Indiana Business Review

Dinosaurs on the Lake? Steel in the Next Decade

A publication of the Indiana Business Research Center, Indiana University School of Business

Spring 1993

Contents

Indiana Business Review
Volume 68, Number 1
Spring 1993

Published four times each year by the Indiana Business Research Center, Graduate School of Business, Indiana University.

Unless otherwise noted, information appearing in the *Indiana Business Review* is derived from material obtained by the Indiana Business Research Center for instruction in the School of Business and for studies published by the Center. Subscriptions to the *Indiana Business Review* are available to Indiana residents without charge.

Dinosaurs on the Lake? Steel in the Next Decade

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What is the future of integrated steel in Indiana? There is no easy answer. In retrospect, many roots of the current questions were apparent even in the heady days of the 1950s and 1960s. Business was booming both nationally and internationally while insufficient attention was given to quality.

Two areas of critical importance to the steel industry—the need for investment in new and modern capital equipment and a skilled, high-quality labor force—were not sufficiently addressed. In addition, American steel was "requested" by the U.S. government to provide maximum technical assistance to foes and friends alike in World War II—with a smile and without any charge.

Busloads of Japanese, Germans, French, Belgians, Dutch, and British descended on individual U.S. plants and received volumes of technical information along with countless scientific suggestions—research "dreams." Unfortunately for the United States, these bright foreign engineers went home and applied the ideas picked up in their U.S. travels to the raw materials, equipment, and processes in their own plants while Americans continued to operate their prewar furnaces and use the same management style.

The end of World War II also brought to the surface the realization that the U.S. was running out of "direct shipping" high-grade iron ore. Although the mines on the Minnesota and Michigan ranges contained vast reserves of low-grade ores, they had to be beneficiated and processed with a great input of capital and energy into taconite pellets—little marbles—that today constitute the bulk of iron units charged into the blast furnaces. Processed taconite raised the price of U.S. iron ore above that of Brazil, Venezuela, Australia, South Africa, Liberia, and others, who supplied Europe and Japan with iron ore in large ships. Jack Lennon, CEO of Continental Resources in New York, stated that the cost of Brazilian ore FOB U.S. was 26-30% below the cost of American ore.

Americans did not seriously consider relocating new plants to the coastal areas of the Atlantic Ocean or the Gulf of Mexico. This would have provided the advantage of low shipping costs enjoyed by France, Japan, Great Britain, and Australia. Instead, American steel clung to its Midwest locations and found itself in a weak competitive position. Only recently, Nucor, a manufacturer specializing in mini-mills, announced location of a 2-million-ton plant with direct reduction at the Mississippi River port of Hickman, Arkansas. The plant will use imported iron ore.

After World War II, American labor-management relations were fragmented. Management was built on layers upon layers of specialists, while antagonistic unions demanded an ever larger share of the corporate pie. To this day, unions insist on—and management complies with—confining workers to narrow sequential job levels with little training and with no interaction with other departments of the plant. In contrast, our competitors in Europe and Japan educate and grade their future workers with respect to literacy, technological understanding, and job attitudes in special training programs operated jointly by the companies and the trade unions.

American integrated plants assumed that steel would remain unchallenged as the principal component for cars, refrigerators, stoves, and appliances. They discounted the potential of such materials as plastics, fiberglass, and laminates. In the early 1970s, the industry handily dismissed the importance of the American mini-mills—which have now captured close to 50% of the U.S. market and may substantially increase their market share in the next decades (see **Table 1**). The interests and initiatives of individual U.S. government departments such as Commerce, Energy, and the EPA were not well coordinated and were ill equipped for funding joint research projects such as those carried out by Japan's MITI (Ministry of International Trade and Industry).

So the American steel industry has not initiated any major innovation since the 1960s. Major processing improvements such as the basic oxygen refining process, continuous slab casting, continuous rolling and annealing, high-intensity blast furnace opera-

Table 1
Steel Output in Million Metric Tons

	1975	*1978-79*	*1982-83*	*1986-87*	*1988-89*	*1990*	*1992-93*
Total U.S. Output	105.82	123.85	71.65	77.45	89.54	88.96	89.65
Output Integrated	89.90	103.70	50.35	44.67	51.05	46.80	45.90
Mills Capability	123.30	122.10	111.10	70.01	63.75	61.80	57.90
Output Mini-Mills	17.92	20.15	21.30	32.78	38.49	42.16	43.75
Capability	18.20	22.40	28.10	33.90	34.00	42.50	44.50
Cost of Scrap	$71.74	$77.98	$58.40	$72.54	$119.20	$116.24	$119.07
Auto Purchases	13.80	18.09	9.70	9.53	10.55	9.47	8.78
Imports	10.90	17.63	15.30	18.65	17.33	15.56	14.12
Western and Developing World Production	306.50	461.45	260.25	264.39	278.55	282.90	284.80
Mini-Mill % of U.S.	16.93	16.27	29.73	42.33	42.99	47.39	48.80
Import % of U.S.	10.30	14.24	21.36	24.08	19.35	17.49	15.75
U.S. % of World	34.52	26.84	27.53	29.30	32.15	31.45	31.48

NOTE: Mini-mill output includes that of producers other than integrated mills.
SOURCES: For Total U.S. Output, Cost of Scrap, Auto Purchases, and Imports, the Survey of Current Business, *various issues, U.S. Department of Commerce, Washington, D.C.; for Integrated Mills Output and Capability as well as World Output, Marcus and Kirsis (Paine-Webber, 1988, 1991); mini-mill and specialty steel output are obtained from Paine-Webber, AISI (1989-92).*

tions, vacuum degassing of liquid steel, and others were conceived in the U.S. but adopted only after they were installed and tested in Europe and Japan. The research spark was almost completely extinguished in the late 1960s; since that time big steel has acquired process and product improvements mostly from abroad. Progress in direct steelmaking, a possible quantum leap for integrated mills, appears to have been stalled. But even if successful, direct steelmaking (if the process is based on taconite pellets) offers little improvement in the economy of iron extraction.[1]

Table 2
U.S. Steel Industry
Deflated Values (1975 = 100)

	1975	*1978-79*	*1982-83*	*1986-87*	*1992-93**
Price per ton ($)	385.10	376.19	328.12	279.15	262.20
Profit/loss per ton ($)	12.08	16.26	-71.89	-7.05	7.45
Labor cost per ton ($)	109.50	99.20	109.55	79.10	54.80
Materials and other costs per ton ($)	135.80	148.80	156.85	157.00	150.60
Fixed costs per ton ($)	127.72	119.93	156.09	124.49	141.90
Capital per employee ($000)	26.8	28.0	45.5	63.3	109.7
Return/Equity	9.1%	6.8%	-19.9%	-79.2%	1.1%
Debt per ton ($)	72.36	56.21	190.72	166.26	178.30
Average age of plant	15.4	15.3	12.3	8.9	10.3
Weighted price index	100.0	127.2	169.3	172.7	189.4
Annual wages of employees	$19,611	$20,567	$23,592	$24,803	$24,922

**1992-93 values are statistical projections.*
NOTE: Tons are metric tons, or tonnes.
The U.S. steel industry reported in the Paine-Webber study are mostly integrated steel companies; the integrated mills are: USX, Bethlehem, LTV, National, ARMCO, Inland, Wheeling-Pitsburgh and Jones and Laughlin, Republic, Youngstown and Kaizer, which exited from the market prior to 1979.

Table 3
U.S. Steel Companies

	Rated Capacity (Mil. Tons)	*Operating Rate (%)*	*Capital Yields*	*Output (Mil. Tons)*	*Number Employees*	*Payroll/ Employee (Dollars)*	*Tons/ Employee*
1975	122.4	71.3	9.1%	87.8	580,570	19,611.45	179.1
1978	109.6	85.4	6.8%	102.7	574,705	26,161.48	220.4
1982-83	108.2	54.7	-19.9%	52.2	369,145	39,940.60	212.5
1986-87	83.2	62.2	-79.2%	57.8	235,062	42,840.20	311.5
1992-93 (Est.)	71.8	78.1	7.1%	56.9	176,312	49,691.10	461.5
Nucor Corporation							
1975	0.4	85.0	17.1%	0.4	2,300	14,282.80	510.1
1978	0.9	85.7	29.9%	0.7	2,800	24,138.20	586.3
1982-83	1.7	75.2	13.0%	1.4	3,650	35,660.00	797.2
1986-87	1.7	99.5	12.1%	1.7	4,500 Steel (1809)	43,180.00	(Steel) 834.8
1992-93 (Est.)	4.4	86.6	13.6%	3.8	5,750 Steel (2800)	50,550.00	(Steel) 1257.7

NOTE: Values are in nominal dollars. Tons are metric tons; 1992-93 estimates for Nucor were made by Nucor's CEO, F. Kenneth Iverson, and converted into metric tons.

Phenomenology of Steel Markets[2]

The post-World War II U.S. steel industry operated as a typical quasi-collusive oligopoly, setting prices to satisfy the profitability requirements of the least efficient producers. Firms that earned economic rents engaged in price shading whenever aggregate demand for steel declined. Uniform labor contracts and base-rate codes allowed costs to be shifted forward to consumers. In turn, labor unions tended to negotiate wage rates and fringes based on affordability of the most efficient producers. A global steel market emerged with new steel-making technologies being developed in foreign countries. Foreign firms supported their new wave of innovations from internally generated funds.

Due to the nature of production functions in integrated steel mills, profits could be earned only when firms operated above 70 to 80% of capacity utilization. Thus it was possible that even small inroads by foreign competitors could rapidly force profits down in the face of unyielding labor and energy costs.

U.S. firms responded by downsizing or abandoning various processes that could not be operated at required levels of capacity utilization. They concentrated on producing cold- and hot-rolled sheet. Moreover, to protect the profitability of downsized industrial plants, an alliance of unions and political protectionists was forged to fend off further foreign inroads into the domestic sheet market.

Although domestic political alliances could be forged in the 1960s and 1970s in an attempt to forestall external competition, in the 1980s and 1990s competition emerged from domestic mini-mills, a sector not subject to xenophobic maneuvers. Mini-mills successfully competed with integrated mills in both domestic and export markets. Nucor, with an Indiana mini-mill location, currently exports about 150,000 tons of wide flange beams annually.

Will integrated steel mills in northwest Indiana become dinosaurs on the lake? To investigate this question we turn to data from Paine-Webber's monumental compilation of the steel industry (Marcus and Kirsis 1988, 1991). We believe that **Tables 2** and **3** are reasonable representations of the U.S. steel industry from 1975 to the present. We also believe that the weighting by several price level indices provides a reasonable deflation of nominal data.

Profits and Losses in Integrated Steel

In the first period, from 1975 to 1978-79, the U.S. steel industry was relatively stable and marginally profitable. Steel imports were rising, but not at an alarming rate. On average, real product prices were stable while unit labor costs declined (as expected) when capacity utilization increased from 71.3% in

1975 to 85% in 1978-79. Unit costs of materials and energy rose marginally, mostly from the delayed effects of the oil crises and partly because of higher electricity costs, propelled by the failure of nuclear energy as an alternative power source. The average age of plants remained at about 15 years. Capital per employee increased slightly from $26,800 to $28,000.

The 1981-83 recession marked a changed outlook for American steel. Steel had been downsizing gradually from a capacity of 122.4 million metric tons in 1978 to 109 million metric tons in 1979, entering the recession with 108.2 million metric tons of productive capacity. Downsizing was done by gradually shuttering older plants and discarding labor-intensive industrial product divisions. During the recession, the average age of plants declined to 12.3 years.

In spite of losses of $71.89 per ton at the recession's trough, the rejuvenated U.S. steel industry weathered the recession with drastic restructuring. The average plant age fell to 8.9 years by 1986. Capital per employee rose from $45,500 in 1982 to $63,320 in 1986 and is estimated at $109,680 for 1992-93. Plant overall capacity has been downsized to 83.2 million tons and is estimated to decline to 71.8 million by 1992-93. Labor costs per ton also dropped dramatically to $79.10 per ton and are estimated to decline to $54.80 per ton in 1992-93. Real prices for crude steel declined from $385 per ton in 1975 to an estimated $262 per ton in 1992-93.

The Promise and the Fall

Steel companies were "leaner and meaner," as their CEOs were fond of saying, but they were not making any real money to pay for the large infusions of new capital. Debt per ton increased from $72 in 1975 to $166.26 (real) in 1986-87. Steel modernization was not simply a response to rising labor costs—that is, factor-enhancing technologies. The newly available product-improving technologies were the real driving force for modernization. Autos and appliances were clamoring for higher-grade sheet, which required new investment mainly at the finishing end, regardless of economic rentability. In economic terms, innovation was lagging behind invention.

Some integrated mills have done better than others. USX, which undertook the most drastic restructuring, has reduced labor costs per ton from $177.60 in 1982 to $52.30 per ton in 1990, the lowest among integrated mills.

From 1975 through 1978-79, labor productivity rose from 179.1 to 220.4 tons per employee per year. Nominal wages increased from $19,611 to $26,161 per employee per year, while real wages either were constant or declined slightly, depending on the index used. Return on capital dropped from 9.1% to 6.8% per year (see Table 3).

The distribution of productivity gains was relatively equitable between capital and labor. The principal beneficiaries were consumers, as the real price of steel declined from $385.10 to $376.19 per ton (see Table 2). Clearly, stiff competition from imports and the domestic mini-mills induced this neo-classical economic scenario.

After the 1982-83 recession, return on capital reflected a loss of 79.2% in 1986. With plant capacity reduced by more than 43%, the burden of retrenchment fell more heavily on the owners of capital than on labor. (We are disregarding the fact that labor has borne the burden of job losses, whereas owners of capital have lost only wealth). The losses to owners of capital were partly due to declining real steel prices, including a falling proportion of high-priced steel in the average product mix. The main beneficiaries once again were consumers, except those who lost jobs. The principal losers were owners of capital, specifically those who had invested in steel companies.

One may argue that capital intensification tends to increase yields to both capital and labor during expansion, while it tends to decrease returns to capital during retrenchment. In other words, steel manufacturers, automakers, and other similar companies may find that simultaneous increases in capital intensity coupled with reductions in plant size (due to declining market demand) may not turn losing firms into profitable ones. One reason for such a turn of events is the discontinuity of capital installations, making the choice of ideal plant size very difficult. (GM may also discover this if its 1992-95 restructuring should fail).

In a typical integrated steel operation, marginal labor costs tend to decline as full capacity is approached. Marginal intermediate product costs and energy (scrap, etc.) tend to rise. In the steel industry, short-run average variable costs tend to be constant over a wide range of capacity utilization (outputs). This hypothesis was confirmed in a global study of 48 steel companies over a period of 15 years conducted by 31 MBA students at Indiana University Northwest in 1992. In several cross-section and time series runs with several control variables such as capital, vintage of plant, and union contracts, capacity utilization (output) failed to explain average variable cost, suggesting linear total costs for steel. This implies that total costs per ton produced are lowest at capacity and rise each time operating rates decline as a consequence of shrinking demand.

The average fixed costs of new technologies will be typically higher than the average fixed costs of plants before new technologies were introduced. The maximum output per plant for the new technologies is higher than for the previously installed capital. However, because of shrinking demand, efficient capacity utilization was not attained. Bethlehem Steel at Burns Harbor was originally designed to produce approximately 10 million tons annually. It has never produced that much.

At full capacity, average total costs for new capital tend to equal or fall below average total costs for the previous technology. However, average total costs for new capital will rise above previous average total costs if previous full capacity output has not been exceeded, as in the 1982-1986 period.

Unit labor costs tend to fall as new technologies are introduced. However, the maximum potential drop in labor costs tends not to be realized. The introduction of new technologies in highly unionized industries, such as steel, often requires concessions to unions in phasing out excess labor. Out of $9 billion in capital improvement costs in 1992, nearly $4 billion was for non-production downsizing expenses.

Given the rigidity of steel prices due to foreign competition as well as competition from domestic mini-mills, the only feasible strategy is to push output toward full utilization in selected plants. The U.S. integrated steel industry was abandoning unprofitable plants and product lines, attempting to operate the remaining plants at capacity utilization rates beyond the break-even point in the period 1982-1987.

The steel companies are indeed between a rock and a hard place. They must accelerate introduction of new technologies because of demand for higher quality steel. However, new capital structures do not become profitable unless output rises, which requires increased or accelerated growth in aggregate demand for steel, more specifically for sheet products.

There is a possibility of expansion by integrated companies into global markets (mostly third-world countries) if NAFTA is ratified. However, mini-mills are likely to threaten the expansion path.

The Labor Supply Function and Wage Rates in Integrated Mills vs. Mini-mills

In certain types of oligopoly, when insulated from foreign competition, the aspect of a labor contract that matters is not the firm's cost but whether each firm in the group is equally affected by the contract. In these cases, the cost of a new labor contract can be shifted to the customers, because the producers using the intermediate product and the consumers of the final product (such as autos) both have few options to secure substitute goods.

Integrated mills were encumbered by inflated salaries, wages, and fringe benefits that were not sustainable under global competition. The convoluted bargaining stances that terminated in a dramatic breakdown in communications between labor and management were laid out in great detail by Hoerr in his incisive book, *And The Wolf Finally Came* (1988).

The foundation for high steel wages began in WWII, when steel companies pirated each others' skilled workers through wage incentives. As a result, the companies agreed, with some prompting from the government, to develop a set of experience- and skill-related categories. The "Standard Hourly Wage Scale" had 35 rigidly defined job classifications, which labor unions had a vested interest in protecting.

To stimulate production in the 1950s and 1960s, firms developed increasingly more complex work incentive plans. These were based on the principle that, at full effort, labor could earn wages approximately 35% higher than base rates. Thresholds were established for each process, including non-measurable floor and shop work, below which only standard hourly rates were earned. It was also established that each crew's performance would be controlled by a single pace leader who would receive an even higher bonus rate. Indices of Pay Performance (IPP), measuring characteristics such as linear feet, thickness, and metallurgical characteristics, were developed. These required a large industrial engineering bureaucracy. Numerous revisions of these indices were made when new products or new technologies were introduced. These revisions resulted in frequent grievances and slowdowns. The unions took the stance that if crews experienced drops in their bonuses, it was management's task to correct the problem. Adapting and defending IPPs became an industrial engineer's nightmare. Many plans in the commercial products divisions were so poorly designed that they sometimes yielded bonuses in excess of 100%.

Clearly, it was in the interest of the unions to protect incentives by writing language into labor contracts that made it difficult for management to make revisions when new and more productive capital was introduced. This created a disincentive for innovation, particularly in the shaped products and special commercial orders divisions.

When the threshold output for incentive pay was set low, as tended to be the case from 1945-1965, labor was anxious to maintain smooth operations and industrial breakdowns were speedily corrected. But the pace of operations became more centrally and electronically controlled, reducing the amount of direct worker involvement in production. In addition, incentive pay thresholds were raised. Thus, the output that had to be attained to earn incentive pay tended to be realized toward the end of the eight-hour turn.

Experienced crews were able to gauge early in the turn whether the threshold output would be attained. If not, no effort was made to maintain the pace of operations, nor would breakdowns be repaired. This was most often true in the commercial products divisions. It occurred less frequently in the highly automated rolling mills. Jealously guarded, inflexible

Table 4
Steel Sector Values

	Price/Ton Shipped		*Material Cost Per Ton*		*Labor Cost Per Ton*		*V/PL*	
	All Steel	*Nucor*	*All Steel*	*Nucor*	*All Steel*	*Nucor*	*All Steel*	*Nucor*
1979	513.60	353.00	206.70	211.30	185.52	62.37	1.65	2.27
1983	529.60	273.00	269.10	175.90	161.91	38.06	1.61	2.55
1987	521.00	293.00	263.80	188.90	128.12	45.56	2.00	2.28
1990-91	518.30	367.70	300.40	236.00	116.29	47.21	1.87	2.79
1992-93 (Est.)	521.20	304.84	308.60	211.70	121.31	40.13	1.75	3.10

NOTE: Table contains the steel sector only. Tons are metric tons; 1992-93 estimates for Nucor were made by Nucor's CEO, F. Kenneth Iverson, and were converted into metric tons. V/PL = (Sales Price Per Ton - Material Cost) / Labor Cost.
SOURCE: Paine-Webber Exhibit NN 3-67, 79, 72, and NN-3-12 all averaged.

job classifications sustained by strong unions were lesser obstacles to productivity in the sheet, strip, and plate divisions. It is not surprising, therefore, that the greatest inroads by non-union mini-mills, which operated more rational labor-management systems, were made in the commercial products division. In addition, it was technologically easier for the mini-mills to gain a foothold in commercial products than in the higher-quality sheet and strip markets.

Major integrated mills currently have profit-sharing plans that represent a more rational approach to wage incentives. However, these plans were slow in their development, and they still retain the old, cumbersome grievance procedures that tend to retard continuous innovation.

At first, integrated mills countered market encroachment by extensive price shading and non-price competition, mainly in the industrial product markets, such as shapes, pilings, rails, bars, pipe, and wire. In this product market they faced a large number of buyers with differential market power. As noted earlier, market opportunities in industrial products, coupled with new steel-making technologies, facilitated the entry of mini-mills into the industrial product market. The mini-mills competed very well, due to lower labor, energy, and capital costs and more efficient, less cumbersome, and lower priced top management. As a result, by 1991 almost the entire industrial product market was abandoned by the integrated mills to domestic mini-mills or foreign producers. The large write-offs forced on the integrated mills caused a widening gap between the costs of the integrated mills and the lower costs of the mini-mills.

Steelmaking Technologies

The integrated steel production process consists of:

1. extracting iron, that is, smelting iron oxide ores into carbon-saturated liquid iron (hot metal);
2. refining iron to liquid steel by the removal of carbon in the basic oxygen process;
3. casting liquid steel into molds to produce slabs, blooms, or billets; and
4. shaping these semifinished products into marketable finished goods: plates, hot strip, rails, sheet, and so on.

The steel process is divided into two basic parts. The front end includes the production of iron (blast), the production of sheet (basic oxygen or BOP), and continuous casting. The finishing end includes primary hot rolling, cold reduction rolling, and strip annealing and coating (including galvanizing, or zinc coating, aluminizing, plastic coating, and laminating).

The chemical composition of steel products is established at the refining (BOP) and ladle metallurgical stage. Productivity at this stage depends, among other factors, on the thickness and width of the slab produced at the caster. The thinner the slab, the fewer rolling stands are needed to reduce the slab to hot strip and then to cold strip product. Nucor uses a new 2" thick caster that processes slabs to steel coils one-tenth of an inch thick without reheating. The latest continuous caster at USX Gary works, installed in 1991, had to be aligned with an existing rolling mill. The caster produces slabs that are seven and one-half inches thick. Under certain conditions, thicker slabs can produce higher-quality flat rolled products.

Mini-mills are recycling plants that melt preheated or cold steel scrap or direct reduced iron (DRI or sponge) in electric arc furnaces (EAFs). The liquid steel obtained is very similar to the liquid product of the basic oxygen process except for the increased level of impurities (such as copper, chromium, nickel, and tin) that is unavoidable when using scrap. In mini-mills, the liquid steel is poured into casting molds and processed in a manner similar to that used in the integrated steel mills.

Mini-mill productivity partially depends on the metallurgical quality of the scrap fed into the furnaces and the thickness of the slabs that are being cast. Mini-mills are not just smaller conventional mills; they represent a significantly different industry, with different economic characteristics. In Table 3 and **Table 4** we compare the entire U.S. steel industry to Nucor, the leading mini-mill producer.

Owing to various technological constraints, Nucor and other mini-mills were originally established to produce primarily commercial grade, lower-quality steel. Because of the absence of a labor-intensive front end, the average sales price per ton shipped was lower for the mini-mills than for the integrated mills.

Mini-mills have steadily increased steel output, employment, and productive capacity. Productivity in the mini-mills is almost three times that of the conventional mills and has increased at a slightly faster rate than conventional mills; 80% for mini-mills compared to 73.4% for integrated mills. Most notable is that the mini-mills' capacity utilization rate in 1986 was almost 100% as opposed to a 62.2% rate in the integrated mills. Returns to the mini-mills' capital averaged almost 20%, and there were no losses—even at the bottom of the 1981-82 recession. Non-union employee compensation for mini-mills was lower than for integrated mills. However, when profit-sharing bonuses were included, mini-mill wages were within the range of integrated steel employee wages. It is reasonable to think that non-union firms may want to offer reasonable compensation (including fringes) to preempt unionization as suggested by the contestable markets hypothesis (Baumol 1982).

Value Added Over Payroll

In 1984, Singer and Lynch made a study of manufacturing in 92 Standard Metropolitan Statistical Areas (SMSAs) over a 10-year period. They found that, in spite of cyclical factors and different product mixes, the ratio of value added to payroll (V/PL) was a good predictor of expansion or contraction of manufacturing capacity and employment in a given industry. When the ratio exceeded 2.0, expansion occurred. A ratio lower or equal to 2.0 was associated with contraction. In the Northwest Indiana SMSA, steel had a V/PL ratio above 2.0 during all the expansion years from 1958 to 1966. The U.S. steel industry had V/PL values below 2.0 during 1975-1991, indicating contraction, whereas in the same period Nucor and most other mini-mills had V/PL values above 2.0, indicating expansion.

Tables 5 and **6** record the proportion of firms with capacity rising or falling given their V/PL ratios. For example, in Table 5 the number .8437 indicates that in the 15 years between 1975 and 1990, 84.4% of mini-mills in the U.S. had V/PL ratios exceeding 2.0 and simultaneously reported rising capacity over time. Similarly, in 5.8% of all recorded events where mini-mill firms had V/PL ratios exceeding 2.0, productive capability was declining. The relationship between V/PL and expansion or contraction is statistically significant. In a market economy, such as the United States, firms or plants are likely to be forced out of the market if their V/PL ratios continue to decline. As long as this condition prevails in the U.S., further downsizing or exit of integrated steel mills is a reasonable prediction.

U.S. Electric Arc Furnace (EAF) Plants and Integrated Plants. We also tested the V/PL hypothesis for individual plants. We identified 46 counties in the U.S. where EAF plants were operated. Several EAF plants were run by integrated steel companies, while others were operated by mini-mills. We consulted the four latest issues of the *U.S. Census of Manufacturing*. The census does not give information on counties with only one plant because of confidentiality. Thus Lake County, Indiana, where there is only one small EAF, was omitted.

The V/PL ratios for the Lake and Porter County steel mills were 1.68 in 1972, 1.50 in 1977, 1.37 in 1982, and 1.42 in 1987. These ratios are associated with corresponding declines in productive capability. **Table 7** gives the number and percent of counties in each category. The data show that initially in 1972, there were nine counties with V/PL ratios greater than 2.0 and 17 counties with V/PL ratios equal to or below 2.0. As time progressed, the number of counties with one or fewer plants increased to 36, due to plant closings. By 1987 there remained only 10 counties with more than one plant, and all surviving plants in those counties had V/PL ratios in excess of 2.0.

Environmental Considerations

The 1990 amendment to the Clean Air Act may affect the production and consumption of metallurgical coke used in blast furnace plants and not affect the scrap-using EAF plants. The U.S. Department of the Interior estimates that the addition of 189 new substances to the existing list of contaminants, plus other ramifications of the Act, will result in the closure of five to

Table 5
U.S. EAF (N=125)

	Expanding or Stable	*Contracting*
V/PL > 2	0.8437	0.0576
V/PL ≤ 2	0.0636	0.0351

Table 6
U.S. Integrated (N=88)

	Expanding or Stable	*Contracting*
V/PL > 2	0.0818	0.0613
V/PL ≤ 2	0.0000	0.8569

Table 7
46 U.S. Counties with EAF and Other Mills

	1972		1977		1982		1987	
	# Counties w/ 1 or More Mills	*Percent Change*	*# Counties w/ 1 or More Mills*	*Percent Change*	*# Counties w/ 1 or More Mills*	*Percent Change*	*# Counties w/ 1 or More Mills*	*Percent Change*
V/PL > 2	9	19.6	14	27.0	6	13.0	10	21.7
V/PL ≤ 2	17	58.7	21	49.1	10	21.8	0	0.0
Counties with only 1 or 0 mills	10	21.7	11	23.9	30	65.2	36	78.3

Table 8
Break-Even Analysis: U.S. Steel Industry

	Break-Even Tons	*Actual Tons*	*AVC (1975=100)*	*Capacity in Mil. Tons*	*Fixed Assets Per Ton of Capacity*
1975	70.2	87.8	245.3	122.4	127.1
1978	89.9	102.7	248.0	119.6	134.5
1982-83	71.8	52.2	271.3	108.2	155.2
1986-87	66.2	57.8	236.1	83.2	178.9
1992-93 (Est.)	53.6	56.9	228.1	71.8	268.9

NOTE: Tons are metric tons.
Source: Paine-Webber

eight steelmaking shops and continuous casters. More than half of these mills may be in Northwest Indiana, because of the low imposed production ceiling of contaminants in this region.

Break-Even Strategies

Table 8 provides steel industry data for break-even analysis. These data indicate that short-run total costs are statistically linear. Plant size helps determine the rate of increase in total costs, because it is related to the amount of fixed costs incurred. Total revenue, however, is not statistically linear.

It appears that in 1978-79, the integrated steel industry was at an equilibrium output earning normal profits. Subsequently, aggregate steel demand declined. Equilibrium could have been restored by either raising prices for higher-quality products, reducing total costs, or a combination of both. Table 1 indicates that steel was not successful in raising real prices due to external market pressures, including competition by mini-mills. Reducing costs did not succeed either, in spite of some small concessions by labor. The equilibrium point corresponded to a per-plant sales level that was unattainable, even after plant closings.

Further reductions in demand for integrated mill products coupled with greater demands on quality forced steel to install technologically more advanced capital in a few plants. This maneuver significantly lowered labor costs. Increasing the percentage of total costs accounted for by fixed costs, while simultaneously attempting to reduce total costs, is a very tricky maneuver for a large organization faced with a multitude of advanced contractual wage, fringe, and financial commitments. As witnessed by the experience of integrated mills, the maneuver rarely succeeds. (GM, which is attempting a similar feat, may also not succeed.)

If one chooses downsizing—that is, achieving equilibrium by lowering fixed costs per plant—the sale of assets in a down market may result in drastic reductions of shareholders' equity, increasing the debt-to-equity ratio. This may have a negative impact on future sources of capital. Moreover, a diminution of sources of capital may impair the introduction of product-improving technologies, thus causing further losses in market share.

The solution adopted by integrated mills was to shed all or most of their shaped products and concentrate on the high-price end of the steel mix—Grade A sheet and strip, which some steel CEOs believed could only be reliably produced by the smelting and refining process associated with integrated mills. If such is the case, a new—possibly temporary—equilibrium point might be reached by weighting more heavily the high-priced end of steel in the average product mix and operating a small number of plants close to full capacity. An example of such a strategy is Inland's high-tech plant in New Carlisle, Indiana. Whether this complex strategy can be achieved by all integrated mills in unprotected international markets is, to say the least, uncertain.

Equilibrium Market Shares: Mini-mills vs. Integrated Plants

We argue that the survival of the integrated mills depends on the ability of the mills to accomplish several tasks. They must select profitable combinations of assets and outputs subject to constraints imposed by global markets. They must also maintain technological superiority in the high-quality sheet and strip market so as to maintain positive revenues at different capacities (an example is Inland's IN-TEK in New Carlisle, a high end finishing mill, which may eventually use input from foreign plants and mini-mills). Integrated mills may hold on to the automobile sheet market for quite a while; it is a market that mini-mills are not yet penetrating and may not as long as more lucrative markets exist for mini-mills than automobile sheet. (Kenneth Iverson, Nucor's chairman and CEO, says, "Nucor produces high-quality steel, suitable for almost all applications *currently not interested in automobile skin*" [italics added].)

Another determinant of integrated mills' survival is the ability to price products competitively, given the high costs of downsizing, constraints imposed by labor contracts, and high costs of intermediate factors, such as energy and environmentally mandated improvements. Finally, survival for integrated mills depends on their ability to stop the devastating hemorrhage of shareholders' equity, which in real dollars fell from $14.92 billion in 1975 to $4.37 billion in 1986.

The ability of mini-mills to displace integrated mills may be handicapped, however. The price of high-density ferrous scrap (Grade A bundles) is rising. Both mini-mills and integrated mills use scrap, but in different proportions (100% for mini-mills versus about 30% for integrated mills). Also, scrap is increasingly degraded by impurities and alloys. (Higher-grade alloyed or coated sheet produces low-grade scrap.)

The rising cost of energy, particularly electrical energy, harms mini-mills. At present, costs for integrated mills tend to rise faster than electric costs. This situation is, however, subject to change. Production bottlenecks may emerge in electric power, as is the case in the northwest United States.

Environmental controls on scrap processing—namely, the expanded list of toxic materials in the 1990 Clean Air Act—may increase processing costs. Financial constraints on new quality-oriented technologies, such as development costs associated with adequate supplies of Direct Reduced Iron (DRI), will also increase mini-mills' costs.

Another factor is the extent to which integrated steel will use EAF technology, thus preempting mini-mill market share. The progress in scrap quality control (monitoring, sampling, testing, and segregation by giant shredders) and in scrapyard automation will also affect mini-mills; if little progress is made, they will be harmed. In addition, improved energy-efficient scrap refining and heating technologies may be difficult to implement.

Output Limits on Mini-Mills

Currently, ferrous scrap is abundant in the United States. More than 10 million tons are exported and real scrap prices have declined (see Table 1). A small amount of high-grade scrap is imported. It is also estimated that almost 40% of potential steel scrap is not collected. As prices rise, this scrap certainly could be retrieved.

If EAF melting becomes economically dominant, scrap will have to be supplemented by DRI, which is needed for diluting contaminants in the scrap. Production of DRI requires specialized oxide reduction technology. The economies of DRI strongly depend on the iron content and physical characteristics of the iron ore and on the cost of the reductant (fuel).

The feasible sources of DRI are Venezuela, Brazil, South Africa, and the Pacific Rim. Hot briquetted iron (HBI) is produced as far away as Malaysia, Iran, India, Saudi Arabia, and Indonesia, among others. Currently, 25 countries produce DRI, and capacity is in excess of 30 million tons. Venezuela has productive capacity in excess of 6 million tons, Mexico in excess of 4 million tons. In contrast, the U.S. produces less than half a million tons of DRI.

Ninety-two percent of steelmaking grade DRI production is gas-based with minimal environmental fallout. The remainder is coal based. HBI prices are only slightly higher than scrap prices, varying from $110 to more than $200 per delivered metric ton. DRI technology is relatively inexpensive and mobile. Unlike even the best quality scrap, DRI has no residuals; thus, DRI prices are comparable to scrap prices. Worldwide productive capacity is increasing at more than 16% per year, whereas capacity utilization is about 64%.

At some point, the U.S. will likely be in the same position with respect to DRI as it is now with respect to oil. Foreign countries with rich ore deposits will build DRI plants, shipping the output to EAF steel plants in the U.S. (possibly under joint international ownership, as is the case with oil wells and refineries) or shipping semifinished products for U.S. finishing operations. Nucor currently uses about 150,000 tons of DRI a year imported from the Ukraine, mainly for flat-rolled products. The firm also contemplates building a coal-based DRI plant in the United States.

Implications for Northwest Indiana

The preceding analysis suggests that, other things being equal, integrated steelmaking may not survive the competition of mini-mills without major technological and organizational restructuring. It may survive longest in northwest Indiana, due to the area's proximity to the Minnesota-Michigan iron ranges—the only remaining commercial iron deposits in the continental U.S. The only viable competitor to the Great Lakes mills is the Sparrows Point plant near Baltimore, which can operate on imported high-grade iron ore. The use of imported ore is not economically feasible for northwest Indiana mills, because even if they switch to higher-grade ore there is an uneconomical 18,000-ton load limit per barge on the Welland Canal on the St. Lawrence Waterway.

Northwest Indiana's integrated steelmakers will continue to exhibit lower costs per ton and greater efficiency than other U.S. locations. USX, with its flagship in Gary, was the only U.S. integrated steelmaker with V/PL ratios above 2.0 in 1984 to 1990 (except for 1986). This may postpone, but not prevent, an inevitable crisis.

This Schumpeterian progression towards a crisis in U.S. steel production is expected to proceed more or less as follows:

Mini-mills, such as Nucor, will reach a two-million ton or greater capacity per plant. In the intervening period, integrated steel mills may continue to hold an output-quality advantage financed by joint ventures with foreign producers. However, as their market share is reduced by the growth in production of high-grade sheet and strip by mini-mills, integrated mills will gradually move further away from their economic break-even points, inducing more financial strains, which result in plant closures and breakdowns in supply.

Steel users will turn to imports to fill the gap. If political pressures cause imports to be restricted, price increases to steel users may further reduce the competitive stance of U.S. manufacturing.

By the next century, most commercial products will be manufactured by mini-mills with high-grade scrap (supplemented by imported DRI), along with improved refining, ladle metallurgy, and rolling technologies. Mini-mills with untapped funds and borrowing power will gradually expand into the integrated mills' traditional sheet markets, underpricing integrated mills because of lower labor costs, more flexible work rules, and more advanced technology.

How likely is the foregoing scenario? Are there countervailing forces? There will be upturns and recoveries in U.S. integrated steel. However, if the present course is followed, the outcome is inevitable. Is there a technological route to pursue? One may observe the caveat that invention is often a random event and no one can predict future breakthroughs with certainty. However, given the known rate of feasible innovation (as distinct from invention), we must of necessity rely on what technology is currently in the literature. Thus, we conclude:

- Innovation at the finishing end will be more readily adopted by mini-mills.
- DRI technology, scrap retrieval, and quality control are likely to significantly reduce or possibly cancel the advantages integrated mills hold over mini-mills in quality sheet and strip production.
- Direct steelmaking (DS), a possible advanced technology of iron-making for integrated mills, is highly questionable and still in its infancy; as pointed out by M. Holowaty (1991), it may not be economically feasible.
- The financial burden of complete technological restructuring of the steel-making process may not be sustainable by integrated mills without large infusions of public funds because of a huge overhang of past losses and a large debt burden.

We may ask, will existing integrated mills in northwest Indiana be replaced by mini-mills in time? That is, will northwest Indiana retain its steel-making position, albeit with a new technology? It is difficult to give a categorical answer, one way or the other. However, the following considerations apply.

Optimal locations for mini-mills have distinctly different characteristics than optimal locations for integrated mill sites, which are located across from the iron range. Mini-mills can locate in any area with an adequate supply of scrap and power—which means almost anywhere in the United States. Moreover, because of their relatively small size and portability, mini-mills can locate where electric rates, taxes, and health care costs are low, where labor is not likely to be unionized, and where scholastic test scores are high. In the past, labor migrated to metropolitan areas where the plants were located. Now plants migrate to rural areas where the non-union workers are. At present there are 87 mini-mills operated by 66 companies that produce steel in 36 states in the continental U.S. and Hawaii.

Moreover, Table 4 shows that integrated mills (excluding USX) have attained a V/PL of more than 2.0 only once in the entire period, during the fast global upturn in steel in 1987. This prompted modernization in several plants, which unfortunately did not continue. We suggest that the advantage melting mills hold over their competitors is not low non-union wages but innovation and technology: the way innovation is managed and the way labor and management are compensated. The U.S. steel industry will be saved not by government, but by a return to basic economics, by linking employee compensation to marginal product. Such compensation causes gains and losses to be shared equitably among labor, management, and asset owners. It is doubtful that the current format of the labor contract in integrated steel can be adapted to mini-mill operations in northern Indiana.

We do not predict with absolute certainty that northwest Indiana steel mills will become dinosaurs on the lake. A good example of integrated steel ingenuity in meeting the mini-mill challenge is Inland's and Bethlehem's upgrading of billet casters to produce high-quality bars. However, considering that 81% of advanced steel-making technologies are of foreign origin and that the U.S. needs new innovation and technology for survival, we would be seriously remiss if we were to ignore the possibility that our long-run analysis might prove to be accurate.

Epilogue

A shrinking market for steel sheets (both cold-rolled and coated) and a growing market for structural grades (buildings, roads, and bridges) will accelerate a shift to mini-mills based on electric arc furnaces. EAF expansion could stimulate growth in the ailing Minnesota-Michigan iron ore ranges, which could supply DRI to mini-mills.

Moreover, the iron ranges could also provide iron ore concentrates to coal-based reduction plants located next to the beneficiation units, thereby eliminating both the expensive pelletizing step and the blast furnace-BOF complex, and possibly reviving steel production in the Midwest. Reductant coal could be shipped from Wyoming or Montana on a straight-line railroad track at low transportation costs to Minnesota, eliminating potential shortages and increasing costs from uncertain supplies of natural gas.

As the production of EAF steel increases, ore reduction plants will expand to compensate for a shortage of domestic steel scrap. Increased availability of domestic DRI may improve the quality of EAF-produced steel, enhancing the U.S. competitive stance in global markets. According to the Center for the Study of American Business, "U.S. mini-mill producers are among the lowest-cost producers in the world" (Burnham 1993). As indicated in Table 1, combined U.S. integrated and EAF steel production has been increasing as a share of world steel output. If the scenario as presented is followed, further increases could be experienced. However, the political feasibility of this scenario was not investigated.

Notes

1. The American Institute of Metallurgical Engineers (AIME) at their meetings in Toronto, Ontario, Canada, on April 5-8, 1992, announced that no progress report could be issued on the "Direct Steel Making Process," a project jointly sponsored by the American Iron and Steel Institute (AISI) and the Department of Energy.

2. Economic phenomenology lets the data guide the analysis without presuppositions and without prior hypotheses. The logically connected phenomena are subsequently investigated in an analytic and predictive model. See Leslie Singer, "Phenomenology of Art Markets," *Journal of Cultural Economics*, June 1988, pp. 27-40.

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Spring 1993

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