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EXIT FROM THE U.S. STEEL INDUSTRY

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I. Introduction

A major theme in the reindustrialization literature of the early 1980s is the apparent difficulty of reallocating capital and labor from "sunset" to "sunrise" industries. Economists tend to assume, without question, the results of neoclassical exit theory: firms exit industries with subnormal profits by closing their highest-cost plants. However, to the author's knowledge, this hypothesis has not been tested with plant-level data. Previous studies of exit behavior have used firm or industry-level data and focused on firm size as a determinant of exit behavior (Franklin, 1974; Marcus, [1967]; Ghemawat, [1985]). This paper develops a test for whether an industry exits from its highest-cost plants, using plant-level data from the U.S. steel industry.

Exit from a plant is difficult to measure because barriers to exit can delay a plant closing until the end of a period of disinvestment (Caves and Porter, 1976; Porter, 1976). In such a case, the production costs of plants at time of exit are not directly comparable to those of plants that have been continually renovated. This paper avoids this difficulty and provides a powerful test of the theory by focusing on exit over time: the decisions firms make to avoid reinvestment before closing a plant.

Neoclassical theory predicts little or no major reinvestment in plants to be closed. The paper uses that prediction to test the hypothesis that U.S. steel firms exited from the industry by disinvesting from those plants least able (given their initial location, capital stock and product mix) to compete with able minimills and imports.[1]

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[1] This interpretation of steel's recent history as that of a decli'ning industry undergoing exit follows from work on the long-run trends in costs and in demand underlying the industry's troubles (Crandall, 1981; Kawahito, 1972).

Since disinvestment is difficult to calculate, the paper examines firms' exit behavior by studying panel data on plant-level investments in 1960-1981. Investment activity in plants that shut down is compared to that of surviving plants to see if firms avoid major renovations of plants prior to closing. Then, an investment-decision model is estimated to see if decisions to reinvest are influenced by the relative profitability of plants.

II. The Model

Specification

The neoclassical prediction for a competitive industry facing a demand curve that has shifted to the left is that high-cost plants will exit, leaving the low-cost plants to produce in the long run. Exiting plants may operate during the transition period between long-run equilibria so long as doing so minimizes firms' losses. However, a firm will not reinvest in an exiting plant.

Assume first, for simplicity, that a plant has a given capital stock that is replaced as a whole. As capital ages, it requires increased maintenance in order to produce the same output, thus raising the average variable cost over time. If revenues are stable over time, the firm earns a declining stream of net revenues from its investment.

To maximize the stream of net returns from the plant, the firm chooses a series of replacement times With revenues and costs constant, the firm always replaces its capital stock after t^* periods, where t^* maximizes the difference between the revenue stream and the cost of investment stream. The optimal t^* is determined by the following marginal condition: replacement occurs when the return from the capital in place is equal to the cost of delaying reinvestment.[2]

[2] See Deily (1985) for details of the model.

The optimal t* depends on expected revenues, expected variable costs, capital costs, and salvage values. Thus, changes in these variables will alter the timing of replacement. In particular, if the present value of the expected quasi-rent from future investments no longer covers expected fixed costs, the firm will continue to operate the capital in place without reinvesting. This decision to delay replacement, if it remains unchanged, is an exit decision since the plant can continue operations only as long as the capital in place continues to function.

The implications of the model are not changed if the plant is a series of discrete pieces of vertically-integrated equipment, each requiring periodic replacement. The return to an investment is its effect on the net revenue stream of the plant. If individual investments reduce the average variable cost,[3] then the net return to reinvestment is the present value of the cost savings, less the new machine's cost. Realization of this return requires that the plant remain open over the relevant horizon, linking the horizon of each piece of equipment to the decision to replace the remaining equipment, which, in turn, is influenced by the horizon of the entire plant.

If the plant's expected total revenue falls below expected total cost, then the plant's lifetime is shortened, thereby shortening the investment horizon for each prospective investment. Machines will not be replaced: as soon as major reinvestment in any of the pieces of equipment becomes necessary, the plant will close.[4]

[3] Total revenues are unaffected by replacement investments as the two obvious sources of change, a plant's capacity and product mix, are held constant.

[4] If possible, the plant would be broken up at this point, with continued operation only of those parts that could be operated for reasonable maintenance charges. The ability to segment a plant would depend on the degree of technical efficiency involved in the vertical integration and on the structure of the markets for those services no longer performed in-house.

With a durable and specific capital stock, this period of disinvestment could be lengthy. In fact, if the salvage value is negative the firm may even continue to run a plant that does not cover variable costs.[5] Thus, in industries with high barriers to exit, changes in investment behavior are the best signal that exit is occurring.[6]

Ideally, empirical support for the neoclassical hypothesis would be data showing that firms' investment plans for high-cost plants had been revised to substitute repairs and maintenance for major renovation. Although data on expectations and intentions of firms are not available, two implications of the theory can be tested using information on major investments actually made in individual steel plants and on the profitability of steel production at the plants.

First, plants that exit, either during the test period or subsequent to it, should have a lower level of reinvestment than those plants still open. Analysis of variance is used to test whether the average level of reinvestment in the closed plants is less than the average for the operating plants.

Second, the leverage supplied by the difference in prospects among differently situated plants during the years 1960–1981 can be employed: if firms behave as predicted by exit theory, then the incidence of major investments should vary across plants in a predictable manner. Data on major investment decisions is regressed on variables that proxy steel plants' future

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5 Salvage value may well be negative: one estimate of employee-related closing costs for steel firms is $50,000 per worker. (Discussion with steel executive, August 1983.)

6 The decision to eschew major modernization during exit does not imply that all capital outlays cease since it will generally be optimal for the firm to continue incidental maintenance and repairs. See Lamfalussy (1961).

profitability, including proxies for future revenues and future cost at each plant each year. The estimating model is:

$$INVAMT_{j,t} = f(PRICE_{j,t}, FMAPRI_{j,t}, PDUM, INLAND_{j}, COST_{j,t}, FMACOST_{j,t}, AGE_{j,t}, SIZE_{j}, KCOST_{t}, PAOC_{t}, QUOTA_{t}, TECH_{t}, (\Sigma\ FIRM\ DUMMY_{i})_{j}),$$

where j is an index of plants, t is the time index, and i is a firm index.

Data on real steel prices, the variables PRICE and FMAPRI, represent the firm's expectations about future revenues to the plant. Since firms generally have more information about future prices than is revealed by simple extrapolation of past values, future revenue projections must be modeled carefully. One way to account for firm information is to assume real prices follow a random walk with a trend, where the trend is not necessarily constant.

The trend is estimated using a simple moving average of changes in steel prices for the next three years. Future revenues are therefore represented with the current level of prices, PRICE, and the moving average of future changes in the level of prices, FMAPRI.[7] Both variables are expected to have a positive coefficient, as increases in expected revenues to a plant would increase its expected profitability, raising the return to reinvestment.

Due to the lack of a single good data-series on steel prices, two different sources were used to create the series. At the point where the data source changes, however, steel prices jump upward. A dummy variable, PDUM, controls for this jump in the data; it is equal to zero for 1960 to 1970 and one for 1971 to 1981, and is expected to have a positive coefficient.

[7] Perfect foresight is not assumed. Rather, this method assumes that firms know the average rate of change and can use that, with the current price level, to estimate future revenues.

An additional dummy variable, INLAND, is included to control for location-related effects on expected revenge not captured by the price data. In particular, this variable is expected to control for variation among plants in vulnerability to import competition. The dummy is zero for plants in coastal locations, and one for all others. It is expected to have a positive coefficient.

Cost data are not available by plant, so several variables capture two aspects of plant costs. First, due to the importance of economies of scale in this industry, each plant's raw-steel capacity, SIZE, is included in the equation. This variable should have a positive coefficient as larger plants have lower costs, increasing their expected profitability.

Plant costs may also vary due to differences in local factor prices. Data were developed for each plant on the cost of a representative bundle of factors used in producing a ton of steel. Implicit in the construction of this bundle is a homothetic Leontief production function, as the weights used to add the factors did not vary over time or among plants. Although this construction ignores factor substitution (which does exist in this industry; see Karlson [1983]; Moroney and Trapani [1981], it should be correlated with local variations in true average variable cost.[8]

Because firms sign long-term labor contracts and are heavily involved in production of iron ore and metallurgical coal, firms are assumed to form expectations about future costs with more information than would be revealed in past data. Thus, the expected factor price bundle is modeled as the

[8] Using plant level output and input levels for the year 1972, Karlson (1983) rejects homogeneity, homotheticity, and constant returns to scale for fully-integrated steel plants. But, plant-level input and output data are not available for many years in the sample used here, which is why the factor price bundle method of controlling for factor price differences is used.

current level of the bundle, COST, and an estimate of its future trend, FMACOST, the average change in COST over the next three years; both are expected to have negative coefficients.

In addition to expected plant profitability, a firm's investment decision is affected by the cost of capital. A variable, KCOST, reflects changes in the real cost of capital and should have a negative effect on investment.

Finally, reinvestment decisions also depend on the age of the capital stock. In a contracting industry, older plants exit first, ceteris paribus (Stigler [1966], pp.191-194). (This vintage effect would be exaggerated if, as seems reasonable to expect, 'younger' plants were low-cost plants.) The age of a plant's capital stock should be inversely related to additional investment in a declining industry.[9]

It has been hypothesized that the burden of controlling pollution reduced profitability in steel. Thus, the cost to the industry of operating pollution control equipment, PAOC, is included to control for changes in pollution regulations and their enforcement over time.

A dummy variable, QUOTA, is included for 1969 to 1972, the years of the Voluntary Restraint Agreements, and for 1978 to 1981, the years of the Trigger Price Mechanism.[10] If these episodes of protection raised the industry's expectations of future profits, then QUOTA would have a positive coefficient.

The variable, TECH, is included to control for technological change, since the availability of new innovations would, ceteris paribus, increase

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[9] In an industry in long-run equilibrium, the opposite relationship would be expected: a plant with older capital would be more likely to receive replacement investment. In a contracting industry, these plants exit first, ceteris paribus.

[10] Though the VRA actually covered the years 1969-74, various researchers have found that they were not binding during 1973-74. See Crandall (1981), p. 103 for references. The Trigger Price Mechanism was in force during 1978 through March of 1980, and again from October 1980 through 1981.

reinvestment. Several major technological developments occurred during the late 1950s and the 1960s, including the second generation hot-strip mill, the basic oxygen furnace, and the continuous caster. It might be possible to argue that the effects of the first two innovations were felt during the entire test period, making it impossible to distinguish a sudden burst of investment. But this cannot be argued in the case of continuous casters, which were still experimental in the early 1960s.

Given the difficulty in determining the year in which major innovations became practical for most steel mills, dummy variables were not used. Instead, the growth rate in output per man-hour for the industry proxies for the availability of new technology, under the assumption that bursts of investment resulting from major innovations reaching an "off-the-shelf" stage of development are associated with higher growth rates of productivity in the industry. This variable is expected to have a positive coefficient.

Finally, firm dummies control for firm economies of scale and any other firm-specific effects that influence exit decisions. One firm is omitted, so each dummy coefficient indicates whether there is a significant difference in a firm's reinvestment level compared to that of Armco, a 'medium-sized' firm. Franklin's (1974) results suggest that dummies of smaller firms' will be negative while Ghemawat's (1985) results suggest the opposite.

Data Description[11]

Data on 43 plants were collected for the years 1960-1981. It is assumed that steel firms obtained new information during 1960 that caused them to reevaluate the profitability of their plants. Specifically, they discovered that imports, which surged dramatically during the long strike of

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[11] A handout describing construction of the data set in much greater detail is in Appendix A.

the previous year, did not recede to their pre-strike levels.[12]

The 43 plants are, with a few exceptions, the steel producing plants of the eight largest steel companies in the U.S. during this period.[13] A list of major investments made in each plant over the test period was assembled, and a cost for each investment was calculated in 1972 dollars.

The cost of each investment is divided by the plant's raw-steel producing capacity in 1960.[14] Investment per ton capacity corrects for the positive correlation between plant size and amount of investment dollars spent arising from the fact that larger plants require larger machines.[15] Because the model focuses on the time at which the firm decides to make an investment, estimated total investment expenditures are assigned to the year the project was announced in the Annual Report, as a proxy for the point of final decision.

Steel prices are constructed for each plant by combining regional steel prices for eight product groups (in dollars per ton) with plant-specific weights. Realized price data was available for the year 1971-1981, but before 1971 the only prices published in the necessary detail were list prices.

[12] The firms began mentioning the 'import problem' in the early 1960s. The stock market appears to have reevaluated future steel profits even earlier: in the late 1950s the ratio of market to book value of steel equities began a long decline relative to Standard and Poor's 400 Industrials (Crandall, 1981, pp. 28-30). The sample ends in 1981 since, due to the lag structure employed, data were not available for later years.

[13] Plants that exited in the early 1960s were excluded, as were plants that manufactured mostly specialty steels. Large electric arc-based mills were included.

[14] Plant capacity data for 1961-1972 were not published. The 1960 capacity data is used in lieu of a complete set of capacity figures.

[15] The investment figure was divided by plant capacity so that the coefficient of the variable SIZE would reflect the influence of economies of scale only.

Plant size is measured as the raw-steel capacity in 1960.

COST is a weighted sum of local prices for metallurgical coal, natural gas, labor, iron ore, and scrap. Although factor prices are plant-specific when possible, data limitations prevent plant-specific weights. Instead, weights developed for a hypothetical plant of one million tons per year capacity are used to sum the factor prices into an approximate cost per ton for these factors.

AGE was the net capital stock, (in 1972 dollars per ton of capacity) at the beginning of the year. The value of the capital stock in 1960 was calculated using major investments made in each plant since 1930, assuming 10% deterioration each year. The stock variable was updated each year to include new investment and additional depreciation. As in the case of the dependent variable, the capital-stock figure was divided by plant capacity to factor out the impact of size itself.

The variable, TECH, is the growth rate in output per man-hour in the industry. As productivity is highly correlated with capacity utilization, the average annual growth rate over a five-year period is used, where the current year is the midpoint of the period.

PAOC is the cost to the industry of operating all pollution abatement equipment in millions of 1972 dollars.

Econometrics

The data used in the estimation are panel data assumed to fit a fixed-effects model where the sources of the fixed effects are modeled explicitly as follows: (1) in 1960, plants were of different sizes, (2) in 1960, plants had equipment of different vintage structure, and (3) plants belonged to different firms, all of which effects are included in the regression equation.

Differential effects among years are also modeled explicitly by inclusion of four variables that vary only across time: the cost of capital, the cost of operating pollution equipment, the quota dummy, and technological change. However, a second equation that includes year dummies is run in order to distinguish the cross-time vs. the cross-plant influence of the output and input price variables.

Because of the incidence of zeros in the dependent variable, the model is estimated with a tobit specification.

III. Empirical Results

The relationship between investment activity and subsequent plant closing is apparent in the mean investment per plant per year open from 1960 to 1981 for two subgroups: those plants that exited during the test period[16] ($34.08/ton-capacity per year open), and those that remained in the industry ($128.27/ton-capacity per year open). Using ANOVA, the hypothesis that the mean investment is the same for the two groups is rejected at the 5% level.

Table A summarizes the tobit estimation results over the entire sample, both with no year dummies (column 1) and including year dummies (column 2). The restriction that the year dummy coefficients equal zero is barely rejected, indicating that much of what they capture is explained by the time series variables included for that purpose.

The coefficients of the three variables COST, FMACOST, and SIZE have the expected signs and are significant, suggesting that firms' investments are influenced by cost considerations. The inclusion of year dummies reduces the coefficients and significance of COST and FMACOST, indicating that much of the

[16] Plants whose exit was announced after 1964 and before 1983 were included in this group. Exit occurred when a plant's steel furnaces were stopped.

negative influence of the factor price variables is due to variation over time rather than across plants. However, the best estimate of the coefficients still indicates a negative effect of factor prices on investment decisions.

The significance of the factor price variables is reduced by their collinearity with the steel price variables. The steel price variables are poor proxies for expected revenues: apparently steel prices rose in response to higher costs, as the industry repeatedly claimed, rather than in response to rising demand. Higher prices thus signaled lower output as the supply curve shifted back. As a result, the coefficients of PRICE and FMAPRI are negative, rather than positive as expected, and significant in the case of FMAPRI, as higher and rising output prices were a sign of higher and rising factor prices both across time and across plants.

INLAND functions somewhat better as an alternative indicator of future demand. The coefficient of this proxy for vulnerability to import competition is positive and large, although not significant.

The coefficient of QUOTA, on the other hand, is both negative and significant, indicating reduced investment during the periods of trade protection. Instead of reacting to stabilized or higher output prices caused by protection, firms behaved as **if** their expectations about future profits decreased during these years. The need for such protection may itself have been the signal. Together, the coefficients of QUOTA and INLAND indicate that firms reacted to import competition by disinvesting.

The coefficient of AGE is positive, as expected, suggesting that firms are less likely to invest in a plant with smaller capital stock per ton capacity, other things equal. However, the coefficient is not significant.

The variables QUOTA, PAOC, TECH, and KCOST vary only across time; the effect of including year dummies is particularly strong in their case. QUOTA's coefficient becomes positive but not significant. Without year dummies, the coefficient for PAOC is negative and significant, though small, indicating that firms reduce investment as the cost of operating pollution control equipment increased. PAOC is not significant when the year dummies are included.

The coefficient of TECH is positive, as expected, though not significant despite the occurrence of important innovations. Possibly the data is not a good proxy for the availability of new technology. If adoption of innovations occurs smoothly over time, rather than causing a sudden elevation in investment, the effects of innovation are hard to detect.[17] Inclusion of the year dummies does increase the coefficient estimate for this variable, raising its significance.

The coefficient of KCOST is positive though not significant. Along with the variable PDUM, this variable indicates an increase in investment during the 1970s, holding everything else constant. While PDUM was expected to be positive, because of the upward jump in the price-series data, KCOST was expected to have a negative influence on investment.

Both of these variables lose significance when the year dummies are added. The dummies are all insignificant, with the exception of 1974, and do not reveal any obvious trend.[18] But the coefficients of 1973 and 1974 are positive and unusually large, implying a surge in investment in those years, which may account for the positive coefficients on PDUM and KCOST. These two years were very profitable for the industry: imports fell and prices rose as worldwide demand for steel increased. The industry may have revised expected demand upward during these years and thus increased investment.[19]

[17] There is a large empirical literature studying the speed of adoption of new technology by the U.S. steel industry. For a recent example, see Karlson (1986).

[18] Regressions that included a time trend and a squared term instead of the year dummies were also tried. The restriction that their coefficients equaled zero was accepted.

[19] This result agrees with Hogan's description of firms as optimistic about future demand in 1973 and 1974 (Hogan, 1984, p. 93).

Of the firm dummy variables, the coefficients of USC, YSC, and BSC show a significant firm effect, indicating investment levels lower than Armco's. These results are interesting, indicating that firms at the ends of the size distribution, whether large or small, invested less than a medium-sized firm.

The model is reestimated for two subperiods, 1960-1970 and 1971-1981, both with year dummies (table B, columns 1 and 3) and without (columns 2 and 4). Although the restriction that the two subperiods followed the same model is accepted, the results for the two periods differ for several variables.[20]

INLAND is negative and insignificant in the 1960s, but became strongly positive and significant in the 1970s. AGE is insignificant in the 1960s; in the 1970s it is positive and its significance increases. The coefficients of QUOTA and PAOC are negative in both periods, but significant only during the 1970s. (While inclusion of year dummies turns QUOTA positive and, in the 1970s, significant, the result is difficult to interpret since the dummies may control variation due to QUOTA.)

The coefficients for the firm dummies also change: while the results of the 1960s mirror those of the full sample, during the 1970s the only firm with a coefficient significantly different from Armco is USC. Finally, the capital cost coefficient is negative and significant in the 1960s, and positive and significant in the 1970s.

The steel-price variables continue to be negatively related to the dependent variable in both periods, while the factor prices are not significant in the 1960s. Plant size is positive and significant in both subperiods. TECH is insignificant in both periods.

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20 The estimations with year dummies could not be compared with this test because to estimate the model over the sub-periods additional years had to be omitted to avoid singularity. The restriction that the year dummies were zero was accepted for the 1960s and rejected for the 1970s

IV. Conclusions

The evidence presented here suggests that firms disinvest from plants that eventually close, and that firms disinvest from the 'right' plants, that is, their investment decisions are influenced by expected return.

Firms appear particularly responsive to plant size and, in the 1970s, to plant age and location. The coefficients indicate that, in a contracting industry facing import competition, firms invest in large inland plants with newer capital stocks.

While it is difficult to sort out the influences on investment over time because of collinearity, it appears that investment is reduced in response to higher factor prices, higher costs related to pollution control, and greater import competition. Further, it appears that the short-term trade protection given to the steel industry may have been associated with reductions in investment.

Coefficient estimates on the firm dummies indicate some kind of firm effect, perhaps related to firm size. The fact that during the 1970s the only significant dummy was that of the largest steel firm, lends support to theories predicting first exit by the largest firms (e.g., Ghemawat and Nalebuff, 1985). However, the sample of firms is truncated: the smallest steel firms are not included.

Finally, the results offer some interesting hints about whether the steel industry was "long-sighted." Although estimates over the full sample show the firms disinvesting from small, old plants on the coasts, such evidence is much stronger during the 1970s, indicating that it took until then for the firms to react strongly to signs of future contraction.

The results also imply that studies of the diffusion of technology in a contracting industry must take disinvestment into account. For instance, measures of the rate of adoption of the continuous caster will be understated if the estimates do not adjust for plant exit.[21]

[21] Oster mentions this point with respect to continuous casters in her study of the adoption of basic oxygen furnaces (Oster, 1982).

TABLE A

Dependent Variable: Real Investment/Ton Annual Capacity
Period: 1960-81

	(1)		(2)	
PRICE	-.05	(.09)	-.04	(.09)
FMAPRI	-1.56*	(.71)	-2.13*	(.80)
PDUM	82.14*	(26.48)	28.53	(41.09)
INLAND	8.38	(9.46)	7.08	(9.55)
QUOTA	-26.02*	(10.95)	1.78	(27.56)
COST	-1.29**	(.74)	-.90	(.90)
FMACOST	-4.63*	(1.75)	-2.68	(2.54)
SIZE	7.22*	(1.82)	6.87*	(1.83)
PAOC	-.16**	(.10)	-.11	(.13)
AGE	.08	(.07)	.09	(.07)
KCOST	3.50	(3.45)	4.22	(11.17)
TECH	.81	(2.58)	16.54	(12.80)
CONSTANT	-114.13*	(26.70)	-272.68*	(85.49)
FIRM DUMMIES:				
BSC (Bethlehem)	-24.19*	(11.40)	-21.49**	(11.37)
ICS (Inland)	-14.12	(19.32)	-9.34	(19.50)
JSC (J&L)	-14.58	(14.25)	-11.48	(14.34)
NSC (National	6.00	(13.18)	-3.83	(13.03)
RSC (Republic)	-19.87	(12.19)	-17.92	(12.27)
USC (United States Steel)	-35.41*	(10.88)	-32.51*	(10.87)
YSC (Youngstown)	-42.43*	(17.46)	-41.79*	(17.47)
YEAR DUMMIES INCLUDED:	NO		YES	
NUMBER SIGNIFICANT:			1	
LOG-LIKELIHOOD	-1089.9		-1075.9	

Standard errors in parentheses. *Significant at 5%. ** Significant at 10%

TABLE B

	1960-1970				1971-1981			
	(1)		(2)		(3)		(4)	
PRICE	-.13	(.24)	-.24	(.26)	-.08	(.10)	-.04	(.10)
FMAPRI	-2.07	(1.53)	-3.82**	(2.16)	-1.19	(.80)	-1.75*	(.81)
INLAND	-11.50	(12.57)	-9.59	(12.67)	32.83*	(16.13)	31.23*	(15.88)
QUOTA	-4.07	(32.27)	4889.18	(5434.87)	-30.45**	(16.38)	72.19**	(41.94)
COST	-1.01	(1.19)	-1.16	(1.28)	-.92	(1.03)	-.43	(1.22)
FMACOST	1.32	(4.98)	4.82	(5.88)	-3.71	(2.51)	-3.42	(3.21)
SIZE	6.70*	(2.46)	7.13*	(2.50)	7.30*	(2.73)	7.24*	(2.71)
PAOC	-.26	(1.39)	-145.40	(159.88)	-.24*	(.11)	-.59	(.59)
AGE	-.005	(.10)	.006	(.10)	.13	(.09)	.17**	(.10)
KCOST	-16.82	(10.70)	-32.26	(27.07)	7.12**	(3.39)	1.56	(8.24)
TECH	-3.96	(4.01)	-2.38	(8.09)	3.88	(4.38)	17.12	(11.88)
CONSTANT	94.93	(67.33)	1446.47	(1572.30)	-337.31*	(113.96)	73.65	(57.99)
FIRM DUMMIES:								
BSC	-27.92**	(15.80)	-27.56**	(15.85)	-18.32	(15.81)	-15.18	(15.33)
ICS	-8.20	(27.16)	-7.74	(27.22)	-18.16	(26.66)	-11.85	(26.00)
JSC	-11.69	(18.68)	-9.98	(18.82)	-10.58	(22.04)	-2.83	(21.45)
NSC	5.78	(17.44)	8.09	(17.47)	-19.02	(20.02)	-12.46	(19.30)
RSC	-21.06	(16.66)	-19.84	(16.77)	-14.53	(17.59)	-7.76	(17.54)
USC	-35.66*	(14.69)	-35.69*	(14.81)	-32.35*	(16.02)	-25.60	(15.60)
YSC	-37.00**	(21.76)	-34.86	(21.93)	-44.77	(31.55)	-37.53	(31.49)
YEAR DUMMIES	NO		YES		NO		YES	
NUMBER SIGNIFICANT	--		0		--		0	
LOG LIKELIHOOD	-678.82		-676.76		-404.24		-392.50	

Standard errors in parentheses. *Significant at 5% **Significant at 10%

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Data Appendix

1. The Sample

Data on 43 plants were collected for the years 1960-1981. The plants were, with a few exceptions, the steel-producing plants of the eight largest steel companies in the U.S. during this period: United States Steel, Bethlehem, Republic, Jones & Laughlin, National, Youngstown, and Inland. Selection of the plants to be included in the sample began with a list of the steel-related establishments owned by these firms in 1960. A steel plant was defined as a plant that contained steel-making furnaces; finishing and fabricating plants, and plants producing pig iron, were eliminated.

Of the plants left in the sample at this point, many were fully integrated from coke ovens through steel-finishing facilities. However, some plants were not fully integrated: for instance, some purchased coke rather than make **it,** and many plants shipped part of the steel as semi-finished shapes to be finished elsewhere. These plants were included in the sample.

Also in the sample were several plants using electric steel furnaces rather than open hearth or basic oxygen furnaces. Those plants with a capacity less than 200,000 tons per year in 1960 were eliminated.

In addition, a few steel plants whose steel furnaces were closed by 1964 were also eliminated since their closing was less likely to be a reaction to the changes in the industry's circumstances focused on here. Further, as this paper focuses on the production of carbon steel, plants primarily devoted to the production of specialty steel, such as stainless or alloy, were excluded.

Next, the Johnstown Works of the United States Steel Corporation was excluded. This plant did produce steel, but used that steel to fabricate heavy equipment, such as tanks, at the plant. Some other plants in the sample had fabricating works but none as large and as important as Johnstown's. This feature made it difficult to evaluate the plant's expected revenue and so it was left out.

After the above plants were excluded 40 plants remained in the sample. Three other plants were added. First the Granite City Steel Company's plant was included from 1960 even though it did not become a part of National Steel until 1971. Second, Bethlehem's Burns Harbor plant and United States Steel's Baytown plant were added. These two plants were built during the 1960s. Burns Harbor entered the sample in 1962, when the first stage of its construction was announced. Baytown entered in 1965.

Plants were dropped from the sample in the year their closing was announced; closing was defined as the permanent shutdown of the steel furnaces. See table 1 for a list of plants in the sample.

2. Dependent Variable

The dependent variable was the amount of money firms announced they would spend on major investment projects in each plant each year. This involved assembling a list of major investments made in each plant over the period and calculating their cost by finding the annual capacities of each project, finding the cost per annual ton of that type of equipment, and multiplying the two.

Data on investment projects was gathered from the corporate reports of the steel firms. The investments used consisted mainly of pieces in the 'hot end' of steel production, including: sinter plants, coke ovens, blast furnaces, direct reduction units, steel furnaces (electric, basic oxygen, and Q-basic oxygen furnaces), slab mills, blooming mills, billet mills, all types of continuous casters, and hot strip mills. Also included were major rebuilds or modernizations of the above, plus investments at a plant in raw materials handling facilities and storage facilities.[1]

The boundary of a steel plant blurs when one examines the relationship between the primary plant and secondary rolling and finishing facilities. The line drawn here was to exclude cold strip mills, tinning and heat treating lines, pipe mills, and wire mills. Independent pieces of pollution control equipment were also excluded.

In most years, firms included a section in their reports announcing new projects and updating the news on current construction. Information was collected on the type of investment, the plant involved, and the year the project was first announced to the stockholders.

The reports varied in completeness of information from company to company and from year to year. Reports ranged from Inland's detailed description of investments in its one steelmaking plant to U.S. Steel's inconvenient, but understandable, practice of simply identifying the area in which a major project was planned or underway.

In order to associate investment projects with particular plants in the latter case, two directories of iron and steel works were used: Iron and Steel Works of the World (Cordero and Serjeantson, eds.) and Directory of Iron and Steel Works of the U.S. and Canada (American Iron and Steel Institute). Both these directories are published triennially, so the actual year when decisions about capital equipment were made is not known. However,

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[1] A switch from integrated steelmaking to electric-based steelmaking, which occurred during the period in several plants, was not counted as a closing. Rather, this investment was considered a switch in technology and a nondefensive investment.

comparison of U.S. Steel's announced plans, with subsequent changes in the directories' lists of the equipment of plants in the region the corporation reported the investment for, made it possible to piece together plant-specific data. There may still be some underreporting in the case of U.S. Steel and some of the other larger firms, but the investments included in the dependent variable are big and thus are very likely to have been announced in at least one of the data sources.

The list of projects was given a rough second check when annual capacities were assigned to each investment. This information was derived from a variety of sources, the most important of which was Institute for Iron and Steel Studies (1983), which included lists and, in many cases, capacities of the major units of capital in integrated steel plants. The two steel plant directories, Hogan (1970), and some other miscellaneous sources, were used as well. In most cases, the earliest published annual capacity obtainable from these sources was used.

The final result was a list of investment projects, their capacities, and the year the project was announced.

The data used to develop the cost-per-annual-ton data came from many sources. The sources differed in several ways: the size of the equipment considered, the year of estimation, the number of different types of equipment covered, and the type of investment considered, that is, new or replacement. At least one estimate was available for most types of investment, and for many investments more than one estimate was available. All available estimates were converted to a dollar-per-annual-ton basis, then converted to 1980 dollars (with the construction cost index discussed below), and compared. In some cases, estimates for the same unit varied according to the size assumed for the equipment, implying the existence of economies of scale in capital costs. See table 2.

The final list of figures used to calculate the cost of investments were selected from these various estimates. The actual numbers chosen were usually those from A.D. Little (1980), unless that figure seemed out of line with the others or unless different numbers for different scales were being employed.

Finally, there were some investment costs, such as blast furnace rebuilds, that had to be estimated in some other way. See table 3 for the final list of cost estimates. A few miscellaneous investments that seemed interesting enough to register, but which had no formal estimate, were assigned a cost of $10 million in 1980 dollars.

Using the figures in tables 2 and 3, along with a cost of construction index, a cost was calculated for each investment project. The construction cost index is published by the Department of Commerce and appears in the Survey of Current Business under Construction Cost Indexes as the Department of Commerce Composite. This index includes residential as well as factory construction, but comparison of the investment cost figures derived using it to those derived by using the Boeckh Index for Commercial and Factory Buildings (which also can be found in the Survey of Current Business), showed little difference.

The index switched base years, from 1972 to 1977, leaving both series incomplete over the entire test period. The 1977-base series was used. Indices for 1960-1963 were obtained by regressing the 1977-base indices on the 1972-base indices in the years both were available (1964-1976). The estimated coefficients were used to fill in the rest of the 1977-base series from the 1972-base series.

These figures were adjusted with the GNP deflator to remove the effect of general changes in the price level, and then divided by plant capacity in 1960. The result is a figure giving the real expenditure per ton of capacity announced in the year.

3. Independent Variables

a. Steel Prices

In order to estimate a plant's expected product prices, information on product prices for four regions (East, West, South, and Midwest) was combined with data on the mix of steel products produced by each plant. The price data was drawn from three separate sources: two series of list prices for the years 1960-1970, and a third series of realized prices for the years 1971-1984.

1971-1984

Since 1971, the government has published figures on the quantity and value of steel shipped by region and by product group. These figures appear in Current Industrial Reports: Steel Mill Products, a publication of the Bureau of the Census. Before 1971, only quantity data is available in these reports.

The eight product groups reported, and used in this work, are: (1) steel ingot and semi-finished shapes, (2) hot-rolled sheet and strip, including tin mill products, (3) hot-rolled bars and shapes, plates, structural shapes and piling, (4) steel wire, (5) steel pipes and tubes, (6) cold-rolled sheet and strip, (7) cold-finished steel bars and bar shapes, and (8) other steel mill products, except wire products (mainly railroad supplies). See table 4.

Price data for these product groups were collected for four regions: Northeast, North Central, South Atlantic, and West. Data was frequently available for smaller regions and even for states. However, this data was often incomplete since complete information would have revealed proprietary data. Even at the four-region, eight-product level, there were missing data in about 19 percent of the cases. The missing numbers were estimated in a variety of ways. (About a third of the estimations involved using a smaller region's figures for the total region for the product involved.)

Among regions, the data for the West was the worst because of the smaller number of plants. Among products, data for 'Other steel mill products' was the worst.

Realized prices were obtained by dividing the value of the tonnage shipped by the quantity. For each year, the result was an 8 x 4 matrix of prices. Unfortunately, the figures included shipments and sales of alloy and stainless steels as well as carbon, so the prices are higher than they would be if those products were not included.

1960-1970

List-price data were used for this period because the Census Bureau either did not publish realized value and quantity of shipments, or did not publish the data regionally for these years. Instead, list prices were gathered for as many products as possible that were in the product groups established by the Census Bureau data. This involved using two separate sources of list-price data.

For product groups one through four, and six and seven, list prices reported in Chilton's Iron Age were used. Each week Chilton's Iron Age published the list prices quoted by individual mills for a variety of products. The magazine collected the data from price books, letters, and telephone calls. The mills were identified by firm and city as well as by region (East, Middle West, West, and South) up until the early 1960s, and by firm and region from then on. The numbers of prices quoted for each product varied by product and by region.

In order to get annual prices for each product group, annual prices for each product covered were first developed from the weekly prices in the following manner. (The same procedure was carried out for each region.)

The weekly mill reports were converted to annual regional numbers, first by finding the arithmetic average (for each product) of all the reported prices in the first magazine issued each month. All prices reported were used, irrespective of whether the mill was part of this paper's sample. All reports were weighted equally, despite the variation that existed in capacity among mills. See table 5 for the list of products used.

For product categories five and eight, the prices quoted in the Engineering News Record were used. The magazine got this data from "monthly market quotations by Engineering News Record field reporters." These prices, which were mill base prices, were quoted by product and by area. Prices for the following products were obtained: reinforcing bars (not reported October 1964 through December 1969), standard and light steel rails, standard spikes, and tie plates.

Some information on the regional prices of wrought steel pipe was also obtained from ENR. ENR quoted the national price per foot of various diameters of pipe, as well as the discounts from list that were available in various locations of the country. These dollar-per-foot prices were based on a dollar-per-net ton price of about $200.

In order to get an annual series of dollar-per-net ton pipe prices for each region, all the product discounts reported for each area were applied to the $200 per-net-ton price and averaged together each month, and the months were averaged to get an annual figure. See table 6 for a list of the products used.

The final result from these two sources was a list of individual products for which annual prices in four regions of the country had been calculated. These annual product prices were combined in weighted averages to get a price for each product group for each year. The weights were developed from 1965 data on product production and shipments, and from the Wholesale Price Index weights for iron and steel products. These weights were used so that each product group price would reflect the different importance of the various individual products and thus match the realized price data of the 1970s more closely.

In the case of new products, or of a lack of prices for some products for some regions, the weights were altered. In the latter case, this usually involved increasing the weight of the most important product of similar type within the category.

The final result of these calculations was a four by eight matrix of prices for each year that matched as closely as possible the realized price data of the 1970s. The eight product prices for the appropriate region were then combined using plant-specific weights to form a weighted product price for each plant.

Plant-Specific Price Weights

The data used to construct plant-specific price weights came from Iron and Steel Works of the World, 1962, which published annual plant capacities for hot-rolled steel products and for other finished products. One set of weights was used for the entire period since this data was no longer published after 1962.

Since all steel products (except ingots) are hot-rolled, a plant's hot-rolled capacity was used as the base. All of the hot-rolled product capacity was allocated among the eight product categories. If the plant had cold-rolled or other finishing capacity, this was subtracted from the hot-rolled capacity (to avoid double counting) and allocated to the proper product category.

Since the Baytown plant of U.S. Steel and the Burns Harbor plant of Bethlehem Steel Corporation did not appear in the 1962 directory, the following product mixes, based on other information about the mills, were assumed: 75 percent plates and structurals and 25 percent pipes and tubes for Baytown, and 50 percent hot-rolled sheet and strip, 25 percent plates and structurals, and 25% cold-rolled sheet for Burns Harbor.

Adjustments Made For Different Data Sources

Examination of the price-data series revealed a jump in prices between 1970 and 1971, when the data sources changed. The basic adjustment made to correct for this jump was to include a dummy variable in the regression equations. However, because of the use of the average future change variable, FMAPRI, additional adjustments were required to correct for the large jump between 1970 and 1971.

A regression of the weighted plant price on time was run for each plant, and the estimated coefficients used to extrapolate a price for 1970. This estimated price was used in the calculation of FMAPRI only when the difference between 1971 and 1970 appeared.

b. Factor Prices

Coal, Natural Gas, and Electricity

Most of the energy-price data was taken from a publication of the Department of Energy prepared by the Pacific Northwest Laboratory called the State Energy Price System, and from subsequent annual updates published by the Energy Information Administration of the Department of Energy. These reports provided state-level dollar-per-million BTU prices for: (1) natural gas, industrial sector, 1960-1984; (2) electricity, industrial sector, 1960-1984; and (3) metallurgical coal, industrial sector, 1970-1984.

Metallurgical coal prices for 1960-1969 were constructed using Wholesale Price Index data and information on the cost of transporting coal. The Department of Commerce reports a monthly price and Wholesale Price Index for both high-volatile and low-volatile metallurgical coal. For each type of coal, the monthly indices were averaged to get an annual figure, which was converted to a dollar-per-ton price using the proportional relationship implied by any one of the monthly indices and prices.

These two price series were then combined with a weight of 0.8 for the high volatile and of 0.2 for the low-volatile, where the weights reflected approximate usage (see Hogan [1971] p. 1497), to get a dollar-per-ton price series for metallurgical coal.

An attempt was then made to include the cross-section variation in price caused by differing plant locations. It was assumed that the national price created above was the price of coal in the Western Pennsylvania-Northern West Virginia area. (The area is the source of a great deal of the metallurgical coal mined in the U.S..) A transportation charge, reflecting the location of each plant (vis-a-vis the mining area), was then added to the assumed base price.

The transportation charge was figured by multiplying the type of transport miles (that is, railroad or ore boat) by the cost per ton-mile of that type of transport, in order to get a transport charge per ton of coal. The data on cost per ton-mile for the various types of transport is discussed below in the section on iron ore prices. The distances of plants from the mining region were partly based on those used in Gold (1980), p. 254. Others were estimated by the author.

In a few cases of plants located far from the western Pennsylvania-northern West Virginia area, for which a local coal source was known, the national coal price, plus the cost of transportation from the local mine was used. Plants in Alabama are a case in point.

Finally, the dollar-per-ton prices developed by this method were divided by 26 to get a dollar-per-million-BTU price.[2]

Scrap

Regional scrap prices were obtained from the Wholesale Price Index. The Department of Commerce reports various regional prices and indices for scrap each month. The data on #1 heavy melting scrap, reported since before 1960, and for #1 bundles, reported since 1962, were used. An annual index was calculated for each product for each of five regions: Pittsburgh, Chicago, Philadelphia, Birmingham, and San Francisco. These annual indices were converted into prices using the proportional relationship of monthly prices to indices.

The prices of the two products were combined to get a final weighted scrap price. The weights, 0.6 for heavy melting and 0.4 for #1 bundles, were derived from the relative sizes of these products' weights in the WPI. (The years 1960-1961 were assigned the heavy melting price by itself). Each plant was then assigned to one of the scrap price regions.

Delivered Iron Ore Price

The delivered price of iron ore was constructed by adding transport charges estimated for each plant, to the national iron-ore price. This overestimated the final price because some transport charges were probably included in the national iron-ore price.

For the years 1960-1976, the national or base price for iron ore was obtained from the U.S. Federal Trade Commission, The United States Steel

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[2] State Energy Price System, Vol. I, p. 68.

Industry and its International Rivals: Trends and Factors Determining International Competitiveness, as cited in Crandall (1981), p. 170. For the years 1977-1984, a price was derived from the WPI indices for regular unscreened Mesabi Ore and pellets. Annual indices were obtained from the monthly reports and converted to prices. The Mesabi price was converted from gross to net tons. The pellet price was converted from dollar-per-iron unit to dollar-per-net ton, by assuming an iron content of 65 percent. The two price series were then weighted and summed with the weight of Mesabi ore equal to 0.4 and of pellets equal to 0.6.

The transport charge was constructed in two parts. Cost per ton-mile figures were approximated for railroad, ore boat, and ocean ship transportation. Then, the distance from mine to plant was figured. The total distance was divided into parts characterized by the type of transport used. The distance on each type was multiplied by the cost per ton-mile of that type and the final overall per ton cost of transportation was obtained by summing across types.

Ocean Ship Rates

Ocean freight rates for coal were used to proxy those for iron ore. The data was obtained from the Coal Trade Freight Report as cited in International Coal Trade from 1960-1977. From 1978-1984 the same data series was cited in International Coal.

International Coal Trade reported freight rates on various routes once a month. An annual cost per ton-mile was calculated by averaging six months' rate data, taking the lower number in the cases where ranges were given, and dividing the annual cost per ton figure by the route distance. Data for two routes were calculated: Hampton Roads to Rio and Hampton Roads to a Chilean port (assumed Valparaiso). Ocean route distances were obtained from Table of Distances (1943).

A simple average of these two series was taken to get a rate for the years 1960-1977. In 1978, International Coal Trade discontinued their reporting. The years 1978-1984 were calculated from tables in International Coal, giving only two observations for each year. Only one route was used for these years: that from Hampton Roads to North Spain (assumed Santandar).

This is clearly a very rough approximation of the cost of shipping iron ore, and there may well be persistent overestimation, since the improvements made in ocean shipping were applied more rapidly to the shipping of iron ore than to that of coal (Manners, 1965, p. 41).

Ore Boat Rates

Figures for ore boat transport costs were derived from data reported by the Interstate Commerce Commission on Class A and Class B (operating revenues greater than or equal to $100,000) water carriers of the Great Lakes region. For the years 1964-1978 data on freight revenue was divided by data on freight revenue ton-miles to get freight revenue per revenue-ton-miles. For the years 1960-1963, for which freight revenue-ton-miles were not reported, a freight rate per ton was calculated and then divided by 417 miles, the average haul in the Great Lakes during the second half of 1963. (See ICC, July 1964).

For the years 1979-1984, for which no data were yet available, data were generated by using two different comparisons of railroad, ore boat, and ocean ship transportation costs--one mentioned in Manners (1965), p. 174, and the other in Gold (1980), p. 254. The average of the estimates derived using the two different analyses was used as the ore boat rate for these years. (The

Manners and Gold transport mode rate comparisons are discussed at greater length below.)

Railroad Rates

Iron ore and coal railroad rates per ton for the years 1962-1969 were obtained by dividing railroads' coal freight revenue by the coal freight carried by railroads. To get revenue per ton-mile, each year's rate was divided by the average haul for that year. The average haul was not available for 1962 or for 1966-1969; for 1962; the average haul was assumed to be 296 miles, and for 1966-1969 it was assumed to be 300 miles. All of these figures are from various issues of Coal Traffic.

Rates for 1969-1984 were figured using the Department of Labor Bureau of Labor Statistics Wholesale Price Index for railroad services. See Fehd (1975) for description and discussion of this index. The index was applied to the 1969 average revenue/ton figure from the coal data, and the resulting rates were divided by the average haul figures found in Coal Traffic (the 1982 figure was used for 1983 and 1984). In the tests, the rates based on coal freight were used from 1962-1969, and the rates generated by the BLS index were used for 1970-1984. The two years 1960-1961 were assigned a rate of $.011/ton-mile.

See table 7 for the three cost-per-ton-mile series.

Evaluation of Transportation Rate Data

The three cost-per-ton-mile series developed here are in line with information from other sources on transport rates, at least relative to each other. Manners (1971) reported a 1967 rule-of-thumb which showed ocean transport rates as 10 percent of the railroad rates and ore boats at about 25 percent of railroad rates. In Gold (1980) the approximation of ocean vessels as 17 percent of railroad rates and ore boats as 33 percent of railroad rates, was used.

Distance

In order to find the total per-ton transport charge, information on the average distance the ore traveled was required. First, each plant was assigned to an area, e.g., the Ohio Valley. Based on the figures developed by Boylan (1980), each area was assigned a certain mixture of transport mode miles from the major sources of iron ore. For example, the Chicago District was assumed to be 100 railroad miles and 300 barge miles from North Michigan mines, 100 railroad and 750 barge miles from North Minnesota mines, etc.

Information was then collected about each firm's iron-ore sources, from: Hogan (1971); American Iron and Steel Institute, Directory of Iron and Steel Works of the U.S. and Canada, various issues; and Cordero and Serjeantson, various issues. Usually firms had mines in several different locations. Sometimes data were available on the specific source of a plant's iron ore. For instance, the U.S. Steel Corporations's Fairfield, Alabama plant received ore from Venezuela. In cases where there were no other data, plants were assigned a mix of output from the firm's different mine locations based on the capacities of the mines. In this way, each plant had a shipping distance by type of transport, attached to it, and the appropriate mix of transport prices could be calculated to approximate the cost of transporting iron ore to the plant.

Labor

The series for the price of labor was derived from data in the American Iron and Steel Institute, Annual Statistical Report. The total employment cost-per-hour for wage workers was added to the total employment cost-per-hour for salary workers. The two components were weighted each year by the relative amount of hours worked by the two groups. See table 8.

Factor Price Weights

Weights for iron ore, coking coal, and scrap were obtained directly from World Steel Dynamics as cited in Office of Technology Assessment (1980). These figures gave the unit material and energy inputs per metric tonne of steel shipped for hypothetical plant with a capacity of one million metric tonnes per year producing plain carbon steel.

However, natural gas usage was reported in terms of thousands of cubic feet used per tonne of steel shipped. In order to convert this to BTUs (the form of the natural gas price data), data from 1976 on millions of BTUs per tonne of steel shipped were used. It was then assumed that the per tonne use of natural gas was the same in 1977 as it had been in 1976. This number, from Office of Technology Assessment (1980), pp. 191, was derived from aggregated industry data. However, since the other weights used (except labor) were developed for a million tonne integrated carbon steel plant rather than for industry aggregates, this number was adjusted to get a figure of 5.91 million BTUs per tonne shipped.

Finally, some further adjustments to the weights for coal, scrap, and natural gas were necessary. Since the coal price data were in dollars per million BTUs, the coal weight was multiplied by 26, which is the approximate number of millions of BTUs per ton of coal. The scrap price data were in dollars per gross ton of scrap; the weight was divided by 1.12 to convert the price data to dollars per net ton. The natural gas weight was divided by 1.1, which is the number of net tons per metric ton, in order to get millions of BTUs per net ton of steel shipped.

The weight for labor was derived from aggregate industry data reported by the American Iron and Steel Institute in the Annual Statistical Report, various issues. For each year during the period 1960-1984 total hours worked by both wage and salary workers was divided by net tons of steel shipped (all grades). The annual figures were averaged to get a final weight of 10.88

man-hours per ton of steel shipped. See table 9 for the final list of weights

The problem of different technologies was only roughly corrected for. Some of the information available seemed to indicate that scrap-based plants relied almost totally on purchased electricity, while another source (Kobrin, 1968) seemed to show that natural gas was also a very important fuel source. It was assumed here that these plants used both types of energy, and that they used them in the same relative proportion as integrated plants used coal and natural gas. Thus ccal prices were replaced with electricity prices for these plants.

The weight for scrap was increased to equal weight for the iron ore price, plus the original scrap weight. The weight for labor was not changed. In the end, the factor prices represented for electric arc-based plants were labor, electricity, scrap, and natural gas.

c. Age

The age, or capital stock variable, was constructed in the following manner. Data on the ages of equipment in place in 1960 were collected, or derived, from Institute for Iron and Steel Studies (1983) and various issues of the Directory of Iron and Steel Works of the U.S. and Canada. The age of a machine was calculated from the year of decision (rather than start up), so the data matched the dependent variable. The cost of each investment was calculated using the initial capacity and 1960 capital prices.

Each piece was then depreciated by 10 percent each year through 1959. (The 10 percent rate assumed a life of approximately 30 years; at that point only about 4 percent of the original value remained. Pieces installed before 1930 were ignored.) The values of the pieces were then summed to get a figure for the value of the stock at the end of 1959.

The pieces included in the stock were: sinter plants, coke ovens, steel furnaces, blast furnaces, primary rolling mills (slab, bloom, and billet), and hot strip mills.

Investment decisions made in subsequent years were added to the stock after the year of announcement. The sum continued to be depreciated, at 10 percent, over the 1960-1981 period. The capital-stock figure was divided by plant capacity to get a real capital stock per ton of capacity.

d. Plant Size

The plants' 1960 capacities were obtained from <u>Iron Age</u>, March 10, 1960, pp. 89-91. Bethlehem's Burns Harbor plant was assigned the capacity listed in Hogan (1971), p. 1546. United States Steel's Baytown plant was assigned the 1973 capacity listed in Institute for Iron and Steel Studies (1979), p. 13.

e. Capital Cost

The cost of construction index described in the discussion of the dependent variable, was used as the cost of capital. The series was adjusted, using the GNP deflator, to remove the effect of general movements in the price level.

f. Cost of Pollution Regulation Compliance

The data series used is the pollution abatement operating cost, in millions of dollars, covering expenditures for all types of pollution. They are taken from the Census Bureau, <u>Current Industrial Reports</u>, "Pollution Abatement Costs and Expenditures," series number MA200.

Data were not available for 1960-1972. Cost for these years was calculated as a geometrically declining series (decrease of 50 percent each year) from the 1973 figure. The figures were converted to 1972 dollars with the GNP deflator. (See table 10).

g. Availability of Technological Innovations

The growth rate of the BLS Index of Output per Man-Hour in the Steel Industry (all employees), as reported in various issues of the AISI Annual Statistical Report, was used to create this series. A five-year moving average of the growth rate was used. If the average growth rate was negative (1968, 1975, 1980), a zero was assigned. See table 10.

Table 1

1	BSC	Lackawanna, NY
2	RSC	Buffalo, NY
3	BSC	Bethlehem, PA
4	BSC	Johnstown, PA
5	BSC	Steelton, PA
6	USC	Fairless, PA
7	ASC	Butler, PA
8	JSC	Aliquippa, PA
9	JSC	Pittsburgh, PA
10	USC	Dusquesne, PA
11	USC	Braddock (Edgar), PA
12	USC	Homestead, PA
13	USC	National, PA
14	ASC	Middletown, OH
15	JSC	Cleveland, OH
16	RSC	Cleveland, OH
17	RSC	Warren, OH
18	RSC	Youngstown, OH
19	USC	Lorain, OH
20	USC	Youngstown, OH
21	YSC	Youngstown, OH
22	YSC	Campbell, OH
23	BSC	Burns Harbor, IN
24	ISC	Indiana Harbor, IN
25	USC	Gary, IN
26	YSC	Indiana Harbor, IN (East Chicago)
27	NSC	Granite City, IL
28	RSC	South Chicago, IL
29	USC	South Chicago, IL
30	NSC	Great Lakes, MI
31	USC	Duluth, MN
32	ASC	Kansas City, MO
33	BSC	Sparrows Point, MD
34	NSC	Weirton, WVA
35	ASC	Ashland, KY
36	RSC	Gadsden, AL
37	USC	Fairfield, AL
38	ASC	Houston, TX
39	USC	Baytown, TX
40	USC	Geneva, UT
41	BSC	Los Angeles, CA
42	USC	Torrance, CA
43	BSC	Seattle, WA

ASC--Armco
BSC--Bethlehem
ISC--Inland
JSC--Jones & Laughlin
NSC--National
RSC--Republic
USC--United States Steel
YSC--Youngstown Sheet & Tube

Source: Author

Table 2

Investment Cost Estimates

The following table lists each piece of equipment and its various cost estimates. Each estimate is given in its original terms and then converted into 1980 equivalent replacement costs. The following conversions were used:

1 year (y) = 350 days (steel shop)
= 350 days (coke ovens, sinter plants)
= 300 days (blast furnace)

replacement = .9 of new investment cost
inflation index = Department of Commerce construction index. (See text)

EQUIPMENT	A.D. Little. 1980 replacement	TBS. 1975 New	Crandall. 1968 New	Russell/Vaughn 1968 New	EPA, 1975 New	OTA, 1978 replacement
Sinter plant	10,000 NTID; $140 mil →$40/TY	(sinter strand) 330.000 TY; $2.87 mil →$12.56/TY	----	annual capital cost of moderate size plant $25/TY →$65.0/TY	----	----
Coke ovens	2,500 NT/D; $260 mil →$297/TY	500,000 T/Y; $61.5 mil →$177.52/TY	500.000 T/Y $222.5 mil →$507.51/TY	700.000; $43/TY →$111.73/TY	660,000 T/Y; $60 mil →$131.22/TY	$220/tonne Y →$253.5/TY
Blast furnaces	10,000 NT/D; $330 mil *$l 10/TY	950.000 T/Y; $43.47 mil →$66.78/TY	----	800,000 TIY; $30 mil →$110.88/TY	1,220,000; $90 mil →$706.5/TY	large modern; $110/tonne Y →$126.7/TY
	----	----	----	----	2,600,000; $156 mil →$86.58/TY	----
Direct Reduction Unit	----	---	----	----	1.2 mil T/Y; $45 mil $37.98/TY	----
Basic Oxygen Furnace	4.1 mil RST/Y; $190 mil →$46.34/RSTY	1.18 mil T/Y; $29.44 mil →$36.09/TY	1.18 mil TIY; $35 mil →$33.84/TY	----	1.71 mil T/Y; $45 mil →$37.98/TY	$55/tonne Y →$63.40/TY
Electric Arc Furnace	700.000 RST/Y; $70 mil →$100/RSTY	----	----	United Nations, 1976 New 1 mil tonnes/Y; 180 mil DM • $90.63/TY 500,000 tonnes/Y; 150 mil DM →$151.02/TY	1.71 mil T/Y; $65 mil → $54.81/TY	$83./tonne Y → $95.7/TY
Continuous caster-slabs	1.6 mil RST/Y; $ 100 mil →$62.5	1.11 mil TIY; $ 52.96 mil →$68.85/TY	1.11 mil T/Y; $62.5 mil →$64.17/TY	Chilton's Iron Age, 1965 $ 10 - 15/TY →$29.5 - $44.37/TY	----	(all caster types) $ 88/tonne Y →$101.40/TY

Table 2 continued

	A.D. Little, 1980 replacement	TBS, 1975 New	Crandall, 1968 New	Russell & Vaughn 1978 New	EPA, 1975 New	OTA, 1978 replacement
EQUIPMENT Billet caster	?00,000 RST/Y; $40 mil →$80/RSTY	----	----	----	----	----
Blooming-billet mill	1.5 mil T/Y; $280 mil →$186.7/TY	----	----	----	----	----
Slab mill	3.2 mil T/Y; $300 mil →$93.75/TY	----	----	----	----	----
Hot Strip Mill	5.8 mil T/Y; $560 mil → $96.6/TY	890,000 T/Y $53.10 mil → $86.13/TY	890,000 T/Y; $101.25 mil → $129.78/TY	----	----	----
Materials handling	Docks $10,000 T/D; $3 mil	Ore Yard ≤60,000 T/Y $5.[illegible]5 mil →$.86 TY	--- →$8.56/TY	----	----	----
		Coal Yard 780,000 T/Y $6.6[illegible] mil →$8.56 TY	Coal Yard 780,000 T/Y, $25 mil → $32/TY	--	----	----

Sources: A.D. Little (1981) Table A.1; Crandall (1981), p. 77; Temple, Barker, and Sloane, Inc. (July 1977) as cited in Crandall (1981) p. 77; Russell and Vaughn (1976); Evironmental Protection Agency (December 1976), pp. 44-45; Office of Technology Assessment (June 1980), p. 319; United Nations (1976), p. 88; Chilton's Iron Age, 8/5/75, p. 54.

TABLE 3

Equipment	Source for Numbers Used
Sinter plant	A.D. Little
Coke ovens	O.T.A.
Blast furnace	A.D. Little
Basic oxygen furnace (& Q-BOP)	Less than 1/mil T/Y--TBS 1.7-2.5 mil T/Y--EPA 3-4 mil T/Y--A.D. Little
Electric furnace	Less than 500,000 T/Y--U.S. 700,000-1 mil T/Y--A.D. Little 1.71 mil--EPA
Continuous casters (all types)	A.D. Little
Hot-strip mills	A.D. Little
Blooming-billet mill	A.D. Little
Slab mill	A.D. Little
Mill modernizations:	Increase in capacity x per annual ton cost of replacement investment
Blast furnace rebuilds:	$161.98/ton of capacity increase (1980) Figure from U.S. Steel expenditure on Gary furnace rebuild.
Ore yard	TBS
Coal yard	TBS
Direct reduction	EPA

Table 4

Product Group	SIC Category	Description
1	33122	Steel ingot and semifinished shapes
2	33123	Hot-rolled sheet and strip, including tin-mill products
3	33124	Plates, structural shapes and pilings, hot-rolled bars and bar shapes
4	33125 & 33155	Steel wire
5	33126 & 33176	Steel pipe and tubes
6	33127 & 33167	Cold-rolled sheet and strip
7	33128 & 33168	Cold-finished steel bar and bar shapes
8	33120	Other steel mill products (rails, wheels, and track accessories)

Source: See text.

Table 5

List of Products from Chilton's Iron Age

Product Group	Product	
1	Billet, Blooms, Slabs:	Carbon rerolling
1		Carbon forging
1		Alloy
3	Piling:	Sheet Steel
3	Shapes, Structurals:	Carbon
3		High-strength, low-alloy
3		Carbon wide-flange
2	Strip:	Hot-rolled
6		Cold-rolled
2		High-strength, hot-rolled, low-alloy
2		Alloy hot-rolled
6		Alloy cold-rolled
3	Bars:	carbon
3		Reinforcing, 1/60 - 6/61; 11/62 - 12/62
7		Cold finished
3		Alloy hot-rolled
7		Alloy cold-drawn
3		High strength hot-rolled, low-alloy
3	Plates:	Carbon
3		Alloy
3		High-strength, low-alloy
4	Wire:	Manufacturer's bright
2	Sheets:	Hot-rolled 18 gauge & heavier
6		Cold-rolled
2		Galvanized (hot dipped)
2		Enameling
2		Long terne
		High-strength, low-alloy hot-rolled
2		Electrogalvanized sheets, as of 7/61
1	Wire Rod:	
2	Tinplate:*	Cokes, until 10167.
2		Electrolytic
2		Blackplate and tin free steel, as of 11/67

*Prices reported in terms of dollars-per-base box. Conversion used: 20 base boxes = 1 ton of steel.

Source: Chilton's Iron Age, various issues

Table 6

List of Products from Engineering News Record

Product		Product Group
Reinforcing Bars		3
Rails:	Standard	8
	Light	8
Track Supplies:	Standard Spikes	8
	Tie Plates	8
Pipe:	2 112 & 3:, Black	5
	2 112 & 3", Galvanized	5
	3 1/2 to 6", Black	5
	3 1/2 to 6", Galvanized	5

Table 7

Cost per Ton-Mile
(dollars)

Year	Ocean Ship	Ore Boat	Railroad
1960	.00083	.0036	.0110
1961	.00092	.0035	.0110
1962	.00084	.0033	.0112
1963	.00097	.0034	.0109
1964	.00107	.0032	.0105
1965	.00102	.0032	.0104
1966	.00091	.0034	.0100
1967	.00076	.0032	.0100
1968	.00076	.0031	.0100
1969	.00073	.0033	.0104
1970	.00114	.0037	.0113
1971	.00069	.0041	.0128
1972	.00072	.0042	.0133
1973	.00153	.0040	.0140
1974	.00229	.0049	.0160
1975	.00103	.0054	.0190
1976	.00079	.0058	.0210
1977	.00108	.0070	.0220
1978	.00116	.0070	.0240
1979	.00258	.0080	.0270
1980	.00353	.0095	.0320
1981	.00303	.0074	.0249
1982	.00144	.0075	.0253
1983	.00153	.0077	.0258
1984	.00148	.0080	.0268

Source: Author's estimates using various sources. See text.

Table 8

Basic Labor-Cost Series, Salary and Wage
(dollars per hour)

YEAR	LABOR COST
1960	3.94
1961	4.12
1962	4.28
1963	4.35
1964	4.45
1965	4.57
1966	4.72
1967	4.84
1968	5.13
1969	5.47
1970	5.77
1971	6.34
1972	7.13
1973	7.71
1974	9.06
1975	10.37
1976	11.43
1977	12.61
1978	13.85
1979	15.37
1980	17.12
1981	19.19
1982	21.41
1983	20.39
1984	20.18

Source: American Iron and Steel Institute, Annual Statistical Report, various issues.

Table 9

Input	Weight*
Iron Ore	1.68
Coking Coal	26.26
Scrap	.125
Natural Gas	5.36
Labor	10.88

*Weights reflect adjustment for units used in the respective price series. See text for discussion.

Sources: Office of Technology Assessment (1980), pp. 190 - 91; American Iron and Steel Institute, Annual Statistical Report, 1977; and author's estimates.

Table 10

YEAR	GROWTH RATE IN OUTPUT PER MAN/HOUR (5-YEAR MOVING AVERAGE)	POLLUTION ABATEMENT OPERATING COSTS (Millions of Current Dollars
1960	3.40	.03
1961	1.58	.06
1962	4.25	.12
1963	4.50	.24
1964	3.70	.48
1965	1.80	.96
1966	1.60	1.92
1967	.70	3.85
1968	0.00	7.70
1969	1.60	15.39
1970	2.10	30.79
1971	4.30	61.58
1972	5.00	123.15
1973	.40	246.30
1974	.40	321.90
1975	0.00	408.50
1976	.40	519.70
1977	3.50	654.60
1978	1.00	761.50
1979	2.90	950.50
1980	0.00	1018.70
1981	2.24	1164.20

Source: See text.

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