The Journal of Economics and Politics

Volume 23 | Issue 1 Article 1

2017

"Firm Behavior in the Mid-Twentieth Century American Steel Industry"

Robert Rogers
Ashland University, rrogers1@ashland.edu

Recommended Citation

Rogers, Robert (2017) ""Firm Behavior in the Mid-Twentieth Century American Steel Industry"," *The Journal of Economics and Politics*: Vol. 23 : Iss. 1 , Article 1.
Available at: https://collected.jcu.edu/jep/vol23/iss1/1

"Firm Behavior in the Mid-Twentieth Century American Steel Industry"

Cover Page Footnote

The author would like to thank the following people, Hanchun Zhang of Northeastern University, Peter Roy of Carrabassett Valley, Maine, and two anonymous referees for helpful editorial and content comments and suggestions.

Introduction

This paper uses a modern statistical technique to analyze a historical situation, the mid-twentieth century American steel industry. The application of modern statistical analysis to this situation is interesting for three reasons. First the seller side of the steel market was so concentrated that perfect competition was unlikely; thus, ascertaining the exact nature of the firm behavior would provide insight into the operation of oligopoly markets. Second, there were some institutional changes during this period. Certain antitrust cases targeted firm practices and mergers (Rogers, 2009). In addition, other regulatory and political changes may have had significant impacts on the steel industry. With this sample, one has an opportunity to test hypotheses on how regulatory changes affected firm behavior. Third, since the data needed to use modern statistical analysis are limited, it is important to see whether a modern statistical technique such as the BLP method can be used in this situation. (See Berry, Levinsohn & Pakes, 1995; Berry, 1994.) Thus, this exercise gives an idea of the ability of modern techniques to analyze historical situations, some of which may have a bearing on modern corporate and government policy.

The steel industry during this 52 year sample period had three characteristics that make a statistical analysis not only interesting but also feasible. First, it was very concentrated on the seller side with fairly high entry barriers. Thus, competitive behavior is unlikely, and therefore, it is important to see how close to the competitive outcome the industry came. Second, in this period the demand composition and seller structure of the industry were relatively stable in that the major producers and users did not change that much. Therefore, there may be enough similar observations to use a statistical model. Third, while much steel data are available, it is not anywhere near as much as is found in the markets where modern statistical analysis has recently been applied such as the cereals, airline, and beer industries. (See Nevo, 2000; Nevo, 2001; Nevo 2003; Berry, Carnall & Spillar, 2006; Berry, Levinsohn, & Pakes, 2004; Dubé, Fox & Su, 2012; Rojas, 2008; Hendel & Nevo, 2006.) Thus, this situation may be a good test of the ability of modern analysis to depict historical situations.

Furthermore, much empirical research has been done on the steel industry in this period, and it is important to see how the conclusions of a BLP analysis compare with this work. This exercise, then, can show us whether modern techniques can support or refute the earlier work. Therefore, in this paper I focus on determining the behavior of the firms in the steel industry during this period.

To accomplish this goal, I first describe the salient characteristics of the mid-twentieth century steel industry and discuss certain plausible theories of steel firm pricing. Second, a theoretical model of steel industry seller behavior is developed. Then, I outline an empirical model of the steel market starting with first a BLP firm demand equation and then its price equation. The latter is used to test the various theories of market behavior. After that, the statistical result are described and analyzed. Finally, in the last section, some conclusions are drawn on the estimation results, and the ability of the BLP model to depict the steel industry of this period is discussed.

Steel Industry 1920-1972

Certain characteristics of the mid twentieth century American steel industry make it amenable to this paper's statistical analysis. First, the seller side of the market was so concentrated that the sellers could keep the price above the competitive level. Second in this 50-odd year period, the steel industry was quite stable; consequently there are enough similar observations of behavior to use statistical analysis. Even with this stability, there was still variation enough to test different hypotheses about changing firm behavior. Here, certain aspects of the industry are discussed to show why our statistical model can be feasible and useful. These aspects are the varying demand conditions, the industry's changing legal and political environment, and the changing market share distribution among sellers. Last, some hypotheses on firm behavior are discussed. From this discussion I can determine whether the model can be used to depict firm behavior and the impact of these government initiatives.

Here I describe the conditions in the steel market that impact on the feasibility of statistical analysis, starting with changes in industry demand. As seen in Table 1, the overall demand level varied widely. The nature of the buyers, however, did not change significantly. This makes the industry especially amenable to statistical analysis. Overall, the 1920s were a time of growth and prosperity with total steel production rising from 47,190,000 to 63,210,000 tons. In contrast, the 1930s were a time of lower demand with total production varying between 15,323,000 in 1932 and 56,637,000 tons in 1937. This situation was a result of depressed conditions in the economy. In the 1940s, World War II precipitated a great increase in demand (from 52,799,000 tons in 1939 to 89,641,600 tons in 1944). In the late 1940s, however, an increase in civilian demand more than made up for the drop in military spending at the end of the war with production reaching 96,836,000 tons by 1950. For the remainder of the period, steel demand continued to grow, however, with setbacks in 1954, 1958, and 1962 due to recessions. Output reached 117,036,000 tons in 1955, 131,462,000 tons in 1965, and 138,747,000 tons in 1972. Thus, this period, 1920 to 1972, was a period of rising steel demand.

With the growing demand, there was some variation in buyer composition, but with two exceptions, the major users remained the same over the whole period. The first exception was the railroad industry which dropped from 23 per cent of steel demand in 1926 to just over 4 per cent in 1965. Not only did the proportion of demand accounted for by railroads decline but also its absolute tonnage.

The other exception to the demand stability pattern was the temporary change in product composition during World War II (1941 to 1945). In that period, two uses increased notably: shipbuilding and airplanes. The former's use of steel rose from 517,771 tons in 1939 (1.3 percent of the total use) to over 12,000,000 ton in 1944. After the war, shipbuilding demand dropped off -- falling to 400,000 tons in 1950. The other major change wrought by the war was the increase in airplane production, but the available statistics do not reveal the airplane steel production share. Hiding this change is that fact that much of the airplane steel was subsumed in the automobile statistics. Among the largest makers of airplanes and airplane engines during the war were General Motors, Ford, and Chrysler. In the automobile industry, the manufacture of passenger cars was essentially abolished, but the fabrication of defense vehicles such as tanks, self-propelled guns, trucks, and, of course, airplanes increased more than enough to take up the slack. As stated above, after the war civilian production not only recovered but increased significantly. Consequently, even with the fall in railroad demand and the changes in the early 1940s due to World War II, the composition of steel in the United States was relatively stable during the five decades of the sample.

As shown in Table 1, the major users of steel, automobiles and construction increased, both proportionately and absolutely, during the sample period. Other large users of steel, machinery and containers, also maintained or increased their market share. Thus, the composition of demand in steel was relatively stable during this period except for the decline in railroad usage.

Before discussing the market share distribution, it is important to appreciate the legal and political environment of the American steel industry. The former was mainly determined by the antitrust laws, while the latter arose from a feeling that steel pricing accounted for the inflation present in the U.S. economy in the 1940s, 1950s, and 1960s. Thus, these situations led to a number of government policies that could have affected the price and quantity outcomes in the steel industry.

At the start of this period, the Justice Department lost the antitrust case intended to break up U.S. Steel (U. S. 417, 1920; Comanor & Scherer, 1995). U.S. Steel was left intact. This situation likely influenced U.S. Steel behavior. There was always a fear on the part of the company that the government would bring back the case. Some claim that these fears brought about a de-emphasis on technological change. While this is not certain, the fear may have led the company to other strategies, such as the optimal yielding of market posited by Stigler (1965) and Gaskins (1972).

Antitrust laws also constrained other steel companies. In the 1920s, the Federal Trade Commission prevented a group of Pennsylvania firms from buying Youngstown Sheet & Tube, and in the 1950s, the Justice Department prevented Bethlehem Steel from buying the same firm. Other anti-merger cases were not so successful. In 1935, the Justice Department failed to stop Republic Steel from buying Corrigan, McKinney and Company, a large Cleveland steel maker.

Possibly, the antitrust cases most relevant to industry behavior were those against basing point pricing in 1924 and 1948. The former case proscribed the Pittsburgh Plus basing point pricing system where there was one basing point, Pittsburgh. The 1948 case banned basing point pricing from any point. Such systems could very well help companies charge higher prices. Basing point pricing was the practice whereby companies charged transportation costs on the assumption that the point of origin was the basing point not the location of the actual originating plant. For instance, a plant located in Lorain, Ohio would charge the customer in Cleveland, the transportation cost from Pittsburgh instead of Lorain. Until 1924, all firms used Pittsburgh as the basing point; between 1924 and 1948, they used a number of other points such as Chicago, Illinois, Bethlehem, Pennsylvania, and Middletown, Ohio. This practice was possibly a way for firms to coordinate on prices (Carlton, 1983). In 1948, however, the system was abolished.

Other government initiatives potentially affecting the steel market outcomes include the National Recovery Administration in the 1930s whereby the government encouraged companies to cooperate in setting prices to counteract the Great Depression. However, this program did not last long -- being declared unconstitutional in the 1935.

During World War II and the Korean War, the government imposed price controls on steel product (and on most products in the economy). While these controls probably discouraged capacity additions, their impacts on pricing may have been attenuated by certain institutional constraints peculiar to the steel industry (Rogers, 2009).

In the 1950s and 1960s, the government often saw the steel industry as a source of price inflation. This led to pressure on pricing decisions by the federal government -- most notably by the Kennedy administration in 1963 -- when U.S. Steel rescinded a price increase ostensibly at the behest of the President. Sources at the time, however, thought that the rescission would have happened anyway (McConnell, 1963). This paper tests the hypotheses of the sources.

Another constraint on American steel company pricing was the growth of imports in the 1960s. A steel strike in 1959 led to buyers successfully searching abroad for suitable steel. This resulted in a great increase in steel imports in the 1960s and subsequent decades outside the sample. This situation may have led to pricing policy changes. As described below, the model can test the hypotheses that these events changed behavior (Mancke, 1968; Rippe, 1970).

To use the BLP model to test these theories on market outcome and firm behavior, one needs data and information on the market share of the sellers in the industry. Table 2 shows the market share of the eight largest steel firms and the competitive fringe including imports. Before analyzing the changes in market share, I now discuss the peculiar nature of these data. The universe from which these market shares are drawn includes not only the sales by American steel firms and foreign exporters to the American market but also an estimate of the total use of steel by the American economy not replaced by new metal production. This statistic is used in the BLP model; as shown below such an estimate can be made from information on the total steel present in the economy and its deterioration as indicated by the depreciation rates. It makes sense to use it throughout this paper. (How it is calculated is explained in section 5a.) The major changes in market share (whatever its particular basis) are the drop in U.S. Steel market share and the increase in the share of some of the smaller steel firms such as Bethlehem Steel, National Steel, Armco, and Inland Steel.

Importantly, the same firms were prominent in the 1960s as were in the 1920s. For much of the period, the same type of people (and sometimes even the same people) ran most of the companies; Eugene Grace ran Bethlehem Steel for four decades, and members of the Verrity and Block families were key executives in Armco and Inland Steel respectively throughout the period. Thus, it is reasonable to assume that the management style and other behavior patterns of the steel firms did not materially change over the period.

The change in market share over time points to some interesting hypotheses. The fall in U.S. Steel market share may have meant that at some point U.S. Steel had lost its dominance. Certain findings and theories support these ideas. Stigler (1965) and Parsons and Ray (1975) essentially assert that U.S. Steel consciously yielded its market share in a way that maximized profits. They posit that U.S. Steel did this by raising their price and yielding market share over a long period of time. Both papers make plausible statistical cases for their hypotheses. Gaskins (1971) develops a theory whereby large dominant firms shed market share in a dynamic profit maximizing strategy. (In some situations a firm's best policy might be to retain its market share. One of these conditions would be that the firm was a low cost producer. This was certainly not true of U.S. Steel.) Essentially, Gaskins posits that a dominant firm maximizes a stream of income over a period consisting of multiple observations. These theories are consistent with the hypothesis that at some point U.S. Steel changed its strategy from that of a Stackelberg leader to Nash-

Bertrand, the behavior hypothesized for non-dominant firms in small numbers markets.

In the 1960s, rising imports and possible interference in pricing by the Kennedy administration may have led to more competitive behavior by U.S. Steel (Mancke, 1968; Rippe, 1970; McConnell, 1963). In section 3 below, the major hypotheses on U.S. Steel and the other firm behavior are summarized.

To sum up, the nature of the mid-20th century steel industry suggests two sets of hypotheses that may be tested using a modern statistical model. The first set posits that changes in economic conditions such as the Depression, the growth of imports in 1960s, and changes in market share distribution could have altered U.S. Steel's behavior. The second set asserts that government policy changes such as the abolition of basing point pricing and the Kennedy pricing intervention may have changed firm pricing behavior.

A Model of Industry Behavior

To model this industry, I assume m profit maximizing firms with each firm j producing a different product. The assumption of differentiated products with each steel company using price as the decision variable may seem counter-intuitive to some familiar with the industry. In the past, steel industry models have assumed homogenous products with quantity as the decision variable (Rogers, 1989). For steel, however, each firm producing a different product is a reasonable assumption. First, there are many types of steel, and different firms produce different product mixes. Certain companies and plants specialize in given different steel products. For instance, the National Steel plant at Weirton, West Virginia made mainly tin-plate for tin cans, while the Inland Steel plant in East Chicago, Indiana made a combination of construction products for the Chicago market and automobile sheet steel. Second, transportation costs are important in the industry; customers essentially view firms at different locations, even those producing the same type of steel, as producing what are essentially different products. Because of transportation costs, they will likely (but not always) pay different prices for the same kind of steel. For more on how location matters to customers, see Karlson (1983). In the long run, firms can change their location by building new plants, but for short run decision-making the plants and their firm output are almost immobile geographically. Consequently, the location of the company and its plants needs to be accounted for in the model.

My model, thus, follows Nevo (2001) by assuming m firms with each producing a different product mix with the below profit function and with price as the decision variable:

$$[(p_{jt} - TVC_{jt})\, M_t\, S_{jt}] - TFC_{jt}, \quad j = 1, m \text{ firms.} \tag{1}$$

Here, p_{jt} is the price of steel for firm j in year t; TVC_{jt} is the total variable cost for firm j in year t; S_{jt} is the market share for firm j in year t; M_t equals the total use of steel in the United States in year t, and TFC_{jt} is the total fixed cost for firm j in year t. To obtain the information (in the form of parameters) necessary to compute this function, I will estimate the demand side of the industry, but first a data problem has to be addressed.

For my data set only one steel price statistic is available for each year. The yearly data points, then, are averages of the prices for sets of different steel products. Therefore, I set up a model where the industry has only one price (p_t). While the one-price assumption is a necessary distortion given the available data, it may not be serious. To see why, consider the composition of the yearly price datum. It is essentially a weighted average of a large number of particular steel product prices, since there are many types of steel products. Since each steel firm produces a number of different products, its average price would be a similar weighted average of steel product prices. The ideal situation would be to have such an average for the products sold by each firm. Since these averages are not available, one must consider an average of the products of the whole industry. There are many types of steel, but in costs they are similar. Thus, it is very likely that this industry index would be highly correlated with the indices for each of the firms (if they existed). Consequently, there may not be a too great distortion when the industry index is used rather than the company indices (which do not exist).

Whatever the price data set used, this paper starts with the assumption of Nash-Bertrand (called below Nash-B) behavior on the part of all the steel firms including U.S. Steel (Nevo, 2000; Nevo, 2001). The Nash-Bertrand assumption is that firms do not react strategically to competitor firm actions; thus, each firm assumes that others do not change prices or quantities in reaction to its actions. Given the above firm model, equation (1), profit maximization, and the Nash-Bertrand assumption, the firm first order conditions are

$$S_{jt}(p_t) + [p_t - MC_{jt}]\ \vartheta\ S_j(p_t)/\vartheta\ p_t, = 0, \ \ j = 1, m \text{ firms.} \qquad (2)$$

Here, p_t equals the industry price average discussed above; MC_{jt} is the Marginal Cost of firm *j*, and $\vartheta\, S_j(p_t)/\vartheta\, p_t$, is the derivative of firm *j* market share with respect to its price. Essentially, in this model, each firm regards its competitor's output as fixed. From the Nash-Bertrand model, this price equation follows:

$$p_t = - S_{jt}(p_t)/[\vartheta\ S_j(p)/\vartheta\ p_t] + MC_j.$$

From these conditions, I arrived at this equation for marginal cost,

$$p_t + S_{jt}(p_t)/[\vartheta\ S_{jt}(p)/\vartheta\ p_t] = MC_{jt}. \qquad (2a)$$

(This function looks strange given the positive sign of the second term, but since $[\vartheta\ S_{jt}(p)/\vartheta\ p_t]$ is negative it is consistent with marginal cost being less than price.)

Another supply side behavioral approach seems plausible for the steel industry, the Stackelberg leadership model on the part of the largest firm, U.S. Steel. Given this firm's much higher market share, it is conceivable that it followed a behavior pattern other than Nash-B. A most plausible alternative model for U.S. Steel is Stackelberg behavior whereby the leader firm in making its pricing decisions anticipates the reactions of the other firms in the industry. Here the first order conditions result in the following markup for the Stackelberg leader, in this case U.S. Steel:

$$p_t - MC_L = - S_{Lt}/[\vartheta\ S_{Lt}/\vartheta\ p_t] + \Sigma\ S_{fj}\ \{[\vartheta\ S_{fj}/\vartheta\ p_t]/[\vartheta\ S_L/\vartheta\ p_t][\vartheta\ S_{fjt}/\vartheta\ p_t]\}, \qquad (3)$$

where *L* equals the leader firm and *fj* = 2, 9, follower firm numbers 2 to *m*. The follower firms would act in the Nash-Bertrand manner assuming the other firm prices and quantities are not affected by their (the follower firm's) actions. The follower firms have the below margins:

$$p_t - MC_{fj} = - S_{fj} / [\vartheta s_{fj} / \vartheta p_{fj}], \text{ fj} = 2, \text{m, follower firm numbers 2 to m.} \quad (3a)$$

Counting as firms, the competitive fringe and the other seven major steel firms leaves eight small firm observations in most years. Models now can be estimated to determine the differences in outcomes between the two regimes.

This paper, thus, uses the above models to test several hypotheses about the behavior of the largest firm, U.S. Steel. The first is that U.S. Steel, acted as a Nash-Bertrand competitor throughout the period. Thus, equations 2 and 2a would apply to U.S. Steel for all observations. The second hypothesis is that this firm operated as a Stackelberg leader throughout the period with the other firms acting as Nash-B followers. Equation 3 would apply for all U.S. Steel observations, and 3a would apply to the other firms in the industry.

The discussion of the changes in market shares and the political and legal environment of the steel industry suggest several other theories on how and when U.S. Steel behavior changed during this period. These hypotheses posit that U.S. Steel changed from a Stackelberg leader to a Nash-Bertrand actor at some point. First U.S. Steel did not expand as fast as the rest of the industry thereby losing market share. This suggests that at some point the optimal U.S. Steel strategy changed from Stackelberg leadership to Nash-Bertrand behavior. The actual point where the change from one strategy to another would be optimal may be determined by first the demand and cost conditions facing the firms and second by the legal and political environment of the industry.

As discussed above, theories on U.S. Steel behavior related to market share are suggested by Stigler (1965), Parsons and Ray (1975), and Gaskins (1972). These theories are consistent with the hypothesis that U.S. Steel shifted from Stackelberg to Nash-Bertrand in the 1930s when the industry was in a depression. Essentially, U.S. Steel had lost so much market share that it could no longer sustain itself as a Stackelberg leader. Thus, one variant of this theory is that the firm returned to Stackelberg behavior in the 1940s, 1950s, and 1960s, when the industry was again prosperous. Another hypothesis is that U.S. Steel permanently switched from Stackelberg to Nash-Bertrand in 1931.

Some scholars posit that changes in the legal and political environment led to changes in U.S. Steel behavior. One theory suggests that the abolition of the Pittsburgh Plus system moved U.S. Steel from Stackelberg to Nash-Bertrand behavior in 1924. Another theory posits that the elimination of the whole Basing Point Pricing system moved the firm away from Stackelberg behavior in 1948 (Carlton, 1983).

The economic and regulatory changes of the 1960s also present testable hypotheses on U. S. Steel behavior. Possibly, the increase in imports beginning in 1959 changed U.S. Steel from Stackelberg to Nash-Bertrand behavior (Mancke, 1968; Rippe, 1970). Another hypothesis is that U.S. Steel made the switch in 1963 after President John F. Kennedy put pressure on its pricing policy (McConnell, 1963).

Table 3 summarizes these theories and their implication for U.S. Steel behavior. The exact setups for these hypotheses are developed below, when the empirical demand and supply models are explained and estimated.

Empirical Model

Buyer Behavior- Demand

Following Berry, Levinsohn, and Pakes (1995), the demand side of the market can be depicted by the following formulation. Assume buyer *i* derives utility from buying or using a unit of steel firm *j*'s product in year *t*:

$$u_{ijt} = (y_{it} - p_t)\,\alpha + X_{jt}\,\beta + \zeta_{jt} + \mu_{ijt}. \qquad (4)$$

Here, u_{ijt} is the utility of buyer *i* from using a unit of firm *j*'s steel in year *t*; y_{it} is buyer *i*'s income in year *t*; p_t is the price of steel in year *t*; X_{jt} is the vector of firm *j*'s known product characteristics in year *t*; α is the parameter for the price-income function; β is a vector of parameters depicting the impact of known firm *j* product characteristics on the buyer's utility; ζ_{jt} depicts the product characteristics not accounted for in the model, and μ_{ijt} is a residual representing the buyer characteristics.

Additionally, the BLP model includes the steel consumed by users but not purchased from the steel companies. One can think of this statistic as the steel consumed during the period *t* but not replaced by new steel. It can be viewed as the depreciation of the stock of steel in the economy. This concept can be depicted by this equation,

$$u_{0t} = (y_{it})\,\alpha + \mu_{i0t}. \qquad (4a)$$

Consumers who choose not to buy new steel products can be viewed as the users of what other modelers call the outside good. Since none of this steel is bought, current price does not impact on the utility of its use, and the firm product characteristics do not matter. How I obtain and develop the data for this part of the model is described in section 5a. Given the extreme value residual distribution and the above utility function, the market share of a firm *j*'s good can be modeled as follows:

$$S_{jt} = \exp(u_{jt}) / (1 + \Sigma \exp(u_{kt})), \qquad (5)$$

u_{jt} being the right hand side of equation (4). (See Nevo 2000; Rasmussen 2007; Train 2009.) The numerator represents the utility to buyers of firm or firm group *j*'s product, while the summation in the denominator depicts the strengths of the other firm or firm group products, the one in the denominator representing the outside good with u_{0t} being set equal to zero.

This equation can be estimated by the logit model (Train, 2009), but there are difficulties with its application to the mid-20th century steel industry. In the logit model, the demand elasticity is a direct function of price, the higher the price the higher the demand elasticity. While there is a certain logic to this relationship, it may not hold in many product markets. Implicit in the logit model is the simplified view of the goods used by the buyer whereby her desire for a good is totally tied to the cost of obtaining it, that is its price, and not idiosyncratic to the nature of the good. In many preference structures, unpopular low priced goods with low market share are attractive only to price-conscious consumers.

Another problem concerns cross-elasticity. With the logit model, the cross elasticity depends on the market share and the price of the second good. Again, the heterogeneous nature of the substitution and complementarities of the good is not taken into account. Often a given good may have a high cross elasticity with a low priced good with a low market share.

There are three solutions to these problems: the Vertical Differentiation model, the Generalized Extreme Value (GEV) model, and the Mixed Logit model (Berry, 1994; Train, 2009). With the first two models, the researcher depicts the substitution and complementarity situations in the model using her knowledge of the market. The third method takes into account buyer characteristics; using them to ferret out the substitution and complementarity patterns.

Since it is difficult to ascertain the substitution and complementarity patterns, I use the third model. Berry, Levinsohn, and Pakes (1995) suggest a variation on this model that seems especially amenable to the steel industry. It is called the BLP model. (See Berry, 1994; Berry, Carnall & Spillar, 2006; Nevo, 2003; Nevo, 2001; Rasmusen, 2007.) The BLP approach starts with equation (4)

$$u_{ijt} = (y_{it} - p_t)\,\alpha + X_{jt}\,\beta + \zeta_{jt} + \mu_{ijt}. \qquad (6)$$

Then, it puts structure on the μ_{ijt}. I posit that a vector of buyer attributes affects the utility of buyer *i* for a given firm's product. However, I do not have good data on these attributes. Therefore, I add vectors of random variables, v_{jit}, to account for these unknown buyer characteristics. Following Berry, Levinsohn, and Pakes (1995), I assume that these buyer attributes can be depicted by variables the individual observations of which are drawn from a normal distribution about zero with a two unit 95 percent value interval. These draws reflect the buyer preference differences for given firms, and they partly reflect the influence of the firm characteristics on the decision of given buyer *i* to purchase the firm's product. The draws are multiplied by the price and a subset of the firm characteristics. Thus, they influence both α_i, the impact of price, p_t, and β_i, the impact of firm product characteristics on the utility of the firm's product. Accounting for buyer attributes, then, results in this equation,

$$u_{ijt} = (y_{it} - p_t)\,\alpha_i + X_{jt}\,\beta_i + \zeta_{jt}. \qquad (6a)$$

Here, the parameters, α_i and β_i, are different for each individual buyer, being denoted as follows:

$\alpha_i = [\alpha_0 + \sigma_p \Sigma v_{ipt}]$, and

$\beta_i = [\beta_0 + \sigma_k \Sigma v_{ijt}]$.

Here α_0 and β_0 are the means of the impacts of Steel Price and the other product characteristic variables, while σ_p and σ_k are parameters that show the difference in the impacts of the product variables on different buyers. The latter are often called the standard deviation variables. These variables are the products of the draws from the normal distribution, v_{ipt} and v_{it}, and the firm characteristic variables, $(y_{it}-p_t)$ and X_{jt}. The draws depict the differing attributes of buyers. This leads to the following specification:

$$u_{ijt} = (y_{it} - p_t) [\alpha_0 + \sigma_p \Sigma v_{ipt}]+ X_{jt} [\beta_0 + \sigma_k \Sigma v_{ijt}] + \zeta_{jt}. \qquad (6b)$$

For estimation's sake, this expression can be reconfigured as follows:

$u_{ijt} = \delta_{ijt} + \mu_{pijt}$, where

$\delta_{ijt} = (y_{it} - p_t) \alpha_0 + X_{jt} \beta_0 + \zeta_{jt}$, and

$$\mu_{ijt} = (y_{it} - p_t) [\Sigma v_{ipt}]\sigma_p + X_{jt} [\Sigma v_{ijt}]\sigma_k. \qquad (6c)$$

Here, the second term, μ_{pijt}, contains the vectors, consisting of the parameters, σ_p and σ_k, along with the variables, v_{ipt} and v_{it}, representing the distribution of the buyer attributes. This allows the impacts of firm characteristics to vary with different buyers. Since this equation does not have a closed form, the model can only be estimated by a simulation technique.

A second problem is the endogeneity between the steel price and market share; this can be solved by the use of instrumental variables for p_t. (The formulation for this instrumental equation is described below.) To show how this equation can be used to test the above discussed hypotheses, I now examine the price equation.

Price Equation

The above formulations of prices (equations 3 and 3a) are now used to estimate price equations for this model. To see how this can be done, I start with this price equation,

$$p_t = MARG_{jt} + MC_{jt}, \quad j = 1, 9. \qquad (7)$$

Here $MARG_j$ equals the firm j's markup over marginal cost (MC_j) as depicted by equations 2, 2a, 3, and 3a depending on the type of firm behavior specified. Estimates based on the parameters of the firm demand models are used to compute these margins. For a Nash-Bertrand firm (or a Stackelberg follower), the mark up in the price equation is

$$MARG_{jt} = - S_j /[\vartheta S_j/\vartheta p_j]. \tag{7a}$$

For the Stackelberg leader, the markup is

$$MARG_{jt} = - S_L /[\vartheta S_L/\vartheta p_L]+ \Sigma S_{fj} \{[\vartheta S_{fj}/\vartheta p_L]/[\vartheta S_L/\vartheta p_L][\vartheta S_{fj}/\vartheta p_{fj}]\}. \tag{7b}$$

To estimate these equations, I first use the parameter results from the demand equation to compute the margin ($MARG_{jt}$), this statistic being calculated from equations 2, 3a, and 3b.

I, then, add some reasonable marginal cost components, including input prices. The major steel production inputs were coal, iron ore, scrap steel, and labor; thus, I use the following prices: for coal, P_{Ct}, iron ore, P_{IRt}, scrap steel, P_{SSt}, and labor, $WAGE_t$. To account for economies or diseconomies of scale, the firm production quantity, q_t, is included in the model. I also add a Time Counter, *TIME*, to take into account technological and institutional changes. Therefore, the price-markup equation would be

$$p_t - MARG_j = \alpha_0 + \alpha_1 q_{jt} +\alpha_2 TIME_t +\alpha_3 P_{Ct} +\alpha_4 P_{IRt} + \alpha_5 P_{SSt} +\alpha_6 WAGE_t. \tag{7c}$$

Given the sample, firm observations over a 53 year period, I have a panel data set. To account for this situation, I use a fixed effect model. To do this, I add dummy variables first for eight of the nine firms or firm groups ($FDUM_j$) and second for four of the five decades in the sample ($Decade_m$). Time enters this model in two ways: the counter-variable which reflects changes in the firm technology, and the decade dummies represent changes in the entire market. The definitions of and data sources for these variables are given in Table 4.

Since quantity (q_{jt}) is determined simultaneously with price (p_t), an instrumental variable technique is used with q_{jt} being the dependent variable in the instrumental variable equation. The instruments in this equation consist of the other independent variables in 7c and some of the exogenous demand variables in 6b.

To determine the difference between the hypotheses of various theories, I use an encompassing test (Davidson & MacKinnon, 1981). I compare the explanatory power of the equations implied by one behavioral theory, say Stackelberg with another theory, Nash-B. Equation (7c) is estimated under different behavior assumptions, and a test is made to see which one has the higher explanatory power. This reformulation of the model clarifies the procedure,

$$p_t = 1*MARG_{jhkt} +\alpha_0 + \alpha_1 q_{jt} +\alpha_2 TIME_t +\alpha_3 P_{Ct} +\alpha_4 P_{IRt} + \alpha_5 P_{SSt} +\alpha_6 WAGE_t, hk=1, 2. \tag{7d}$$

Here $MARG_{j1}$ is the margin under hypothesis 1 (Nash_B, equations 2 and 3b), and $MARG_{j2}$ is the margin under hypothesis 2 (Stackelberg, equation 3). *J* tests (described below) are, then, used to determine which of these two models has the highest explanatory power.

Data and Estimation Technique

Data

In this section, I first discuss the data set; then, I summarize the estimating model, and last I describe the particulars of the estimation technique. Other than market share, the demand and price model data (outlined in Table 4) consist of firm product characteristics, input prices, and the randomly distributed variables reflecting buyer attributes. With the exception of some market shares, the data for these variables are available for the entire sample (1920-1972). The market share data consist of the shares for the eight largest firms are often called the “Big Eight”, and that for the industry fringe including imports: the source being the American Iron and Steel Institute (1910-1975). For these variables all the necessary data are available except for the market share of National Steel for the years, 1920-1929 and 1938-1945 (see Table 2). The fringe of small producers (including imports) is assumed to be another firm, and consequently there are nine firms or firm groups for each year except for years when National Steel data are not available. In those years, there are only eight firm observations, National Steel data being aggregated with the fringe output.

Another data problem is the outside good. To find the data for this variable, I posit that the people who are not buying steel are still using it. I assume the stock of steel was depreciated at the rate of 7 per cent per year by these people using the metal but not buying any. This percentage is the average ratio between the capital consumption allowance (the macroeconomic measure of depreciation) and GDP for the United States between 1947 and 1972. I have also assumed that the total stock of steel in the United States consisted of the entire output produced since 1880 minus the amount resulting from the deterioration of seven percent of the stock in each year. When I varied both the deterioration rate and the beginning year, the stock for each year did not change that much. Very little steel was produced before 1880, and the resulting stock in any given year was not sensitive to the variation in the depreciation between 10 and 1 percent. (Variations in the depreciation rates do not significantly affect the posited consumption level of the outside good and the theoretical amount of steel in the economy. Higher depreciation rates mean that the posited amount of steel available in a year would be smaller; this would counteract the positive impact of these higher depreciation rates on the amount of the outside good, the estimate of steel being used but not replaced.)

The major product characteristic for which firm data are readily available is location. Steel has relative high transportation costs, and steel plants are not that mobile; thus, often the location of a steel plant determines the buyer decision on which company to patronize. The average location of each firm is represented by the weighted averages of the longitudes ($FLong_j$) and latitudes ($Flat_j$) of its plants, the weights being plant capacity divided by the total firm capacity for given years (American Iron and Steel Institute, 1910-1975).

To portray the characteristics of the firms other than location, a firm dummy variable is used for seven of the eight largest firms and the aggregate fringe production. U. S. Steel is used as the base firm without a dummy. The firm dummy portrays the difference in unaccounted-for product characteristics between the firms.

Over time, changes in buyer perceptions led to changes in the utility obtained by buyers from the products of given firms. To depict these changes a time counter, Time, is added to the model. Many unobserved variables affect the outcome of the competitive process in the steel industry, and they are depicted by the symbol, ζ_{jt}.

To better appreciate the model, one must further examine the sample. There are 53 years, each with either eight or nine observations representing the eight largest steel companies as well as the competitive fringe. This specification gives us 459 observations, eight or nine for each of the 53 years. As stated above, observations are available for all variables except for market share for National Steel in some years.

I now depict the buyers as best I can with the available information. For each of the three firm variables, *Steel Price*, $FLong_j$, and $Flat_j$, I draw 100 random observations from normal distributions with a mean of zero and a 95 per cent range from +1 to -1. Then, I multiply the draws, v_{ipt}, v_{i1t}, and v_{i2t}, by the three firm demand variables, *Steel Price*, $FLong_j$ and $Flat_j$, for each of the 53 years. Then, I take a random sample of 40 from each yearly distribution. These interaction variables are included in the firm market share equation.

Summary of the Estimating Equations

Here the estimating models for firm market share and price are outlined. The demand equation model can be represented as follow:

$$S_{jt} = \exp(u^*_{jt}) / (1 + \Sigma \exp(u^*_{kt})).$$

Here this equation can be operationalized as follows:

$$S_{jt} / S_{0t} = \exp(u^*_{jt}),$$

where S_{0t} is the share of the outside good. (For the derivation of this formula, see Berry 1994; Berry, Levinsohn & Pakes, 1995). This formulation can be converted to the following:

$$\ln (S_{jt} / S_{0t}) = u^*_{jt}$$

where $u^*_{jt} = - p_t\, \alpha_0 + FLong_{jt}\, \beta_{01} + FLat_{jt}\, \beta_{02} + FDUM_{Bethehem}\, \beta_{03} + FDUM_{Republic}\, \beta_{04}$

$+FDUM_{National}\, \beta_{05} + FDUM_{Jones\&Laughlin}\, \beta_{06} + FDUM_{Armco}\, \beta_{07} + FDUM_{Youngstown}\, \beta_{08}$

$+ FDUM_{Inland}\, \beta_{09} + FDUM_{Fringe}\, \beta_{10} + Time\ \beta_{11} + \zeta_{jt},$

$$+ -p_t[(1/40)\Sigma_1^{40}\, v_{ipt}]\sigma_p + FLong_{jt}\, [(1/40)\Sigma_1^{40} v_{i1t}]\, \sigma_1 + Flat_{jt}[(1/40)\, \Sigma_1^{40}\, v_{i2t}]\sigma_2 \qquad (8a)$$

or

$$u^*_{jt} = \delta^*_{jt} + \mu_{pijt},$$ where δ^*_{jt} is δ_{ijt} with the y_{it} cancelled out.

For this model, y_{it} cancels out in the market share equation, and the model includes u^*_{jt} and δ^*_{jt} instead of u_{jt} and δ_{jt}.

The price equation depicting firm supply is, then,

$$p_t = 1{*}MARG_{jhk} + \alpha_0 + \alpha_1 q_{jt} + \alpha_2 \, TIME + \alpha_3 P_{Ct}, + \alpha_4 P_{IRt} + \alpha_5 P_{SSt}, + \alpha_6 WAGE_t, \quad h=1, 2. \qquad (8b)$$

Here $MARG_{jhk}$ is calculated from the markup formula for the two hypothesized forms of behavior, Nash-Bertrand, *hk* equals 1, and Stackelberg, *hk* equals 2. These equations are estimated using the below instrumental variable equations for p_t on the demand side and q_{tj} for the firm supply side.

$$\begin{aligned} p_t = {} & \theta_0 + \theta_1 FLong_{jt} + \theta_2 FLat_{jt} + \theta_3 FDUM_{Bethehem} + \theta_4 FDUM_{Republic} + \theta_5 FDUM_{National} \\ & + \theta_6 FDUM_{Jones\&Laughlin} + \theta_7 FDUM_{Armco} + \theta_8 FDUM_{Youngstown} + \theta_9 FDUM_{Inland} + \theta_{10} FDUM_{Fringe} \\ & + \theta_{11} Time + \theta_{12} P_{Ct} + \theta_{13} P_{IRt} + \theta_{14} P_{SSt} + \theta_{15} WAGE_t + v_{tj} \qquad (8c) \end{aligned}$$

and

$$\begin{aligned} q_{jt} = {} & \pi_0 + \pi_1 FLong_{jt} + \pi_2 FLat_{jt} + \pi_3 FDUM_{Bethehem} + \pi_4 FDUM_{Republic} + \pi_5 FDUM_{National} \\ & + \pi_6 FDUM_{Jones\&Laughlin} + \pi_7 FDUM_{Armco} + \pi_8 FDUM_{Youngstown} + \pi_9 FDUM_{Inland} + \pi_{10} FDUM_{Fringe} \\ & + \pi_{11} Time + \pi_{12} P_{Ct} + \pi_{13} P_{IRt} + \pi_{14} P_{SSt} + \pi_{15} WAGE_t + w_{tj} \qquad (8d) \end{aligned}$$

with v_{tj} and w_{tj} being residuals. This formulation is very similar (but not identical) to that of the two Stage Least Squares model used to estimate conventional product supply and demand equations. It is different in that the price and quantity reduced form models do not include all firm price and quantity exogenous variables. This is the standard practice with BLP models.

Estimation Technique

This paper's first goal is to estimate equations (8a and 8b). Since equation 8a is not a closed form, an iterative estimation procedure has to be used (Berry, Levinsohn & Pakes, 1995; Nevo, 2000; Rasmussen, 2007). One starts this procedure with initial parameter values for u^*_{jt} and δ^*_{jt}. For the former, one can use a logit model to estimate a predicted value for δ^*_{jt}. Since price is endogenous, an instrumental variable procedure is required. In additional to the exogenous demand variables, the prices for the following important inputs into steel manufacturing are used as instruments: coal, iron ore, scrap steel, and steel labor (shown in equations 8c).

Given an initial parameter estimates for the predicted value of δ_{ijt}, a nonlinear search technique can be used to estimate the parameters of μ_{pijt}. From the first estimates of the μ_{pijt} parameters, a new value for δ^*_{ijt} is computed. New δ^*_{ijt} parameters are estimated and used to find new values for the μ_{pijt} parameters by the nonlinear search method. From there, a new δ^*_{ijt} is computed from the new μ_{pijt} parameters. The procedure is repeated until the change in residual reaches a minimal level which comes close to maximizing the likelihood function. This is called the contraction method (Berry, Levinsohn & Pakes, 1995).

For the price equation, the above-described instrumental variable estimation model is used because q_t, the quantity of steel, is endogenous.

Results

Demand

The results of the demand model estimation method are shown in Table 5. The coefficients for the mean parameter values and the standard deviations, v_p, v_{long}, and v_{lat}, are all significant, except for the mean for latitude ($Flat_{jt}$) and the standard deviations for steel price (p_t) and longitude ($FLong_{jt}$). The steel price mean has the expected negative sign, and it is highly significant. The insignificant coefficients are included in the model because zero standard deviation coefficients for Steel Price and Longitude are not inconsistent with economic theory. Neither is the insignificant coefficient for the mean of latitude. Essentially, it is reasonable that the mean impact of the $Flat_j$ could be not significantly different from zero, while there is a significant variation in the reactions of different customers to geographic latitude. The significant negative coefficient for $FLong_j$ indicates that other things equal the farther east the firms were located the greater the demand for their steel. (As one goes east in North America, longitude numbers decrease.) The significant standard deviation parameters indicate that these effects varied for different users. The positive and significant coefficient for Time, the time counter variable, indicates that over time steel demand rose. The dichotomous variables for the smaller steel firms and the competitive fringe are negative and significant. This likely reflects short run capacity limitations rather than any ingrained buyer preference for the products of U.S. Steel.

Price Equation

Table 6 displays the results of two different versions of the price equation for my model. One is for the sequence where all firms, including U.S. Steel, acted in a Nash-Bertrand fashion, and the other is for a sequence of events when U.S. Steel permanently switched from the Stackelberg behavior model to Nash-Bertrand in 1931. (The markup of price over marginal cost is determined by demand parameters estimated above and firm behavior. To calculate the margins (in 8b), one feeds these demand parameters into equations 2a, 3, or 3a depending on the hypothesis being tested.) As discussed below, the latter model is one of the two most likely; that is why it is displayed.

The estimated parameter values in these price equations are plausible. All the input prices have positive coefficients, and three are significantly above zero on a one tail test. In both models, the Time counters are above zero, and the quantity variables are not significantly different from zero on a two tail test. The sign could be either negative or positive for either of these variables.

These two equations seem quite plausible as do the equations arising from the other behavioral models. I now discuss the results of the markup model estimates and their implications for firm behavior.

Behavioral Hypotheses

Here, I use the price model results to determine what behavioral pattern best fits the data. As stated above, Table 6 shows estimates of the price equations under two sets of assumptions: (1) Nash-Bertrand behavior by all firms and (2) the model combining the Stackelberg behavior by U.S. Steel for part of the sample (1920-1930) with Nash-B for the rest of the sample and for the whole sample for the other firms. As described below, I test several other hypotheses on the behavior of U.S. Steel. To do this, I use J-tests to compare the explanatory power of different sequences of behavior of U.S. Steel (Davidson & MacKinnon, 1981). To set up a J test, one estimates two models with two different non-encompassing sets of variables. Then, one adds the predicted value of one of the models to the other. Using the t value for coefficient of this expected value variable, one determines whether the second model adds explanatory power to the first. As is shown below, the results can be ambiguous in two situations; first, neither of the two models adds to the explanatory power of the other with both *t* values being insignificant. Second, both t values can be significant implying each model adds to the explanatory power of the other. The most desirable result is that one *t* or *J* value is significant while the other is not; this indicates that one model unambiguously adds explanatory power to the other.

Tables 7 and 8 display the test results between pairs of sequences of U.S. Steel and other firm behavior patterns. Table 7 shows a set of *J* tests comparing the basic Nash-B model whereby all firms acted in a Nash-Bertrand manner throughout the sample to several alternative patterns of behavior.

The first comparison in Table 7 is between the two Nash-Bertrand hypotheses: one with a competitive fringe setting price equal to marginal cost, and one with the fringe acting like the rest of the industry in a Nash-B fashion. Two *J* tests are used: one for the hypothesis that the competitive fringe model adds to the explanatory power of the Nash-Bertrand fringe model, and one for the assertion that the latter fringe model adds to the explanatory power of the first model. As shown in the table, the tests indicate that neither model adds explanatory power to the other. The *t* values or J tests are respectively -0.188 and 0.187.

I now proceed on the assumption that Nash-Bertrand behavior on the part of the fringe is the more likely hypothesis. Theory would predict that the fringe firms, most of whom have some product differentiation advantage, would behave as Nash-Bertrand competitors, pricing at a point where they enjoy some margin over marginal cost. Given this reasonable supposition as well as the ambiguous results, I proceed on the assumption of the fringe acting in a Nash-Bertrand manner.

As shown in Table 7, a second set of J tests compares (1) the model with all firms (including U.S. Steel and the fringe) acting in a Nash-Bertrand manner with (2) the Stackelberg model with U.S. Steel performing as a leader throughout the sample and with the rest following Nash-B strategies. The J tests are both insignificant (on a two tail test) indicating that neither behavioral hypothesis adds to the exploratory power of the other. The statistical results are again inconclusive.

As discussed above, it is likely, however, that U.S. Steel changed its behavior at some point during the period. The literature suggests several hypotheses. One is that during the depression, 1930-1940, the industry became more competitive. This change could have arisen from several developments in addition to the drop in demand brought about by hard times. (They are discussed in sections 2 and 3, above.) To examine these hypotheses, I set up two sequences for U.S. Steel: one hypothesizes a change from

Stackelberg to Nash-Bertrand in the 1930's and a reversion to the Stackelberg behavior for the rest of the sample. The other posits that U.S. Steel became a Nash-Bertrand firm in 1931 and remained that way for the rest of the sample.

As shown in Table 7 (comparison 3), the *J* test results support both the hypothesis that all the firms acted in a Nash-Bertrand fashion throughout the sample and the theory that U. S. Steel switched from Stackelberg leadership to NashB only in the 1930's. *J* tests indicate that both models increase the explanatory power of the other; this implies inconclusive results.

A comparison between the hypothesis with Nash-Bertrand behavior for all firms in all years and the sequence of U.S. Steel permanently switching from Stackelberg to Nash-B behavior in 1931 shows that the predicted value of the latter sequence adds to the explanatory power of the former, but the predicted value for Nash-B does not add power to the 1931 permanent switch model.

Comparisons 5, 6, 7, and 8 in Table 7 contrast the Nash-B hypothesis with a set of other hypothetical behavior sequences whereby U.S. Steel switched from Stackelberg to Nash-Bertrand behavior at different dates as posited by different theories of steel company behavior. Two of these theories are the basing point pricing hypotheses whereby U.S. Steel switched to Nash-B behavior in 1924 and 1948 respectively. For the comparison between Nash-B and 1924 the results are inconclusive, but *J* tests do indicate that the 1948 sequence adds explanatory power to the Nash-B model without the Nash-B model adding to the power of the 1948 change sequence.

Comparisons 7 and 8 indicate that there are no significant differences in explanatory power between the Nash-B sequence and first, the theory whereby U.S. Steel behavior changed in 1960 with the increase in imports, and second, the sequence with the change occurring in 1963 with the Kennedy intervention in steel pricing.

Table 8 compares the sequence with U.S. Steel permanently switching from Stackelberg to Nash-B behavior in 1931 with six other behavioral sequences. In comparison 1, the permanent 1931 change model is contrasted to the sequence with U.S. Steel acting as a Stackelberg firm throughout the sample. The J tests indicate that the 1931 change sequence is more likely with a t value of 40.372. In comparison 2, when the permanent 1931 sequence is compared with that of U.S. Steel switching to Nash-B from Stackelberg in the 1930s and returning in 1940, the permanent U.S. Steel change improves on the temporary change model, but the latter does not improve on the other.

In comparison 3 where the 1931 permanent change model is compared to the 1924 basing point price model, the former adds to the explanatory power of the latter, but the 1924 model does not add to the 1930s permanent change model.

When the permanent 1930s change model is compared to the 1948 basing point price model in comparison 4, neither model adds power to the other. This result may arise from the correlation between the two sequences. The 1930s model has only 18 observations (out of 459) different from 1948 basing point model.

In the Table 8 comparisons 5 and 6, the 1930s permanent change model is compared to sequences whereby U. S. Steel switches to Nash-Bertrand behavior respectively in 1960 due to the increase in imports, and 1963 due to the Kennedy intervention. *J* tests indicate that the 1930s sequence adds explanatory power to both the 1960s models, but in neither case does the reverse occur. Appendix I shows the results of other sequence comparisons.

Thus, the most likely sequences are those where U.S. Steel permanently went from a Stackelberg leadership role to a Nash-Bertrand player in 1931 and 1948.

Conclusion

This paper uses the parameters from the BLP demand model to determine steel firm behavior in the sample period, 1920-1972. It estimates the price-margin model under different assumptions about firm behavior. In the two most likely sequences of events, U.S. Steel acted as a Stackelberg leader early in the period and followed a Nash-Bertrand strategy later in the sample. These two most likely sequences disagree on the date of the change: one positing 1931 and the other, 1948.

This paper's project has succeeded in arriving at not unreasonable results. The above findings that U.S. Steel switched from Stackelberg to Nash-B behavior in either 1931 or 1948 are consistent with the previous literature on steel firm behavior. This indicates that the BLP approach has the potential for modeling and testing more complicated behavior patterns.

Consequently, it is evident that reasonable BLP or similar models can be constructed from the data available on the steel industry. The industry in this period had some quite good information but also some data problems. Thus, there may be data limitations for which new solutions are needed. Even with these limitations, the plausible results of this paper bode well for historians using similar data sets on other industries or markets. Apparently, the BLP model is not only an effective way to portray contemporary markets but also a way to analyze historical situations.

Table 1. The Breakdown of Sector Steel Usage by Percentage, 1926, 1935, 1950, and 1965.

Buyer Industry	1926	1935	1950	1965
Steel Production (tons)	54,090,000	38,184,000	96,836,000	131,462,000
Automobiles	14.5	25.0	21.7	26.5
Construction	19.5	14.5	17.1	28.9
Railroads	23.5	6.5	6.7	4.2
Containers	4.0	11.5	8.9	7.3
Machinery	4.0	4.0	8.0	15.8
Exports	5.0	3.5	3.9	2.7
Others	29.5	35.0	33.7	14.6

Source: Rogers (2009)

Table 2. The Market Share of the Eight Largest Steel Firms and the Competitive Fringe Including Imports for Selected Years in the Sample.

Steel Firm/ Year*	1920	1930	1940	1950	1960	1970
US Steel	33.15	25.67	23.29	21.71	16.23	13.78
Bethlehem Steel	3.51	8.15	10.87	10.43	9.48	9.04
Republic	1.69	3.59	6.21	5.90	4.58	4.32
National Steel	NA**	1.34	NA**	3.21	3.42	4.33
Jones & Laughlin	3.98	3.32	3.40	3.41	3.43	3.06
Armco	0.66	1.20	2.13	2.73	2.95	3.47
Youngstown Sheet & Tube	1.88	2.49	2.91	2.85	2.48	2.26
Inland Steel	1.38	2.11	2.95	2.53	3.04	3.10
Fringe* **	26.83	15.22	16.33	14.75	15.43	20.24
Outside Good****	26.92	36.91	31.93	32.46	38.95	36.41

Source: Rogers (2009)

* The denominator in these market share figures in the total of the steel used in the United States which consists of the production of the "Big Eight", the Fringe, and the Outside Good.

** Data are not available for National Steel for some years. For those years, its data are included in the fringe.

*** This is the market share of the smaller American firms combined with imports.

**** This is called the outside good which is an estimate of the total American use of steel accounted for by the steel used up by consumers but not replaced by new product.

Table 3. The Hypotheses on U.S. Steel Behavior to be Tested.

Hypotheses on U.S. Steel Behavior	Years U.S. Steel followed a Stackelberg Strategy	Years U.S. Steel followed a Nash-Bertrand Strategy	References
Only Nash-Bertrand	0	1920-1972	
Only Stackelberg	1920-1972	0	
Switch from Stackelberg to Nash-Bertrand, 1931 and return	1920-1930, 1940-1972	1931-1939	Stigler, 1965 Gaskins, 1972
Permanent Switch from Stackelberg to Nash-Bertrand, 1931	1920-1930	1931-1972	Stigler, 1965 Gaskins, 1972
Switch from Stackelberg to Nash-Bertrand, 1924 on the Ban of Pittsburgh–Plus Pricing	1920-1924	1925-1972	Carlton, 1983
Switch from Stackelberg to Nash-Bertrand, 1948 on the Ban of All Basing Point Pricing	1920-1948	1949-1972	Carlton, 1983
Switch from Stackelberg to Nash-Bertrand on the Increase in Imports, 1959	1920-1959	1960-1972	Rippe , 1970 Mancke, 1968
Switch from Stackelberg to Nash-Bertrand with the Kennedy Pricing Pressure 1963	1920-1962	1963-1972	McConnell, 1963

Table 4. The Product and Buyer Characteristic Variables.

The Firm Characteristic Variables:

Steel Price (p_t)*= deflated composite steel-price index compiled by American Iron and Steel Institute (1910-1975).

$FLong_{jt}$ = Σ w_{jh}*PlantLong $_{jh}$, where PlantLong $_{jh}$ equals the longitude of plant $_{jh}$ in $firm_j$, and w_{jh} equal the ratio of the steel capacity of plant $_{jh}$ to the capacity of $firm_j$, j= 1, m firms, h = 1, k_j plants,

Flat $_{jt}$ = Σ w_{jh}*PlantLat $_{jh}$, where $PlantLat_{jh}$ equals the latitude of plant $_{jh}$ in $firm_j$ and w_{jh} equal the ratio of the steel capacity of plant $_{jh}$ to the capacity of $firm_j$, j= 1, m firms, h = 1, k_j plants, and

FDUM $_j$ = 1, if firm j (other than U.S. Steel) and zero otherwise. These variables are also used in the Price equation.

Time = a time counter valued at 1 in 1920 and rising in yearly increments to 53 in 1972. This variable is also used in the Price Equation.

The Buyer Characteristic Variables:

v_{ipt} = the buyer interaction variable with Steel Price, derived by taking random sample values from a normal distribution with a mean 0 and a 95 per cent interval of -1 to 1. It is multiplied by p_t.

v_{ilongt}= the buyer interaction variable with FLong $_j$, derived by taking random sample values from a normal distribution with a mean 0 and a 95 per cent interval of -1 to 1. It is multiplied by $FLong_{jt}$.

v_{ilatt}= the buyer interaction variable with FLat $_j$ derived by taking random sample values from a normal distribution with a mean 0 and a 95 per cent interval of -1 to 1. It is multiplied by $FLat_{jt}$.

The Supply Variables*

q_t = Firm production quantity in year t. (Rogers 2009).

P_{Ct}*= Price Index for coal (U.S. Bureau of Mines 1960-73),

P_{IRt}*= Price Index for iron ore (***Iron Age*** 1916-75),

P_{SSt}*= Price Index for steel scrap (***Iron Age*** 1955-73),

$WAGE_t$*= Yearly Wage Income of steel production labor (U.S. Bureau of the Census, 1947-73), and

$Decade_m$ = Dummy Variable equaling one if the observation is in decade k and zero otherwise, m = 1930s, 1940, 1950s, and 1960-72.

* These variables are set in 1972 dollars. All the variables on this page are available for the years, 1920 to 1972. The dates on the sources only indicate their publication year -- not the years for which the data were available.

Table 5. Estimates of the Parameters of the Demand Model for the American Steel Industry, 1920-1972.

Dependent Variable: $\ln(S_{jt} / S_{0t}) = u^{*}_{jt}$, as shown in equation (8a)

Variable		Estimated Coefficients	Standard Errors	t Values
Means	Intercept	-0.1305		
	Steel Price (p_t)	-0.0149	0.0019	-7.989 **
	FLong $_{jt}$	-0.1601	0.0348	-4.600 **
	Flat $_{jt}$	0.0129	0.0693	0.186
	$FDUM_{Bethehem}$	-1.7834	0.2155	-8.276**
	$FDUM_{Republic}$	-2.1369	0.1166	-18.335**
	$FDUM_{National}$	-2.6199	0.1300	-20.153**
	$FDUM_{Jones\&Laughlin}$	-2.6679	0.1540	-17.322**
	$FDUM_{Armco}$	-2.4770	0.1543	-16.056**
	$FDUM_{Youngstown}$	-2.4601	0.0974	-25.267**
	$FDUM_{Inland}$	-1.9533	0.1719	-11.363**
	$FDUM_{Fringe}$	-0.3385	0.0897	-3.772**
	Time	0.0411	0.0044	9.308**
Standard Deviations				
	Steel Price (p_t)	-0.0008	0.0015	-0.514
	FLong $_{jt}$	0.0280	0.0414	0.676
	Flat $_{jt}$	1.3129	0.1169	-11.226**

Data sample 1920-1972, Number of Observations 459

Residual standard error: 0.3992 on 446 degrees of freedom
Wald test: 223.3 on 12 and 446 degrees of freedom, probability value: less than 2.2e-16

** Significance level 0.01
* Significance level 0.05

Table 6. Estimates of the Parameters of the Price Model for the American Steel Industry, 1920-1972, under Different Assumptions about Firm Behavior.

Dependent Variable: [p_t -1*$MARG_{jhk}$]. The margin is subtracted from price, as shown in equation (8b).

Variable	**Nash-Bertrand Model Coefficients**+	**U. S. Steel Switching from Stackelberg to Nash-Bertrand in 1930 Model Coefficients**+
Intercept	-0.8480	-68.5100
Steel Quantity (q_{jt})	0.0014	-0.000003
	(1.801)	(-0.003)
Time	2.1770	2.5400
	(6.724)**	(7.140)**
Price of Coal	0.8687	0.6617
	(3.673)**	(2.545)**
Price of Iron Ore	5.2570	4.8560
	(8.700)**	(7.313)**
Price of Scrap Steel	0.0337	0.1105
	(0.410)	(1.225)
Wage	0.0027	0.0030
	(1.754)*	(1.757)*

t Values are in parentheses below the coefficients.

Adjusted R^2	0.8946	0.8879
Wald test:	223.3	202.5
Probability Value:	< 2.2e-16	< 2.2e-16

** Significance level 0.01
* Significance level 0.05

+ The sample in this case is a panel consisting nine steel firms or groups for each year in series of 53 years. The Panel method used is the fixed effects method whereby I use dummy variables for each firm in the sample (except for U.S. Steel which is the base) and for each decade in the time series part of the sample (except for the 1920s period which is the base). The results for panel variables (for decades and firms) are not displayed.

Table 7. Comparisons of Some Different Firm Behavior Regimes by J Tests with Model 1 Being Nash-B with Nash-B Fringe

Comparison	Model 1	Model 2	J test for Model 1 Explaining Model 2	J test for Model 2 Explaining Model 1	Conclusion
1	**Nash-B with Nash-B Fringe**	**Nash-B Competitive Fringe**	-0.188	0.187	Inconclusive
2	**Nash-B with Nash-B Fringe**	**U. S. Steel Stackelberg, All Sample**	1.758	-1.332	Inconclusive
3	**Nash-B with Nash-B Fringe**	**U. S. Steel Switching from Stackelberg to Nash-B in 1931 And Return**	-3.482**	5.137**	Inconclusive
4	**Nash-B with Nash-B Fringe**	**U. S. Steel Switching from Permanently Stackelberg to Nash-B in 1931**	-0.209	9.728**	Model 2 stronger
5	**Nash-B with Nash-B Fringe**	**Basing point Pricing U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1924**	-3.857**	10.460**	Inconclusive
6	**Nash-B with Nash-B Fringe**	**Basing point Pricing U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1948**	-1.702	6.193**	Model 2 stronger
7	**Nash-B with Nash-B Fringe**	**Imports U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1960**	0.502	-0.662	Inconclusive
8	**Nash-B with Nash-B Fringe**	**Kennedy Intervention U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1963**	0.524	-0.574	Inconclusive

** Significance level 0.01 and * Significance level 0.05

Table 8. Comparisons of Some Different Firm Behavior Regimes by J Tests with Model 1 Being U. S. Permanently Switching from Stackelberg to Nash-B in 1931.

Comparison	Model 1	Model 2	J test for Model 1 Explaining Model 2	J test for Model 2 Explaining Model 1	Conclusion
1	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**U. S. Steel Stackelberg All Sample**	40.372**	-0.119	Model 1 stronger
2	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**U. S. Steel Switching from Stackelberg to Nash-B in 1931 and Returning in 1940**	11.730**	-0.167	Model 1 stronger
3	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**Basing point Pricing U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1924**	3.079**	-0.178	Model 1 stronger
4	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**Basing point Pricing U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1948**	0.289	0.023	Inconclusive
5	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**Imports U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1960**	3.562**	-0.110	Model 1 stronger
6	**U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1931**	**Kennedy Intervention U. S. Steel Permanently Switching from Stackelberg to Nash-B in 1960**	5.035**	-0.127	Model 1 stronger

** Significance level 0.01 and * Significance level 0.05

References

American Iron and Steel Institute (1910-1975). *Annual Statistical Report*. Washington DC: American Iron and Steel Institute.

Berry, S. T. (1994). Estimating discrete choice model of product differentiation. *RAND Journal of Economics*, 25, 2, 242-262.

Berry, S., M. Carnall, & P. Spillar (2006). Airline hubs: Costs, markups and the implications of customer heterogeneity. In Darin, L. *Advances in Airline Economics*. Amsterdam and Boston: Elsevier.

Berry, S., J. Levinsohn, & A. Pakes (1995). Automobile prices in market equilibrium. *Econometrica*, 63, 4, 841-890.

Berry, S., J. Levinsohn, & A. Pakes (2004). Differentiated products demand systems from a combination of micro and macro data: The new car market. *Journal of Political Economy*, 112, 1, 68-105.

Carlton, D. W. (1983). A reexamination of delivered pricing systems. *Journal of Law & Economics*, 26, 1, 51-70.

Comanor, W.S. & F. M. Scherer (1995). Rewriting history: The early Sherman monopolization cases. *International Journal of the Economics of Business,* 2, 2, 263-289.

Davidson, R. & J. G. MacKinnon (1981). Several tests for model specification in the presence of alternative hypotheses. *Econometrica*, 49, 781–793.

Dubé, J-P., J. T. Fox & C. Su (2012). Improving the numerical performance of static and dynamic aggregate discrete choice random coefficients demand estimation. *Econometrica*, 80, 5, 2231–2267.

Gaskins, D. W. (1971). Dynamic limit pricing: Optimal pricing under threat of entry. *Journal of Economic Theory,* 3, 306-22.

Hendel, I. & A. Nevo (2006). Measuring the implications of sales and consumer inventory behavior. *Econometrica*, 74, 6, 1637–1673.

Iron Age (1955-1973), 175-213.

Karlson, S. H. (1983). Modeling location and production: An application to U.S. fully-integrated steel plants. *Review of Economics and Statistics*, 65, 1, 41-50.

McConnell, G. (1963). *Steel and the Presidency, 1962*, New York: Norton.

Mancke, R. (1968). The determinants of steel prices in the U.S.: 1947-65. *Journal of Industrial Economics*, 16, 2, 147-160.

Nevo, A. (2000). Mergers with differentiated products: The case of the ready-to-eat cereal industry. *RAND Journal of Economics*, 31, 3, 395-421.

Nevo, A. (2001). Measuring market power in the ready-to-eat cereal industry. *Econometrica*, 69, 2, 307-342.

Nevo, A. (2000). Practitioner's guide to estimation of random-coefficients logit models of demand. *Journal of Economics & Management Strategy*, 9, 4, 513-548.

Nevo, A. (2003). New products, quality changes, and welfare measures computed from estimated demand systems. *Review of Economics and Statistics*, 85, 2, 266-275.

Parsons, D. O., & Ray, E. J. (1975). The United States steel consolidation: The creation of market control. *Journal of Law and Economics*, 18, 1, 180-219**.**

Rasmusen, E. (2007). The BLP method of demand curve estimation in industrial organization. *Manuscript* (http://www.rasmusen.org/published/blp-rasmusen.pdf)**.**

Rippe, R. D. (1970). Wages, prices, and imports in the American steel industry. *Review of Economics and Statistics*, 52, 1, 34-46.

Rogers, R. P. (2009). *An economic history of the American steel industry*. London and New York: Routledge.

Rogers, R. P. (1989). The measurement of conjectural variations in an oligopoly industry. *Review of Industrial Organization*, 4, 1, 39-65.

Rojas, C. (2008). Price competition in U.S. brewing. *Journal of Industrial Economics*, 56, 1, 1-31.

Stigler, G. J. (1965). The dominant firm and the inverted umbrella," *Journal of Law and Economics*, 8, 167-172.

Train, K. (2009). *Discrete choice methods with simulation.* New York: Cambridge University Press, 2nd ed.

U.S. Department of Commerce, Bureau of Census (1919-75). *Census of Manufactures 1919-1972.*

U.S. Department of the Interior, Bureau of Mines (1960, 1964, 1966, 1970, and 1973). *Minerals Yearbook: Fuels.*

United States v. *United States Steel Corporation et al.*, U. S. 417(1920).

Appendix I. Comparisons of Some Different Firm Behavior Regimes by J Tests

Model /Model

J Test for Difference between the Below Regime+

	Nash-B with Nash-B Fringe	U. S. Steel Switching from Stackelberg to Nash-B and return	U. S. Steel Switching from Stackelberg to Nash B Permanently
Nash-B with Nash-B Fringe		-3.482** 5.137**	9.728** -0.209
Nash-B Competitive Fringe	-0.188 0.187		
U. S. Steel Stackelberg, All Sample	1.758 -1.332	-10.51** 11.91**	40.372** -0.119
U. S. Steel Switching from Stackelberg and Returning in 1941	5.137** -3.482**		11.730** -0.167
U. S. Steel Switching from Stackelberg to Nash-B Permanently in 1931	-0.209 9.728**	-0.167 11.730**	
Basing Point Pricing U. S. Steel Switching from Stackelberg to Nash-B Permanently in 1924	-3.857** 10.460**	-2.282* 8.831**	3.079** -0.178
Basing Point Pricing U. S. Steel Switching from Stackelberg to Nash-B Permanently in 1948	1.702 6.193**	2.561* 16.280**	0.283 0.023
U. S. Steel Switching from Stackelberg to Nash-B Permanently in 1960	0.502 -0.667	-6.751** 15.280**	3.562** -0.110
Basing Point Pricing U. S. Steel Switching from Stackelberg to Nash-B Permanently in 1963	0.524 -0.574	-8.045** 14.480**	5.035** -0.127

+ The upper J test statistics is the test for the hypothesis that the model at the top of the page adds explanatory power to the model on the left-hand side.

** Significance level 0.01
* Significance level 0.01