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UNOBSERVABLE TRANSACTIONS PRICE AND THE MEASUREMENT OF A SUPPLY AND DEMAND MODEL FOR THE AMERICAN STEEL INDUSTRY

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I. Introduction

In this paper a simultaneous supply-and-demand model of the U.S. steel industry for the years 1920 to 1972 will be developed. In the past considerable doubt on the feasibility of such a study has been expressed (Rowley 1971, pp. 64-66), and in recent years very few studies have been done.[1] Rowley thought that the econometric problems were insurmountable citing issues such as multicollinearity and identification. These, however, can be overcome by the standard simultaneous estimation techniques, but one situation cited by Rowley can not be handled by the usual methodology. In times of falling demand, steel firms often give secret price concessions or discounts to some customers. Consequently, since the price indexes often do not reflect actual transaction prices, an errors-in-variables problem exists. Because the errors in the price variable are not independent of the other variables in the model, the usual methods of correcting for the problem cannot be used. This paper, then, will demonstrate a special instrumental variables technique to deal with the situation.

Another problem is the oligopolistic nature of the steel industry. Price does not necessarily equal marginal cost, and in order to measure supply some method must be found to account

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[1] Hekman (1978) measured regional supply and demand curves for the American industry, and Jondrow et al., (1975) did a similar study for the whole industry with special attention to imports; but the latter paper used a very small sample which lacked degrees of freedom.

for the difference. Here this difference will be subsumed in the constant of the supply relation. By using intercept-dummy variables, account is taken of changes in the structure or conduct of the industry that might affect the price-marginal cost disparity. Since both of the problems discussed above exist in other markets, this study may have a wider application than to just the steel industry.

The next section will set up the supply-and-demand model taking into account the imperfections in the market. In section III we will develop a correction to take into account the errors in the variables, and in section IV the results will be shown and discussed.

II. The Supply-and-Demand Model

To develop the model we will first focus on demand conditions and then on supply conditions. While steel products are quite numerous, output in gross tonnage will be used as the quantity variable for this study. Except for some specialty items, the price and physical composition of the various steel products are quite similar; so this variable probably accurately reflects the production of the industry.

Demand

Because of its flexibility, a constant elasticity demand curve for steel will be used:

$$Q_d = \alpha P^f , \qquad \text{II:1}$$

f = demand elasticity,

P = deflated composite steel-price index compiled by Metal Statistics 1973, and

Q_d = the amount of steel consumed in the United States for any year; i.e., apparent consumption which is assumed equal to U.S. production plus imports minus exports.[1]

Two other variables significantly influence the demand for steel: the state of the economy (especially capital spending and manufacturing output) and the price of substitutes. Past empirical work [Hekman 1976, 1978] has shown value-added in manufacturing (net of value-added in iron and steel) to be a good indication of the level of demand for steel, but a similar variable--an index of total industrial production--will be used because it is available for more years.[2]

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1 Here steel is assumed to be a product undifferentiated as to source of supply. The data source for quantity is American Iron and Steel Institute 1910-1975.

2 This variable, the manufacturing output index compiled by Kendrick (1961 and 1973), is highly correlated with the value-added in manufacturing (0.997). It is available for more years than is the value-added figure, but one problem is that the change in steel and iron industry output is not netted out. On the other hand, steel and iron account for only about 4 percent of the value added in manufacturing, and the industry does use its own product; so it is not clear that the adjustment is too important.

The price of nonferrous metals will be used to represent the price of substitutes. Therefore, the demand function is as follows:[1]

$$Q_d = b_0 P^f GMAN^{b_1} PNF^{b_2} e^v \ , \qquad \text{II:2}$$

where

GMAN = the index of manufacturing production compiled by Kendrick [1961 and 1973], and

PNF = deflated price of substitutes, represented by the BLS index of nonferrous metal prices.

For ease of estimation, this function can be put in a log-log form.

$$\ln Q_d = \ln b_0 + f \ln P + b_1 \ln GMAN + b_2 \ln PNF + v \ . \qquad \text{II:2a}$$

Two other influences are hypothesized to have affected the demand for steel. First, the amount of steel used per amount of manufacturing or aggregate GNP has decreased over time.[2] (See Rowley 1971, pp. 68-71). This has happened because of increases in substitutes and the movement of GNP growth, both aggregate and manufacturing, away from steel-using goods.

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1 Aluminum is the closest single substitute for steel, but other metals represented in the nonferrous index are also substitutes. So both the aluminum price and PNF were tried in experiments, but PNF usually worked better. Since there are other substitutes, the metal price variables are not completely representative, but the market conditions for the unrepresented substitutes would impinge on the prices of both aluminum and nonferrous metals in general. Therefore, the substitution effects are likely to be adequately captured by the metal price indexes.

2 For instance, between 1929 and 1972 real GNP grew 272 percent and manufacturing output grew 395 percent, while apparent steel consumption increased by only 141 percent.

Developments in the use of steel not accounted for by the model may have led to this change. Since an appropriate continuous proxy for this change does not seem to exist, an intercept dummy variable will be used:

ID = 1 for the years before 1945 and zero afterwards.

The major justification for using 1945 as the break point is the great increase in aluminum capacity brought on by World War II.

The second possible explanation for deviations from the demand function is the Depression. In the model, changes in manufacturing activity are included, but the construction industry was also an important user of steel (18 percent of the total in 1968). Its activity was especially low during the Depression. Also production in the manufacturing sectors which used steel most intensively (autos and capital goods) decreased disproportionately during the Depression. Therefore a dummy variable, DEP, for the Depression will be included, where

DEP = 1 for the years 1930-39 and zero otherwise.

To sum up the following model will be used to measure steel-industry demand:

$$\ln Q = \ln b_0 + f \ln P + b_1 \ln GMAN + b_2 \ln PNF + b_3 ID + b_4 DEP + v. \quad II:3$$

Supply

In order to incorporate supply into the analysis, we first show how cost and output are related and then take firm behavior into account. Therefore, an industry supply curve on the assumption of product market competition will first be derived. To do this, one needs to understand the conditions under which production occurs.

In the production of steel, the following inputs: coal (C), iron ore (IR), labor (L), steel scrap (SS), and capital (K) account for 90 percent of the cost [Hekman 1976, p. 14]. Consequently, the steel production function can be represented as follows:

$$Q = F(C, IR, L, SS, K), \qquad \text{II:4}$$

where Q = the total tonnage of steel production produced and imported for consumption in the United States, and

C, IR, L, SS, K represent the amounts of the various production factors used by the industry.[1]

Past empirical work on the cost function for steel [Hekman 1978] suggests that a Cobb-Douglas function adequately represents the technology of steel production.[2]

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1 Here we assume that imports are produced by about the same methods and inputs as domestic steel. In the early part of our period, this probably was not true, but imports were small. In the later part of the period when imports became significant, world markets definitely developed in coal and iron ore and probably also in scrap and capital. This writer does not believe that differences in the input markets will badly distort the results because changes in many of the factor prices such as those for capital and labor are highly correlated across nations.

2 Using the less restrictive transcendental log function, Hekman found that in a period roughly corresponding to our sample, the Cobb-Douglas specification fit the data for the supply functions of the three major steel-producing areas of the country. The Cobb-Douglas function is a special case of the transcendental log production function. The transcendental function is less restrictive in that as production rises or falls it is possible for the marginal rates of substitution between inputs to vary without the factor proportions changing. (See Christensen and Greene 1976.)

Some modifications are required for our purposes. First, since our analysis involves a long time period, technological change should be taken into account. This phenomenon can be modeled by introducing a time variable, T, as follows:

$$Q = AT(t)^{d1}C^{B1}IR^{B2}L^{B3}SS^{B4}K^{B5}e^{u}. \qquad \text{II:5}$$

Technological changes tend to be incremental in this industry; so a continuous time variable would seem appropriate.[1]

Also, one has to consider that in the short run, some types of capital cannot be varied, and short run demand conditions often dictate an immediately planned output not equal to the maximum allowed by the amount of available fixed capital. The best way to account for this phenomenon is to consider the fixed capital a separate factor of production; here it will be referred to as K_F. (See Caves, Christensen, and Swanson 1979 for a similar treatment.) Therefore, equation II:5 becomes:

$$Q = AT^{d1}C^{B1}IR^{B2}L^{B3}SS^{B4}K^{B5}K_F^{B6}e^{u}. \qquad \text{II:6}$$

From this function, we can derive a cost function. It can be shown that given certain regularity conditions, the average cost function is the dual of the production function. (See Diewert 1974; Varian 1978, pp. 34-48; and Nerlove 1965, pp. 100-31.)

In further developing the cost model, however, problems exist with K_F, fixed capital. At any given time it does not

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1 For examples of its use, see Solow [1957] and Christensen, Jorgenson, and Lau [1973].

vary; therefore its price cannot affect immediate costs. But changes in the amount of K_F over time will alter the level of total and average cost. To account for this situation a measure of the stock of the fixed capital should be included in the cost function. (See Caves, Christensen, and Swanson, 1981 and Lau, 1976). No good measure of the amount of K_F is available; so we resort to a proxy variable. Given the available data, the best proxy is steel-furnace capacity.[1] When all the input prices are included in the cost function, the following Cobb-Douglas equation results:

$$TC = C_0 Q^{C1}\ T^{C2}\ CAP^{C3}\ P_C^{C4}\ P_{IR}^{C5}\ P_L^{C6}\ P_{SS}^{C7}\ P_K^{C8}\ e^u, \qquad \text{II:7}$$

where

TC = total cost for the industry,

T = T, a variable representing technological change which takes on the value 1 in period 1 and rises to t in period t,

CAP = steel furnace capacity for the industry [American Iron and Steel Institute 1916-60, and Bosworth 1976].

P_C = price index for coal [Bureau of Mines 1960-73],

P_{IR} = price index for iron ore [Iron Age 1916-75],

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[1] It is not totally representative, but it is available for the entirety of the sample. In addition, many people would consider capacity endogenous. While capacity usually changes due to factors outside of shortrun conditions, these conditions can impinge on the decision to alter capacity. This could lead to measurement biases because the CAP variable would be influenced by the exogenous variables in the system. But the CAP_i variable used here is for the beginning of the year so the conditions reflected by the current regression variables would not have yet affected it.

P_L = price index for labor [Bureau of the Census 1947-73],

P_{SS} = price index for steel scrap [Iron Age 1955-73], and

P_K = price index for capital, taking into account both equipment cost and interest [Bureau of the Census 1975 and Moody's 1975].

u = multiplicative residual term.

(P_K is included in the function because there are types of capital that can be varied.)

For a competitive industry, the supply curve equals the marginal cost curve which can be derived as follows:

$$MC = C_1 TC/Q. \qquad \text{II:8}$$

So a log-log MC equation would thus be:

$$\ln MC = \ln C_1 + \ln C_0 + (C_1 - 1)\ln Q + C_2 \ln T + C_3 \ln CAP \qquad \text{II:9}$$
$$+ C_4 \ln P_C + C_5 \ln P_{IR} + C_6 \ln P_L + C_7 \ln P_{SS} + C_8 \ln P_K + u.$$

Here the constant, $\ln C_1 + \ln C_0$, can be collapsed into one term, C_{00}, and (C_1-1), into CM_1.

A model of perfect competition is not accurate, however, since steel is an oligopolistic industry. Therefore, price will not equal marginal cost; rather it is generally marked up over that cost.[1] Price, then, can be related to the industry MC as follows:

$$P = (1 + m)MC, \qquad \text{II:10}$$

where m = the percentage markup divided by 100.

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[1] In such industries, the traditional supply function which is independent of demand conditions does not really exist. So here the discussion is actually referring to the amount supplied at any given price under a given set of demand, market structure, and behavior conditions. This concept can be called a quasi-supply relation.

Before this equation can be estimated, we must find a method to adjust the model for variations in this markup, but these changes cannot be readily predicted. One way to attack the problem would be to hypothesize how the underlying conditions determining the markup might have changed over time.[1]

The literature suggests that over time institutional developments occurred that might have led to radical changes in steel-firm conduct. One watershed would be the ostensible demise of the basing-point pricing system in 1948. Hekman [1978] found that this change led to lower prices, other things equal.[2]

A second change seems to have occurred around 1960. [For discussions of the change see Mancke 1968, Rippe 1970, and Tarr's analysis in the FTC Staff Report 1977]. The combination of increased imports and market-share deterioration by U.S. Steel apparently led to a more competitive environment.

Evidence also indicates that at least some firms acted more independently during the depression in the 1930's than

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1 An ideal methodology would be to find the variables that directly affect the steel firms' behavior and put them in a third simultaneous equation determining markup. The theory, however, is not clear on just what variables would appear in such a function, and probably many of those variables would not be available for our sample period. An obvious candidate for inclusion in this equation would be a measure of market structure such as concentration.

2 This system was in effect in various forms in the steel industry from about 1900 until the FTC cement decision in 1948. (F.T.C. vs. Cement Institute et al., U.S. 683, pp. 712-21, 1948).

they did before and later. (See Weiss 1971, pp. 177-79 and Daugherty, De Chazeau, and Stratton 1937, pp. 667-71.) The economic conditions of the industry may have led to a weakening of any leadership position by U.S. Steel, the largest firm, or of any collusive scheme among the larger firms. Consequently, we will hypothesize that the markup determining mechanism in the 1930's could have been considerably different from that of the other periods in the sample.

Since the markup of price over cost (m in II:10) is embedded in the constant, a way to parameterize the changes in expected markup would be to add intercept-dummies for the times when the institutional environment might have changed. Therefore the following function is hypothesized:

$$\begin{aligned} \ln P = {} & \ln C_{000} + CM_1 \ln Q + C_2 \ln T + C_3 \ln CAP + C_4 \ln P_C + C_5 \ln P_{IR} \\ & + C_6 \ln P_L + C_7 P_{SS} + C_8 \ln P_K + C_9 D_1 \\ & + C_{10} D_2 + C_{11} DEP + u \end{aligned} \qquad \text{II:11}$$

where $\ln C_{000} = \ln(1+m) + \ln C_1 + \ln C_0$, the intercept implied by equations II:9 and II:10 less the appropriate dummy values,

$CM_1 = C_1 - 1$,

D_1 = 1 for the period before 1949 when the basing point price system was in effect, and 0 otherwise,

D_2 = 1 for the period before 1960, and 0 otherwise,

DEP = 1 for the period 1930-39, the years of the Depression, and 0 otherwise.[1]

It is convenient for the analysis below to recast this equation as follows.

$$\ln Q_S = g_0 + g_1 \ln P + g_2 \ln T + g_3 \ln CAP + g_4 \ln P_C$$
$$+ g_5 \ln P_{IR} + g_6 \ln P_L + g_7 \ln P_{SS} + g_8 \ln P_K \qquad \text{II:12}$$
$$+ g_9 D_1 + g_{10} D_2 + g_{11} DEP + w$$

This equation derived by solving II:11 for Q shows the quantity supplied at a given price. Since the relationship is simultaneous the equation can be estimated for either Q or P.

As developed so far, we have a simultaneous-equation system consisting of II:3 and II:12. From these equations estimates of the demand and supply functions can be made. To use certain efficient estimation techniques, namely Two and Three Stage Least Squares, the reduced form estimate for P must be found. It is as follows:

$$\ln P = \gamma_0 + \gamma_1 \ln GMAN + \gamma_2 \ln PNF + \gamma_3 ID + \gamma_4 \ln T + \gamma_5 \ln CAP + \gamma_6 \ln P_C$$
$$+ \gamma_7 \ln P_{IR} + \gamma_8 \ln P_L + \gamma_9 \ln P_{SS} + \gamma_{10} \ln P_K$$
$$+ \gamma_{11} D_1 + \gamma_{12} D_2 + \gamma_{13} DEP + w. \qquad \text{II:13}$$

With this equation, the above mentioned techniques can be used to estimate equations II:3 and II:12.

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[1] The institutional influences accounted for by the dummies were in many periods operating at the same time. For instance, during the thirties, the depression years, the basing-point price system was in effect; so both influences impinged on the steel market. To illustrate, other things equal, the expected difference between price in 1935 and in 1925 would be C_{11}, but the difference between 1935 and 1955 when the basing-point pricing system was no longer in effect would be $C_{11} + C_9$.

III. Published Prices and Transaction Prices

The above model would be adequate for our purposes if the available data were reliable, but the published steel prices upon which the composite indexes are based may not accurately reflect the actual transaction prices. The source used, the price index published by American Metal Markets, is an average of a large number of prices for many different steel products. Within most of the products are a number of grades or variations on quality. All these products and grades would have different prices. Also, the actual price of the product can depend on the location of the buyers and sellers. While ostensibly transportation costs are reflected in the price, often steel firms will absorb them. So at any given time, a steel-price index is an average of prices for many products and subproducts for customers at a large number of locations.

Price discrimination complicates the problem further. The demand elasticities of given customers for a given firm's products vary. Some customers, due to location, can purchase steel from a larger number of mills than can others. Some buyers use their steel in a process where the substitution of other products is possible and cheap. Some users purchase so much steel that sellers would readily give them a lower price--lower than could be explained by any difference in handling costs. The very largest customers, such as auto companies and heavy-equipment manufacturers, have the option of building their own mills.[1] So at any given time, different steel customers may pay a different price for the same product.

In many if not most markets, these kinds of variations are always present, but composite price averages reflect the situation at a given time because changes in the published prices tend to be correlated with changes in real prices. In steel, however, much evidence shows that the published changes in composite prices may not reflect the real changes due to the presence of price shading. Many writers believe that price shading in steel was common for many periods [Oxenfeldt 1951; Rowley 1971, p. 88; Parsons and Ray 1975; and Tarr in the FTC Staff Report 1977 pp. 173-97]. Oxenfeldt showed that price concessions did occur in the late thirties and very early forties at times when capacity utilization was low [pp. 500-502]. Furthermore, Rowley concluded that there may have been price shading in other periods. Also Tarr's analysis of the trade press showed extensive differences between transactions and list prices between 1965 and 1974. Therefore, given this literature, it is necessary to at least be aware of the problem of an inaccurate price series.

In steel, the nature of the market may make it advantageous for firms to deviate from their published prices for some customers. Generally the deviations occur when the demand curve moves. Because steel use is tied to cyclical items like

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1 Ford did, and International Harvester bought a steel mill.

capital spending and big ticket consumer products, this curve is often subject to radical shifts.

When demand falls, firms have a very strong interest in keeping book prices up because some buyers will be willing to pay the old prices. On the other hand, others will demand lower prices and threaten to take their business elsewhere. In order to keep the latter customers, firms will grant under-the-table discounts. If a firm were to lower book prices, however, it would lose the difference between the two prices for the customers willing to pay the old price. Moreover, it is not clear that the firm would necessarily keep the buyers wanting a discount, because other firms might retaliate on seeing the book price lowered. Therefore, to prevent retaliation and retain some customers, firms will discount to many of them while holding the book price the same.

This process is generally not the end of the story; eventually discounts will become so prevalent that the bulk of the steel buyers will have the ability to demand and get a lower price. When this occurs, the companies will then change the book prices to more closely reflect reality.

When demand is increasing, the firms face a similar set of incentives in reverse. With rising demand, customers cannot obtain as many under-the-table discounts because they cannot find alternative sources of supply. This also gives steel firms the option to narrow the discounts that have been granted in the past. These changes can happen without the book price being altered. As in the falling demand situation, however, eventually a point is reached where it is advantageous for firms to change the book price.

There is, however, an added complication to the increasing price situation arising from the interaction of the industry size and structure and the role of the Government. Historically, U.S. Steel and sometimes the other larger companies have lagged behind the smaller firms in raising prices. While the small companies would usually follow U.S. Steel on book prices, in times of high demand they would often charge somewhat higher real transactions prices. The larger companies have always been constrained by their fear of governmental intervention. This fear, then, has led them to mitigate somewhat their real price increases. The attitude of U.S. Steel was very similar to that of a public utility; the firm always feared that if it were to take full advantage of its position, the Government would intervene. One authority stated,

> Steel executives may be likened to executives of a public utility. They aim for the maximum profit in a way that will not unduly arouse Congress, the antitrust authorities, or the general public [Oxenfeldt 1951, p. 508].

This situation would be much more relevant to U.S. Steel or Bethlehem, the number-two company, than to the smaller producers. So the latter firms may thus be able to raise some prices faster than the larger firms. Consequently, the price index which usually reflects the book prices of the larger companies may deviate from the real average price when demand is increasing for this reason as well.

Before developing a way to deal with this phenomenon, a further discussion of supply is needed. Supply conditions in the steel industry change more slowly than demand conditions. Over time, increasing factor prices have pushed the supply curve up. On the other hand, increasing capacity and technological progress have somewhat compensated for this tendency by pushing the curve to the right [Gold 1976]. Factor prices do not seem to move in wide gyrations, and capacity has increased only in small increments. Even when new plants have come on line, they are usually phased in over a number of years. Technological progress has also been incremental; in contrast to many other markets (computers for instance), new innovations are only slowly adopted by the steel industry.[1]

At times, however, it can be shown that if the factor prices for all firms are moving in tandem, then, book price variation due to supply changes might reflect transactions price changes. This occurred when firms encountered industrywide union wage negotiation [Morkre 1968], but up until the late 1930's there was no such industrywide negotiation. Also, in the sixties, firms would not automatically raise prices in

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[1] For instance, with the Basic Oxygen Furnace (BOF) a superior steel furnace, the first U.S. plant was built in the early fifties, but by 1970, only 48 percent of the industry capacity was BOF.

response to negotiated wage increases. Consequently, steel firms operate in an environment of slowly changing supply and widely fluctuating demand conditions. The deviations of real prices from book prices are thus a function of changing supply and demand but generally with demand changes having the greater influence.

This problem is technically errors in variables where the stochastic nature of the independent variables leads to biases in the ordinary-least-squares estimation technique. Several methods have been used to deal with this condition, among them various kinds of instrumental variable. (See Johnston 1972, pp. 281-92.) Usually the methods depend on either an exact knowledge of the error distribution of the variable in question or the assumption that this error has a normal distribution independent of any other variables in the equation.

With the measurement error found in the composite steel-price indexes, however, these methods are inappropriate. The relationship between price discounting and the state of supply and demand means that the measurement error in price is correlated with the exogenous variables in the two relationships--especially demand. Thus, the usual parameter estimates are biased because there is still an error in the first-stage predicted value that is correlated with the exogenous variables, namely the difference between the reported and transactions prices.

To sum up, these two variables probably deviate, and only slowly do changes in the former reflect changes in the latter. Also, the variables affecting this deviation when prices are rising differ somewhat from those affecting it when prices are falling. In the former case, fears of antitrust action and other Government intervention may have led some firms to either hide or defer some price increases. On the other hand, in both situations, differences in the price elasticities among customers can lead to real prices changing faster than reported book prices.

Consequently, a way to account for these conditions must be developed. A partial-adjustment model will be used to derive an appropriate instrumental variable. The change in the natural logarithm of book price is a function of the difference between the logarithms of new real price and the old book price,

$$\ln P_t - \ln P_{t-1} = \alpha(\ln P_t^* - \ln P_{t-1}) \qquad \text{III:1}$$

where $\alpha < 1$,

P_t^* = transactions price in time t,

P_t = book price in time t.[1]

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[1] We examined the special attributes of setting this equation in log form. Multiplicatively it is as follows:

$$\frac{P_t}{P_{t-1}} = \frac{P_t^{*\alpha}}{P_{t-1}^{\alpha}} .$$

It appears that the deviation of real and book prices can be modeled in terms of ratios as well as in terms of differences.

(footnote continued)

Solving this equation for $\ln P_t^*$, one arrives at

$$\ln P_t^* = \frac{\ln P_t - \ln P_{t-1}}{\alpha} + \ln P_{t-1} \ . \qquad \text{III:2}$$

This model of real price has three advantages, the real price deviation from book price is a function of previous price changes. Also the model reflects the tendency of book price changes to eventually follow transactions price changes. Third, if past writers on steel were generally wrong and book prices do reflect transactions prices, expression III:1 will collapse into

$$\ln P_t = \ln P_t^* . \qquad \text{III:1a}$$

This would occur when α equals one, a hypothesis that can be statistically tested.

Equation III-2 can be substituted into equations II:3 and II:12 in the supply and demand system to correct for the errors in variable problem. This gives us the following system:

(footnote continues)

While the linear form of the adjustment equation (III:1) means that the ratio of book price change ($P_t - P_{t-1}$) to the partial adjustment ($P_t^* - P_{t-1}$) is constant, the log form of III:1 makes this ratio a variable. An examination of the behavior of this equation over a plausible sample shows that the larger the real price decrease, the more the ratio of $P_t - P_{t-1}$ to $P_t^* - P_{t-1}$ falls, meaning that with large decreases in real prices, book changes tend to follow real changes more closely. On the other hand, the opposite is true with the price increases. Scrutiny of the behavior of the log equation over the range of our sample, however, shows that it closely mimics the linear model.

$$\ln O_d = \ln b_0 + f \ln P_t^* + b_1 \ln GMAN + b_2 \ln PNF + b_3 ID + b_4 DEP + v$$

III:3

$$\ln O_s = \ln g_0 + g_1 \ln P_t^* + g_2 \ln T + g_3 \ln CAP$$

$$+ g_4 \ln P_C + g_5 \ln P_{IR} + g_6 \ln P_L + g_7 \ln P_{SS} + g_8 \ln P_K + g_9 D_1$$

$$+ g_{10} D_2 + g_{11} DEP + w$$

where P_t^* = the left hand side of III:2.

The problem of simultaneity between Q and P_t^* still exists. Therefore we need to derive an instrumental variable for or a first stage estimate of $\ln P_t^*$. One can use III:3 to solve for a reduced form equation for $\ln P_t^*$

$$\ln P_t^* = g_0 + B'Y_t + R'X_t + z_t, \qquad \text{III:4}$$

where B' and R' are vectors of first-stage parameters and Y_t and X_t are respectively the vectors of exogenous demand and supply variables.

This is the equivalent to equation II:13, the reduced form for the system with II:3 and II:12. Substituting III:4 into III:1 we then arrive at

$$\ln P_t - \ln P_{t-1} = \alpha g_0 + \alpha B'Y + \alpha R'X - \alpha \ln P_{t-1} + \alpha z_t. \qquad \text{III:5}$$

The predicted value of this equation ($\ln P_t \hat{-} \ln P_{t-1}$) can be employed to find the instrument for $\ln P_t^*$ to use in III:3. Measuring equation III:5 also gives us an estimate of α which also can be used to solve for the predicted real price log, as follows:

$$\ln \hat{P}_t^* = \frac{(\ln P_t \hat{-} \ln P_{t-1})}{\hat{\alpha}} + \ln P_{t-1} \text{ ,} \qquad \text{III:6}$$

where ($\ln P_t \hat{-} \ln P_{t-1}$) = the predicted value of ($\ln P_t - \ln P_{t-1}$) equal to III:5 less the residual term, αz_t.

$\hat{\alpha}$ = the measured value of α.[1]

This equation essentially measures the expected value of $\ln P_t^*$ which is the combination of the expected value of

($\ln P_t - \ln P_{t-1}$) divided by $\hat{\alpha}$ and the expected value of $\ln P_{t-1}$ which since lagged list price is predetermined <u>vis a vis</u> III:3 equals $\ln P_{t-1}$. Equation III:6 can now be used as a first stage

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[1] There is a peculiarity about the variance of ($\ln P_t - \ln P_{t-1}$) about its predicted values. The difference between the predicted value, ($\ln P_t \hat{-} \ln P_{t-1}$), and ($\ln P_t - \ln P_{t-1}$) has two components, one arising from the difference between $\ln \hat{P}_t^*$ and $\ln P_t^*$, and the other arising from the difference between $\hat{\alpha}$ and α. To see how this effects the results we should solve for the following:

$$(\ln P_t \hat{-} \ln P_{t-1}) - (\ln P_t - \ln P_{t-1}).$$

The value of this difference is $\hat{\alpha} z_t$, a scalar of z_t, the difference between $\ln \hat{P}_t^*$, and $\ln P_t^*$. This scalar cannot change the estimation results.

estimate in III:3, and second and third stage measurements can be made for the system.[1]

So in measuring the supply and demand equations for steel, we take advantage of the tendency of book price to eventually follow transaction prices. To summarize the full system that we are measuring can be viewed as follows:

$$\ln Q_d = \ln b_0 + f\,\frac{(\ln P_t - \ln P_{t-1})}{\alpha} + f\ln P_{t-1} + b_1\ln GMAN + b_2\ln PNF$$

$$+ b_3 ID + b_4 DEP + v$$

III:3a

$$\ln Q_s = \ln g_0 + g_1\,\frac{(\ln P_t - \ln P_{t-1})}{\alpha} + g_1\ln P_{t-1} + g_2\ln T + g_3\ln CAP$$

$$+ g_4\ln P_C + g_5\ln P_{IR} + g_6\ln P_L + g_7\ln P_{SS} + g_8\ln P_K + g_9 D_1$$

$$+ g_{10} D_2 + g_{11} DEP + w$$

$$\ln P_t - \ln P_{t-1} = \alpha(\ln P^*_t - \ln P_{t-1}).$$

IV. The Results

We will now estimate a model of the steel industry that takes into account the difference between reported and transaction prices as shown in III:3a. The first two equations of

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[1] Our theory predicts that when prices are rising, the speed at which book prices adjust to transactions prices may deviate from that of when they are falling. Therefore, the partial-adjustment model could be set up to take the adjustment velocity difference into account, but with this sample we do not have enough observations to accomplish the task.

the system are nonlinear in the parameters, since f and g_1 both appear in a ratio form with α. On the other hand, the α coefficient can be measured from the reduced form for the third equation. With the estimated α used in the formula for the price instrument, linear methods can be employed to measure the first two equations. This procedure is analogous to two stage least squares. By using the estimated residual covariance matrix from this technique, three stage estimates can be made. These procedures take into account the usual simultaneity problem. As it happens, these methods are identical with the most commonly used nonlinear estimates, nonlinear two and three stage least squares (see Amemiya 1974, Jorgenson and Laffont 1974 and Hausman 1975).

Tables I and II show respectively the various estimates of the demand and supply equations. The demand-equation results seem quite reasonable; the corrected R^2's are high: .970 for the 2SLS estimate and .963 for the 3SLS estimate. All the regression coefficients have the expected signs. Manufacturing activity (GMAN) has a positive effect on steel consumption. Other things equal increases in nonferrous-metal prices seem to have led to greater steel use. For both techniques, the intercept dummies for after 1945 and the depression have the predicted signs. Last and most important, the coefficients for price, P_t^*, equalling demand elasticity in our specification are less than zero.

Table I

The Adjusted Instrumental Variable (AIV) Estimates for the Demand Curve of the U.S. Steel Industry for the Periods 1920-40 and 1946-72

Estimation techniques	The adjustment variable[1] (α)	Constant (a)	$\frac{\ln P_t - \ln P_{t-1}}{\alpha}$ and $\ln P_{t-1}$ (P^*_t)	Manu-facturing output (GMAN)	Nonferrous-metal prices (PNF)	The intercept dummy (ID)	The dummy for depression (DEP)	R^2	F-value
2SLS	0.645 (5.60)	11.870	-0.738 (-3.78)**	0.930 (10.40)**	1.290 (7.64)**	0.240 (2.58)**	-0.041 (-0.79)	.970	305.65
3SLS		11.869	-0.725 (-3.67)**	0.924 (10.21)**	1.281 (7.50)**	0.235 (2.49)*	-0.044 (-0.82)	.963	123.04

[1] The adjustment variable is the same for all the estimates since it is estimated for the third equation of III:3a.

* Significant at the 95-percent level of a one-tail test.

** Significant at the 99-percent level on a one-tail test.

\+ Significant at the 95-percent level on a two-tail test.

++ Significant at the 99-percent level on a two-tail test.

Table II

The Adjusted Instrumental Variable (AIV) Estimates for the Supply Curve of the U.S. Steel Industry for the Periods 1920-40 and 1946-72

					Price of					Dummy variable for				
stimation echnique used	Constant	$\frac{\ln P_t - \ln P_{t-1}}{\alpha}$ and $\ln P_{t-1}$ (P^*_t)	Technological change (T)	Capacity (CAP)	Coal (P_C)	Iron Ore (P_{IR})	Labor (P_L)	Scrap Steel (P_{SS})	Capital (P_K)	Basing point pricing (D_1)	The 1960's (D_2)	The Depression (DEP)	R^2	F-value
2SLS	7.628	1.467 (0.76)	0.178 (0.55)	-0.036 (-1.83)	-0.715 (-2.78)**	-1.513 (-2.15)**	0.825 (2.38)	0.675 (4.42)	-0.956 (-0.42)	-0.519 (-2.92)**	-0.026 (-0.14)	-0.095 (-0.68)	.924	52.73
3SLS	7.842	1.580 (0.80)	0.203 (0.62)	-0.036 (-1.79)	-0.737 (-2.83)**	-1.536 (-2.16)**	0.811 (2.31)	0.657 (4.25)	-1.068 (-0.46)	-0.523 (-2.91)**	-0.011 (-0.06)	-0.110 (-0.78)	.963	123.04

* Significant at the 95-percent level on a one-tail test.

** Significant at the 99-percent level on a one-tail test.

\+ Significant at the 95-percent level on a two-tail test.

++ Significant at the 99-percent level on a two-tail test.

The available tests for significance support the veracity of the demand model.[1] The coefficients for Price, GMAN, and PNF are significant at the 1 percent level. The coefficients for the intercept dummy for the years after 1945 are significant at the 5 percent level, but the variable for depression fails the significance test for both estimating techniques even though its signs are correct.

On the other hand, the results for the supply equation are not as promising. Input prices seem to be the source of the problem. For both estimating procedures, two of the input price variables (labor and scrap steel) have the wrong signs. (Since Q is the dependent variable, they should be negative.)

A possible reason for the unpredicted signs is that the steel industry is a large buyer in these input markets. Labor markets are usually local, and steel firms tend to be large employers in given areas. There are few alternative uses for scrap steel. Consequently, conditions in the steel industry may have had a significant effect on these prices implying simultaneity in the relationship between the dependent quantity variable and the input price variables. This simultaneity would lead to biased parameter estimates (see Johnston 1972, pp. 341-46 and Maddala 1977, pp. 242-52). To correct for this problem, one would have to enlarge the model to include the

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[1] With the 2SLS and 3SLS, only asymptotic t tests can be made with confidence (Maddala, 1977, p. 239).

equations for various input prices. For our purposes, however, the gain in accuracy from this extension is not worth the cost of developing a model that would include supply and demand equations for some of the input markets.

Advancing technology, other things equal, would lead to increasing production, and T has the predicted sign, but it is insignificant for both techniques. The coefficient for the Depression variable, DEP, should have a positive sign in the supply equation, but the results indicate a negative influence. Perhaps the depressing effect of economic conditions on the decision-makers' psychologies may have counteracted the positive effect on output of any weakened collusion. Particularly interesting are the other coefficients for the changes in behavior. The abolition of basing-point pricing and the advent of the 1960's did lead to increases in output, and the coefficients of the former were statistically significant.[1]

The parameter estimates for steel price and capacity are not significantly different from zero. Theory does not predict the sign of the latter, but the former should be positive which it is.[2] Probably the fact that the steel industry rarely

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1 The dummy variables were parameterized to have a value of one in the earlier periods for D_1 and D_2 and one during the depression for DEP.

2 Increased capacity may lead to either higher or lower average and marginal cost, depending on economies of scale. Past work on plant scale economies in steel would suggest a flat industry supply curve in that the smallest efficient steel plant would (footnote continued)

operated near capacity somewhat attenuated the effect of price on output. The capacity variable was not significant for either equation on a two tail test.

In spite of some ambiguous supply-side results, at this point we have plausible estimates of demand elasticity, -0.738 and -0.725. They seem to be in accord with earlier estimates of shortrun demand elasticity (see Yntema, 1939 and Rowley, 1971, pp. 66-74). Yntema (1939) found elasticities in a range between -0.3 and -0.8, but his methodology was crude and he had a limited number of observations. Using intuitive methods, Rowley (1971, pp. 66-74) estimated an elasticity of -0.8.[1]

V. Conclusion

This paper develops and measures the demand and supply functions for the American steel industry correcting for errors in the price variable. Generally it can be said that the demand

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(footnote continues)

account for only a small percentage of total industry output [See Bain 1956 and Tarr 1978]. So possibly increasing the total amount of capacity and presumably fixed capital may not affect average or marginal cost. On the other hand, even though no individual plant economies exist, there may be economies of agglomeration as the industries supplying the steel-industry increase in size; so increases in measured capacity may lower costs.

[1] Hekman's estimates of demand elasticity (1976 and 1978) are comparable with ours, but they are larger in absolute value than ours as one would expect for regional estimates. So consistency exists between the two estimates.

measurement is successful, but problems persist in the supply equation. For the supply equation, some input price coefficients have the wrong signs; this is propably due to the simultaneity in the relationship between these input prices and steel output. Both labor and scrap steel are sold in markets where the steel industry is an extremely large user. Consequently to better model supply, one might add to the system price and output equations for labor and scrap steel or develop instruments for those price variables.

The theory that reported and transactions prices deviate is supported by the statistical significance of the difference between the adjustment variable, α, and one (the t value here being 3.08). Consequently we can state with some confidence that we have made a good attempt to deal with this problem. If at a later date more accurate price data become available, then, comparisons can be made between this model and those using the accurate data.

In summary, this experiment seems to contradict earlier assertions that econometric techniques cannot be applied to steel. Ironically our demand elasticity estimates, -0.738 and -0.725, are not very different from the deductive estimate of Rowley (about -0.8), a critic of applying econometrics to the steel market (1971, pp. 66-74). Consequently, the results may not only be useful to people studying steel but also to those estimating demand and supply in other industries with similar measurement problems.

REFERENCES

Amemiya, T. "The Nonlinear Two-Stage Least-Square Estimator." Journal of Econometrics 2(1974):105-110.

American Iron and Steel Institute. Annual Statistical Report. Washington, D.C.: American Iron and Steel Institute, 1910-1975, various issues.

__________. Directory of Iron and Steel Works for the United States and Canada. Washington D.C.: American Iron and Steel Institute, 1964, 1967, 1970 and 1974.

American Metals Market. Metal Statistics 1974. New York: American Metals Market Fairchild Publications, Inc., 1974.

Bain, J. S. Barriers to New Competition. Cambridge: Harvard University Press, 1956.

Bosworth, B. "Capacity Creation in Basic-Materials Industries." Brookings Papers on Economic Activities 2 (1976).

Caves, D. W.; Christensen, L R. and Swanson, J. A. "Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads, 1955-74." American Economic Review 71, no. 5 (December 1981):994-1002.

Christensen, L. R.; Jorgenson, D. W. and Lau, L. J. "Transcendental Logarithmic Production Frontiers." Review of Economics and Statistics 55 (February 1973):28-45.

Daughterty, C. R.; De Chazeau, M. G. and Stratton, S. S., Economics of the Iron and Steel Industry. New York: McGraw-Hill, 1937.

Diewert, W. E. "Applications of Duality Theory." Frontiers of Quantitative Economics by M. D. Intriligator and D. A. Kendrick. Amsterdam, Oxford: North Holland Publishing Co., (1974):105-71.

Federal Trade Commission Staff Report, R.M. Duke, R.L. Johnson, H. Mueller, P.D. Qualls, C.T. Roush, and D.G. Tarr. The United States Steel Industry and Its International Rivals: Trends and Factors, Determining International Competitiveness, 1977.

Gold, B. "Tracing Gaps Between Expectations and Results of Technological Innovations: The Case of Iron and Steel," The Journal of Industrial Economics 25, no. 1 (September 1976):1-28.

Hausman J. A. "An Instrumental Variable Approach to Full Information Estimators for Linear and Certain Nonlinear Econometric Models." Econometrica 43, no. 4, (July 1975):727-38.

Hekman, J. S. "An Analysis of the Changing Location of Iron and Steel Production in the Twentieth Century," Ph.D. dissertation, University of Chicago, 1976.

__________. "An Analysis of the Changing Location of Iron and Steel Production in the Twentieth Century." American Economic Review 68, No. 1 (March 1978):125-133.

Iron Age, vols. 175-213. 1955-73.

Johnston, J. Econometric Methods. New York: McGraw-Hill, 1972.

Jorgenson D. W. and Laffont, J. J. "Efficient Estimation of Nonlinear Simultaneous Equations with Additive Disturbances." Annuals of Economic and Social Measurement 3, no. 4 (October 1974):615-40.

Jondrow, J., Devine, E., Jacobson, L., Katz, A., O'Neil, D. Removing Restrictions on Imports of Steel, chapter V, Arlington, VA.: Public Research Institute, 1975.

Kendrick, J. W. Postwar Productivity in the United States. New York: National Bureau of Economic Research, 1973.

__________. Productivity Trends in the United States. Princeton: Princeton University Press, 1961.

Lau, L. J. "A Characterization of the Normalized Restricted Profit Function." Journal of Economic Theory 12 (February 1976):131-63.

Maddala, G. S. Econometrics. New York: McGraw-Hill, 1977.

Mancke, R. "New Determinants of Steel Prices in the U.S.: 1947-65." Journal of Industrial Economics 16, no. 2 (April 1968):147-60.

Moody's Investors Service. Moody's Industrial Manual. New York: Moody's Investors Service, 1910-1975.

Morkre, M. E. "Short-Term Price Change in the Steel Industry." Ph.D. dissertation, Northwestern University, 1968.

Nerlove, M. Estimation and Identification of Cobb-Douglas Production Functions. Chicago: Rand-McNally College Publishing Co., 1965.

Oxenfeldt, A. R. Industrial Pricing and Market Practices. New York: Prentice-Hall, 1951.

Parsons, D. O. and Ray, E. J. "The United States Steel Consolidation: The Creation of Market Control." Journal of Law and Economics 18, no. 1 (April 1975):180-219.

Rippe, R. D. "Wages, Prices, and Imports in the American Steel Industry." Review of Economics and Statistics 52 (February 1970):34-46.

Rowley, C. K. Steel and Public Policy. London: MGraw-Hill, 1971.

Solow, R. W. "Technical Change and the Aggregate Production Function." Review of Economies and Statisties 39 (1957): 312-20.

Tarr, D. G. "The Minimum Optimal Scale Steel Plant in the Mid-1970's." Atlantic Economic Review, forthcoming.

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

U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States: 1980 (101th edition), 1980.

U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, 1975 Supplement, 1976.

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

Varian, H. R. Microeconomic Analysis. New York: W. W. Norton 1978.

Weiss, L. W. Case Studies in American Industry. New York: John Wiley & Sons, 1971.

Yntema, T. O. "Pamplet No. 5, A Statistical Analysis of the Demand for Steel, 1919-1938." Introduced into the Record of the Temporary National Economic Committee or Exhibit No. 1411, 1940.