdot \text{Investment Turnover}
\]

where ROS = Income/Revenues and Investment Turnover = Revenues/Investment. Both ROI and ROS are aggregate measures of performance that often fail to shed light on underlying causes of high or low performance. For instance, a firm pursuing a cost leadership strategy may improve its productivity and lower its prices (Porter, 1980). The impact of these two managerial actions may be offsetting, and no change may be registered in the ROS ratio to reflect these actions.

Profitability ratio

We define the unscaled profitability ratio as the ratio of a firm’s sales revenues to its expenses in a time period. It bears a one-to-one correspondence to the commonly used ROS ratio as seen below:

\[
\text{ROS} = \frac{\text{Income}}{\text{Revenues}} = \frac{\text{Revenues} - \text{Expenses}}{\text{Revenues}} = 1 - \frac{1}{\pi}
\]

where \( \pi = \text{Revenues}/\text{Expenses} \) is the profitability ratio. More formally, we define the unscaled profitability ratio for a period \( t \) as:

\[
\pi_t = \sum_{m=1}^{M} p_m y_{m,t} / \left( \sum_{v=1}^{V} w_v x_{v,t} + \sum_{f=1}^{F} w_f x_{f,t} \right)
\]

(1)

where:

- \( y_{m,t} \) = actual quantities of output \( m \) during period \( t \), \( t = 1, \ldots, T; \ m = 1, \ldots, M \);
- \( p_m \) = price per unit of output \( m \) during period \( t \);
- \( x_{v,t} \) = actual quantity of variable input \( v \), \( v = 1, \ldots, V \), during period \( t \);
- \( w_v \) = cost per unit of variable input \( v \) during period \( t \);
- \( x_{f,t} \) = actual quantity of fixed input \( f \), \( f = 1, \ldots, F \), during period \( t \);
- \( w_f \) = cost per unit of fixed input \( f \) during period \( t \).

Our interest is in comparing a firm’s performance over time or with other firms. Therefore, we define profitability ratio (PFTBLT) as:

\[
PFTBLT_t = \frac{\pi_t}{\pi^0}
\]

(2)

where \( \pi^0 \) represents the unscaled profitability ratio for a base level (or benchmark) determined as in Equation 1. Depending on the purpose of

\[\footnote{For instance, the unit of measurement (cost driver) for the fixed input 'facility maintenance, heating and lighting' could be 'square feet area', and the cost per unit could be determined as the ratio of the total cost for facility maintenance, heating and lighting to the total facility area measured in square feet.} \]
the analysis, the base level denoted by 0 is defined as a firm’s own performance during some period in the past, as the average or the best of its own performance over several past periods, as some technically determined standard, as a budgetary projection, as another firm’s performance, or as the average or the best performance of the industry as a whole.

Our point of departure is the approach suggested by the American Productivity and Quality Center (APC, 1981; Miller, 1984). Their approach decomposes the profitability ratio into a productivity and a price recovery ratio. However, the APC productivity and price recovery ratios are confounded by changes in product mix and capacity utilization (Banker, Datar, and Kaplan, 1989). Therefore, we propose a set of four component ratios which augment the profitability ratio measure in analyzing changes in strategic performance (Banker, Chang, and Majumdar, 1993). Specifically, we decompose the profitability ratio into productivity ratio (PRDTVT), price recovery ratio (PRCREC), product mix ratio (PRDMIX), and capacity utilization ratio (CAPUTL). When the four ratios are multiplied together, we obtain the profitability ratio.

**Productivity ratio**

This ratio compares the cost of the actual usage of inputs to the cost of the standard level of inputs required for the production of actual outputs, all costs being determined at the same actual input prices. Standards can be established relative to ‘average’ or ‘best practice’ data. We describe here the version of the method where standard input requirement is calculated based on the average input usage for the entire data sample. The productivity ratio helps evaluate whether a firm is becoming more or less efficient in its operations. It also helps assess whether a firm is likely to obtain a cost advantage over its competitors because it can use its resources more efficiently (Porter, 1991). Firms pursuing a cost leadership strategy are likely to focus efforts on improving their productivity ratio.

**Price recovery ratio**

This ratio compares the values of outputs and inputs at current and base level prices, holding output quantities constant at their actual levels, and input quantities constant at the standard levels required for actual outputs. It measures how effective the firm is in maximizing output prices while minimizing input prices. Firms pursuing a differentiation strategy, including firms with strong marketing and product development skills, command higher output prices, and tend to exhibit a high price recovery ratio. In addition, firms with strong purchasing abilities, either through scale economies or through alliances with suppliers, can significantly lower their input prices. Such a competitive advantage is also reflected in a high price recovery ratio.

**Product mix ratio**

This ratio compares the unscaled profitability ratios of current and base-level output mixes, holding both output and input prices constant at base levels and setting input consumption at standard levels. It measures the profitability impact of change in the product mix relative to the base level. Thus, this ratio reflects improvements in the allocative efficiency of the firm in focusing its resources on the more profitable products.

**Capacity utilization ratio**

This ratio compares standard input costs for actual outputs determined at standard capacity utilization levels with those at actual capacity utilization levels, holding input prices constant at their base levels. Standard input costs increase less than proportionately with capacity utilization to the extent fixed costs are a part of the cost structure of a firm. Therefore, this ratio increases with actual capacity utilization, and exceeds 1 if and only if the actual capacity utilization exceeds the standard capacity utilization. The ratio is more sensitive to changes in capacity utilization when the proportion of fixed costs is higher. While the productivity ratio described earlier measures the change in the efficiency of a firm in utilizing input resources at actual capacity utilization levels, the capacity utilization ratio measures the efficiency in the utilization of capacities of fixed resources. Firms seeking a cost advantage over their rivals often strive to maintain a high capacity utilization ratio.
Standard quantities and capacity utilization

The calculation of the performance ratios requires standards and benchmarks. We assume a Leontief-type fixed proportions technology, with an added modification for variable and fixed input resources as commonly classified in management accounting. Leontief technology coefficients are interpreted in terms of standards for input requirements. The standard quantity \( z_v^t \) of variable input \( v \) required in a period \( t \) is defined as:

\[
z_v^t = \sum_{m=1}^{M} \alpha_{mv} y_m^t \quad \text{for all} \quad v = 1, \ldots, V \\
\text{and all} \quad t = 1, \ldots, T
\]  

(3)

where \( \alpha_{mv} > 0 \) is the standard input requirement per unit of output \( m \). The standard input requirement is based on firm or industry data. For instance, it may be calculated by regressing input quantities \( x_v^t \) by input category on the \( M \) outputs \( y_m^t \), using observations for the \( t = 1, \ldots, T \) time periods.\(^2\)

The standard quantity \( z_f^t \) of fixed input \( f \) at actual output capacity level is defined as:

\[
z_f^t = \beta f_k^t \quad \text{for all} \quad f = 1, \ldots, F
\]  

(4)

where \( k^t \) denotes total output capacity during period \( t \), and \( \beta_f > 0 \) are the standard fixed input requirements per unit of output capacity that is made available in each period. These standards may be estimated, for instance, by regressing actual fixed input quantities \( x_f^t \) on the output capacity \( k^t \) for the \( t = 1, \ldots, T \) periods. The standard quantity \( q_f^t \) of fixed input \( f \), based on standard capacity utilization rate \( \gamma^0 \), is defined as:

\[
q_f^t = \beta_f \sum_{m=1}^{M} \frac{y_m^t}{\gamma^0} \quad \text{for all} \quad f = 1, \ldots, F
\]  

(5)

where \( \gamma^0 = \sum_{m=1}^{M} \frac{y_m^0}{k^0} \) is the standard capacity utilization rate, \( k^0 \) is the base-level output capacity, and \( \sum_{m=1}^{M} \frac{y_m^t}{\gamma^0} \) measures what the output capacity level would have been, given the actual outputs, if the capacity utilization rate was maintained at the standard level.

Base-level prices and quantities

Base-level data on output and input prices and quantities are generated from data for prior periods, budgetary projections, data from a competitive firm, or industry averages. For multiple evaluations, such as for multiple \( (T > 1) \) periods (or multiple firms), we employ a normalization that sets base-level prices and quantities as the weighted averages over all periods (and firms) in the sample being analyzed. Thus, base-level prices for a multiperiod sample are calculated as follows:

\[
p_m^0 = \sum_{t=1}^{T} p_m^t y_m^t / \sum_{t=1}^{T} y_m^t \quad \text{for all} \quad m = 1, \ldots, M
\]  

(6)

\[
w^0_v = \sum_{t=1}^{T} w_v^t x_v^t / \sum_{t=1}^{T} x_v^t \quad \text{for all} \quad v = 1, \ldots, V
\]  

(7)

\[
w_f^0 = \sum_{t=1}^{T} w_f^t x_f^t / \sum_{t=1}^{T} x_f^t \quad \text{for all} \quad f = 1, \ldots, F
\]  

(8)

Base-level output capacity and output quantities are calculated as follows:

\[
K^0 = \sum_{t=1}^{T} k^t / T
\]  

(9)

\[
y_m^0 = \sum_{t=1}^{T} y_m^t / T \quad \text{for all} \quad m = 1, \ldots, M
\]  

(10)

Base-level input quantities are based on standard input requirements and standard capacity utilization rate as follows:

\[2\] Specifically, using variable input and output data \( (x_v^t \text{ and } y_m^t) \) for \( t = 1, \ldots, T \) time periods, estimate the linear function \( x_v^t = \sum_{m=1}^{M} \alpha_{mv} y_m^t \) and set \( \alpha_{mv} \) equal to \( \hat{\alpha}_{mv} \), the estimated coefficients from the regression, so that the standard input quantities \( z_v^t \) equal \( E(x_v^t | y_m^t) \), \( m = 1, \ldots, M \), the expected value of the input consumption required to produce the actual output levels (Kaplan and Atkinson, 1987).
\[ x_v^0 = z_v^0 = \sum_{m=1}^{M} \alpha_{mv} y_m^0 \text{ for all } v = 1, \ldots, V \] (11)

\[ x_f^0 = z_f^0 = q_f^0 = \sum_{m=1}^{M} \beta_{mf} y_m^0 / \gamma^0 \text{ for all } f = 1, \ldots, F \] (12)

As we shall see below, an advantage of these normalizations for generating base-level data is that they simplify the calculation and the interpretation of various performance ratios.

**Performance ratio definitions**

The performance ratios can now be defined based on the above terms. The productivity ratio (PRDTVT) is defined as the ratio of the productivity ratio for the period \( t \) to the base-level productivity ratio as follows:

\[ \text{PRDTVT}' = \frac{\left( \sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 z_f^0 \right) / \left( \sum_{v=1}^{V} w_{v}^0 x_v^0 + \sum_{f=1}^{F} w_f^0 x_f^0 \right)}{\left( \sum_{v=1}^{V} w_{v} x_v^0 + \sum_{f=1}^{F} w_f x_f^0 \right) / \left( \sum_{v=1}^{V} w_{v} x_v^0 + \sum_{f=1}^{F} w_f x_f^0 \right)} \] (13)

As a result of the normalization in Equations 11 and 12, the denominator of Equation 13 equals 1 and the productivity ratio is reduced to:

\[ \text{PRDTVT}' = \frac{\sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 z_f^0}{\sum_{v=1}^{V} w_{v}^0 x_v^0 + \sum_{f=1}^{F} w_f^0 x_f^0} \] (14)

The price recovery ratio (PRCREC) is defined as:

\[ \text{PRCREC}' = \frac{\sum_{m=1}^{M} p_m^0 y_m / \sum_{m=1}^{M} p_m y_m}{\left( \sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 z_f^0 \right) / \left( \sum_{v=1}^{V} w_{v}^0 x_v^0 + \sum_{f=1}^{F} w_f^0 x_f^0 \right)} \] (15)

The ratio in the numerator can be interpreted as the output price ratio and that in the denominator as the input price ratio.

**Analyzing Changes in Performance**

The product mix ratio (PRDMIX) is defined as:

\[ \text{PRDMIX}' = \frac{\sum_{m=1}^{M} p_m^0 y_m / \sum_{m=1}^{M} p_m^0 y_m}{\sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 q_f^0} \] (16)

The capacity utilization ratio (CAPUTL) is defined as:

\[ \text{CAPUTL}' = \frac{\sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 q_f^0}{\sum_{v=1}^{V} w_{v}^0 x_v^0 + \sum_{f=1}^{F} w_f^0 x_f^0} \] (17)

With the normalization in Equation 12, the capacity utilization ratio becomes:

\[ \text{CAPUTL}' = \frac{\sum_{v=1}^{V} w_{v}^0 z_v^0 + \sum_{f=1}^{F} w_f^0 q_f^0}{\sum_{v=1}^{V} w_{v} x_v^0 + \sum_{f=1}^{F} w_f x_f^0} \] (18)

Thus, CAPUTL is the ratio of the standard cost at standard capacity utilization to the standard cost at actual capacity utilization. It may be verified easily by multiplying the four component ratios together that:

\[ \text{PFTBLT}' = \text{PRDTVT}' \cdot \text{PRCREC}' \cdot \text{PRDMIX}' \cdot \text{CAPUTL}' \] (20)

**Data requirements**

The full ratio analysis described above requires data on prices (or costs per unit) and quantities of outputs, variable inputs, and fixed inputs. A common approach to collecting these data is to
begin with the output values (revenues) and input cost data available from an organization's financial statements. The next step is to determine price indexes for each of the outputs and inputs through sources such as company records and industry statistics. These sources include appropriate indexes published by public agencies such as the Bureau of Labor Statistics and the Office of Economic Statistics. These price indexes can be used as surrogates for the true prices because ratio computations require information accurate only up to a multiple. The analysis also requires data on capacity levels. These data are available for firms in several industries from industry or trade associations, financial analyst reports, or are simply estimated as the maximum observed production level adjusted for known additions to and deductions from capacity during the period under consideration. Finally, it can be seen from the formulas for the ratios in Equations 14, 15, 16 and 18 that data are required also for standard quantities of both variable and fixed inputs. As noted earlier for Equations 3 and 4, the standard quantities may be estimated by regressing input quantities on output quantities or capacity levels.

All the data required for the full decomposition are thus available from or estimated based on public sources. However, the reliability of the data employed (especially items such as capacity levels and price indexes), and hence that of the resultant ratios, may be improved if the researcher has access to internal company records. In case the researcher decides that available data on capacity levels (driving the fixed input quantities) are largely unreliable, then the default alternative is to treat all fixed inputs like variable inputs, as being proportionate to output quantities. This treatment of all inputs as variable inputs is implicit also in the APC method. In our approach, however, the additional decomposition of the product mix ratio remains available. Specifically, when capacity data are not available, we set the standard quantities of \( z_f \) and \( q_f \) of fixed input \( f \)

\[
\begin{align*}
\alpha_{mf} y_m & \quad \text{for all } m = 1, \ldots F \quad \text{and} \\
\beta_{mf} k_m & \quad \text{for all } f = 1, \ldots F 
\end{align*}
\]

required for the remaining three ratios. For this restricted ratio analysis, changes in performance due to capacity utilization are now confounded mainly with the productivity ratio (PRDTVT) as this is the ratio that reflects the different standards now employed for fixed inputs.

A further variation of our ratio decomposition method is available for the case when output capacities are associated separately with each of highly differentiated outputs instead of a single common capacity associated with the aggregate of all outputs as in our earlier analysis. In this case, the standard quantity \( z_f \) of fixed input \( f \) is defined as:

\[
z_f = \sum_{m=1}^{M} \beta_{mf} k_m \quad \text{for all } f = 1, \ldots F \quad (21)
\]

where \( k_m \) denotes the capacity for each output \( m = 1, \ldots M \) during period \( t \). The standard quantity \( q_f \) of fixed input \( f \) based on standard capacity utilization rate \( \gamma_m \) for output \( m \), is then defined as:

\[
q_f = \sum_{m=1}^{M} \beta_{mf} y_m / \gamma_m \quad \text{for all } f = 1, \ldots F \quad (22)
\]

where \( \gamma_m = y_m / k_m \) is the standard capacity utilization rate and \( k_m \) is the base-level capacity for output \( m \). Notice that capacity levels and utilization rates are now defined individually for each output. The four ratio definitions, however, remain the same as before as given in Equations 14–16 and 18. Development and application of this modified approach to a study of the airline industry during its transition to deregulation are found in Banker and Johnston (1995).

**ILLUSTRATIVE APPLICATION OF PERFORMANCE RATIO ANALYSIS**

To illustrate the computation and use of the performance ratios, we collected 4 years of annual data from a major worldwide producer of aluminum and aluminum products. Both the industry and firm data have been disguised for this illustration. We shall refer to the firm as Aluminum Corporation. Aluminum products compete in many markets, and face price competition from
a number of substitutes such as steel, iron, copper and synthetic materials. Competition with both domestic and foreign producers is based primarily on price, availability, quality and service. The price depends largely on the market demand forces. Thus, the industry is a commodity-type industry.

Currently Aluminum Corporation operates 65 plants in the U.S.A. and employs over 30,000 people. Its operations encompass the refining of bauxite into alumina, the production of primary and reclaimed aluminum, and the fabrication of aluminum and aluminum alloys into a range of semifinished and finished products. Its management reports classify two principal product groups.

1. Primary Aluminum Products include refining of bauxite into alumina, the smelting of aluminum from alumina, the recycling of used and scrap aluminum, and sales of various semifinished aluminum mill products. These are upstream activities within the value chain.

2. Finished Aluminum Products encompass the manufacture and sales of various finished aluminum products, including flexible packaging products, containers, household foils, and aluminum building products. These are downstream activities within the value chain.

Output for both product groups is measured in thousands of tons. Production capacity is defined as the available annual smelting capacity for aluminum production measured in thousands of tons. Input costs are classified into five categories. Four categories—materials, energy, manufacturing labor, and selling, general, and administrative (SG&A)—are considered to be variable inputs as they vary primarily with the volume of output. Capital cost, including plant maintenance, interest and depreciation cost, is considered to be a fixed input since it is related to the capacity made available, rather than the actual level of output. Table 1 presents a summary of Aluminum Corporation’s sales revenues and expenses for a recent 4-year period.

**Interpretation of the ratios**

Details of the calculation of the performance ratios appear in the Appendix. The calculated values of the performance ratios for the 4-year period for Aluminum Corporation are presented in Table 2 and displayed graphically in Figure 1. We now briefly relate the ratios to other company and industry information to illustrate how they may be useful in understanding changes in strategic performance. In interpreting the ratios in this illustration, it is important to bear in mind that they compare performance in a current period with the sample averages over the 4-year period. Therefore, these performance ratios measure the difference between current performance and average performance over the last 4 years. Because of our normalized choice of the base level, the average performance ratios are identically equal to 1 in each case. Therefore, the performance ratios for each year, in fact, provide a scaled measure of performance for that year itself, and to assess change relative to a preceding or succeeding year, we must compare the ratios for the 2 years.

Table 2 and Figure 1 reveal that the profitability ratio increases for the first 3 years, but drops dramatically in the fourth. Productivity rises slightly between years 1 and 2, falls in year 3, and continues to decline further in year 4. Both price recovery and capacity utilization ratios behave in a manner similar to the profitability ratio. The product mix ratio remains almost constant over the 4 years.

An increase in the demand for aluminum products during year 2, following depressed prices and low demand in earlier years, had enabled the firm to regain its profitability. The increased sales, along with higher prices, resulted in increases in the firm’s price recovery and capacity utilization ratios. The firm’s profitability increased dramatically in year 3. This increase resulted principally from continuing strong demand realized in major markets, particularly the aluminum can, electrical products and transportation markets. In year 4, the firm’s profitability dropped slightly because of the continuing lower productivity coupled with lower demand in the transportation and construction markets. The declining trend in productivity was caused primarily by the firm’s use of old and inefficient aluminum production plants. Also contributing to the decline in profitability were the higher prices paid for purchases of raw materials used in the production of aluminum and aluminum scrap because of the tight supply of these materials.
Table 1. Aluminum Corporation: comparative income statements (amounts in millions of dollars)

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Base level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From the sale of primary aluminum products</td>
<td>$1964.614</td>
<td>$2402.739</td>
<td>$3227.908</td>
<td>$3554.078</td>
<td>$2787.335</td>
</tr>
<tr>
<td>From the sale of finished aluminum products</td>
<td>1772.391</td>
<td>1879.548</td>
<td>2403.877</td>
<td>2529.547</td>
<td>2146.341</td>
</tr>
<tr>
<td>Total revenues</td>
<td>$3737.005</td>
<td>$4282.287</td>
<td>$5631.785</td>
<td>$6083.625</td>
<td>$4933.676</td>
</tr>
<tr>
<td><strong>Expenses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>$8964.499</td>
<td>$1065.851</td>
<td>$1346.698</td>
<td>$1543.689</td>
<td>$1220.908</td>
</tr>
<tr>
<td>Energy</td>
<td>948.158</td>
<td>989.218</td>
<td>1231.853</td>
<td>1270.676</td>
<td>1082.308</td>
</tr>
<tr>
<td>Manufacturing labor</td>
<td>1277.843</td>
<td>1399.831</td>
<td>1713.448</td>
<td>1961.535</td>
<td>1546.308</td>
</tr>
<tr>
<td>Selling, general and administration</td>
<td>262.400</td>
<td>289.400</td>
<td>339.000</td>
<td>364.100</td>
<td>309.514</td>
</tr>
<tr>
<td>Capital</td>
<td>529.889</td>
<td>506.104</td>
<td>706.063</td>
<td>743.799</td>
<td>582.423</td>
</tr>
<tr>
<td>Total expenses</td>
<td>$3914.789</td>
<td>$4250.404</td>
<td>$5337.062</td>
<td>$5883.799</td>
<td>$4741.431</td>
</tr>
<tr>
<td>Income before taxes</td>
<td>($177.784)</td>
<td>$31.883</td>
<td>$294.723</td>
<td>$199.826</td>
<td>$192.215</td>
</tr>
</tbody>
</table>

Table 2. Aluminum Corporation: performance ratios

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Base level</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFTBLT</td>
<td>0.9174</td>
<td>0.9682</td>
<td>1.0141</td>
<td>0.9937</td>
<td>1.0000</td>
</tr>
<tr>
<td>PRDTVT</td>
<td>1.0050</td>
<td>1.0128</td>
<td>0.9547</td>
<td>0.9542</td>
<td>1.0000</td>
</tr>
<tr>
<td>PRCREC</td>
<td>0.9307</td>
<td>0.9581</td>
<td>1.0448</td>
<td>1.0392</td>
<td>1.0000</td>
</tr>
<tr>
<td>PRDMIX</td>
<td>1.0011</td>
<td>1.0002</td>
<td>1.0001</td>
<td>0.9989</td>
<td>1.0000</td>
</tr>
<tr>
<td>CAPUTL</td>
<td>0.9797</td>
<td>0.9976</td>
<td>1.0165</td>
<td>1.0032</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Figure 1. Aluminum Corporation: performance ratios

Profitability can increase because of temporary strong demand and consequently higher prices realized for products and higher utilization of existing capacity. Our performance ratio analysis shows that the increase in the profitability of Aluminum Corporation was because of the increased price recovery and capacity utilization. However, these changes were caused primarily by exogenous forces. Since the industry is commodity like, the firm is not in a position to strategically maneuver continuing improvements in its price recovery performance. As far as
internal capabilities are concerned, our analysis highlights a decrease in productivity which was masked by the favorable price recovery and capacity utilization changes in the aggregate profitability ratio.

The identification of the weakness in productivity performance is important because it alerts management to the potential of being trapped in a weak competitive position once the cyclical demand in an industry such as aluminum ceases to buoy up price recovery and capacity utilization. In fact, anticipating such a situation, Aluminum Corporation initiated several new capital investment projects beginning in year 4 to improve its productivity. Furthermore, it has sought to shift the emphasis from the production of primary aluminum to the higher-margin finished products resulting from its downstream conversion activities (Stuckey, 1983). Our framework for performance ratio analysis thus suggests a possible strategic shift of focus to enhance profitability, a microlevel detail that may not be revealed by the traditional ROI analysis.

A further question of interest for this illustrative example is the insight provided by the restricted ratio decomposition that is possible when no capacity-related information is available. As noted earlier, the capacity utilization ratio is identically equal to 1 in such a case. The revised calculations of the other ratios without using any capacity data appear in panel A of Table 3. The favorable impact of higher capacity utilization in years 3 and 4 is now confounded with productivity changes in the revised productivity ratio, dampening the decline in the productivity ratio in the last 2 years. The fact that industry-wide-level changes result in a favorable impact on capacity utilization and consequently on profitability is lost in this restricted ratio decomposition, while the true extent of the decline in productivity is also masked. Notice, however, that the price recovery ratios are not affected materially when capacity data are not employed.

Similar confounding of capacity utilization changes with productivity changes occurs also for the APC productivity ratios that appear in panel B of Table 3. The APC price recovery ratios are very close to those computed for our original full decomposition and also for our restricted analysis. In fact, the insights from our restricted analysis (when capacity data are assumed to be not available) and the APC ratio analysis are very similar in this illustration because the product mix has been relatively invariant over the 4-year sample period and hence its omission in the APC method does not further confound the insights from its computed ratios. In general, of course, with a changing product mix (and capacity utilization), the use of the APC method will distort both price recovery and productivity ratios.

ANALYSIS OF STRATEGIC PERFORMANCE IN THE U.S. TELECOMMUNICATIONS INDUSTRY

We have illustrated in the previous section how our framework for performance ratio analysis can be used by a firm to track changes over a period of time. In this section, we shall illustrate how a firm may compare its performance to the performance of other firms in its industry and how an industry analyst may evaluate changes occurring in an industry over a period of time.

A significant restructuring has taken place in U.S. telecommunications over the last two decades. The world’s biggest regulated industry has been gradually opened to competition, and a natural experiment ventured into to assess what impacts such measures have had in the U.S. telecommunications market (Bolter, McCon-
naughey, and Kelsey, 1990). In this section, we assess how individual local exchange telecommunications firms’ performance has changed over a period of 13 years spanning this experiment. Analyzing firms’ performance following events of such contemporary importance is of major interest, and detailed microlevel longitudinal studies can shed light on the evolution of performance patterns (Burton and Obel, 1986; Ginsberg, 1988; Reger, Duhaime, and Stimpert, 1992; Ruefli, 1986; Smith and Grimm, 1987). We demonstrate here how our framework for performance ratio analysis may be used for such a study.

Local exchange companies form a very visible and important sector of the telecommunications industry, with annual revenues in 1987 of over $75 billion. This segment of the industry has experienced relatively less deregulation compared to the long-distance segment and to the airline industry. They continue to face price and some entry regulation by the state public utilities commissions (Johnson, 1986). Many of them still retain a dominant position in their local markets. Nonetheless, increased competitive pressure is being experienced by these companies as several growing areas are being progressively made more competitive (Crandall, 1991; Gill, McFarlan, and O’Neill, 1989).

Revenues from big business customers account for a significant part of revenues of the companies (Langdale, 1982; Meyer et al., 1980), and these customers are free to choose alternative suppliers. The Open Skies decision permitted satellite channels to compete with land-based lines, and the Computer Inquiry II decision permitted value-added networks to be provided. Many local exchange companies also provide long-distance services within their jurisdictional areas, called Local Access and Transport Areas (LATA). While intra-LATA long-distance services are regulated for some of these companies, in several highly populated states these services have been progressively deregulated and local exchange companies face competition from AT&T, MCI and other operators. In addition, as managers recognized that the era of toll calls subsidizing local services was gradually coming to an end, and that regulators were unlikely to pass through full compensatory increases to consumers, they were likely to perceive incentives to take the actions necessary to improve profitability in the changing environment.

Data and measures

We measure the performance of local exchange companies in the U.S. telecommunications industry for 1975, 1978, 1981, 1984 and 1987. By 1978, technology-driven measures to liberalize the industry were being implemented. In 1981 political moves to liberalize began, ending in the 1984 divestiture by AT&T. The year 1981 also represents the middle of the recessionary period from 1980 to 1982. Thus, we have a span of 13 years critical in the history of the industry.

There are about 50 major local telephone operating companies in the U.S.A., with 1987 annual revenues exceeding $100 million. They include all erstwhile Bell operating companies and independents such as Rochester Telephone, companies belonging to GTE, United Telecommunications, Central and Continental Groups. We calculate performance ratios for 35 of these companies. The other companies are not used because of missing data. Data are obtained from the annual Federal Communications Commission publication entitled Statistics of Communications Common Carriers. All telephone companies are subject to uniform reporting requirements for filing financial and operating data with the Federal Communications Commission. These data include detailed breakdown of revenues, costs, assets, physical outputs and physical inputs.

Consistent with the industry literature (Crandall, 1991; Green, 1992; Shin and Ying, 1992) we measure physical input in terms of the total number of annual (1) local and (2) toll calls. Miscellaneous revenues are apportioned between local and toll revenues. Production capacity is measured in terms of the total access lines in place, as it signifies a firm’s overall ability to service customers. We categorize maintenance and depreciation costs as fixed costs based on production capacity and traffic, commercial, general office and other expenses as variable costs which vary with the volume of activity (local and toll calls).

Benchmarking of individual firm performance relative to its industry

We begin by illustrating how the performance of one firm, Chesapeake and Potomac Telephone Company operating in Washington, DC (C&P), may be evaluated relative to a base level
reflecting overall industry performance. C&P is a local monopoly; that is, its share of the local residential and small business customer connections in the District of Columbia is 100 percent, although several large establishments use alternative telecommunication channels. Table 4 presents the performance ratios for C&P and the corresponding averages for the industry. The trends in these ratios for C&P are graphically depicted in panel A and the average of similar ratios for the industry appear in Figure 2(b). We find that the trend in C&P’s profitability ratio is generally consistent with the overall industry trend, except in the year 1981 when C&P experienced a much steeper decline than the average for the industry. This decline in C&P’s profitability in 1981 is attributable to the sharp drop in its price recovery which, unlike the case for the industry overall, is not compensated by any improvement in productivity. More differences become apparent when we analyze the component ratios in detail.

The productivity of C&P was lower than the industry average in 1975, but it has increased to a level well above the average in 1987. After the decline in productivity in 1981 noted earlier, we find handsome gains in 1984 continuing into 1987.

The decline in price recovery for C&P has generally matched a similar trend for the industry. While the price recovery ratio for C&P had dipped below the industry average in 1978 and 1981, C&P management appears to have been successful in holding its price recovery above industry averages in 1984 and 1987.

The product mix ratio for C&P has consistently been well below the industry average. This pattern is explained in part by the high proportion of large establishments in C&P’s business area

| Table 4. Descriptive statistics for performance ratios for the U.S. telecommunications industry and Chesapeake and Potomac Telephone Company (C&P) |
|-----------------|------|------|-------------|---------|------|------|------|
| Ratio           | Year | C&P  | Industry mean | Standard deviation | 25%  | 50%  | 75%  |
| Profitability ratio | 1975 | 0.9680 | 1.0310 | 0.0795 | 0.9800 | 1.0166 | 1.0940 |
|                 | 1978 | 0.9880 | 1.0235 | 0.0635 | 0.9888 | 1.0113 | 1.0525 |
|                 | 1981 | 0.8982 | 0.9744 | 0.0520 | 0.9431 | 0.9689 | 1.0169 |
|                 | 1984 | 0.9309 | 0.9867 | 0.0396 | 0.9657 | 0.9910 | 1.0164 |
|                 | 1987 | 0.8770 | 0.9580 | 0.0358 | 0.9396 | 0.9552 | 0.9809 |
| Productivity ratio | 1975 | 0.7918 | 0.8922 | 0.1419 | 0.8168 | 0.8978 | 0.9980 |
|                 | 1978 | 0.9289 | 0.9387 | 0.1618 | 0.8524 | 0.9299 | 1.0641 |
|                 | 1981 | 0.9054 | 0.9626 | 0.1699 | 0.8447 | 0.9443 | 1.0986 |
|                 | 1984 | 1.1561 | 1.0282 | 0.2312 | 0.8074 | 1.0611 | 1.1651 |
|                 | 1987 | 1.2313 | 1.1197 | 0.2078 | 0.9534 | 1.1307 | 1.2642 |
| Price recovery ratio | 1975 | 1.6049 | 1.5584 | 0.3189 | 1.3286 | 1.5264 | 1.6555 |
|                 | 1978 | 1.2375 | 1.3635 | 0.2716 | 1.1712 | 1.2745 | 1.5410 |
|                 | 1981 | 1.0674 | 1.1868 | 0.2348 | 1.0127 | 1.1452 | 1.3362 |
|                 | 1984 | 0.9322 | 0.8729 | 0.1929 | 0.7065 | 0.8438 | 1.0070 |
|                 | 1987 | 0.8107 | 0.7263 | 0.1615 | 0.5851 | 0.7168 | 0.8469 |
| Product mix ratio | 1975 | 0.8695 | 0.9412 | 0.0823 | 0.8800 | 0.9246 | 0.9633 |
|                 | 1978 | 0.9114 | 0.9864 | 0.0901 | 0.9298 | 0.9622 | 1.0283 |
|                 | 1981 | 0.9311 | 1.0144 | 0.0863 | 0.9623 | 0.9870 | 1.0810 |
|                 | 1984 | 0.7161 | 0.9864 | 0.1532 | 0.8405 | 0.9799 | 1.1209 |
|                 | 1987 | 0.7160 | 1.0546 | 0.2072 | 0.8801 | 1.0062 | 1.2205 |
| Capacity utilization ratio | 1975 | 0.8760 | 0.8190 | 0.0805 | 0.7657 | 0.8135 | 0.8623 |
|                 | 1978 | 0.9430 | 0.8442 | 0.0705 | 0.7944 | 0.8447 | 0.8841 |
|                 | 1981 | 0.9982 | 0.8754 | 0.0692 | 0.8226 | 0.8786 | 0.9183 |
|                 | 1984 | 1.2061 | 1.1869 | 0.0913 | 1.1205 | 1.1907 | 1.2345 |
|                 | 1987 | 1.2271 | 1.1917 | 0.0974 | 1.1280 | 1.2040 | 1.2461 |
that can access alternative telecommunication channels for the more lucrative (to C&P) toll calls. While the product mix ratio did improve slightly between 1975 and 1981, this trend is punctuated by a sharp drop in 1984 relative to 1981.

C&P has continued to enjoy a capacity utilization ratio above the industry average. However, after the sharp increase in average capacity utilization for the industry between 1981 and 1984 (experienced also by C&P), the difference between C&P’s performance and the industry average has become much smaller than in the earlier years. This change may be explained in part by the fact that C&P’s price recovery has not dropped as steeply as the industry average after 1981.

Analysis of the local exchange telecommunications industry

The performance ratio information displayed in Table 4 and Figure 2 also provides interesting insights into the changes in the industry between

Figure 2. Performance ratios: (a) Chesapeake and Potomac Telephone Company; (b) U.S. telecommunications industry
1975 and 1987. Profitability falls between 1975 and 1978, continuing into 1981. It increases slightly in 1984 relative to 1981, but then falls again in 1987 relative to 1984 and also relative to 1981. The productivity ratio increases monotonically between 1975 to 1987. The price recovery ratio decreases monotonically between 1975 to 1987. The product mix ratio on the other hand rises between 1975 and 1981, falls in the period between 1981 and 1984 and then rises again. The capacity utilization ratio increases monotonically between 1975 and 1987, but the trend is marked by the sharp increase in 1984 relative to 1981. It appears that the dramatic drop in price recovery between 1975 and 1987 has been counterbalanced mainly by increasing productivity and capacity utilization. While the product mix ratio has improved, it has not improved as steeply as the productivity and capacity utilization ratios.

Statistical tests of the differences in industry averages (Wilcoxon, 1945) between successive years in our sample appear in Table 5. These tests confirm our more casual discussion above of the visual patterns in the graphs displayed in Figure 2(b). The general patterns in the performance ratios for the U.S. telecommunications industry appear to be consistent with expectations for an industry undergoing gradual liberalization. Because market liberalization increases the number of suppliers with no concomitant change in the number of buyers, there is a drop in the overall profitability margins (Spence, 1977). Since high profitability margins are correlated with monopoly and market power (Cowley, 1985; Cowling and Waterson, 1976; Prescott and Ventakraman, 1990), firms’ profitability margins are adversely affected when monopoly power is reduced. We note from Table 5 that the average profitability ratio for 1975 is not significantly different from that for 1978; however, profitability dropped significantly (p < 0.0001) between 1978 and 1981, after price competition was allowed to take place. This decline in profitability may be due, at least in part, to recessionary forces prevalent in 1981. In fact, we find that the average profitability for 1984 is greater than that for 1981. However, the average profitability for 1987 is significantly lower than that for both 1984 and 1981, consistent with the progressive increase in competitive pressures faced by local exchange companies.

A more competitive environment is expected to lead to improvements in efficiency in operations because costs cannot be passed on to consumers through rate-of-return mechanisms which exist in regulated industries (Leibenstein, 1976; Selten, 1986). In addition, technological advances in recent years are likely to result in substantial productivity gains. This expectation is borne out by the data as the productivity ratio increases significantly between each pair of successive years.

Recent changes in telecommunications technology have enabled minimum efficient scale size to become small enough to permit several viable competitors to enter the industry and provide alternative sources of supply (Shepherd, 1983). With contemporaneous relaxation of entry regulation in the local area toll call market segment, we expect the potential entry of new competitors to result in lower prices (Kahn, 1988). The price recovery ratio declines significantly in every period from 1975 to 1987.

The statistical tests reveal that the increase in the product mix ratio increases monotonically and significantly over the period we study, except for the year 1984, when the actual decline relative to 1981 is not statistically significant. This indicates a gradual shift in the product mix in favor of the more lucrative toll calls despite the increase in the potential competition in this market segment (Agnew and Romeo, 1981; Smith and Grimm, 1987).

Table 5. U.S. telecommunications industry: Wilcoxon test results for differences in the performance ratios between successive periods

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year pairs</td>
<td>and</td>
<td>and</td>
<td>and</td>
<td>and</td>
</tr>
<tr>
<td>1975</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profitability ratio</td>
<td>-0.1960</td>
<td>-5.0120</td>
<td>2.2300</td>
<td>-3.6770</td>
</tr>
<tr>
<td>Productivity ratio</td>
<td>3.9965</td>
<td>2.8000</td>
<td>1.7918</td>
<td>4.1110</td>
</tr>
<tr>
<td>Price recovery ratio</td>
<td>-4.8973</td>
<td>-5.0611</td>
<td>-5.1100</td>
<td>-4.7008</td>
</tr>
<tr>
<td>Product mix ratio</td>
<td>4.9956</td>
<td>4.2090</td>
<td>-1.0318</td>
<td>4.2420</td>
</tr>
<tr>
<td>Capacity utilization ratio</td>
<td>4.3240</td>
<td>4.8310</td>
<td>5.1590</td>
<td>1.4240</td>
</tr>
</tbody>
</table>

The upper number in each cell is the Wilcoxon z-value. The lower number in each cell is the p-value.
Finally, we find a large statistically significant increase in the capacity utilization ratio between 1975 and 1984. However, the ratio plateaus out between 1984 and 1987 after the sharp increase in 1984 relative to 1981. This suggests that the adjustment to a new higher level of capacity utilization was relatively rapid following the end of the recession and the AT&T divestiture in 1984.

Our overall results show several interesting dynamic patterns at work in the industry. Gradual market liberalization changes the incentives for the local exchange companies whose effects are revealed in their performance ratios. In fact, in no period is the transition more dramatic than between 1981 and 1984, coinciding with the recovery from recession and the divestiture by AT&T.

CONCLUSION

In this paper we described a new framework to analyze changes in strategic performance. Decomposing the profitability component of the ROI formula to evaluate how profitability changes because of changes in productivity, price recovery, product mix and capacity utilization provides a basis for understanding sources of change in strategic performance. We demonstrated how this new approach may be used by a firm to analyze its performance over time. We found that the improved performance of our illustrative firm over a 4-year period could be attributed to higher price recovery and capacity utilization due to a surge in industry-wide demand. Detailed analysis of component ratios was necessary to uncover a strategic weakness reflected in a decline in its productivity over the same period.

We also illustrated how a firm may use our approach to evaluate its performance relative to other firms in its industry. Specifically, we analyzed the performance of local exchange telecommunications firms in transition to deregulation and examined changes in industry performance over time. The average profitability ratio for the industry declined over time due to a substantial decrease in the price recovery ratio. An analysis of only the aggregate profitability ratio, however, masked the improvements in productivity, capacity utilization and product mix that are consistent with expectations about how market liberalization impacts industry performance. Thus, in both our illustrations it was apparent that the detailed information provided by the component ratios was useful in understanding the performance consequences of changes in competitive environment and business strategy.

REFERENCES


APPENDIX: DETAILED CALCULATION OF PERFORMANCE RATIOS FOR ALUMINUM CORPORATION

In this appendix we present step-by-step details about the calculation of the performance ratios for Aluminum Corporation as a reference for researchers and analysts who wish to implement our method in other contexts.

Calculation of base-level quantities and prices

In Table 1, base-level revenues for the two product groups are constructed as averages of corresponding sales revenues over the 4-year period. For instance, the base-level revenues for Primary Aluminum Products is $2787.335. It was computed as the average (= ($1964.614 + 2402.739 + 3227.908 + 3554.078)/4) of the revenues for the 4 years. To obtain base-level costs for each input category, we multiply base-level input prices from Table A1 by their corresponding base-level input quantities from Table A2. The derivation of the base-level input prices and quantities is described below.

Table A1. Aluminum Corporation: Output and input price indices

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Base level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>$K/ton</td>
<td>2.5695</td>
<td>2.7926</td>
<td>3.4241</td>
<td>3.5424</td>
<td>3.1222</td>
</tr>
<tr>
<td>Finished</td>
<td>$K/ton</td>
<td>5.3563</td>
<td>5.4088</td>
<td>6.3393</td>
<td>6.9038</td>
<td>6.0291</td>
</tr>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>$K/ton</td>
<td>0.1625</td>
<td>0.1753</td>
<td>0.2023</td>
<td>0.2238</td>
<td>0.1930</td>
</tr>
<tr>
<td>Energy</td>
<td>$K/kwh</td>
<td>0.0490</td>
<td>0.0470</td>
<td>0.0470</td>
<td>0.0470</td>
<td>0.0474</td>
</tr>
<tr>
<td>Manufacturing labor</td>
<td>$K/fte</td>
<td>49.0987</td>
<td>50.6679</td>
<td>57.6342</td>
<td>63.6226</td>
<td>55.6206</td>
</tr>
<tr>
<td>SG&amp;A</td>
<td>Index</td>
<td>1.0000</td>
<td>1.0134</td>
<td>1.0457</td>
<td>1.0871</td>
<td>1.0396</td>
</tr>
<tr>
<td>Capital</td>
<td>%</td>
<td>14.57</td>
<td>14.70</td>
<td>16.96</td>
<td>16.76</td>
<td>15.85</td>
</tr>
</tbody>
</table>

Note: $K$ denotes thousand dollars, kwh denotes kilowatt hours and fte denotes full time equivalent employees.

Table A2. Aluminum Corporation: Capacities, and output and input quantities

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Base level</th>
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</thead>
<tbody>
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<td>Outputs</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>K ton</td>
<td>1498.20</td>
<td>1438.70</td>
<td>1339.30</td>
<td>1558.80</td>
<td>1458.75</td>
</tr>
<tr>
<td>Finished</td>
<td>K ton</td>
<td>764.60</td>
<td>860.40</td>
<td>942.70</td>
<td>1003.30</td>
<td>892.75</td>
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<tr>
<td>Inputs</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>K ton</td>
<td>5515.80</td>
<td>6081.80</td>
<td>6655.80</td>
<td>6896.40</td>
<td>6325.95</td>
</tr>
<tr>
<td>Energy</td>
<td>B kwh</td>
<td>19.35</td>
<td>21.05</td>
<td>26.21</td>
<td>27.04</td>
<td>22.83</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>K fte</td>
<td>26.03</td>
<td>27.63</td>
<td>29.73</td>
<td>30.83</td>
<td>27.80</td>
</tr>
<tr>
<td>SG&amp;A</td>
<td>$M</td>
<td>262.40</td>
<td>285.57</td>
<td>324.18</td>
<td>334.92</td>
<td>297.72</td>
</tr>
<tr>
<td>Capital</td>
<td>$M</td>
<td>3637.20</td>
<td>3443.30</td>
<td>4161.90</td>
<td>4436.90</td>
<td>3674.59</td>
</tr>
</tbody>
</table>

Note: K ton denotes thousand tons, B kwh denotes billion kilowatt hours, K fte denotes thousand full time equivalent employees, and $M$ denotes million dollars.
given in Table A2. Actual output quantities and capacity are obtained from company data. Input quantities are calculated by dividing the input costs from Table 1 by their corresponding input price indices from Table A1. The base-level capacity and output quantities are the means of the annual capacities and output quantities respectively, over the 4 years. The base-level input quantity for each input is computed by multiplying the standard input requirement per unit of each output from Table A3 by the corresponding actual output quantity from Table A2, and then adding up over all outputs requiring that input. For instance, the base-level quantity for materials is calculated as \(4.921 \cdot 892.75 + 5.429 \cdot 356 = 6,325,947\) thousand tons.

For specificity, we illustrate below the calculations for input standards and performance ratios for year 1.

### Standards for resource consumption

Table A3 reports the standards characterizing the production technology (in the aggregate) for Aluminum Corporation. These standards are developed using historical production and engineering data. The standard capacity utilization rate of 85.6 percent in panel C is obtained by dividing the total tonnage for base-level outputs by the base-level output capacity \((=892.75 + 356.00)/1,458.75\)).

To calculate the standard quantities for variable inputs for year 1, we multiply the standard variable input requirement per unit of output from panel A of Table A3 by the corresponding actual outputs for year 1 in Table A2, as follows:

\[
\text{Materials} = \sum_{m=1}^{2} \alpha_{m1} y_{m}^{\text{year 1}} = [4.921 \cdot 764.60] + [5.429 \cdot 330.90] = 5,559.053
\]

\[
\text{Energy} = \sum_{m=1}^{2} \alpha_{m2} y_{m}^{\text{year 1}} = [0.018 \cdot 764.60] + [0.019 \cdot 330.90] = 20.050
\]

\[
\text{Manufacturing labor} = \sum_{m=1}^{2} \alpha_{m3} y_{m}^{\text{year 1}} = [0.012 \cdot 764.60] + [0.048 \cdot 330.90] = 25.058
\]

\[
\text{SG&A} = \sum_{m=1}^{2} \alpha_{m4} y_{m}^{\text{year 1}} = [0.129 \cdot 764.60] + [0.514 \cdot 330.90] = 268.346
\]

These standard input quantities appear in Table A4.

The standard quantity of the fixed input, capital cost, based on actual capacity and standard input requirement per unit of capacity, is calculated by multiplying the standard input requirement from panel B of Table 4 by the actual capacity for year 1 from Table A2 as follows:

\[
\text{Capital cost} = \zeta_{\text{year 1}}^{\text{Capital cost}} = \beta_{m}^{\text{year 1}}
\]

\[
= [2.519 \cdot 1498.20]
\]

\[
= 3,773.965
\]

---

**Table A3. Aluminum Corporation: standards characterizing the production technology**

**Panel A: Variable input quantities per unit of output**

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Primary</th>
<th>Finished</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable input</td>
<td>(\alpha_{1v})</td>
<td>(\alpha_{2v})</td>
<td>tons per ton of output</td>
</tr>
<tr>
<td>Materials</td>
<td>4.921</td>
<td>5.429</td>
<td>M kwh per ton of output</td>
</tr>
<tr>
<td>Energy</td>
<td>0.018</td>
<td>0.019</td>
<td>Fte per ton of output</td>
</tr>
<tr>
<td>Manufacturing labor</td>
<td>0.012</td>
<td>0.048</td>
<td>$K per ton of output</td>
</tr>
<tr>
<td>SG&amp;A</td>
<td>0.129</td>
<td>0.514</td>
<td></td>
</tr>
</tbody>
</table>

**Panel B: Fixed input (capital cost) per unit capacity: $2519 per ton capacity**

**Panel C: Standard capacity utilization rate: 85.6%**

*Note: M kwh denotes million kilowatt hours, and $K denotes thousand dollars.*
Table A4. Aluminum Corporation: Standard input quantities for actual outputs

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>K ton</td>
<td>5559.053</td>
<td>6120.606</td>
<td>6697.703</td>
<td>6926.425</td>
</tr>
<tr>
<td>Energy</td>
<td>B kwh</td>
<td>20.050</td>
<td>22.090</td>
<td>24.173</td>
<td>25.021</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>K fte</td>
<td>25.058</td>
<td>27.005</td>
<td>29.514</td>
<td>29.627</td>
</tr>
<tr>
<td>SG&amp;A</td>
<td>$M</td>
<td>268.346</td>
<td>289.190</td>
<td>316.061</td>
<td>317.268</td>
</tr>
<tr>
<td><strong>Fixed input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital (based on actual capacity utilization)</td>
<td>$M</td>
<td>3773.965</td>
<td>3624.085</td>
<td>3373.696</td>
<td>3674.591</td>
</tr>
<tr>
<td>Capital (based on standard capacity utilization)</td>
<td>$M</td>
<td>3223.790</td>
<td>3554.556</td>
<td>3890.030</td>
<td>4030.694</td>
</tr>
</tbody>
</table>

*Note:* K ton denotes thousand tons, $M$ denotes million dollars, B kwh denotes billion kilowatt hours and K fte denotes thousand full-time equivalent employees.

The standard quantity of the fixed input, capital cost, based on standard capacity utilization rate and standard input requirement per unit of production capacity, is obtained by dividing standard input requirement (from panel B of Table A3) by the standard capacity (1,279.789) required for the production of the actual outputs in year 1 (from Table A2) as follows:

$$
\text{Capital cost} = q_{f,\text{year}1} = \beta_f \sum_{m=1}^{2} y_{m,\text{year}1} / \gamma^0
$$

$$
= 2.519 \cdot (764.6 + 330.9) / 0.856 = 3223.790
$$

The standard capacity for actual outputs is 1279.789 in year 1, determined above by dividing the total output tonnage (764.4 + 330.9) by the standard capacity utilization rate (85.6%).

**Calculation of the productivity ratio**

The productivity ratio (PRDTVT) is obtained by dividing the total cost of standard input quantities required for the production of actual year 1 outputs (based on standard input requirement rates, actual capacity and actual input prices), by the actual total cost for year 1 from Table A2. The total cost of standard inputs at actual input prices is presented in Table A5. It is the sum of input costs, computed with the actual input prices in Table A1 and corresponding standard input quantities in Table A4. Thus, adding together standard materials cost ($903.521 = 0.1625 \cdot 5559.053$), energy cost ($982.445 = 0.049 \cdot 20.050 \cdot 1000$), manufacturing labor cost ($1230.335 = 49.0987 \cdot 25.021$), selling, general, and administration cost ($268.346 = 0.1457 \cdot 3223.790$) and capital cost ($549.814 = 0.049 \cdot 3223.790$), we obtain

Table A5. Aluminum Corporation: Standard costs at actual prices (amounts in millions of dollars)

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>$903.521</td>
<td>$1072.655</td>
<td>$1355.183</td>
<td>$1550.401</td>
</tr>
<tr>
<td>Energy</td>
<td>982.445</td>
<td>1038.215</td>
<td>1136.149</td>
<td>1175.987</td>
</tr>
<tr>
<td>Manufacturing labor</td>
<td>1230.335</td>
<td>1368.275</td>
<td>1701.016</td>
<td>1884.933</td>
</tr>
<tr>
<td>SG&amp;A</td>
<td>268.346</td>
<td>293.067</td>
<td>330.514</td>
<td>344.905</td>
</tr>
<tr>
<td>Total variable costs</td>
<td>$3384.647</td>
<td>$3772.212</td>
<td>$4522.862</td>
<td>$4956.226</td>
</tr>
<tr>
<td><strong>Fixed input (based on actual capacity)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>$549.814</td>
<td>$532.676</td>
<td>$572.345</td>
<td>$658.255</td>
</tr>
<tr>
<td>Total costs of standard inputs at actual prices</td>
<td>$3934.461</td>
<td>$4304.888</td>
<td>$5095.207</td>
<td>$5614.481</td>
</tr>
</tbody>
</table>
$3934.463, as the total cost of standard inputs reported for year 1 in Table A5.

Total actual cost for year 1, obtained from the income statement in Table 1, is $3,914.789. Therefore, the PRDVT ratio for year 1 is calculated as follows:

\[
\text{PRDVT}_{\text{Year 1}} = \frac{3934.462}{3914.789} = 1.0050
\]

It indicates that the productivity in year 1 was 0.5% (= 1.0050/1.0000) above the base level of 1.0000.

**Calculation of the price recovery ratio**

Price recovery ratio (PRCREC) is calculated as the ratio of Paasche’s (1874) output price index weighted by output quantities to Paasche’s input price index weighted by input quantities. Specifically, we obtain the numerator for the PRCREC ratio by dividing the actual total revenues for year 1 in Table 1 by the corresponding sum of revenues based on actual output quantities but calculated with base-level output prices from Table A1. Thus, the numerator for the year 1 PRCREC ratio is \(0.8527 = \frac{3737.005}{4,382.263}\), where \(4,382.263 = 3.1222 \cdot 764.6 + 6.0291 \cdot 330.9\) is the sum of revenues at base level prices reported in panel A of Table A6. The denominator of 0.9162 (= 3934.463/4294.178) is determined by dividing the total cost of standard inputs of $3934.463 (from Table 6) by the sum of input costs, $4294.178 (from panel B of Table A6), calculated with base-level input prices (from

<table>
<thead>
<tr>
<th>Table A6. Aluminum Corporation: Revenues and costs at base-level prices (amounts in millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Revenues at base-level output prices</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Year 1</strong></td>
</tr>
<tr>
<td>Primary</td>
</tr>
<tr>
<td>Finished</td>
</tr>
<tr>
<td>Total revenues</td>
</tr>
</tbody>
</table>

**Panel B: Standard input costs at base-level input prices and actual capacity**

<table>
<thead>
<tr>
<th><strong>Variable inputs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
</tr>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Energy</td>
</tr>
<tr>
<td>Manufacturing labor</td>
</tr>
<tr>
<td>SG&amp;A</td>
</tr>
<tr>
<td>Total variable costs</td>
</tr>
</tbody>
</table>

**Fixed input (based on actual capacity)**

| Capital     | $598.174  | $574.418   | $534.731   | $622.369   |
| Total standard input costs at actual capacity | $4294.178  | $4605.418  | $4943.377  | $5122.864  |

**Panel C: Standard cost based on base-level input prices and standard capacity utilization**

<table>
<thead>
<tr>
<th><strong>Variable inputs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
</tr>
<tr>
<td>Total variable costs (from panel B)</td>
</tr>
</tbody>
</table>

**Fixed input (based on standard capacity utilization)**

| Capital     | $510.971  | $563.397   | $616.570   | $638.865   |
| Total standard input costs at standard capacity utilization | $4206.975  | $4594.397  | $5025.216  | $5139.360  |
Table A1) and standard input quantities (From Table A4). The standard cost reported in panel B of Table A6 adds together materials cost (= $1072.897 = $0.193 \cdot 5559.053), energy cost ($950.365 = $0.0474 \cdot 1000 \cdot 20.050), manufacturing labor cost ($1393.763 = $55.6206 \cdot 25.058), selling, general, and administration cost ($278.979 = $1.0396 \cdot 268.346), and capital cost ($598.174 = $0.1585 \cdot 3773.965).

The PRCREC ratio for year 1 is then computed as follows:

\[
\text{PRCREC}_{\text{year 1}} = 0.8527/0.9162 = 0.9307
\]

**Calculation of the product mix ratio**

The product mix ratio (PRDMIX) is obtained as the ratio of Laspeyres' output quantity index weighted by the base-level output prices, to Laspeyres' input quantity index weighted by base-level input prices. The numerator (output quantity index) of 0.8882 (= 4382.263/4993.682) is obtained by dividing the sum of input costs at base-level output prices from panel A of Table A6 by the total base-level revenues from Table 1.

The denominator (input quantity index) of 0.8873 is obtained by dividing the standard cost ($4206.975 from panel C of Table A6) by the total base-level costs ($4741.459 from Table 1). Standard cost of $4206.975 is determined by adding together standard materials cost ($1072.897 = $0.193 \cdot 5559.053), energy cost ($950.365 = $0.0474 \cdot 2000 \cdot 20.050), manufacturing labor cost ($1393.763 = $55.6206 \cdot 25.058), SG&A ($278.979 = $1.0396 \cdot 268.346), and capital cost ($510.971 = $0.1585 \cdot 3223.790) using standard input requirements and base level prices.

The ratio itself, is determined as \( \text{PRDMIX}_{\text{year 1}} = 0.8882/0.8873 = 1.0011 \).

**Calculation of the capacity utilization ratio**

The capacity utilization ratio (CAPUTL) is computed as the ratio of the sum of standard costs $4206.975 from panel C of Table A6 (used earlier in the computation of the denominator of PRDMIX) to the sum of input costs $4294.178 from panel B of Table A6 based on base-level input prices (used earlier in the computation of the denominator of PRCREC ratio). Thus:

\[
\text{CAPUTL}_{\text{year 1}} = 4206.975/4294.178 = 0.9797
\]

**Calculation of the profitability ratio**

The profitability ratio (PFTBLT) for year 1 is determined as the ratio of the unscaled profitability ratio for the year and the corresponding ratio computed with the base-level data. The unscaled profitability ratio for year 1 is 0.9546, determined as the ratio of total revenues ($3737.005) to total expenses ($3914.789). The unscaled profitability ratio with base-level data is 1.0405, determined as the ratio of total base-level revenues ($4933.682) to total base-level expenses ($4741.459). The profitability ratio for year 1 is then calculated as:

\[
\text{PFTBLT}_{\text{year 1}} = 0.9546/1.0405 = 0.9174
\]

Finally, we verify that the profitability ratio for year 1 equals the product of the four component ratios:

\[
\text{PFTBLT}_{\text{year 1}} = 1.0050 \cdot 0.9307 \cdot 1.0011 \cdot 0.9797 = 0.9174
\]