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How to measure company productivity using value-added: A focus on Pohang Steel (POSCO)

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Abstract How should the performance of a manufacturing company be assessed, relative to firms making similar products, at home and abroad? This paper shows how company-level productivity measures can be developed from public financial data to provide a more comprehensive gauge of firm performance than profit rates alone. As a specific example, we focus on the Korean steelmaker, POSCO. Founded four decades ago, POSCO is commonly regarded as the world's most efficient and profitable integrated steel producer, and our analysis documents POSCO's superior record of profitability and labor productivity. We find, however, that a broader assessment of POSCO's performance is tempered by the firm's high capital intensity relative to producers in Japan and the United States.

Keywords Productivity · Performance assessment · Steel industry · POSCO · Value-added

As producers in emerging economies strive to catch up to established rivals abroad, much attention has been paid to determinants of their success (Mathews, 2006; Tybout, 2000). How should the performance of these companies be compared and assessed? What metrics should be used to track the progress of a manufacturing firm and its performance on the world stage? Conventional comparisons of business performance are based on measures of accounting profits, or if companies are publicly-traded, stock prices. Such measures denote returns to investors but are unlikely to reflect the full

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value created by the enterprise. Similarly, a vast range of metrics have been proposed for managers to benchmark and improve elements of organizational performance (Kaplan & Norton, 1992; Neeley, Gregory, & Platts, 1995). To assess a firm's overall economic contribution, however, more comprehensive measures are required.

What are some of the more comprehensive measures of performance? We argue that one such comprehensive indicator is productivity. While various productivity measures are in use, all gauge the efficiency with which inputs are converted to useful outputs. This paper advances a framework in which productivity corresponds to the total economic value created by the capital and labor employed within the enterprise. If productivity rises over time, additional value is created and economic wealth grows. The gains flow to various parties, including the firm's employees, customers and shareholders. Using appropriate data, the distribution of economic value among these stakeholders can be identified (Lieberman & Balasubramanian, 2007). Typically, only a small part of the total value created by the enterprise flows as profits to the firm's shareholders.

In making international comparisons of firm performance, benchmarks based on productivity can be more insightful than more standard measures of profitability. Profitability alone is unlikely to provide an accurate gauge of performance, particularly for companies that are young or growing rapidly. For example, Japanese companies have historically been less profitable than their American counterparts, but their remarkable productivity performance in sectors such as autos and electronics led to rapid growth in global market share in the 1970s and 1980s.

Despite their usefulness as a performance indicator, comprehensive assessments of company productivity are rare. One reason is that methods of productivity measurement have largely been advanced by economists, whose efforts have typically focused on comparisons at the industry or national level (e.g., Caves, 1992; Jorgenson, 1995). Another reason is that standard accounting practices emphasize the computation of profits rather than productivity. Nevertheless, we show that the data in corporate financial statements can often be adapted to yield estimates of a company's productivity and its change over time. Drawing from such data, a growing number of productivity comparisons at the firm level have begun to emerge (e.g., Brynjolfsson & Hitt, 2003; Lieberman & Dhawan, 2005; Oum & Yu, 1998; Schefczyk, 1993).

We demonstrate a method for performing firm-level productivity analysis, applied to the specific example of the Pohang Iron and Steel Corporation (now officially known as POSCO), a Korean company founded in 1968. POSCO's outstanding record of productivity growth has made it arguably the world's most efficient steelmaker. High productivity has also led to robust profitability. Among the world's major steel producers, POSCO has regularly ranked number one in total profits and return on sales. Goldman Sachs (2003) in its October 2003 report concluded that POSCO remains "one of the best steel companies in the world in terms of margins and returns." For a brief period POSCO also served as the world's largest steelmaker, but a worldwide trend of consolidation has left POSCO bereft of this claim.[1]

[1] Usinor of France, Arbed of Luzembourg, and Aceralia of Spain merged to form Arcelor, and in 2006 Arcelor was acquired by Mittal Steel, becoming the largest steelmaker in the world as Arcelor-Mittal. Two major Japanese producers, Kawasaki Steel and NKK Corporation, merged in 2003 to become JFE Steel. As of December 2006, POSCO is ranked as the third largest steelmaker after Arcelor-Mittal and Nippon Steel.

How does POSCO's performance stack up?

To put POSCO's performance in international perspective, we compare POSCO's historical productivity record with that of counterparts in Japan and the United States. Our calculations focus on the steel industry and POSCO most specifically, but our methods are general and can be applied to firms in other manufacturing industries.

Table 1 provides an overview of POSCO's historical sales, profitability and productivity relative to major international competitors. It compares POSCO with Nippon Steel and USX, the largest steel producers in Japan and the United States, respectively. The comparisons in Table 1 span decade intervals from 1973, when POSCO began operations, through 2003, just prior to a dramatic rise in global steel prices that led to robust profitability throughout the steelmaking sector.

The first panel of the table, which gives total sales in terms of tons shipped, documents the rapid growth of POSCO. POSCO's output grew by more than 14% per year, as compared with net declines in output shown for both Nippon Steel and USX. By 2003, POSCO's output was virtually identical to that of Nippon Steel.

The second panel shows that POSCO has been consistently more profitable than its rivals. For the years shown in Table 1, POSCO's return on sales ranged from 15

Table 1 Comparison of POSCO with Japanese and American Steel Producers, 1973 to 2003.

					Annual Growth Rate
	1973	1983	1993	2003	1973–2003
1. Total sales (tons shipped ×1,000)					
POSCO	534	7,706	21,183	28,202	14.1%
Nippon Steel	31,400	26,700	25,320	29,902	−0.2%
USX	26,100	NA	9,969	14,399	−2.0%
2. Operating profit/sales					
POSCO	20%	16%	15%	21%	
Nippon Steel	10%	3%	4%	5%	
USX	12%	NA	−3%	−8%	
3. Labor productivity (a) (Value-added per worker hour)					
POSCO	1,664	6,431	13,010	21,586	8.9%
Nippon Steel	4,492	5,371	9,245	17,130	4.6%
USX	5,209	NA	5,565	5,640	0.3%
4. Fixed capital per employee (b)					
POSCO	19.2	73.0	94.6	130.7	6.6%
Nippon Steel	27.8	33.0	39.5	67.4	3.0%
USX	8.9	NA	28.0	25.0	3.5%
5. Fixed capital per ton shipped (c)					
POSCO	142.9	137.2	101.1	89.8	−1.5%
Nippon Steel	71.2	80.1	56.6	37.1	−2.1%
USX	63.3	NA	60.5	40.3	−1.5%
6. Multifactor productivity (d)					
POSCO	51.6	62.6	107.1	133.5	3.2%
Nippon Steel	78.6	82.6	131.6	182.4	2.8%
USX	126.9	NA	101.8	103.9	−0.7%

(a) 1980 yen per hour.

(b) Millions of 1980 yen.

(c) Thousands of 1980 yen.

(d) Nippon Steel = 100 in 1980.

to 21%, whereas the profit rates of Nippon steel and USX were substantially lower. Indeed, USX had financial losses in 1993 and 2003, and Nippon Steel's return on sales was only one-fourth the rate earned by POSCO in those years. (Table 1 is based on operating profits, but comparisons of net profits are similar.) Clearly, POSCO has maintained high profit rates compared to competitors.

The third panel describes POSCO's remarkable growth in labor productivity. From 1973 to 2003, POSCO's labor productivity (measured as value added per worker hour) grew at an average annual rate of 8.9%, roughly twice the growth rate of Nippon Steel. At USX over the same period, labor productivity was stagnant. By 1983, POSCO's labor productivity exceeded that of Nippon Steel, and POSCO's advantage expanded further over subsequent decades. By 2003, POSCO's labor productivity was roughly four times that of USX, and 26% higher than Nippon Steel.

Thus, the upper panels in Table 1 support the conventional view of POSCO as a dramatic success story in terms of productivity and profitability (Duvall, 2002; Bremner, Ihlwan, & Roberts, 2004). Our analysis shows, however, that this positive view must be tempered by the fact that POSCO utilizes more capital input than its competitors. The fourth and fifth panels of Table 1 document POSCO's high capital intensity. By our estimates, POSCO's fixed capital per employee, initially just below the capital–labor ratio of Nippon Steel, grew quickly to reach more than twice Nippon's level. Measured on the basis of investment per ton shipped, POSCO's fixed capital has been roughly twice Nippon's level since the 1970s.

These calculations show that POSCO has been extremely capital-intensive relative to competitors. High capital intensity is likely to account for at least part of POSCO's extraordinary labor productivity and profitability. Firms with greater capital intensity must earn a higher return on sales, other things equal, to provide normal financial returns to investors. Therefore, part of POSCO's high return on sales must be attributed to the firm's capital intensity.

The observations in Table 1 suggest that to produce each unit of output, POSCO utilizes more capital than competitors, but much less labor. As we show later in this paper, capital and labor inputs can be combined to yield a single multi-factor index of productivity. The bottom panel in Table 1 compares POSCO's performance in this way, relative to a benchmark level of 100 corresponding to the multi-factor productivity of Nippon Steel in 1980. By this standard, POSCO shows faster productivity growth than Nippon Steel and USX. However, POSCO's multi-factor productivity remains consistently below that of Nippon Steel. Thus, over the entire period from 1973 to 2003, POSCO's labor productivity advantage was more than offset by Nippon's superior efficiency in utilization of capital.

The comparisons in Table 1 suggest that simple performance ratios can be misleading. While POSCO has grown and improved dramatically, Nippon Steel is arguably the superior performer when capital and labor inputs are jointly considered. Below, we elaborate on these points and provide details of the productivity calculations.

Brief history of POSCO

As South Korea (hereafter Korea) began to industrialize in the 1960s, the country lacked a viable steel industry. Some small and inefficient facilities were in operation, but most were obsolete. In 1967, Korean President Chung-Hee Park sought to build Korea's first large-scale steel mill. To head the company, he tapped Tae-Joon Park, a former army general.

Efforts to obtain foreign support for the venture were discouraging. The World Bank performed a study and concluded that Korea's plan for an integrated steel mill was "a premature proposition without economic feasibility."[2] Ultimately, Park was able to obtain technology and funding from Japan as part of Korea's claim for compensation following the Japanese occupation of Korea (1910–1945). The Korean government also provided major investment subsidies, as part of the Korean economy's heavy and chemical industry drive of the 1970s (Auty, 1991; Stern, Kim, Perkins, & Yoo, 1995).[3] Construction of the Pohang plant began on April 1, 1970, and the first stage of the plant began operation 5 years later. In 1985 a second plant in Kwangyang began construction.

Riding on the increasing world demand for crude steel, POSCO steadily increased its production to over 20 million tons with the completion of Kwangyang in 1992, rising to 30 million tons, or about 60% of Korea's total steel output, by 2004. High rates of plant utilization, combined with rapid and efficient start-up of new facilities, contributed to POSCO's profitability and successful productivity record. Moreover, the company maintained a distinctive culture, shaped by Tae-Joon Park, who served as chairman for more than 20 years (Amsden, 1989; Hayes & Cho, 1992).

By the time it was privatized in 2000, POSCO had established its reputation as one of the largest, most profitable, and productive steelmakers in the world. It was listed on the Korea, New York, and London Stock Exchanges. It had re-established a strategic alliance with its original partner, Nippon Steel. POSCO not only dominated the steel industry in Korea, where the shipbuilding and automobile industries were main national exports, but by 2002, overseas sales represented 30.6% of POSCO's production. Indeed, the rise of POSCO was widely viewed as one of the great success stories of the Korean economy.

To assess POSCO's historical performance, we now consider the basic methodology of productivity measurement.

Measuring company productivity

Productivity measures

"Productivity" represents the efficiency with which physical inputs are converted to useful outputs. Various productivity measures can be computed, depending on the treatment of inputs and outputs. *Single-factor* productivity ratios, such as labor productivity or capital productivity, give output per unit of a single input type. *Multi-*

[2] World Bank report, quoted in Amsden (1989: 291).

[3] POSCO was a major project in the Heavy and Chemical Industry (HCI) Plan, launched in 1972 as a part of five-step national economic planning. The HCI Plan focused on the "strategic industries" of iron and steel, machinery, non-ferrous metals, electronics, shipbuilding, and petrochemicals. The objective of this policy was to help overcome Korea's limits of being a small domestic market, and emphasize construction of large-sized facilities to achieve economies of scale (Rhee, 1994).

factor or *total-factor* productivity ratios take into account the fact that multiple inputs are jointly used.[4]

In this study we emphasize productivity measures that are based on the concept of value-added, which corresponds to the difference between the firm's sales and its purchases of raw materials and outside services. In computing the productivity measures, all inputs and outputs must be taken as real rather than nominal quantities. Accordingly, all accounting values of output and capital input must be adjusted for inflation, and the firm's capital stock must be depreciated in an economically-meaningful way.

Labor productivity is the most common productivity measure, partly because it is the easiest to compute. Labor productivity corresponds to output per unit of labor input (or value-added per worker-hour, as computed in this study). Labor productivity at the level of the economy as a whole provides an indicator of a nation's real income per capita, or average economic welfare. Growth in labor productivity for an individual company helps to raise the national average and hence contributes to the welfare of the nation as a whole.

Capital productivity is output per unit of capital input. Capital productivity is more difficult to compute and more arbitrarily measured than labor productivity, since it requires procedures for evaluating the magnitude of capital input. Unlike labor productivity, capital productivity is not directly interpretable as an indicator of economic welfare, but it does provide an indicator of the efficiency of resource use.

Measures of materials and energy productivity can also be computed. However, most companies provide little public information on their raw materials and energy usage. Moreover, these inputs are by definition excluded when output is measured in terms of value-added. Therefore, we are forced to ignore materials and energy productivity in our analysis, even though POSCO's financial performance may depend, in part, on the efficiency with which raw materials and energy are procured, transported and utilized in POSCO's plants.

Labor and capital productivity are only partial indexes and can thus give misleading indications. For example, labor productivity can often be augmented by simply raising the level of capital input—i.e., at the expense of capital productivity. Indeed, companies that make excessive investments in automation will see their overall efficiency fall, despite a gain in labor productivity. Multi-factor productivity, which attempts to measure the change in output net of the changes in all inputs, is commonly regarded as a more suitable measure of overall efficiency. As computed in this study, multi-factor productivity is a weighted average of labor and capital productivity.

Productivity statistics are conventionally developed and reported for national industries. Numerous international comparative studies of productivity have been performed at the industry level (e.g., Baily & Gersbach, 1995; Jorgenson, 1995; Van Ark & Pilat, 1993), and statistical analysis has often been applied at this level to better understand the nature of economic growth in emerging economies (e.g., Chen, 1997; Felipe, 1999; Norworthy & Malmquist, 1983; Sato, 2005; Truett & Truett,

[4] Additional details on productivity measurement are provided in various sources including Coelli, Rao and Battese (1998), Lieberman, Lau and Williams (1990), Mammone (1980), and publications of the American Productivity Center.

1997; Yuhn & Kwon, 2000). Identical concepts apply for productivity comparisons at the level of individual companies, although the data sources are different.

Data requirements

Our productivity measures for POSCO are derived from information in POSCO's annual financial reports from 1973 to 2003, supplemented by government data on the prices of steel and capital goods.[5] (A file available from the authors gives details on the productivity computations for POSCO and the methods for making international comparisons.) The productivity estimates for representative US and Japanese steel producers, which are compared with POSCO, are described in Lieberman and Johnson (1999).

In this study, we emphasize the measurement of productivity based on the amount of "value-added" by a company during its fiscal year. "Value-added" is simply the difference between the firm's total sales and its purchases of raw materials and contracted services. Through the efforts of employees and the application of capital, the firm "adds value" to its purchases of raw materials. In the steel industry the latter consist primarily of iron ore, scrap, limestone, coal, and other energy inputs. POSCO's nominal value-added was calculated as the sum of all employee compensation, depreciation, operating income, and (non-income) taxes.[6] These data were gathered from POSCO's annual financial reports from 1973 to 2003. Nominal value-added was divided by a steel price deflator[7] to give real value-added, measured in constant 1995 won.

To compare values across international producers and over time, all monetary values must be converted to a real common currency (in this study, constant 1980 yen). A "purchasing power parity" approach was used for this purpose, based on relative steel prices in the three countries. Output data for POSCO were first adjusted for inflation, using annual steel prices identified by dividing the firm's annual revenue by its output tonnage. The resulting values in 1995 won were converted to 1995 yen, based on the 1995 ratio of steel prices in Korea and Japan, and finally to 1980 yen, based on the change in Japanese steel prices between 1980 and 1995. These calculations make use of the fact that steel is a relatively homogeneous product that can serve as the basis for a purchasing power parity exchange rate. In other industries (and for capital goods inputs in general) similar calculations can be

[5] The data on value-added, capital investment, and total number of employees are from POSCO annual reports (1968–2006). Data on working hours are from POSCO's internal reports and authors' estimates. For most companies, working hours are not reported, although estimates can be developed from government data.

[6] Equivalently, value-added can be computed by subtracting the costs of purchased materials, services and utilities from the firm's total revenue. However, complete information on these items is seldom provided in company financial reports, so the summation approach is preferable.

[7] This price deflator was calculated by dividing POSCO's sales by its tons shipped, using data from annual reports data. Alternatively, a more general price deflator for the steel industry could be used. Such price deflators are commonly published by government sources and thus are available for most industries. For firms that are significantly diversified, a weighted average of industry price deflators is required.

supported by government price indexes and purchasing power parity exchange rates available in the literature.

Labor productivity

The standard measure of productivity reported in the steel industry is tons of steel produced per worker-hour (or conversely, man-hours per ton). This measure requires a physical measure of output (tons) and has some serious shortcomings (see Lieberman & Johnson, 1999). Our measure of labor productivity, "value-added" per worker-hour, is more general and can be computed for a range of industries. The two measures of labor productivity in the steel industry are very highly correlated.

Capital productivity

We measure capital productivity as value-added per unit of capital stock. One estimate of a firm's capital stock is the value of its net property, plant, and equipment, as reported in standard financial statements. Although readily available, such figures may be subject to accounting biases. Given differences in accounting practices, the biases can vary among firms and countries, particularly when inflation is a factor. To minimize these biases, we use the "perpetual inventory method," to estimate the real capital stock.[8] This series can be computed for a given firm, starting from the initial year of data, using the equation:

$$\text{Real Capital Stock} = K_t = (1 - d)K_{t-1} + I_t$$

where K_t is the real capital stock in year t, d is the annual rate of economic depreciation, and I_t is the firm's gross investment in year t adjusted for inflation. We assume that d, the real depreciation rate, was equal to 10%.[9]

Capital productivity is defined as:

$$\text{Capital productivity} = \text{Value-added}/\text{Real capital stock},$$

where value-added and capital stock are measured in constant currency for the same base year. A file available from the authors gives details of this calculation.

Multi-factor productivity

Taken alone, neither labor productivity nor capital productivity gives an overall picture of a firm's efficiency. Multi-factor productivity (MFP), which attempts to measure the change in output net of the changes in all inputs, is commonly regarded as a more appropriate measure. As computed in this study, multi-factor productivity

[8] For a more detailed explanation of this method, see Hulten and Wykoff (1981) and Lieberman et al. (1990).

[9] We considered 10% reasonable given the composition of the gross capital stock and the rates of economic depreciation estimated by Hulten and Wykoff (1981).

is a weighted average of labor and capital productivity, where the weights are determined by the relative amounts of labor and capital employed by the firm.[10]

Productivity comparison among steel producers

We now draw comparisons between POSCO and integrated steelmakers in Japan and the United States. A natural benchmark for comparison is Nippon Steel, historically the largest Japanese steel company, which provided early technical assistance to POSCO and serves as an alliance partner today. In addition, we selected NKK and Kawasaki Steel (which merged in 2003 to form JFE) as representative Japanese steelmakers, and USX (formerly United States Steel), as the representative producer in the United States. The data for these companies were collected and analyzed in the same manner as that described for POSCO.[11]

Figure 1 plots historical data on labor productivity, measured as real value-added per worker-hour. Of the five companies, POSCO exhibits the highest rate of labor productivity growth, and USX by far the lowest. In the late 1950s and early 1960s, USX's value-added per worker-hour was several times above the level of the three Japanese producers, but by the turn of the millennium USX's labor productivity was only about half that of its Japanese rivals. The labor productivity level of POSCO, initially below that of the Japanese, reached parity with the Japanese in the 1980s and exceeded the average Japanese level by the 1990s. Although the patterns in Figure 1 are based on value-added per worker-hour, similar findings hold when labor productivity is measured in terms of "tons per man-hour," the metric more commonly used in the steel industry.

Labor productivity can be a misleading indicator for a number of reasons. In a capital intensive industry such as steel making, labor costs today represent only a small proportion of total costs, and hence efficient labor utilization can easily be offset by inefficiencies in capital or materials use. Even if capital and labor are both utilized efficiently, substitution between these inputs must be considered; other things equal, a more capital intensive firm will show higher labor productivity. Moreover, by outsourcing unskilled, low-wage service jobs such as cleaning and security, a firm can reduce headcount without much change in value-added; hence, differences in outsourcing choices can affect the measured labor productivity.

[10] We used the following standard formula to compute multi-factor productivity:

$$\text{Change in MFP from year } t \text{ to year } t+1 = [\ln Q_{t+1} - \ln Q_t] - (1 - s_t)[\ln K_{t+1} - \ln K_t] - s_t[\ln L_{t+1} - \ln L_t]$$

where Q_t is the firm's value-added in year t, K_t is the capital stock, L_t is labor input, s_t is the fraction of value added which is paid to employees, $(1-s_t)$ is the fraction which goes implicitly as a payment to capital, and "ln" refers to logarithms. We set MFP for each year relative to a base index of 100 for POSCO in 1975. Ideally, materials and energy inputs should also be included in the MFP calculations, but sufficient information is not normally available in company annual financial reports. To perform inter-firm comparisons, we established each firm's MFP relative to Nippon Steel in the year 1980 by substituting the comparison firm values for the t-subscripted variables, and values for Nippon Steel for the $t-1$ subscripted variables. Labor's share, s_t, was taken as the average of the shares for Nippon and the comparison firm in 1980.

[11] The data and computations are described in Lieberman and Johnson (1999).

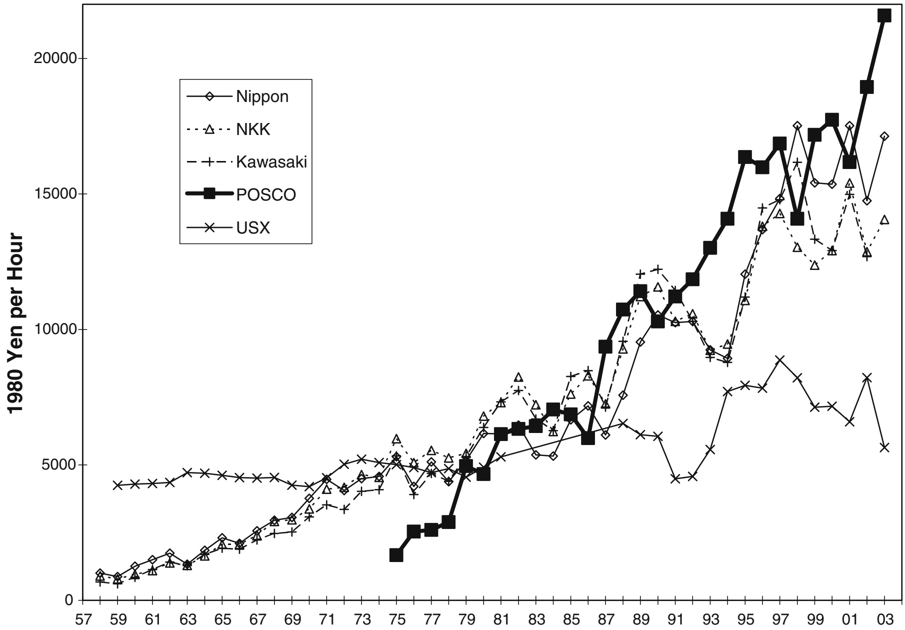

Figure 1 Labor productivity comparison (Value added per worker-hour)

To shed light on potential substitution between capital and labor input, Figure 2 plots the level of fixed investment per employee for the five producers. Annual measures of capital stock were obtained using the perpetual inventory method described above. Based on the assumption of a 10% annual depreciation rate for

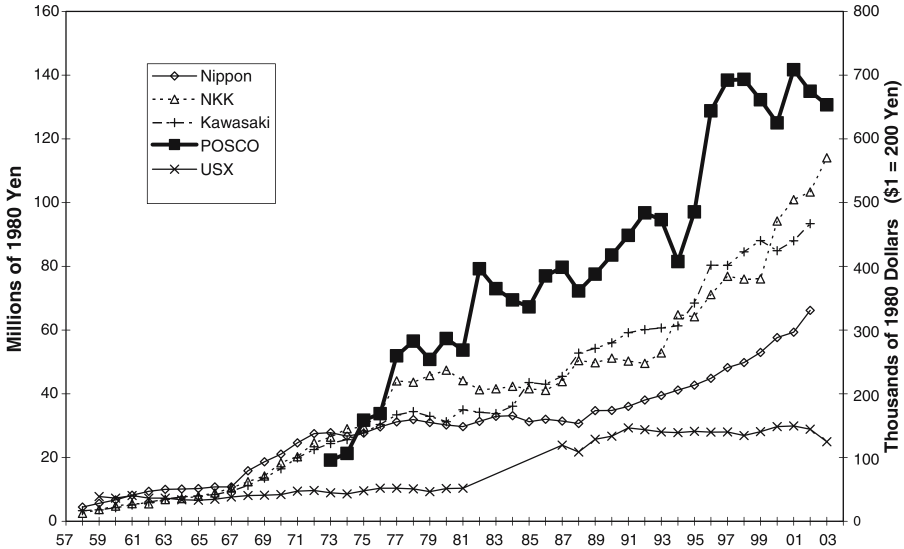

Figure 2 Comparison of fixed capital per employee

each of the five firms, this method helps to standardize the capital stock measure and minimize the impact of inter-firm differences in accounting.

As shown in Figure 2, POSCO's fixed investment per employee exceeded that of the Japanese producers almost from the opening of the Pohang Works. By 2003, POSCO's investment per worker had risen to about twice the level of Nippon Steel, and five times the level of USX. NKK and Kawasaki maintained higher rates of investment than Nippon Steel in recent decades, and their capital per employee becomes intermediate between Nippon and POSCO. As shown previously in Table 1, POSCO's high capital intensity stands out to a similar extent when capital stock is measured relative to company output (tons shipped) rather than employment. Such comparisons suggest that POSCO's rapid growth in labor productivity, evident in Figure 1, was derived at least in part from the firm's high rate of investment in plant and equipment.

It is perhaps surprising that despite Korea's comparatively low wages and scarcity of capital following the Korean War, POSCO has emerged as the world's most capital-intensive steel producer. Part of the explanation may lie in the South Korean government's decision to provide large financial subsidies for steel making and other heavy industries in the 1970s. While the wisdom of this allocation of resources has been questioned (Auty, 1991; Stern et al., 1995), in POSCO's case there have been considerable benefits, not only in the firm's impressive growth and performance, but also indirectly through the availability of high-quality steel to serve key downstream industries in Korea, such as auto making and shipbuilding.

Given POSCO's disproportionate investment, the firm's capital productivity, defined as value-added per unit of capital stock, remains below that of the other steel producers over the entire period examined. For example, in 1993 POSCO's capital productivity was 38% below that of both Nippon and USX, and 17% below NKK. Roughly speaking, capital productivity tends to be ranked across the companies in the reverse order of labor productivity. This implies that the steel companies have made very different choices in terms of degree of automation and capital labor ratio. POSCO, the youngest of the five firms, has become the most capital-intensive producer, whereas USX, the oldest firm, is the least capital-intensive. The fact that capital intensity is inversely correlated with age of firm in this sample suggests that more recent entrants to the steel industry may have tended to substitute more sophisticated capital equipment for labor in the production process. To some extent, the evolution of integrated steel making technology has made this shift desirable from the standpoint of product quality. However, differences in the cost of capital available to steel producers may also be an explanation. In POSCO's case, the Korean government channeled investment funds at low interest rates to establish and grow a strong domestic steel making firm. Although explicit capital subsidies were lacking in Japan, some analysts have suggested that Japanese steel producers enjoyed a low cost of capital that American companies could not match in the 1970s and 1980s (Lieberman & Johnson, 1999).

Differences in capital/labor intensity are motivated by technological substitution possibilities available when a plant is built, and perhaps more importantly, by international differences in factor prices. Economic theory predicts high capital intensity in countries where wages are high relative to capital costs. In the case of steel, however, we find the most capital-intensive producer, POSCO, in the country with the lowest historical labor costs; whereas the least capital-intensive producer, USX, is in the country with the highest historical labor costs. One possibility is that the capital subsidies in Korea were sufficient to offset the early differential in labor costs. As wages have risen in Korea and Japan, one would expect to find growth in the use of capital relative to labor, and indeed that is consistent with the evidence. Yet, in recent years we have seen convergence in wage rates across the three countries, but the differences across the five producers in the use of capital relative to labor have been persistent. In general, there is little evidence to support the idea that inter-firm differences in capital intensity should be positively correlated with differences in labor costs. One possibility is that POSCO and the more capital intensive Japanese producers may have over-invested in equipment and technology, despite the labor productivity and quality benefits.

The concept of multifactor productivity provides a comprehensive performance indicator incorporating both capital and labor inputs. Figure 3 compares multi-factor productivity among the five producers. Each firm's multi-factor productivity is computed as an index number relative to a benchmark level of 100 for Nippon steel in 1980. The index corresponds to a weighted average of the firm's labor and capital productivity, using the input proportions as weights. Given the relative importance of capital input in the steel industry, capital productivity has a greater weight than labor productivity in computing each firm's multifactor productivity index.

Figure 3 reveals relatively small differences in multifactor productivity among the international steel producers, as compared with vast differences in labor productivity and capital intensity shown in Figures 1 and 2. This is consistent with the idea that the Japanese, Korean and American producers have made diverse choices in the ratio of capital to labor; when these choices are netted out, the differences in overall efficiency are comparatively small in scope.

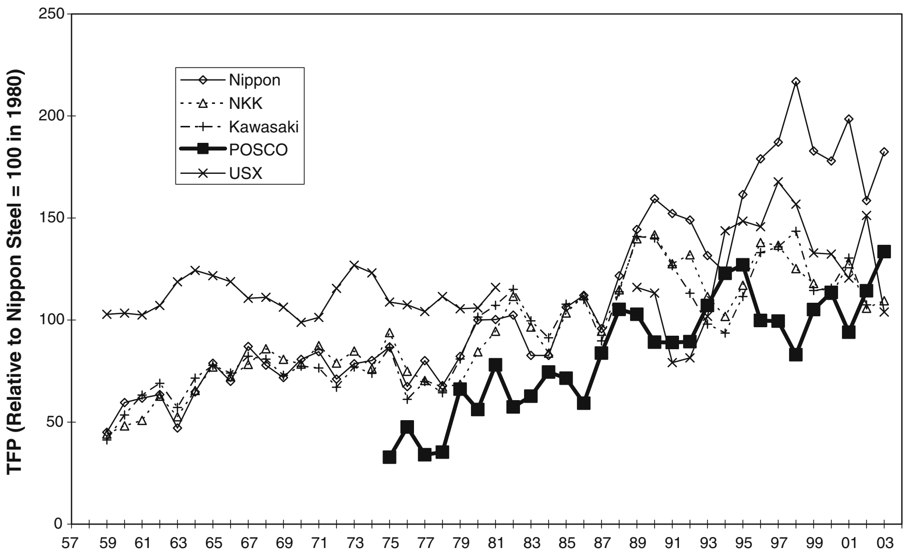

Figure 3 Comparison of multifactor productivity

The pattern in Figure 3 also raises questions regarding the magnitude of POSCO's superior performance. POSCO's multifactor productivity starts in the 1970s at about half the US and Japanese level, ultimately rising to about parity. POSCO's growth rate is positive and larger than that shown for any other producer. Nevertheless, the moderate level shown for POSCO's multifactor productivity implies that the firm's high investment in capital stock offsets its advantage in labor productivity. Depending on the weight given to capital investment, POSCO's productivity advantage diminishes, or in the case of Figure 3, disappears.[12] Indeed, our calculations suggest that the overall productivity leader in recent decades has been Nippon Steel, which began to moderate its plant and equipment investment relative to NKK, Kawasaki and POSCO starting in the 1980s.

To summarize, POSCO's labor productivity grew rapidly from the start of operations and was the highest among the five major steel makers by the 1980s. Yet POSCO has been more capital intensive than the other companies, which gives POSCO a comparatively modest level of multi-factor productivity. In general, integrated steelmakers in each country have made very different choices about the proportion of capital versus labor used in their factories. The net result is that the five firms use vastly different amounts of capital investment per worker, but have similar levels of multi-factor productivity. This raises questions about POSCO's superior performance. POSCO's profitability and labor productivity advantage can be attributed, in part, to the firm's high capital intensity.

Conclusion

In this paper we have described methods for estimating the productivity of manufacturing companies, using public data provided in many corporate financial statements. We have shown how meaningful comparisons of labor and multi-factor productivity can be drawn across companies operating in different countries. Such productivity comparisons provide a supplement to more conventional, profit-based measures of firm performance. Our findings demonstrate the potential for using productivity metrics to assess the performance of fast-rising companies in the world's emerging economies.

Specifically, we have applied productivity methods to assess the historical performance record of POSCO, a steel company that is commonly regarded as one of the great success stories of the Korean economy. Although most assessments of POSCO have been positive, there has been much disagreement about the company's degree of success (Amsden, 1989; Auty, 1991; D'Costa, 1994; Stern et al., 1995; Sato, 2005). Prior studies have typically considered performance indicators such as labor productivity or profits relative to revenue. As our analysis suggests, such

[12] These calculations are sensitive to the weights assigned to capital and labor input in the MFP formula, which are conventionally based on income shares. In the calculations underlying Figure 3, POSCO's weights for labor input are lower than corresponding values for the US and Japanese producers, given that POSCO's wages have been lower. POSCO's proportion of value-added paid to labor ranged from 10 to 27% over the sample period, while the implicit proportion paid for capital services ranged from 73 to 90%. If the US or Japanese weights are used for POSCO, the firm's MFP appears higher.

indicators may be biased or misleading, given POSCO's high investment-intensity compared to rivals in Japan and the United States.

We have shown that POSCO's capital investment, relative to sales, has been more than twice the level of Nippon Steel and USX. Hence, relative to the threshold return on sales necessary for these firms to earn their basic cost of capital, POSCO requires a return of at least twice that level (assuming that firms have the same capital costs). Thus, part of the superior return on sales achieved by POSCO is an artifact of POSCO's higher capital intensity. (A detailed assessment of POSCO's financial performance is beyond the scope of this paper.)

Another view of these findings is that POSCO's rise has been closely tied to the process of capital accumulation. Analysts have praised POSCO's rapid achievement of efficient scale and the firm's management and utilization of investment. By all accounts, POSCO built its plants quickly and efficiently, and the firm has maintained high rates of utilization over decades (Auty, 1991; Stern et al., 1995; Sato, 2005). Thus, there is little evidence to suggest that POSCO has done a poor job of building or running its facilities. One can argue, however, that POSCO may have invested more than the optimal amount of capital as compared with foreign rivals. Such behavior may have been encouraged by the investment subsidies initially provided by the Korean government.

Overall, this study highlights the advantage of considering multiple measures of firm performance. Productivity and profitability are different metrics; successful performance in one dimension does not necessarily imply success in the other. An inefficient firm can achieve high profitability merely because it has access to low-cost labor, capital or materials. Alternatively, a firm with high productivity will suffer financial losses if its input costs greatly exceed those of competitors. Moreover, as we have shown, a firm may excel at one measure of productivity at the expense of another, as in the case where greater investment augments labor productivity at the expense of capital productivity. By considering a range of performance indicators, the biases inherent in any single measure can be avoided.

Our example of POSCO demonstrates insights that can be drawn from productivity analysis of a large-scale steel company. An American or European firm could have served the same purpose, but given the growing interest in POSCO as a global company, POSCO provides a useful platform. Comparison of POSCO with major Japanese and American competitors shows the value of using Asian companies to illustrate context-free knowledge (Tsui, 2004) and test general theories (Meyer, 2006, 2007). Beyond the context of the steel industry, the rapid rise of manufacturing companies throughout the Asia Pacific region provides a rich laboratory for additional productivity-oriented studies on the determinants of success among challenger firms (Matthews, 2006).

References

Amsden, A. H. 1989. *Asia's next giant: South Korea and late industrialization*. New York: Oxford University Press.

Auty, R. M. 1991. Creating competitive advantage: South Korean steel and petrochemicals. *Tijdschrift voor Economic en Social Geografie*, 82: 15–29.

Baily, M. N., & Gersbach, H. 1995. Efficiency in manufacturing and the need for global competition. *Brookings Papers on Economic Activity (Microeconomics)*. Washington DC: Brookings Institution, pp. 307–358.

Bremner, B., Ihlwan, M., & Roberts, D. 2004. POSCO: One sharp steelmaker. *Business Week*, August 30.

Brynjolfsson, E., & Hitt, L. M. 2003. Computing productivity: Firm-level evidence. *Review of Economics and Statistics*, 85: 793–808.

Caves, R. E. 1992. *Industrial efficiency in six nations*. Cambridge, MA: MIT Press.

Chen, E. K. Y. 1997. The total factor productivity debate: Determinants of economic growth in East Asia. *Asian-Pacific Economic Literature*, 11: 18–38.

Coelli, T. J., Rao, D. S. P., & Battese, G. E. 1998. *An introduction to efficiency and productivity analysis*. Boston: Kluwer.

D'Costa, A. P. 1994. State, steel and strength: Structural competitiveness and development in South Korea. *The Journal of Development Studies*, 31: 44–81.

Duvall, M. 2002. POSCO: The next big steel. *Baseline Magazine*, 1(7): June.

Felipe, J. 1999. Total factor productivity growth in East Asia: A critical survey. *The Journal of Development Studies*, 34: 1–41.

Goldman Sachs. 2003. *POSCO*. New York: Goldman Sachs.

Hayes, R. H., & Cho, D.-S. 1992. Pohang iron and steel company (POSCO). *Harvard Business School Case* #9-693-041.

Hulten, C. R., & Wykoff, F. C. 1981. The measurement of economic depreciation. In C. R. Hulten (ed.). *Depreciation, inflation, and the taxation of income from capital*. Washington, D.C.: The Urban Institute Press.

Jorgenson, D. W. 1995. *Productivity, vol. 2: International comparisons of economic growth*. Cambridge, MA: MIT Press.

Jorgenson, D. W., & Kuroda, M. 1992. Productivity and international competitiveness in Japan and the United States, 1960–1985. *Economic Studies Quarterly*, 43: 313–325.

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

Lieberman, M. B., & Balasubramanian, N. 2007. *Measuring value creation and its distribution among stakeholders of the firm*. Working paper, UCLA Anderson School of Management.

Lieberman, M. B., & Dhawan, R. 2005. Assessing the resource base of Japanese and U.S. auto producers: A stochastic frontier production function approach. *Management Science*, 51(7): 1060–1075.

Lieberman, M. B., & Johnson, D. 1999. Comparative productivity of Japanese and US steel producers, 1958–1993. *Japan and the World Economy*, 11: 1–27.

Lieberman, M. B., Lau, L. J., & Williams, M. D. 1990. Firm-level productivity and management influence: A comparison of U.S. and Japanese automobile producers. *Management Science*, 36: 1193–1215.

Mammone, J. L. 1980. Productivity measurement: A conceptual overview. *Management Accounting* (June): 36–42.

Mathews, J. A. 2006. Dragon multinationals: New players in 21st century globalization. *Asia Pacific Journal of Management*, 23: 5–27.

Meyer, K. E. 2006. Asian management research needs more self-confidence. *Asia Pacific Journal of Management*, 23: 119–137.

Meyer, K. E. 2007. Asian contexts and the search for general theory in management research: A rejoinder. *Asia Pacific Journal of Management*, 24: 527–534.

Neely, A., Gregory, M., & Platts, K. 1995. Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management*, 15: 80–116.

Norworthy, J. R., & Malmquist, D. H. 1983. Input measurement and productivity growth in Japanese and US manufacturing. *American Economic Review*, 73: 947–967.

Oum, T. H., & Yu, C. 1998. *Winning airlines: Productivity and cost competitiveness of the world's major airlines*. Boston: Kluwer.

POSCO Annual Reports, 1968–2006. South Korea: POSCO.

Rhee, J.-C. 1994. *The state and industry in South Korea: The limits of the authoritarian state*. New York: Routledge.

Sato, H. 2005. 'Total factor productivity versus realism' revisited: The case of the South Korean steel industry. *Cambridge Journal of Economics*, 29: 635–655.

Schefczyk, M. 1993. Operational performance of airlines: An extension of traditional measurement paradigms. *Strategic Management Journal*, 14: 301–317.

Stern, J. J., Kim, J., Perkins, D. H., & Yoo, J. 1995. *Industrialization and the state: The Korean heavy and chemical industry drive*. Cambridge, MA: Harvard Institute for International Development.

Truett, L. J., & Truett, D. B. 1997. The Korean metals industry and economic development. *Journal of Asian Economics*, 8: 333–347.

Tsui, A. S. 2004. Contributing to global management knowledge: A case for high quality indigenous research. *Asia Pacific Journal of Management*, 21(4): 491–513.

Tybout, J. R. 2000. Manufacturing firms in developing countries: How well do they do, and why? *Journal of Economic Literature*, 38: 11–44.

Van Ark, B., & Pilat, D. 1993. Productivity levels in Germany, Japan, and the United States: Differences and causes. *Brookings Papers on Economic Activity (Microeconomics)*. Washington DC: Brookings Institution, pp. 1–69.

Yuhn, K.-H., & Kwon, J.-K. 2000. Economic growth and productivity: A case study of South Korea. *Applied Economics*, 32: 13–23.

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