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ECONOMIES OF SCALE IN THE NORTH AMERICAN IRON ORE (TACONITE) INDUSTRY

by

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I. Introduction

Past observers of the iron ore mining industry have stated that iron ore mining is quite capital intensive and have implied that extensive economies of scale are present. Recent research has asserted that joint vertical ownership of the mines have prevented the move toward efficient utilization of capacity. Taken together, these assertions imply significant economies of scale exist in the taconite industry and that the industry could make significant strides toward more efficient capacity utilization. Iron mining has undergone, however, vast structural changes during and since the industrial revolution.

Mining became highly centralized during the 1890's and was characterized by various, somewhat unstable pooling arrangements prior to the 1890's. Richard Mancke (1972) indicated that between 1896 and 1901 a drastic, vertical reorganization of iron ore markets took place in response to the threat of resource foreclosure in 1896. The threat arose because of Andrew Carnegie's 50-year ore requirements contract from John D. Rockefeller's extensive Mesabi Iron Ore properties. By 1900 the largest American producers of pig iron and crude steel had become, through vertical integration, self sufficient in iron ore. Mancke notes that subsequently ore prices collapsed as a result of the destruction of this pool.

By 1952 the four major ore firms (Pickands Mather, M.A. Hanna Company, Cleveland Cliffs, and Ogleby Norton) sold about one-third of total production, while about half was absorbed by the nine largest steel companies on the basis of single/joint ownership. The remaining 17 percent went to the same companies on the basis of long term contracts. During the 1950's deep ore deposits were depleted and the beneficiating of surface ores grew and dominated the output mix by the 1960's. Correspondingly, considerable gains in steel smelting technology were achieved using the enriched taconite ore pellets (Kakela, 1977). A

restructuring of the industry followed. Some ore firms, interested in developing a taconite ore deposit, set up a joint venture and retained some stock interest, while several customers of ore subscribed for the remaining shares. The joint venture then hired an ore firm on a management contract to develop the property and the stockholders in the mining companies shared costs and ore in proportion to their ownership of stock. The joint venture corporation and its parents were in a good position to spread the risks of fluctuating demands for ore and the high capital costs more evenly (Gold, 1984).

During the early 1980's a severe contraction in both the steel and ore industries initiated another major restructuring. According to Peter Marcus and Karlis Kirsis (April, 1989), by 1988 North American production reached 95 million long tons from a 1983 low of 67.1 million long tons (1981 peak of 121 million long tons). In 1982, 16 pellet plants were operational in the U.S., while four small ore plants were closed. By 1988 six additional plants were closed and eight of the remaining ten U.S. plants had cut capacity varying from 19 to 50 percent. Only Hibbing Taconite increased capacity, by 11 percent (Marcus and Kirsis, p. 18). Canadian adjustments were similar, though not as severe.

Through successful concession bargaining and extensive labor lay-offs the production costs have come down by more than 30 percent since the early 1980's. Much of this reduction was achieved by labor productivity gains of over 50 percent since 1982. Also decreases in the costs of energy and materials were accompanied by concessions in royalties and state taxes. Significantly, the ore industry has become more concentrated, especially since Cleveland Cliffs acquired Pickands Mather in December 1986. The top three iron ore producers control 94 percent of North American capacity--Cleveland Cliffs controls 40

percent, USX controls 32 percent, and M.A. Hanna controls 22 percent. With the top three iron ore producers controlling 94 percent of production, oligopolistic pricing is likely to return, at least in periods of strong demand (Marcus and Kirsis, June 1988, p. 21).

Interestingly, for all of the rationalization of capacity which this industry has undergone, past studies (Raab and Steinnes, 1989) have indicated that high cost plants have been operated at full and beyond full capacity and some low cost plants have been operated well below capacity. This anomaly seems to result from of the joint vertical ownership of the mines which prevented the move toward efficient utilization of capacity. Moreover, the measurement of the extent of economies of scale suggests that perhaps more consolidations of capacity are still prevented by the distribution of ownership claims in the industry (Raab and Steinnes, 1989).

We will estimate statistically a quasi, long-run average cost (LAC) of production and use it to test empirically for the optimal scale of plant. Results will indicate that the optimum scale of plant appears "large" both in absolute terms and relative to the industry. Past statistical studies in the private sector tend to show an L-shaped LAC, implying that beyond the minimum efficient scale of plant costs tend to remain constant as plant size increases. This is not the case in the taconite industry.

II. The Notion of Scale Economies and Their Measurement

Basic microeconomic theory predicts cost curves that are u-shaped. Short-run cost curves (SAC's) initially exhibit declining average costs because of the spreading of fixed costs over a larger range of output and rising average costs (at mid-ranges of output) because of diminishing returns attributable to a high ratio of variable inputs to fixed inputs. Long run

costs, however, are not determined by the laws of production. If the LAC is u-shaped its declining portion generally is attributable to specialization of task, division of labor, large scale engineering relationships, and finally to more efficient information retrieval, organization, and transfer. The rising portion of the LAC occurs when any of the above factors are carried to a scale of operation where they no longer cause per unit costs to decline, or the administrative and bureaucratic apparatus becomes too cumbersome. These plausible, but nonetheless, ad hoc explanations must be empirically measured to establish the actual shape of the LAC for any particular industry. A proposition central to industrial organization is that the shape of the LAC should determine the number and size distribution of firms, and therefore the level of competition which is technologically possible in the industry. The measurement of cost functions, therefore, is an important aspect of applied micro analysis.

Theoretically, the LAC is a scale or planning curve which envelopes the SAC's representing various plant sizes and a given level of technology. Measurement of the scale of an actual industry will only approximate a theoretical LAC. However, an estimated function usually can reveal the extent of scale economies for the purposes of evaluating an efficient size distribution of firms within the industry.

The measurement of cost functions, as distinct from those derived from production functions, is empirically the same, whether measured for the short run or the long run. Similarly, both short and long run cost functions have been estimated by both time series and cross section techniques, using both accounting and engineering data. (See summaries of past studies in Mansfield; 1991, p. 204-206). As might be expected, public utilities tended

to exhibit economies of scale in the 1950's but by 1970's unexploited economies of scale were much smaller. Moreover, Christensen and Greene (1980-81, p. 655) assert that by the 1980's electricity generation was provided by firms operating in the essentially flat (efficient) area of the LAC. For most other general manufacturing industries, statistical cost studies, including the survivor method (see Stigler; 1958), demonstrate that marginal and average cost curves are usually horizontal over large ranges of plant size. Moreover, in only a minority of industries have diseconomies of scale been detected for very large plants (Scherer; 1990, p. 113).

III. Estimation Results

Our intent is to estimate the long-run cost structure of the North American iron ore (taconite) industry, using available data, and draw conclusions as to the efficiency of the industry. In addition, we will discuss the recent structural changes in the industry and consider whether there is likely to be movement toward more efficient size in the future.

Private industries, unlike regulated public utilities with stringent cost and output reporting mandates, have much less available data, and correspondingly less sophisticated analyses of costs have been possible. The vertically integrated and joint venture character of the taconite industry has made income and profit statements both unreliable and inapplicable to the ore segments. While information on production can be obtained from various sources (e.g., production tax records and the American Iron and Steel Institute), cost data are harder to estimate. Some cost information can be obtained from state records, county mine inspection reports, and steel firms 10 K returns. Using these sources, as well as direct interviews with the mines and the steel companies, Kirsis and Kakela (June 1988, pp. 24-26,

40-41) have estimated recent (1987) costs for 15 North American mines. Estimates provided by the same authors for earlier years have been substantiated by other sources (see Raab and Steinnes, 1989).

Kirsis and Kakela (1988) provided two observations (of costs per ton) for each mine, one at full (90%) capacity and one at current (1987) capacity. Thus, the estimation results are based on a sample of 30 cross-section observations of the 15 North American taconite plants. Account will be taken of the two observations by use of a binary variable (FULL = 1 if full capacity observation; 0 if not).

In addition to the FULL binary variable, there are two other independent variables which are used, operating rate and number of owners. We expect the former to lower costs on efficiency grounds and the latter to lower costs if multiple owners can allocate production capacity more efficiently by lowering inventory costs.

Primarily, the estimates provided have to do with the relationship between costs and the level of output. While we view the estimates as indicative of the long-run cost structure (or curvature), it should be noted that the observations are actually on various short-run cost curves. Hence, these expected or stochastic costs are higher than the theoretical (long-run) costs (see McGuigan and Moyer, 1989, pp. 429-431).

While microeconomic theory suggests that cost curves (i.e., the relation between cost and output) should be non-linear, statistical estimates for most manufacturing industries have often failed to verify the existence of the theoretical curvature (see Mansfield, 1991, and McGuigan and Moyer, 1989). One reason is that not many firms will be observed beyond the most efficient (i.e., lowest AC) size (of output). As will be seen, the mine data used do

display a significant curvature and, thus, provide one of the few statistical verifications of micro cost theory.

Cost functions can be specified, and estimated, with either total cost (TC) or average cost (AC) as the dependent variable. The independent variable is output (Q) and the curvature is determined by the type of polynomial specified. For example, total cost might be linear, quadratic or cubic, which would imply average cost curves that are constant, linear or quadratic, respectively. Also, a reciprocal term (1/Q) is required in the average cost function if it is to correspond to a total cost function with a constant (fixed cost) term. Average costs might also be estimated using linear and quadratic specifications though they suggest a total cost function without a constant term.

From an empirical standpoint estimating TC or AC is making use of the same cost data and so the estimates provided are comparable. One difference, statistically, is that a regression equation with TC, rather than AC, as the dependent variable will result in higher R^2 values. The reason is that by using TC the equation estimated is explaining scale whereas when AC is used this is not true. The situation is analogous to demand estimation where geographic areas are used as observations. Unless quantity (demanded) is measured on a per capita basis the resulting regression will have a high R^2 because scale is being measured on both sides of the equation. Thus, our emphasis will be on the AC estimation results (Table 1) though comparable TC results are also provided (Table 2).

In Table 1 results are provided for AC with Q, Q^2, and 1/Q which, as noted, corresponds to a cubic TC specification. In fact, the corresponding cubic TC functions are estimated in Table 2 and, as suggested above, the R^2 for AC (Table 1) is lower than for TC

(Table 2). Most important in Table 1 (and 2) is that the non-linear (Q) terms are able to achieve significance, especially after the other independent variables (equations 2 and 3 of each table) are added. The significance of the non-linear values of Q suggest a traditional u-shaped AC curve (with a minimum between 9 and 10 million tons). We intend to graph and discuss the implications of this curvature in the next section.

It should be noted that the other variables (see columns 2 and 3) have the hypothesized signs though the binary variable (FULL) fails to achieve significance. While Tables 1 and 2 are comparable, or consistent, specifications of cost, it is possible, statistically, to explore more complex functions (in terms of Q). In Table 3 AC is estimated as a cubic function and each term (of Q) achieves significance. Also, a slightly higher R^2 is found than in Table 1 when 1/Q was included. While omitting 1/Q implies a TC without a constant, the result in Table 3 does suggest a (relative) minimum in the 9 to 10 million output (Q) range. Thus, all three tables confirm this to be the efficient scale for the iron ore industry. The other independent variables in Table 3 maintain the signs and significance found in Tables 1 and 2.

Table 1

Dependent Variable: ATC

	Equation 1	Equation 2	Equation 3
Reciprocal of Output	-15.23 (-2.19)**	-18.17 (-2.90)***	-18.20 (-2.89)***
Output	-5.12** (-2.34)	-5.77 (-2.89)***	-5.89 (-2.93)***
Output Squared	0.24 (1.48)	0.28 (1.69)*	0.29 (2.03)*
Operating Rate		-14.58 (-2.30)**	-14.67 (-2.30)**
Number of Owners		-0.58 (-1.93)*	-0.57 (-1.88)*
Binary Full Capacity=1			-1.03 (-.85)
Constant	52.53	70.63	71.39
R^2	0.544	0.666	0.676
F	10.33***	9.58***	8.01***

NOTE: t-values in parentheses:

* significant at the 10 percent level
** significant at the 5 percent level
*** significant at the 1 percent level

Table 2

Dependent Variable: TC

	Equation 1	Equation 2	Equation 3
Output	56.937 (4.65)***	60.806 (5.34)***	60.725 (5.36)***
Output Squared	-6.168 (-2.55)**	-6.825 (-3.11)***	-6.887 (-3.15)***
Output Cubed	0.308 (2.24)**	0.338 (2.75)**	0.346 (2.82)***
Operating Rate		-75.30 (-2.25)	-75.882 (-2.28)**
Number of Owners		-3.31 (-2.06)**	-3.241 (-2.03)*
Full			-7.089 (-1.104)
Constant	-19.086	53.980	58.253
R^2	0.933	0.952	.954
F	120.499***	94.376**	79.57***

NOTE: t-values in parentheses:

* significant at the 10 percent level
** significant at the 5 percent level
*** significant at the 1 percent level

Table 3

Dependent Variable: ATC

	Equation 1	Equation 2	Equation 3
Output	4.253 (1.88)*	5.051 (2.342)**	5.037 (2.335)**
Output Squared	-1.090 (-2.44)**	-1.221 (-2.937)***	-1.231 (-2.960)***
Output Cubed	.061 (2.38)**	.066 (2.848)***	.068 (2.901)***
Operating Rate		-11.944 (-1.886)*	-12.043 (-1.901)*
Number of Owners		-.615 (-2.024)*	-.603 (-1.984)*
Full			-1.218 (-.997)
Constant	29.304	40.867	41.601
R^2	.556	.663	.677
F	10.861***	9.443***	8.033***

NOTE: t-values in parentheses:

* significant at the 10 percent level
** significant at the 5 percent level
*** significant at the 1 percent level

IV. Summary and Conclusion

As is evident from Figures 1, 2, and 3 based on Equation 1 of Tables 1, 2, and 3, minimum efficient scale (MES) falls within a range of approximately 9 to 10 million tons of ore. Theoretically, the 1987 output of 73.2 million tons could be produced by considerably fewer than the 15 firms operating in 1987. Approximately eight of the largest firms (5 to 12 million tons of output) operating at full capacity could lower costs by approximately 30 percent.

Interestingly, this argument for rationalization in the taconite industry parallels the conclusions of Christiansen and Greene (1980-1, p. 383) for electric utility companies. Evidently both the taconite industry and the electrical utilities have cost structures where scale economies are important and increasing industrial concentration would be efficient. In manufacturing industries, however, the opposite claim is made. For manufacturing industries, MES is low and, therefore, more MES plants and multiplant firms could more competitively produce national outputs and result in significantly lower industrial concentration (Scherer, p. 1165). Clearly, public policy initiatives regarding the taconite industry must be cognizant of significant scale economies and diseconomies in the industry. Also, the large absolute size of a single producer relative to North American demand makes this mining industry very different from most other manufacturing industries and may require treatments different from conventional antitrust or public regulation.

Figure 1

Scale of Operation
Average Total Cost

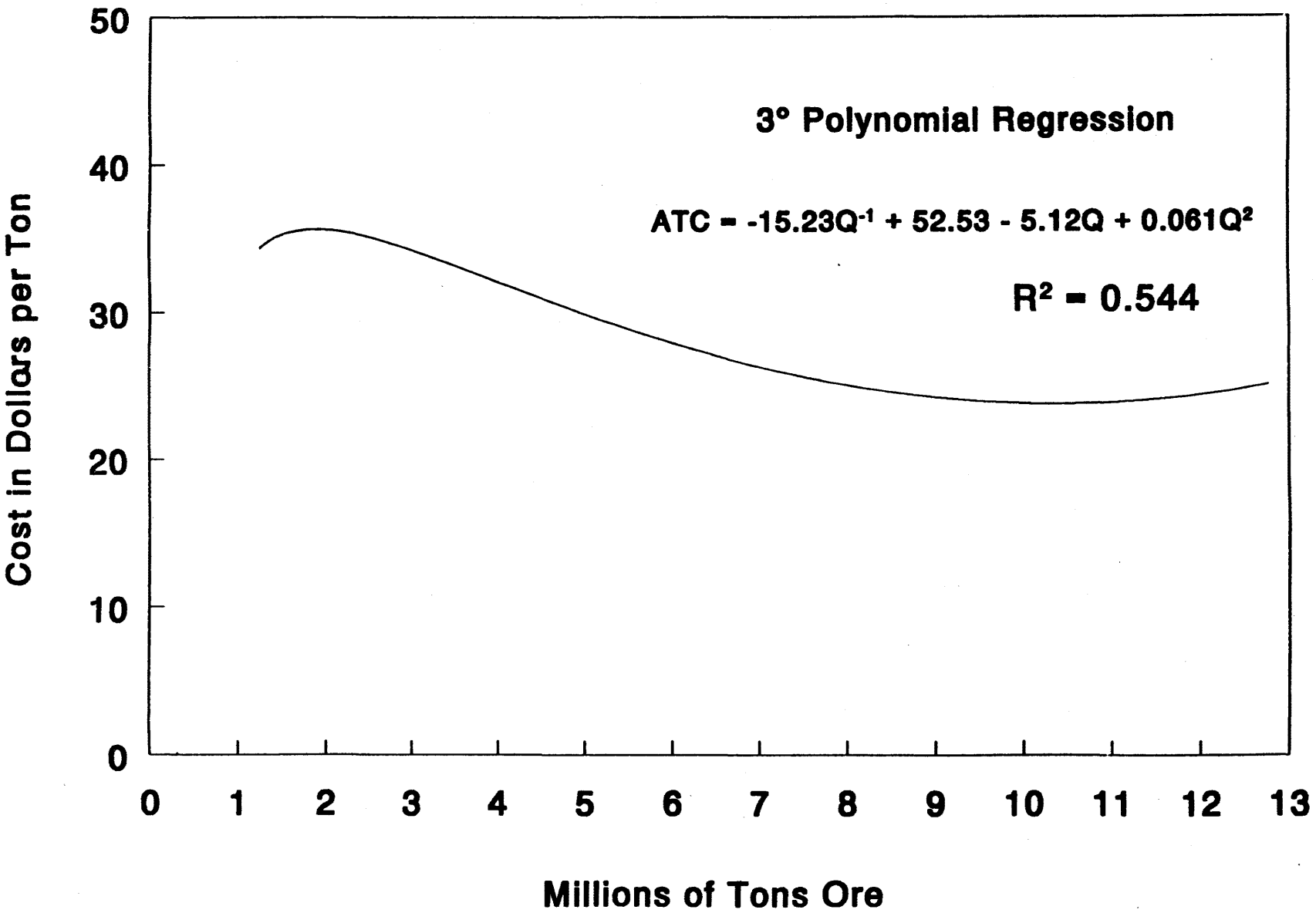


Figure 2

Scale of Operation

Total Cost

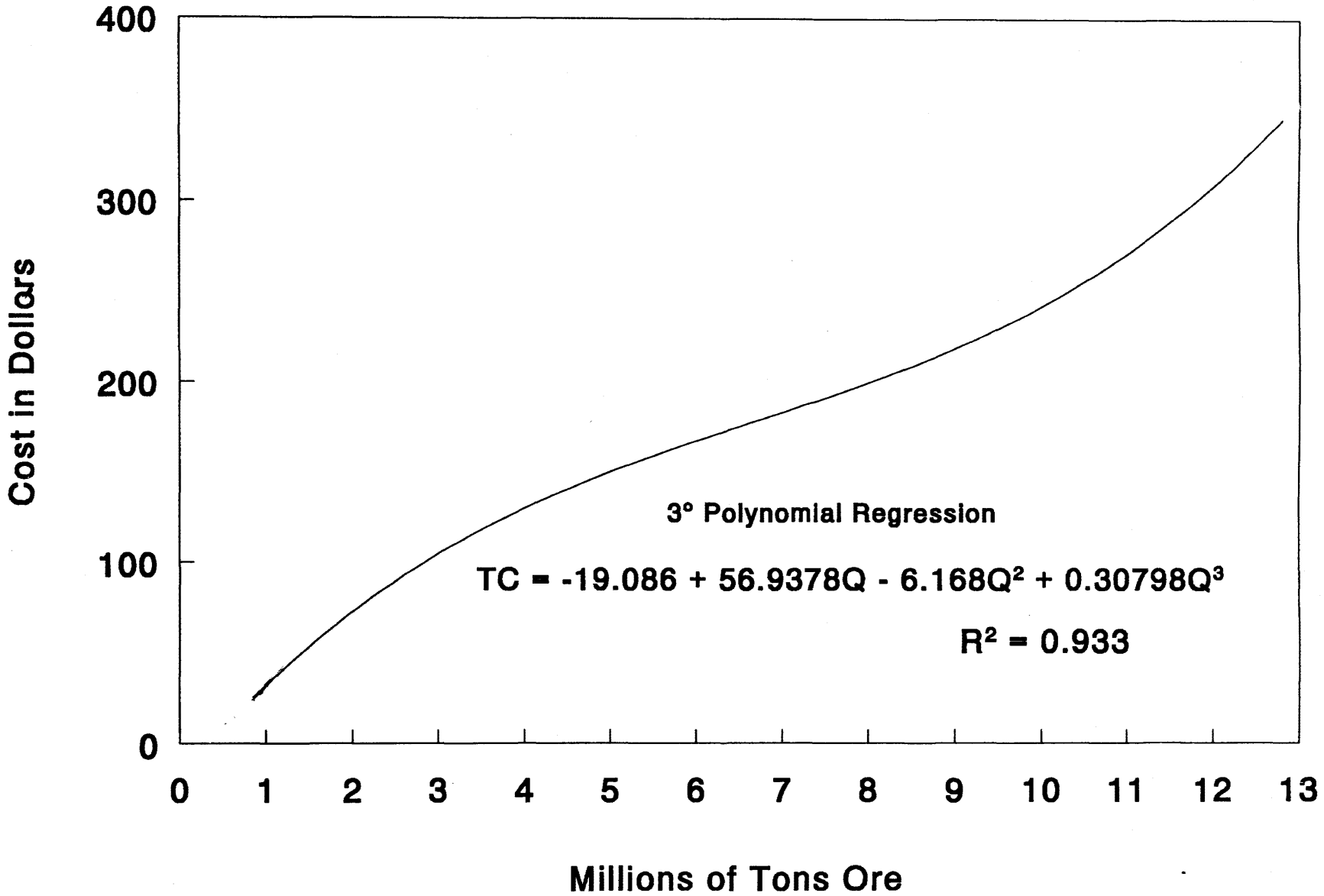
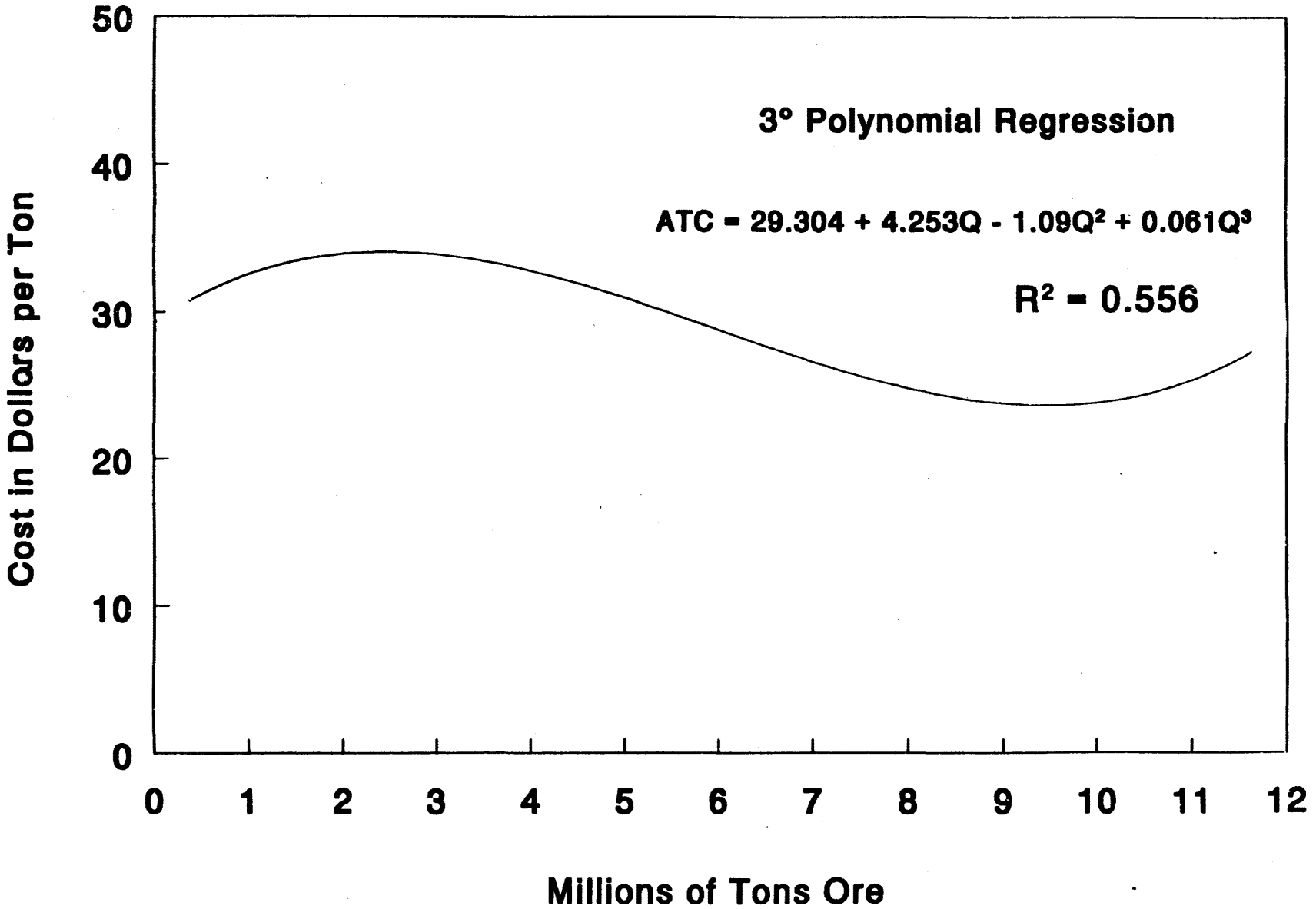


Figure 3

Scale of Operation
Average Total Cost



Bibliography

Christensen, Laurits R. and Green, William H. "Economies of Scale in U.S. Electric Power Generation." Journal of Political Economy, 1980-81, pp. 655-676.

Gold, B.; Peirce W.S.; Rosegger, G., and Perlman, M. (1984). Technological Progress and Industrial Leadership: The Growth of the U.S. Steel Industry (Lexington, MA: Lexington Books), pp. 360-1.

Kakela, Peter J. "Pelletized vs. Natural Iron Ore Technology, Energy, Labor, and Capital Changes." Center for Advanced Computation, University of Illinois at Urbana-Champaign, Illinois (1977).

Mancke, Richard B. "Iron and Steel: A Case Study of the Economic Causes and Consequences of Vertical Integration." 10 J. Industrial Econ. 220 (1972).

Mansfield, Edwin. Microeconomics. (Norton, New York, 1991).

Marcus, Peter F. and Kirsis, Karlis M. (April 1989). World Steel Dynamics. "The North American Iron Ore Peak?" Paine Webber Incorporated.

_____ (June 1988). World Steel Dynamics. "The Rebound of the Threatened North American Iron Ore Industry," Paine Webber Incorporated.

McGuigan, J. and R. Moyer, Managerial Economics, 5th Edition (West, St. Paul, 1989).

Raab, R. and Steinnes, D. "Vertical Ownership as an Impediment to Rationalization in Iron Ore Mining." The Antitrust Bulletin, Vol. 34, No. 4, Winter 1989, pp. 847-867.

Scherer, F.M. and Ross, David. Industrial Market Structure and Economic Performance (Houghton Mifflin; Boston, 1990).

Stigler, George. "The Economies of Scale." Journal of Law and Economics, Vol. 1, October 1958, pp. 54-71.