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ENTRY INTO AND EXIT FROM THE U.S. STEEL INDUSTRY

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ENTRIES INTO AND EXITS FROM
THE STEEL INDUSTRY

ABSTRACT

This paper examines entry into and exit from the U.S. steel industry during the last three decades. It first looks at the entry-with-new-technology strategy and the resultant performance of these entrants which gives rise to leap-frog type competition. Then a simple model of exit behavior based on technological change and obsolescence is derived. It is found that ineffectiveness and inefficiency contribute equally to the exit from the steel industry and is exemplified through the use of the integrated steelmaking sector's performance.

INTRODUCTION

How to compete is the central issue of the business level strategy. The behavior of incumbent firms, entering, and exiting have significant impact on competition. Analyzing entry and exit conditions is the first step toward studying competitive strategies and is particularly useful from two perspectives. From an incumbent firm's perspective, understanding entry conditions helps the firm to identify an important source of competition and to formulate an appropriate strategy to cope with it. Additionally, an understanding of the reasons for exits helps the incumbent firm avoid losing competitiveness and forceful displacement from the market. From a potential entrant's perspective, understanding entry conditions provides guidelines toward entry strategy.

Although entry and exit behaviors have been examined extensively, very few studies have examined entries and exits for a particular industry simultaneously, especially under the context of technological change. This study focuses on a particular entry strategy, the entry-with- new-technology strategy, and the resulting exits, all within the context of the U.S. steel industry.

During the last two decades, the most significant structural changes in the U.S. steel industry have been the penetration of foreign steel, notably Japanese steel, and the emergence of minimills. With a scale of less than one million net ton annual capacity, minimills, by employing Electric Arc Furnace and continuous casting as their primary steelmaking technologies, have successfully made inroads into the markets that were originally dominated by integrated steel mills. Japanese steelmakers have also acquired a significant share of the U.S. market. As the demand for steel has remained stagnant, these entries have forced some integrated steel firms to close their plants with sizable losses.

In order to understand how entries and exits impact competition within the steel industry, the following questions have been asked:

(i) What are the techno-economic conditions facilitating entry?
(ii) What are the strategies used by entrants?
(iii) How well do the entrants perform relative to existing firms?
(iv) What are the techno-economic characteristics of exits?

The first section of this paper addresses the first three questions while the second section employs discriminant analysis to investigate the characteristics of exit behavior.

ENTRY

The decision of whether to enter an industry depends on the perceived profits after entry as compared to the costs involved in overcoming entry barriers. Entry studies either focus on the entry barriers inherent to a particular industry which increase the costs of entry, such as economies of scale (Bain 1956; Zannetos 1966; Serghiou and Zannetos 1982), or on incumbent firms' strategies which deter entry by reducing post-entry profits such as limiting pricing (Gaskin 1971), excess capacity (Spence 1977), and spatial competition (Hay 1976, Schmalensee 1978.) As noted by Bernheim (1984), studies on entry deterrence strategies either ignore the sequential aspect of entry deterrence or are extremely asymmetric, focusing on a dominant incumbent firm. The sequential aspect of entry is not included from the strategic viewpoint because a firm's strategy should consider not only one entrant, but all potential entrants. Extremely asymmetric treatment is not realistic for many industries and thus narrows the applicability of the models to managerial decision making. Other problems with entry studies are that, with few exceptions (Gaskin 1971; Harrigan 1981a), most of these studies lack empirical evidence. Furthermore, most entry deterrence studies assume identical production function for potential entrants and incumbent firms. However, under continuous technological change, this assumption does not hold and thus entry behavior needs to be analyzed from a different angle.

The notion of critical fixities, first proposed by Zannetos _et_ _al_ (1982) and elaborated by Tang and Zannetos (1986), could explain entry behavior under continuous technological change. As Tang and Zannetos (1986) show, unless the marginal cost of the existing equipment minus the gains from waiting for advanced equipment exceeds the average cost of the new equipment plus switching costs, a firm will not adopt a process innovation. The combined effects of the marginal cost and switching cost on restraining innovation adoption represent the consequence of the critical fixities of a firm. A corollary of this proposition is that entries and exits will occur. If an innovation is not advanced enough to bring down the average cost, critical fixities will cause existing firms to not adopt a process innovation even though this will put them in a cost-disadvantageous position relative to the entrants with the new technologies. If prices are determined by the dominant old technology, entrants with the new technology will make an extra profit. Therefore, under continuous technological change, entrants will outperform existing firms. In other words, the critical fixities of the incumbent firms create "certain unimitability," as opposed to "uncertain imitability" (Lippman and Rumelt 1982), and certain unimitability acts as an "entry facilitator," as opposed to an entry barrier.

Before using the notion of critical fixities to explain entry behaviors in the steel industry, an understanding of steelmaking technologies is necessary. For those readers familiar with steelmaking technologies, this section may be skipped.

Steelmaking Technologies

The major reasons that steel is a widely used material are its high strength, reasonable stiffness, and ductility. These properties are largely determined by the chemical composition of steel. The purpose of steelmaking is to obtain the desired chemical composition by eliminating unwanted elements found in the iron ore or scrap, from which steel is made (Peters, 1983).

The basic process of steelmaking from iron ore is to first obtain liquid iron by burning iron ore with coal, and then refine the liquid iron into liquid steel. The refinement is done in one of two kinds of furnaces: the Open Hearth (OH) or the Basic Oxygen Furnace (BOF). Then, the liquid steel is rolled or cast, and formed into the desired shapes. Steel plants that produce steel products through these processes are called "integrated" steel mills. Another method of making steel is to refine scrap in an Electrical Arc Furnace (EF) and then roll, or cast the liquid steel into the desired shapes.

The steel industry has experienced significant changes in each of the steelmaking stages. First, massive cheap iron ore reserves were discovered in Brazil and Australia in the 1960s. Second, gigantic blast furnaces were developed in the 1960s, which increased by six times the daily output rate.

Third, the BOF was commercialized in 1954 and soon replaced the OH as the dominant steelmaking technology. The BOF, however, requires more hot metal (liquid iron) than the OH.[1] If hot metal supply is not sufficient, converting an OH shop to a BOF shop requires additional hot metal production facilities such as blast furnaces and sinter plants. Fourth, continuous casting, developed in the late 1960s and early 1970s, replaced ingot casting as the main casting technology. Continuous casting can reduce labor requirements by two-thirds and can also reduce the economies of scale in casting to roughly an annual capacity of half a million tons (Battelle Memorial Institute, 1964). Finally, in the 1960s, the capacity of the EF was enlarged significantly. As the scale of the EF increased, and as the economies of scale in casting decreased, it became economical to produce low carbon steel through the EF and continuous casting at an annual capacity less than 1 million tons.

Combining the EF and continuous casting created the so-called "minimills", steel mills with less than a 1 million ton annual capacity. Continuous casting plus relatively cheap scrap provide minimills significant cost advantages over integrated mills. However, because scrap contains a significant amount of "tramp elements"--unwanted elements that cannot be removed by the EF, the BOF, or the OH--the steel made from minimills cannot be rolled into steel sheets and strips because tramp elements are detrimental to their quality. Thus, those integrated mills which produce steel sheets and strips are immune from competition with minimills. As shown below, all these technical characteristics have had significant strategic impact on the steel industry. The next section discusses the entry of minimills using the notion of critical fixities.

Entrants and Their Performance

Because an EF shop uses 100% scrap and thus does not need blast furnaces and iron ore processing equipment to supply hot metal, converting an OH shop to an EF shop will make hot metal producing facilities useless. Mainly because of this and lower scrap prices, the marginal cost of the OH was lower than the average cost of EF (Tang 1985). Therefore, using the notion of critical fixities, the OH shops of the early 1960s should not have been replaced by the EF, even though the average cost of the OH was higher than that of the EF[2] and/or accounting profits were negative.

As integrated mills were not willing to switch to the EF, minimills equipped with the EF and continuous casting easily surpassed the integrated mills. If prices are set by the cost of the dominant technology, in this case, the OH, the minimills, using the new EF technology, can earn an extra profit. Motivated by this profit, some existing firms which have knowledge of the EF may exploit their expertise by expanding their facilities. Additionally, new firms may be formed to take advantage of the new technology and some steel product distributors may vertically integrate backward. All of these changes have occurred in the steel industry in the last two decades.

A partial list of entrants with new technologies is given in Table 1. Only one of these entrants, McLouth Steel, used the BOF to enter the integrated steelmaking business. This is because substantial economies of scale in both hot metal production and steelmaking stages created high entry barriers for those intending to use the BOF. However, over twenty minimills entered the low carbon steel market by using the EF. These minimills essentially produced low-end steel products such as steel bars and wire rod. Over 90 percent of these minimills also employed another major innovation: continuous casting. At the same time, integrated steelmakers were slow in switching to the EF; only four OH shops have been replaced by EF shops in the last two decades.[3]

Additionally, because of critical fixities, integrated steelmakers were also slow in adopting the BOF; it wasn't until after the early 1960s that the BOF was widely used.[4] This reluctance to switch to the BOF created opportunities for entrants using the BOF to earn extra profits. Hence, McLouth Steel and Japanese integrated steelmakers who agressively adopted the BOF in the 1950s and 1960s, respectively, entered the integrated steel business. These facts clearly show that the reluctance of existing firms to adopt new technologies prompted entry of new firms to the industry.

Insert Table 1 about here

Since these entrants were motivated by the extra profit that could be realized through the use of new technologies, the performance of these entrants is hypothesized to be better than that of the existing firms. The following section compares the profitability of one company, McLouth Steel and several minimills to that of large integrated steel firms.

Performance of Entrants: Two Cases

The BOF Case: McLouth Steel

In the early 1950s, before entering the integrated steel sector, McLouth was engaged in the stainless steel business, using the EF as its primary steelmaking technology. In 1954, McLouth opened the first BOF shop in the U.S. To supply hot metal to its BOFs, McLouth also built a new blast furnace, one of the largest in the country. Four years later, McLouth added two larger

BOFs, and an even larger blast furnace: based on its height and diameter, this blast furnace was the largest in the U.S. at the time. Through this combination of modern blast furnaces and BOFs, McLouth had one of the most advanced steelmaking facilities in the U.S.

Because the marginal cost of the OH was less than the average cost of the BOF in the early 1960s, most steel companies were not willing to adopt modern steelmaking technologies. Since McLouth's competitors were not willing to imitate its strategy, one would expect that McLouth's profitability would be higher than other integrated steel companies.

Table 2 compares the return on investment (ROI) and the return on sales (ROS) of McLouth Steel and the eight largest steel companies for the periods 1956-59 and 1960-66. As this table shows, after McLouth finished its BOF shop in 1960, its profits rose while the other companies' profits fell. During 1956-1959, McLouth's profitability was below the average of the eight largest steel companies. However, in the following period, 1960-1966, McLouth's average profitability was 30 percent higher than these companies. These results conform to the prediction that entrants will earn an extra profit by using the new technologies that existing firms are not willing to adopt.

Insert Table 2 about here

However, the superior performance of McLouth did not last long. In 1980, McLouth went bankrupt. One reason is that McLouth's advantages turned to disadvantages. McLouth was the first U.S. steel firm to adopt the BOF. At the time, 1954, the BOF technology was rather premature; furnace size was as small as 35 tons. In 1958, McLouth added two 110 ton BOFs. However, in the 1960s, the size of the BOF increased significantly and the BOF was capable of refining 300 tons of liquid steel within 40 minutes. As McLouth's competitors adopted larger and more efficient BOF's, McLouth's advantages began to disappear. Despite the advance in BOF technology, McLouth added two 110-ton BOFs, in 1968, not the new 300-ton ones, to replace its 35-ton BOFs. As a result, McLouth had five 110 ton BOFs, whose production capacity could have been replaced by two modern 300 ton BOFs. Perhaps the reason McLouth adopted the less efficient BOFs was that it had to maintain compatibility of cranes and transportation equipment between new furnaces and its existing 110 ton furnaces. This need for compatibility would have increased switching costs if McLouth had added 300 ton furnaces.

The McLouth case illustrates that, although early adopters of a new technology gain a temporary cost advantage, other firms can come in later with a better technology. As these other firms enter the market, the critical fixities prevent the original early adopters from using the better technology. The McLouth case also illustrates the leap-frog type competition which can result from continuous technological change.

The same situation seems to be repeating itself in the case of Japanese steelmakers. After two decades of dominance in the world steel market, Japanese integrated steelmakers now are threatened by Korean and Taiwanese steelmakers, who are using better technologies to penetrate the Japanese market.

The Minimills Case

In the previous section, Table 1 we gave a list of companies that entered the low carbon steel market by using the EF and continuous casting. Among those firms, only a few went public and among these, only four are engaged primarily in the carbon steelmaking business, competing directly with the large, integrated steel mills. They are Nucor Steel, Florida Steel, Quanex Steel, and Northwestern Steel and Wire.

In Table 3, the performance of these four minimills is compared with that of integrated steel firms. Due to data availability, only ROS is used as the performance indicator.[5] For the period from 1970 to 1982, on the average, the four minimills earned an 11.05 percent return on sales while integrated firms earned only a fraction of that, 3.48 percent. Since minimills are less capital-intensive than integrated mills, the ROI of minimills must be even higher than that of integrated mills. Some of the integrated mills would rather have suffered an accounting loss than replace their out-of-date facilities. For example, Kaiser Steel was in the red 7 out of 11 years and yet did not replace its OHs until 1978, twenty years after its first BOF installation.

To further control for time effects, a two-way ANOVA is employed to analyze the variance of ROS. The year and the technology, integrated mills versus minimills, are two independent variables. The ANOVA results are given in Table 4 which show that both the technology and the year have significant impact on the performance of steel mills. The significance of the year variable reflects the sensitivity of the steel industry to general economic conditions. The significance of the technology variable rejects the null hypothesis that there is no performance difference between minimills and integrated steel companies. Tables 2, 3, and 4 clearly indicate how entrants took the opportunities created by both technological advancement and the critical fixities of existing firms to earn an above-average profit.

Insert Tables 3 and 4 about here

In a stagnant industry such as the steel industry,[6] these entrants forced some plants to close. According to American Iron and Steel Institute's Directory, there were 53 integrated steel works which produced carbon steel by employing the blast furnace and the OH in 1960. By 1983, sixteen of them were permanently shutdown, four were replaced by the EF, and only thirty-three integrated steel works were still in operation. Although all integrated plants faced the same structural exit barriers and the same threats from minimills and imports, one might wonder why only some plants were closed, thereby causing significant financial losses for their firms. The characteristics of these exits are investigated below and a simple model is derived which seeks to explain the exit decision of an integrated mill.

EXIT

Generally speaking, a firm will exit from its current operation if the discounted net cash flow from continuing operations is less than the discounted net cash flow of exit. The unit cash flow from current operations is the difference between the unit price and the marginal cost, $P\text{-}MC_{old}$. Let C_{EXIT} be the unit cash flow of exit.

Then if $$C_{EXIT} > P - MC_{Old} \qquad (1)$$

a firm will choose to exit from its current operations. Thus, other things being equal, the higher the price of output, the lower the marginal cost of current operations, the lower the switching costs, and the higher the exit cost, the less likely the firm will exit.

Research on exit has centered on the factors which are believed to affect either marginal costs or exit costs. A typical example is Caves and Porter's (1976) pioneering study of exit barriers. Some exit barriers such as capital intensity, investments in R&D and marketing, and quality image, may reduce marginal costs. Other exit barriers, such as asset specificity, shared facilities, managerial emotional attachments, may increase exit costs and thus reduce the net cash flow of exit and thereby deter exit. Porter (1976), Caves and Porter (1976), and Harrigan (1980, 1981b, 1982) empirically examined several factors contributing to or deterring exit from different industries. Our research is different from Porter and Harrigan's in several aspects. First, our unit of analysis is the plant, not the firm, which allows us to examine the exit behavior more closely. Second, structural exit barriers, excess capacity, and unfavorable environment have been found to affect exit decisions. Building upon these findings, we further investigate the factors responsible for the closing of certain plants although all integrated steel plants face the same economic forces. Third, we study the exit behavior during the period the industry experienced significant technological change. Furthermore, the above simple exit equation is inadequate if the main reason for a firm's exit is technological obsolescence which leads to the loss of competitiveness.

We first correct the exit equation. Under technological change, the technologically obsolete firm has an additional alternative if it wants to continue its current operations: replace the old equipment with the new. The cash flow of this alternative is:

$$P \equiv AC_{NEW} - SC \qquad (2)$$

where AC_{new} is the average cost per unit using the new equipment and SC is the unit switching cost. Applying the case to the steel industry, the old technology was OH and the new technologies were the BOF and the EF. Thus, to close an aged OH plant, the unit net cash flow of exit must be greater than the cash flow of the other two alternatives. Therefore, if

$$C_{exit} > \text{Max } [P-MC_{old}, P-AC_{new} - SC] \qquad (3)$$

a steel firm will close its integrated plants. Since industry specific exit barriers, such as asset specificity, are inherent, one can reasonably assume that each steel plant faces the same unit exit cash flow, but not the same switching costs. Given the same cash flow of exit per unit, equation (3) indicates that the lower the price of the product, and the higher the MC_{old}, the higher AC_{new}, and the higher the SC, the more likely it is that the integrated plant will be closed.

Several factors that affect the price, MC_{old}, AC_{new}, and SC need to be discussed and tested. Then these factors will be used to explain the exit from the steel industry. But before delving into that let us have one last look at Tables 2, 3 and 4 to stress once again, the importance of what we have found. The general trend shown in Table 2 is downward. Although, the trend is not as pronounced as in the years 1970-82 shown in Table 3, no integrated firm reached the average return on sales realized by the minimills. These results, as Table 4 shows, for both technology and the time effect are significant at the .0001 level.

Hypotheses

First, due to the substantial economies of scale of the BOF, the annual production capacity of a plant affects the AC_{new}. Small plants are likely to have higher AC_{new} if they had been converted to the BOF. To reduce the AC_{new}, the plant has to be expanded. This includes the expansion of all facilities such as blast furnaces, sinter plants, and rolling capacities. In a stagnant market, these expansions are hardly justifiable. Therefore, it is expected that the smaller the annual production capacity of an integrated steel plant, the more likely it is that it will be closed.

Second, a typical integrated steel plant has several blast furnaces. Since technological advancements in steelmaking and ironmaking have resulted in increased production capacity, the average annual capacity of blast furnaces is an indicator of their efficiency. Integrated plants with smaller blast furnaces are more likely to have higher marginal costs and thus are more likely to be closed.

Third, since switching to the BOF requires more hot metal, low hot metal availability increases switching costs. (Hot metal availability is measured as the ratio of annual pig iron capacity to annual steelmaking capacity.) Therefore, low hot metal availability will increase the likelihood of a firm's closing.

Fourth, as minimills enter the market, the prices of products made by the EF could be lower because the EF has a lower average cost. However, minimills cannot produce steel sheet and strip due to tramp elements in the scrap. Those integrated plants producing sheet and strip do not compete with minimills. Also, since sheet and strip are made by rolling slabs, not billets or blooms, converting to produce steel sheet and strip from products similar to those of minimills requires the change of casting as well as rolling machines, which is prohibitively expensive. Therefore, it is expected that a lower percentage of sheet and strip capacities would decrease the possibility of the survival of an integrated steel plant.[7]

In summary, it is hypothesized that those plants characterized by small size, small average size of blast furnace, low hot metal availability, and low steel sheet production capacity are likely to be closed. Since the dependent variable is dichotomous, ordinary least squares estimates are not efficient and thus hypothesis tests are invalid (Aldrich and Nelson, 1984; Pindyck and Rubinfeld, 1981); therefore, discriminant analysis is used to test these hypotheses.

Empirical Analysis

For purposes of this analysis, two types of exits are used. The first type is the exit from the integrated steelmaking business, including four OH shops that shut down their integrated steelmaking facilities and replaced them with the EF. The second type is the exit from the steel industry, comprised of only those steel plants that were permanently shut down before 1983.[8] The results of the discriminant analysis are summarized in Table 5.

Insert Table 5 about here

The two discriminant functions using the two different exits show significant discriminant power with the chi-square of the two equations significant beyond the .001 level. Also, close to eighty percent of the cases are correctly classified. These results indicate that the overall explanatory power of these two discriminant functions, consisting of the four prediction variables mentioned above, is adequate. Standardized canonical coefficients indicate that the size of the steel plant, the annual capacity of blast furnaces, and the percentage of steel sheet capacity contribute more or less equally to the discriminant function. As is shown, their signs are consistent with expectations. However, hot metal availability appears to contribute only marginally.[9] The significance of the scale factor is consistent with

Harrigan's (1982) findings that small scale, in cases where capital investment is important, increases the possibility of exit.

Comparison of the discriminant functions of the two types of exit shows that the contribution of the product mix variable to the discriminant function increases as the four EF replacements are included in the analysis. The standardized canonical coefficient of SHTH, a measure of hot rolled steel sheet and strip capacity, increases from 0.422 to 0.635, as hypothesized. In addition, for those exits from the integrated steel business, the product-mix variable contributes the most to the discriminant function. These results reflect the technological limitation of the EF. Because steel sheet and strip cannot be made from the steel produced by the EF, having strip and sheet production capacity would reduce the possibility of converting an integrated OH shop to an EF shop. Therefore, the product-mix variable becomes more significant for the sample that includes the four OH shops which are replaced by the EF.

Interestingly, the discriminant function can provide some predictions regarding future closings of integrated steelmaking facilities. Using both equations, the five plants which have the highest negative discriminant scores but which have not been shut down before 1983 are: CF&I's Pueblo plant, United States Steel's Duquesne plant, Republic Steel's Buffalo plant, Republic Steel's Gadsden plant, and Wheeling-Pittsburgh Steel's Monessen plant. According to the discriminant function, these plants should have been shut down before 1983 but they were not. Therefore, it is predicted that they will be closed before other integrated plants that were in operation in 1983. This prediction is largely in line with what actually occurred. In 1983, the first three plants were closed and discussion was underway about selling the fourth. The fifth went bankrupt in 1985. Thus, we have here an indication of the predictive power of the discriminant functions.

These exits can be viewed as victims of technological innovations. The impact of the EF and continuous casting can be seen from the fact that integrated plants which produce products similar to minimills are likely to be forced to close because of the high switching costs of converting non-competitive steel products to steel sheet and strip. This reflects the ineffectiveness (undesirable output)of an integrated steel plant relative to its minimill rivals. The impact of the BOF is revealed by the fact that the small size of an integrated plant created high switching costs and thus significantly reduced its chances for survival. Also, not surprisingly, efficiency plays an important role in plant closings.

CONCLUSION AND STRATEGIC IMPLICATIONS

This paper exemplifies a techno-economic-strategic analysis in which key characteristics of technologies are first analyzed, economic consequences are then derived, and strategic implications are followed. Additionally, it demonstrates how technological innovations coupled with critical fixities of a firm can partially explain the entry, exit, and performance of firms in the U.S. steel industry. Because of the reluctance of existing firms to switch to new technologies, entrants using these new technologies entered the low carbon steel market and earned an extra profit. The existing integrated firms would rather have suffered accounting losses than replace their obsolete equipment as long as the cash flow remained positive. However, entrants into the integrated steel industry having new technologies, such as McLouth and the Japanese steelmakers, enjoyed only short-term cost advantages. Critical fixities associated with new technologies inhibited them from adopting more advanced technologies. Yet this leap-frog type competition has not been observed for minimills. This difference may be explained as follows:

(i) minimills are less capital intensive than integrated mills, and therefore critical fixities are not as serious as for integrated mills and

(ii) the minimill sector is still expanding, creating many opportunities to adopt new technologies.

Therefore, the entry-with-new-technology strategy should be evaluated in light of future technological changes and expansion possibilities.

Finally, it was shown that, as the demand for steel leveled off, those entrants forced some existing firms to close their plants and even forced some integrated firms to go bankrupt. These exits are characterized by high switching costs resulting from small size, and low competitiveness resulting from improper product mix. It is shown that inefficiency (caused by small furnaces) and ineffectiveness (caused by improper product mix) contribute equally to the exits.

Thus by examining relative weaknesses and strengths of competing technologies, OH, BOF and EF, one can derive some investment implications for steel firms using different technologies. For example, integrated steel firms should not have invested in steel bar mills which can not compete with minimills. Rather, they should have developed advanced strip and sheet technologies to avoid competition from minimills.

Simultaneously analyzing entry and exit caused primarily by technological change provides an example of economic analysis of the ecology of an industry. Unlike some of the organizational ecology literature (Hannan and Freeman 1977), it is shown that the birth and death of the firm are not determined by the organization form, but by some specifically defined techno-economic characteristics.

The research presented here has a number of limitations. First, some important variables such as demand fluctuations, although implied are not considered in analyzing entries and exits. Also managerial and corporate exit barriers are not incorporated in our analysis. As dominant firms in the steelindustry gradually diversify away from the steel business, these barriers to exit may become significant. Finally, although our models are universal, by means of homogenizing measures and controlling for general economic conditions, we apply the model only to a particular industry. It needs to be shown whether the model could also be applied to other industries experiencing continuous technological change, such as the semiconductor industry.

FOOTNOTES

1. The BOF requires at least 70 percent of hot metals for its charge.

2. See Battelle Memorial Institute (1964), and United Nation's (1962) studies.

3. One of these four OH shops, Bethlehem Steel's Johnston shop, was originally planned to be replaced by the BOF. However, in the construction process a flood ruined the hot metal production facilities and thus Bethlehem decided to replace the OH shop with an EF shop which requires no hot metal.

4. Tang (1985) has shown that the marginal cost of the OH was less than the average cost of the BOF. Thus, according to the notion of critical fixities, integrated steelmakers should not have switched to the BOF.

5. Integrated steel companies began their diversification in the 1970s. As a result, their performance cannot represent the performance of their steelmaking business. To correct this, we use the information of their steelmaking business as presented in the business segment section of their annual reports. If business segment data are not available, we use corporate data. It should be kept in mind that each company has its own definition of "steelmaking" and each company has its own policies on allocating corporate expenses and transfer pricing. The use of business segment information also leads us to choose ROS as the performance indicator because information on "identifiable assets" and depreciation

for a particular business segment is not always available. Further analyses show that the results do not differ significantly if corporate data are used.

6. From 1960 to 1981, the annual steelmaking capacity in the U.S. grew less than 1% per year (Barnett and Schorsch, 1983).

7. Only hot-rolled strip and sheet capacity is counted because cold-rolled strip and sheet capacity can be utilized by purchasing hot-rolled strip and sheet from other companies.

8. All the prediction variables are 1960 values. In other words, we intend to use the data available in 1960 to predict the exit behavior in subsequent years.

9. Probit analysis also yields similar results.

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Table 1

A Partial List of Entrants into the Low Carbon Steel Market after 1954

Year	Company	Steelmaking Furnace	Casting Machine	Annual Capacity as of 1982 (in net tons)
1954	McLouth	BOF	Ingot	1,000,000
1961-66	Border Steel	EF	Continuous	200,000
1963-70	Intercoastal Steel	EF	?	80,000
1964-78	Roblin Steel	EF	Continuous	200,000
1965-81	Florida Steel*	EF	Continuous	1,578,000
1966	Tennessee Forging	EF	Continuous	160,000
1967-79	North Star Steel*	EF	Continuous	1,140,000
1967	Keystone Group	EF	Continuous	800,000
1967	Witteman Steel	EF	Ingot	60,000
1968	Nucor Corporation*	EF	Continuous	2,000,000
1968-75	Northwestern Steel & Wire*	EF	Continuous	2,400,000
1968-82	Marathon Steel	EF	Continuous	175,000
1968-75	Marion Steel	EF	Continuous	250,000
1968	Owen Electric Steel	EF	Continuous	100,000
1969	Korf Industries	EF	Continuous	700,000
1970	Cascade Steel Rolling Mills	EF	Continuous	275,000
1971	Razorback Steel	EF	Continuous	120,000
1971-79	Connors Steel	EF	Continuous	200,000
1971	New Jersey Steel	EF	Continuous	200,000

Table 1 (continued)

1974	Mississippi Steel Division	EF	Continuous	180,000
1974-83	Quanex Corporation	EF	Continuous	460,000
1975	Auburn Steel	EF	Continuous	250,000
1975	Chaparrel Steel	EF	Continuous	950,000
1976	Charter Electric Melting	EF	Continuous	120,000
1977	Tamco	EF	Continuous	300,000
1979	Raritan River Steel	EF	Continuous	600,000

? Means information on casting method is not available.

Definition of Entrants: New firms entering the market with new technologies or existing firms expanding their steelmaking capacities over three times its original capacity in 1960.

* Indicates firms that expanded their capacities aggressively by using new technologies.

Source: Iron and Steel Society, AIME Complete Listing: Electric Arc Steelmaking Furnaces in United States, Warrendal, PA.: Iron and Steel Society, AIME, 1982. Richard Diley and William Pietrucha, Steel Industry in Brief: Data Book, U.S.A., Green Brook, NJ.: Institute of Iron and Steel Studies, 1983. American Iron and Steel Institute, Directory of Iron and Steel Works of U.S. and Canada, Washington, D.C.: American Iron and Steel Institute, various years. Association of Engineers, Directory, Iron and Steel Plants, Pittsburgh, PA: Association of Iron and Steel Engineers, 1984.

Table 2

Performance Comparison Between McLouth and the Eight Largest Steel Companies

	1956-1959		1960-1966	
Company	ROI	ROS	ROI	ROS
McLouth	9.33	9.94	14.83	14.63
Armco	14.50	13.43	9.93	10.44
Bethlehem	13.61	13.26	9.41	9.95
Inland	15.14	13.99	12.40	12.95
Jones & Laughlin	8.95	9.21	8.51	8.75
Kaiser	6.75	13.11	5.04	8.30
National	12.70	14.09	10.96	12.32
Republic	15.45	12.74	7.99	8.33
United States	15.17	16.12	8.23	10.95
Largest eight Average	12.78	13.24	9.06	10.25

Source: Moody's Investors Service Inc., Moody's Industrial Manual, New York: Moody's Investors Service Inc., 1956-1966.

Table 3

Return on Sales (ROS) for Minimills and Steelmaking Segment in Integrated Steel Frims (in Percentage)

Minimills			Steelmaking Segment		
Company	Period	ROS	Company	Period	ROS
Nucor	1970-82	11.72	USS	1970-82	2.85
Northwestern Steel and Wire	1970-82	13.06	Bethlehem	1970-82	2.87
Quanex Steel	1974-82	9.95	Inland	1970-82	7.24
Florida Steel	1970-82	9.47	Republic	1970-82	2.11
			Kaiser	1970-82	0.65
			National	1970-82	3.41
			Armco	1970-82	3.25
			LTV	1970-81	3.75
			Wheeling-Pittsburgh	1970-82	1.30
			Interlake	1970-82	3.56
			Lone Star	1970-82	7.33
Average ROS: $\overline{X}$=11.05					$\overline{X}$=3.48

Source: Annual Reports, various years

Table 4

Results of Analyses of Variance for Return on Sales

Source	df	SS	F
Technology	1	2106.8	114.34*
Year (1970-1982)	12	4429.4	20.03*
Error	177	3261.6	

*$p < 0.0001$

Table 5

Discriminant Analysis Results of Exits

	Eq. No.	Standardized Canonical Coefficients				No.* Obs.	Chi-square	Canonical Corr.	Eigen-value	Percentage of cases correctly classified
		SIZE	BFCAP	HMA	SHTH					
Exits from steel industry	1	0.496	0.579	0.050	0.422	46	21.63**	0.634	0.674	83.4
Exits from integrated business	2	0.563	0.406	0.130	0.635	50	23.36**	0.631	0.662	78

* Kaiser Steel, McLouth Steel, and Jones and Laughlin's Aliquippa plant are excluded due to thier BOF capacity.

** Indicates significance level beyond the 0.001 level.

Definitions of Prediction Variables:

SIZE:	annual steelmaking capacity (in million tons) as of 1960
BFCAP:	average annual capacity of blast furnaces as of 1969
SHTH:	hot-rolled steel sheet and strip capacity as a percentage of total hot-rolled products capacity as of 1960
HMA:	hot metal availability, measured as pig iron capacity over steelmaking capacity.

Source: American Iron and Steel Institute (AISI), Directory of Iron and Steel Works in U.S. and Canada, (Washington, D.C., AISI), various years. Stone, Joseph, L-D Process Newsletter, Chicago; Kaiser Engineers, various issues.