Estimating the Price Elasticity of Ferrous Scrap Supply

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Contents

ILLUSTRATIONS

Figures

Tables

1. Introduction

Nathan Associates Inc. analyzed the relationship between ferrous scrap prices and the quantities of obsolete ferrous scrap recovered from the national inventory and supplied to the U.S. market for scrap. Nathan assembled a database of quarterly observations on scrap prices and quantities transacted from 1985 through 2009, as well as on factors other than price that affect the supply of and demand for scrap. Simultaneous equation models of scrap supply and demand in log-linear form were specified and estimated using two-stage least squares. Nathan found that since their earlier study of 1979, the sensitivity of obsolete ferrous scrap supply to changes in scrap prices has increased. A 10 percent increase in scrap prices elicits an 8.85 percent increase in the quantity of obsolete scrap supplied to the U.S. market. Although steel producers sometimes call for limits on scrap exports based on claims that domestic scrap supplies are inadequate, the Nathan study in combination with the firm's studies of the growing national inventory of obsolete ferrous scrap reveals that additional supplies of obsolete ferrous scrap will be recovered from the national inventory and supplied to the U.S. market as scrap prices increase.

Building on a long history of estimating the national inventory of obsolete ferrous scrap,[1] Nathan Associates Inc. recently completed an update of its first study[2] of the price elasticity of ferrous scrap supply. This report presents the update. It focuses on the relationship between changes in the price of ferrous scrap and the amount of obsolete ferrous scrap recovered from the national inventory and supplied to the market.

Steel manufactures sometimes claim the supply of scrap is insufficient for their needs. Hence, they call for limitations on exports of scrap.

However, Nathan Associates has demonstrated in its past studies of scrap inventories that, in fact, the national inventory of obsolete ferrous scrap has continued to build as more and more ferrous containing end-use products reached the ends of their useful lives and were discarded. In our most recent update, the national inventory as of December 31, 2009 was 1.18 billion tons, 1.04 million tons of which accumulated from 2004 through 2009. During this period, discarded end-use products contained an average of 87.2 million tons of ferrous

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[1] Obsolete ferrous scrap is ferrous material that exists in discarded end-use products such as automobiles, household appliances, construction materials, and others. For the most recent Nathan Associates Inc. study of the national inventory of obsolete ferrous scrap, see "Iron and Steel Scrap: Accumulation and Availability as of December 31, 2009," Institute of Scrap Recycling Industries, Inc. (ISRI), Washington, DC, 2010.

[2] See Robert R. Nathan Associates, Inc., "Price-Volume Relationships for the Supply of Scrap Iron and Steel: A Study of the Price Elasticity of Supply," Scrap Metal Research and Education Foundation, Washington, DC, Jan. 8, 1979.

material of which 65 million tons were recoverable. Forty-seven and one-half million tons were recovered annually, leaving 17.5 million tons of recoverable but unrecovered scrap each year. After accounting for annual corrosion losses, 17.31 million net tons were added each year to the national inventory of obsolete ferrous scrap.

Definition of National Inventory (Potential Reserves) of Obsolete Ferrous Scrap

Material that is of known or inferred quantity in a condition that allows for immediate use and which is available for recovery within the constraints of known technology and higher but realistic prices.

Hence, the issue is not availability, but instead how much higher the price of scrap must be to incentivize the recovery of additional scrap. While all manufactures seek to minimize their cost of materials, the economics of supply and demand combined with the recyclable nature of ferrous scrap ensure that additional scrap can be obtained at prices higher than manufactures currently pay. The question is how much higher.

Our 1979 study was the first to estimate the price elasticity of obsolete ferrous scrap supply. It examined the period 1961 through 1976. Quarterly data were used to estimate average quarterly elasticities, as well as the average elasticity over the entire period. The average price elasticity of obsolete scrap supply over the entire period was 0.833. Total scrap supply, which includes prompt industrial scrap[3] and obsolete scrap, was less sensitive to a change in price. Its elasticity was 0.365.

Our current study differs from the original in three substantive ways. First, we developed a newer database covering 1985 through 2009. In this more recent timeframe, steelmaking relied more heavily on the electric arc furnace (EAF) process, a process in which the metallic charge is 100 percent scrap.[4] In 1960, EAF steel production totaled approximately 8.4 million tons. By 1995, it totaled 42.4 million tons or 39 percent of total steel production.[5] Hence, the market for scrap in our period of analysis was different from the market that existed during the period of our original study.

The second difference pertains to factors included in our analysis that explain demand for and supply of ferrous scrap. Most notably, we used apparent steel consumption instead of foundry and mill shipments of iron and steel as a factor affecting the supply of purchased total (prompt plus obsolete) scrap.

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[3] Prompt industrial ferrous scrap is a by-product of industrial manufacturing. It consists of items such as punchings, stampings, turnings, and borings.

[4] The steelmaking industry includes EAF producers or minimills and integrated steel producers which rely on the basic oxygen furnace (BOF) technology. The metallic charge to the BOF consists of 60 percent to 70 percent hot metal from the blast furnace and 20 percent to 40 percent steel scrap. See "Commentary: Introduction to Electric Arc Furnace Steelmaking," The Electric Power Research Institute, Inc. (EPRI), Center for Materials Production (CMP), 1997, which is available at http://www.p2pays.org/ref/10/09046.pdf.

[5] See "Commentary: Introduction to Electric Arc Furnace Steelmaking."

Finally, in this update we specified and estimated models in log-linear form. Previously, they were not. Hence, average elasticities had to be calculated for changes in average prices and quantities.

Log-linear models allow estimation of elasticities that do not vary with price and quantity. Consequently, they are often referred to as constant elasticity models.

From 1991 through 2009, prices and quantities of ferrous scrap moved similarly (Figure 1). When price increased, more obsolete scrap was recovered and recycled.[6] From 1991 through 2009, the Pearson correlation coefficient[7] between price and recovered obsolete scrap was 0.86 (Table 1), which indicates a significant degree of positive correlation.

The price of scrap and inventory net additions—recoverable obsolete scrap less obsolete scrap recovered—moved inversely. When the price of scrap increased, net additions to inventory decreased. This inverse relationship is to be expected given the positive correlation between the amount of obsolete scrap recovered and changes in the price of scrap. The Pearson correlation coefficient between price and net inventory additions was -0.79. However, a correlation coefficient is not an elasticity. To measure elasticity, more complex statistical analysis is required.

Here, we present an econometric analysis of scrap supply and present estimates of price elasticity. Our report is organized into four chapters. Following this introduction, Chapter 2 presents a discussion of the basic economics of supply elasticity and econometric modeling of supply and demand. Chapter 3 discusses the data requirements of our study and identifies sources we relied on to construct our database. Chapter 4 presents and discusses the specifications of models we estimated. Chapter 5 presents our results. The database is in Appendix A. Appendix B presents additional results of our analysis of scrap demand.

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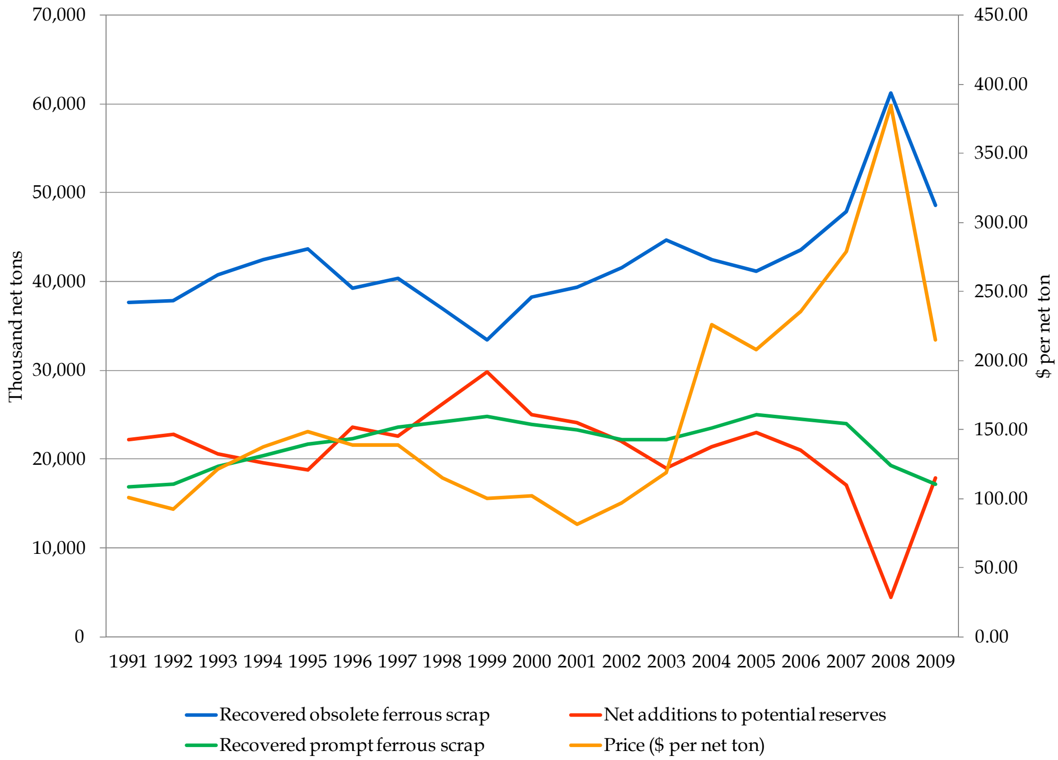
[6] Note the lack of co-movement between price and the quantity of recovered prompt scrap, which is to be expected given that prompt scrap is a waste product of manufacturing end-use products. It is relatively easy to recover by the need to simply clear the shop floor. Hence, the availability of prompt scrap is largely unconnected to ferrous scrap prices.

[7] The Pearson correlation coefficient is the standard statistical measurement of linear dependence (correlation) between two variables. Its value ranges from -1 to +1. Values closer to either -1 (indicating negative correlation) or +1 (indicating positive correlation) indicate stronger correlation.

Figure 1

Price, Net Additions to Inventory, and Recovered Scrap, 1991-2009



SOURCES: Price ($ per net ton) is calculated from the price ($ per metric ton) series reported by the U.S. Geological Survey (USGS) in its annual publication Minerals Commodity Summary for Iron and Steel Scrap, 1996-2010, available online at http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/index.html#mcs. See Appendix A, Table A-2 of the recent Nathan Associates Inc. study of the national inventory of obsolete ferrous scrap, "Iron and Steel Scrap: Accumulation and Availability as of December 31, 2009," Institute of Scrap Recycling Industries, Inc. (ISRI), Washington, DC, 2010 for data on recovered obsolete scrap, recoverable prompt scrap, and net additions to potential reserves.

Table 1

Correlation between Price and Scrap Recovered

Scrap Quantity	Pearson Correlation Coefficient
Recovered Obsolete scrap*	0.861
Recovered Prompt scrap	0.012
Net Additions to potential reserves*	-0.789

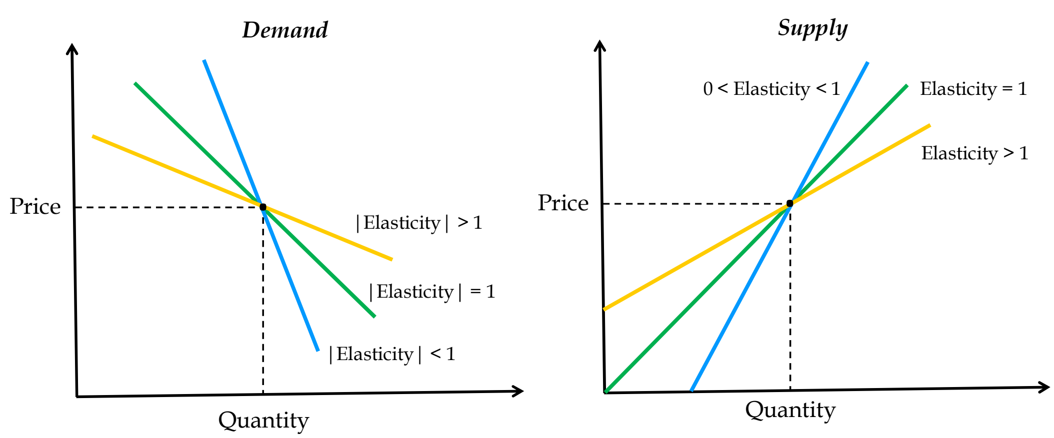
*NOTE: * indicates the correlation is statistically significant at the one percent level which implies a probability of one percent or less that the correlation occurred by chance.*
SOURCE: Nathan Associates Inc.

2. Background

Price elasticity of demand or supply is simply a way of characterizing the sensitivity of product quantity demanded or supplied to a change in the price of the product. It is measured by the ratio of percentage change in quantity (demanded or supplied) to percentage change in price. If the percentage change in quantity exceeds the percentage change in price, demand or supply is more sensitive to a change in price. If the percentage change in quantity is less than the percentage change in price, demand or supply is less sensitive to a change in price.

Figure 2 illustrates the basic idea of demand and supply elasticity. Generally speaking, the steeper the demand or supply curve, the less sensitive it is to a change in price—it is less elastic. The flatter the curve, the more sensitive it is to a change in price—it is more elastic.

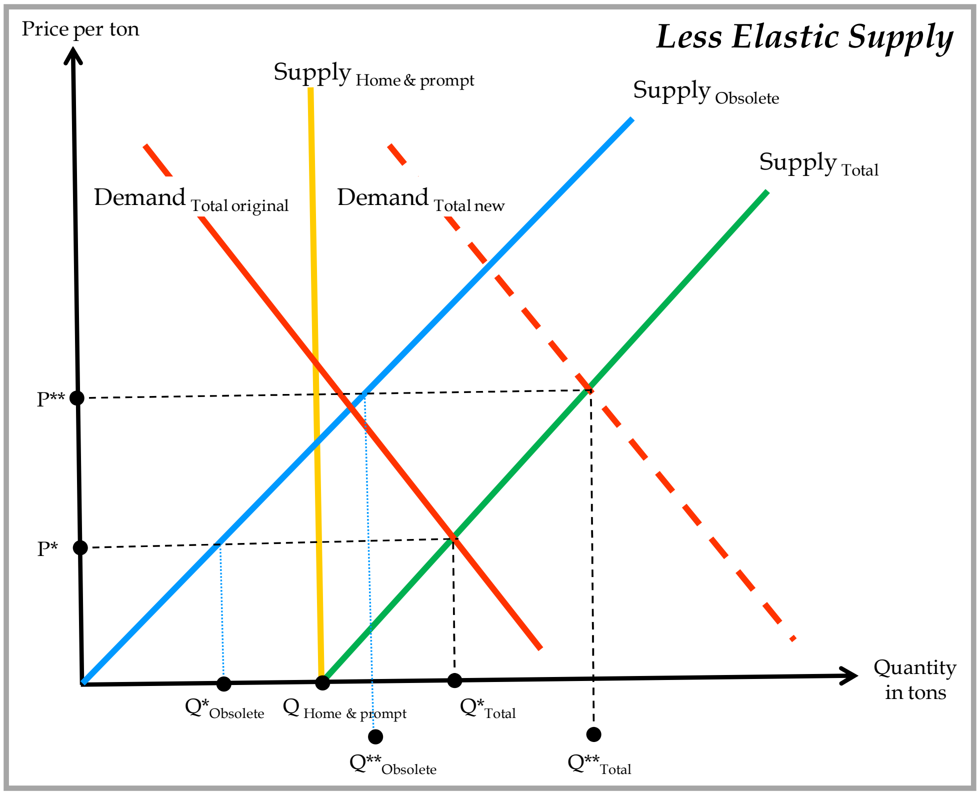
Figure 2
Price Sensitivity of Demand and Supply as Measured by Elasticities

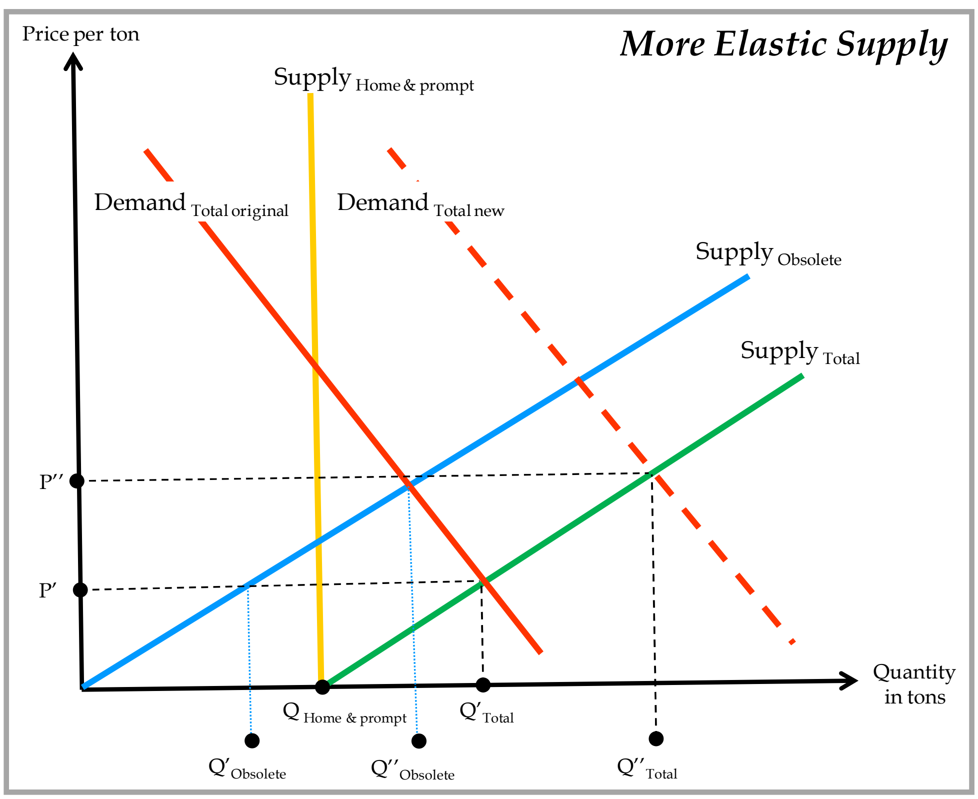


2.1 Relevance of Elasticity

Before proceeding, it is useful to consider how supply elasticity affects market-clearing prices and quantities (Figure 3). Total ferrous scrap supply (the green line of Figure 3) consists of home and prompt scrap (the yellow line), as well as obsolete scrap (the blue line). Home scrap is reprocessed in the steel mill in which it was produced. It is not supplied to the scrap

Figure 3
Effects of Supply Elasticity on Market-Clearing Prices and Quantities





market. Prompt scrap is supplied to the market, but amounts supplied do not vary significantly, if at all, with scrap prices. Instead, prompt industrial scrap supplied to the market varies with manufacturing activity. As manufacturing increases, additional prompt scrap is generated, removed from the shop floor, and supplied to the market. On the other hand, the quantity of obsolete scrap supplied does vary with scrap prices. As prices increase, additional obsolete scrap will be recovered and supplied.

Consider first the effects when demand remains constant. Market clearing prices and quantities are determined when demand equals supply, that is, where the red solid line representing demand in Figure 3 intersects the green line representing total ferrous scrap supply. When supply is more elastic, as depicted in the bottom panel of Figure 3, the total supply curve is flatter and the market-clearing quantity of scrap is greater ($Q'_{Total} > Q^*_{Total}$) and the market clearing price of scrap is lower ($P' < P^*$).

Now consider a shift in demand. Assume a new minimill opens. As a result, at every price point, the quantity of scrap demanded will increase. The demand curve shifts to the right, as illustrated in the top and bottom panels of Figure 3 by the dashed red line.

Not surprisingly, with a more elastic supply of obsolete ferrous scrap, the increase in demand for scrap has a greater effect on quantity supplied and price. The quantity supplied is greater ($Q''_{Total} > Q^{**}_{Total}$) and the price paid is lower ($P'' < P^{**}$) when supply is more elastic.

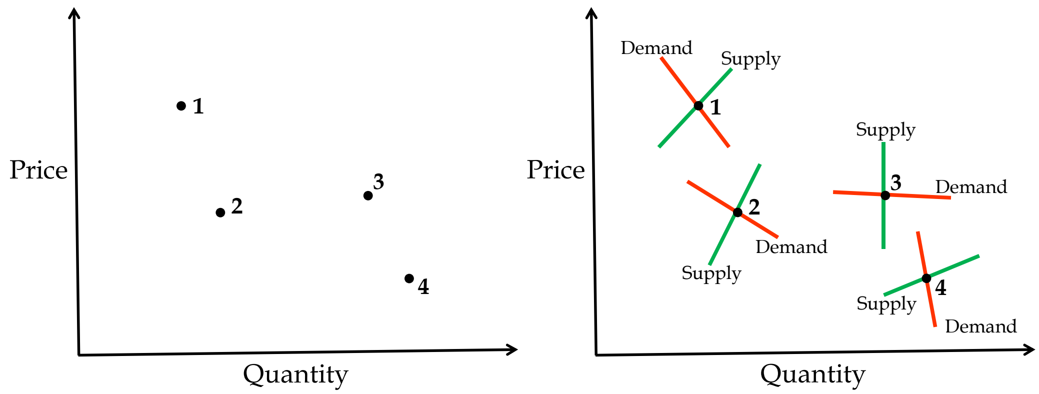
With scrap supply more sensitive to a change in scrap price, an increase in demand for scrap will result in additional quantities of obsolete ferrous scrap being recovered from the national inventory and supplied to the scrap market.

2.2 Why the Need to Model Demand and Supply?

The previous discussion reveals a conundrum. Prices and quantities available for calculating a supply or demand elasticity are transaction data. We do not observe market demand or supply *schedules*, that is, what a consumer would be willing to pay or the price a supplier would be willing to accept. We observe only the prices and quantities transacted—the points of intersection between demand and supply curves (Figure 4). For example, in the top panel of Figure 3, P^* and Q^*_{Total} would be reported, but additional price-quantity combinations along the total supply curve would not.

Figure 4

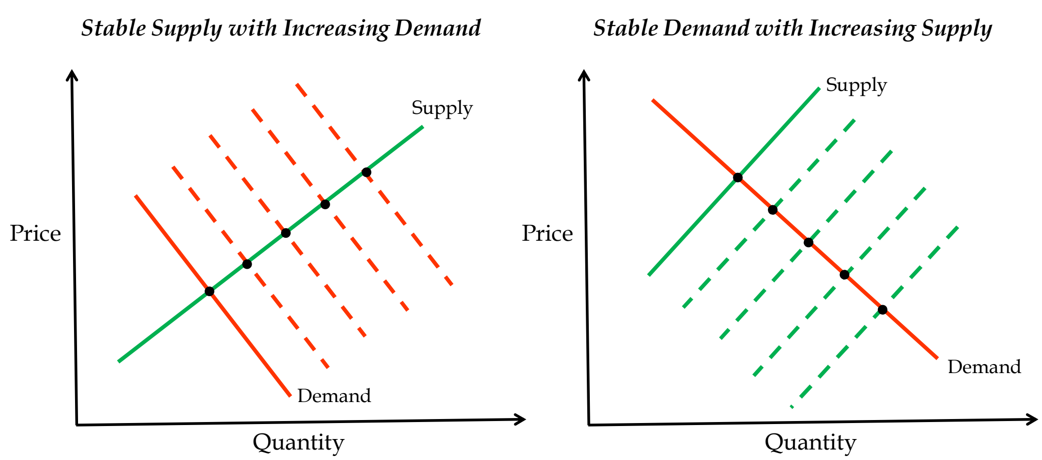
Price and Quantity Data Are Transaction Amounts



Compounding this conundrum is the fact that quantity demanded, quantity supplied, and price are determined simultaneously, which might lead to an identification problem (Figure 5). When we observe price-quantity combinations, we might be observing movement along a supply curve or movement along a demand curve. For example, as one's income increases, one's consumption will likely increase, that is, demand will increase. The demand curve will shift to the right. With a stable supply curve, points of intersection between demand and supply curves would trace points along the supply curve. On the other hand, consider a market in which demand is stable but supply is increasing, perhaps from technological innovation that allows additional quantities supplied to the market at each price point. In this case, the supply curve shifts to the right and points of intersection between demand and supply would trace points along the stable demand curve.

Figure 5

The Identification Problem



Because data reported are transaction data; the determination of price, quantity supplied, and quantity demanded occur simultaneously; and factors other than price affect supply and demand we cannot calculate elasticity as simply the ratio of a reported percentage change in quantity to a reported percentage change in price. Instead, we must specify and estimate a model of demand and supply, including factors affecting quantities supplied and demanded other than price.

2.3 A Basic Model

The simplest model of demand and supply consists of the following two simultaneous equations plus the identity or equilibrium condition:[8]

1. Demand function: $Q^d_t = A_1 + A_2P_t + u_{1t}$

2. Supply function: $Q^S_t = B_1 + B_2P_t + u_{2t}$.

   Equilibrium condition: $Q^d_t = Q^S_t$

where Q^d_t is quantity demanded at time t, Q^S_t is quantity supplied at time t, P_t is price at time t, u_{1t} is the effect on demand of factors other than price, such as income, and u_{2t} is the effect on supply of factors other than price, such as weather. The A's and B's are structural parameters. We expect A_2 to be negative (a negative correlation between price and quantity demanded which results in a downward sloping demand curve) and B_2 to be positive (a positive correlation between price and quantity supplied which results in an upward sloping supply curve).

The equilibrium condition can be re-written in the parameters of the model and solved for P_t as follows:

3. $A_1 + A_2P_t + u_{1t} = B_1 + B_2P_t + u_{2t}$

4. $P_t = \pi_1 + v_{1t}$

where $\pi_1 = (B_1 - A_1) \div (A_2 - B_2)$ and $v_{1t} = (u_{2t} - u_{1t}) \times (A_2 - B_2)$.

We can now substitute the P_t equation into either the demand or supply equation (equation 1 or 2, respectively) to solve for Q_t as follows:

5. $Q_t = \pi_2 + v_{2t}$

where $\pi_2 = (A_2B_1 - A_1B_2) \div (A_2 - B_2)$ and $v_{2t} = (A_2u_{2t} - B_2u_{1t}) \div (A_2 - B_2)$.

This simple model illustrates the simultaneity and identification problems discussed earlier. Regarding simultaneity, notice from equation 1 that if u_{1t} is positive, Q^d_t will be greater at every P_t, that is, the demand curve will shift to the right. Once this happens the intersection of the new demand curve with the unchanged supply curve will occur at a new P_t which then feeds back into the supply curve of equation 2. A shift in either u_{1t} or u_{2t} changes P_t and Q_t. Price and quantity are said to be jointly dependent. Regarding the identification problem,

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[8] The discussion in the section closely follows Damodar N. Gujarti's Chapter 15, Simultaneous Equation Models, in *Essentials of Econometrics – 3rd ed.*, McGraw-Hill Irwin, 2006.

notice that equations 4 and 5, which are referred to as the "reduced form" of the model, include the four structural parameters (the A's and B's) of the model. However, one cannot estimate four parameters in a model of only two equations. One needs at least four independent equations to estimate four parameters. In this model, demand and supply are *under-identified*.

2.4 Estimating the Model

Estimating a model of simultaneous equations first requires determining whether the model's specification is under-identified, exactly identified, or over-identified. If the model is under-identified, such as our simplest model, no statistical technique can be used to estimate the model's structural parameters. If the model is exactly identified, the method of indirect least squares can be used. If the model is over-identified, the method of two-stage least squares (2SLS) can be applied.

Before turning to a description of 2SLS, which is the technique we applied to estimate the parameters of our ferrous scrap models, consider how one can determine whether a model is under-, exactly, or over-identified. The simplest way is to count the number of endogenously determined variables, which is equivalent to the number of equations in the model, and the number of exogenously determined variables (variables whose values are determined outside the model). In our simplest model, there are two endogenous variables and no exogenous variables. Although the supply and demand equations in the simplest model include terms that capture the total effect of factors other than price on demand (the u_{1t} term) and supply (the u_{2t} term), these terms are stochastic (random) error terms.

The rules in making a determination of identification are as follows:

- If the total (k) number of variables (both endogenous and exogenous) that are excluded from the model's equation under consideration is less than the number of endogenous variables in the model minus one (m – 1), the equation is under-identified, that is, *the equation is under-identified if* $k < m - 1$.
- If the total (k) number of variables (both endogenous and exogenous) that are excluded from the model's equation under consideration equals the number of endogenous variables in the model minus one (m – 1), the equation is exactly identified, that is, *the equation is exactly identified if* $k = m - 1$.
- If the total (k) number of variables (both endogenous and exogenous) that are excluded from the model's equation under consideration is greater than the number of endogenous variables in the model minus one (m – 1), the equation is over-identified, that is, *the equation is over-identified if* $k > m - 1$.

Returning now to our simplest model, in both the demand and supply equations (equations 1 and 2, respectively), there are no exogenously determined variables so none is excluded from either (k =0). Hence, for both supply and demand equations, k is less than (m – 1), that is, 0 < 1, and both are revealed to be under-identified, a result that was previously determined by deriving the reduced form of the model and realizing its two equations contained four structural parameters.

Now consider modifying the simplest model by including income in time t (I_t) as an exogenous factor in the determination of demand. This augmented simple model can be written as

6. Demand function: $Q^d_t = A_1 + A_2P_t + A_3I_t + u_{1t}$
7. Supply function: $Q^S_t = B_1 + B_2P_t + u_{2t}$.

Here, m remains equal to two, but k equals zero in the demand function and one in the supply function. Hence, in our augmented model the demand function is under-identified (k < m - 1) while the supply function is exactly identified (k = m – 1). By adding income to the demand function, the supply function is identified. This result was illustrated in the left panel of Figure 5 above. Recall how a shifting demand curve (caused by increasing income) with a stable supply curve allowed identification of price-quantity combinations along the supply curve.

As a final example, consider two more modifications to our simplest model. In addition to adding income to the demand function, we add a binary variable (S_t) that equals one during summer months and zero otherwise. Such a factor is often included to account for seasonal differences in demand. We also add price in the period prior to t to the supply function. This revised model can be written as

8. Demand function: $Q^d_t = A_1 + A_2P_t + A_3I_t + A_4S_t + u_{1t}$
9. Supply function: $Q^S_t = B_1 + B_2P_t + B_3P_{t-1} + u_{2t}$.

In this revised model, m remains equal to two. However, k in the demand function now equals one because P_{t-1} (which is an exogenous variable because its value is known at time t) is excluded from the demand function. The value of k in the supply function equals two because it excludes I_t and S_t. Hence, the demand equation is exactly identified (k = m – 1) and the supply equation is over-identified (k > m – 1).

When an equation is over-identified, 2SLS can be used to estimate its structural parameters. 2SLS applies the standard statistical method of ordinary least squares (OLS)[9] twice. First, a proxy for P_t that is not correlated with the error term u_{2t} of the supply curve must be specified

[9] See Gujarati, Chapter 6 for an introduction to OLS.

and estimated. One such proxy is P_t itself as a function of all exogenous variables in the model, such as:

10. $P_t = C_1 + C_2I_t + C_3S_t + C_4P_{t-1} + w_t$

where w_t is a random error term.

After estimating P_t, one substitutes the estimated values into the supply equation and estimates its parameters using OLS once again. In other words, the supply function is estimated by regressing $Q^S{}_t$ on estimated P_t's, as follows, not on the original P_t's.

11. $Q^S{}_t = B_1 + B_2(\text{Estimated}P_t) + B_3P_{t-1} + e_t$

where e_t is a random error term.

2.5 Logarithmic Transformation for Estimating Elasticity

Recall that elasticity is defined as the percentage change in quantity divided by the percentage change in price. Elasticity can be written as follows:

$$[(Q_{New} - Q_{Old}) \div Q_{Old}] \div [(P_{New} - P_{Old}) \div P_{Old}],$$

which can be rewritten as

$$(dQ/Q) \div (dP/P),$$

and finally as

$$(dQ/dP) \times (P/Q).$$

In the supply function of the simplest model, quantity supplied was specified as a linear function of price as follows:

$$Q^S{}_t = B_1 + B_2P_t + u_{2t}$$

In this linear function, $dQ^S{}_t/dP_t$ equals B_2 and $P_t/Q^S{}_t = P_t\ /(B_1 + B_2P_t + u_{2t})$. Hence, the supply elasticity can be rewritten as

$$B_2 \times [P_t/(B_1 + B_2P_t + u_{2t}]$$

and one sees that supply elasticity varies with price. Even with the parameters (B_1 and B_2) of the function estimated, one cannot calculate elasticity until a price is given, and the calculated value can be different for different prices.

However, a logarithmic transformation of the supply function enables calculation of a constant elasticity. Rewrite the supply function by taking the natural logarithm (ln) of both sides of equation 2 above as follows:

12. $\ln(Q^S_t) = B_1 + B_2 \times \ln(P_t) + u_{2t}$

Recognizing a change in the logarithm of a number is a relative or proportional change, that is, $d(\ln Q^S_t)$ equals dQ^S_t/Q^S_t and $d(\ln P_t)$ equals dP_t/P_t, we see that B_2, which equals $d(\ln(Q^S_t))/d(\ln(P_t))$, is the percentage change in quantity (dQ^S_t/Q^S_t) divided by the percentage change in price (dP_t/P_t). The estimated price parameter (B_2 in equation 12 above) is the price elasticity of supply, and, more important, it is constant and does not vary as price varies. By transforming the function into a log-linear form, we can estimate a constant price elasticity.

Having introduced these basic concepts, we next turn to a discussion of the data required to model ferrous scrap supply and demand.

3. Data

Our study focuses on the responsiveness of ferrous scrap supply to changes in price. Hence, a database of amounts purchased, prices, factors affecting scrap supply, and factors affecting scrap demand must be assembled. Our database consists of quarterly observations for 1985 through 2009. It is presented in Appendix A.

3.1 Generating a Series on Purchased Obsolete Ferrous Scrap

We must distinguish between obsolete and prompt scrap to determine the amount of obsolete scrap recovered from the national inventory. However, statistics on purchased scrap are available for total prompt and obsolete. Reported data do not separate purchased prompt from purchased obsolete scrap. Hence, we begin by deriving a historical series on purchased amounts of obsolete ferrous scrap. We do so by relying heavily on our most recent study of the national inventory of obsolete ferrous scrap.[10]

3.1.1 START WITH TOTAL PURCHASED SCRAP RECEIPTS

Annual amounts of total purchased scrap are reported in the U.S. Geological Survey (USGS) of the U.S. Department of the Interior. Net receipts include receipts of scrap from brokers, dealers, and other outside sources, plus receipts from other own-company plants, minus shipments. Receipts are reported in thousand metric tons. The series can be constructed by subtracting shipments from receipts for 1985 through 1990 as reported in USGS Table 1: Salient U.S. Iron and Steel Scrap and Pig Iron Statistics.[11] For years after 1990, the series is reported as net receipts of ferrous scrap for all manufacturing types in Table 1: Salient U.S. Iron and Steel Scrap, Pig Iron, and Direct-Reduced Iron Statistics of the Minerals Yearbook.[12] We converted annual net receipts into quarterly amounts using U.S. quarterly total crude steel

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[10] See Nathan Associates Inc., "Iron and Steel Scrap, Accumulation and Availability as of December 31, 2009," Institute of Scrap Recycling Industries, Washington, DC, 2010 for additional details on the derivation of obsolete scrap consumption.

[11] See http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/stat/tbl1.txt.

[12] The Minerals Yearbook is an annual publication of USGS. It is available as portable document format (pdf) files at http://minerals.er.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/.

production reported by the World Steel Association (formerly the International Iron and Steel Institute).[13]

3.1.2 ESTIMATE PROMPT SCRAP GENERATED

We applied the following three-step process to estimate quantities of prompt scrap generated:

- First we calculated annual total amounts of ferrous material consumed by manufacturers of end-use products.[14]
- Next we disaggregated annual total amounts into 19 iron and steel consuming sectors,[15] such as construction materials, consumer durables, and automotive, among others.
- Then we multiplied sector-specific prompt scrap generation rates, that is, prompt scrap generated during the manufacture of ferrous-containing end-use products, by the quantities of ferrous material consumed by each sector. Rates are based on a study by Hogan and Kolke.[16] They range from six percent to 31 percent, with an average across all 19 ferrous consuming sectors of 16.6 percent.[17]

3.1.3 DERIVE PURCHASED OBSOLETE SCRAP

Purchased obsolete scrap is purchased total scrap less scrap imports plus scrap exports less prompt scrap generated. Prompt scrap generated is reduced 1.5 percent to account for waste before subtracting it from trade adjusted purchased total scrap.[18] Imports and exports are reported by USGS at http://minerals.usgs.gov/ds/2005/140/ironsteelscrap.pdf.

3.2 Scrap Prices

For scrap prices, we used the producer price index (PPI) for iron and steel scrap published by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor.[19] It measures average monthly change in prices received by domestic producers of iron and steel scrap. To derive a quarterly series, we averaged monthly values across three-month periods.

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13 See http://www.worldsteel.org/?action=stats&type=steel&period=latest.

14 Derived from various sources such as the American Iron and Steel Institute, the Census of World Casting published by Modern Casting, and Current Industrial Reports published by the U.S. Census Bureau.

15 As defined by the American Iron and Steel Institute.

16 William T. Hogan and Frank T. Koelble, "Purchased Ferrous Scrap Demand and Supply Outlook," Industrial Economic Research Institute, Fordham University, New York, June 1977.

17 Based on personal conversations with researchers, the Steel Recycling Institute, USGS, and presentations given at the International Iron and Steel Institute, we found that the results of the 1977 study by Hogan and Kolbe remain accurate.

18 The waste percentage figure, or a prompt recovery rate of 98.5 percent, is based on an internal study conducted by the Steel Recycling Institute in 2000. This information was provided in a telephone conversation with the Steel Recycling Institute on 1/18/05.

19 The PPI for iron and steel scrap is reported as series WPU1012 at ftp://ftp.bls.gov/pub/time.series/wp/wp.data.11a.Metals10-103. Additional information is available at http://www.bls.gov/.

3.3 Factors Affecting Scrap Supply Other than Price

Factors other than scrap price that are likely to affect scrap supply include the cost of processing scrap, transportation cost, fluctuations in steel mill and foundry shipments, scrap trade, and events that can shock an economy into abnormal performance.

3.3.1 SCRAP PROCESSING COST

Data on scrap processing cost *per se* are not available. However, the major drivers of processing cost include labor cost, energy cost, and cost of raw materials.

Hence, we constructed a cost index as a proxy for scrap processing cost and included it in our supply function. The index is a weighted composite of the three major drivers, with weights of 10.5 percent for labor cost, 7.0 percent for energy cost, and 82.5 percent for raw material cost.[20] For labor cost, we used BLS-reported private sector average hourly earnings of production and nonsupervisory employees.[21] For energy cost, we used the BLS producer price index (not seasonally adjusted) for fuels and related products and power.[22] For raw materials, we used the BLS producer price index (not seasonally adjusted) for industrial commodities.[23]

3.3.2 SCRAP TRANSPORTATION COST

Because prices of ferrous scrap are quoted at the point of delivery, transportation cost is an important factor affecting scrap supply.

As a proxy for transportation cost, we included railroad revenue per ton-mile of transported waste and scrap in our supply function. It is reported by the Surface Transportation Board (STB) of the U.S. Department of Transportation (DOT).[24] Data are annual through 2007. We estimated values for 2008 and 2009 using the historical compound annual growth rate from

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[20] Weights provided by a large processor of ferrous scrap.

[21] See series CES0500000008, average hourly earnings of production and nonsupervisory employees, at http://data.bls.gov/pdq/SurveyOutputServlet?years_option=all_years&output_view=data&periods_option=all_periods&output_format=text&reformat=true&request_action=get_data&initial_request=false&data_tool=surveymost&output_type=column&series_id=CES0500000008.

[22] See series WPU05, fuels and related products and power, at http://data.bls.gov/pdq/SurveyOutputServlet?years_option=all_years&output_view=data&periods_option=all_periods&output_format=text&reformat=true&request_action=get_data&initial_request=false&data_tool=surveymost&output_type=column&series_id=WPU05.

[23] See series WPU03THRU15, industrial commodities, at http://data.bls.gov/pdq/SurveyOutputServlet?years_option=all_years&output_view=data&periods_option=all_periods&output_format=text&reformat=true&request_action=get_data&initial_request=false&data_tool=surveymost&output_type=column&series_id=WPU03THRU15.

[24] Revenue per ton-mile can be obtained by downloading a 2.94MB Excel workbook at http://www.stb.dot.gov/stb/industry/econ_rateindex.html. Click on "Click here to view Rate Study workbook" and save the file. The sheet titled "Summary_Statistics" contains waste and scrap (commodity code 40) revenue per ton-mile (RPTM) for 1985 through 2007. Each year has an entry for short, medium, and long haul trips. We combined revenue and ton-miles reported for each distance category and divided total revenue across all three distance categories by total ton-miles across all three distance categories to calculate RPTM across all three categories in each year.

2005 through 2007. We made no attempt to estimate a quarterly series. Instead, we used the annual statistic for each quarter of the year.

3.3.3 APPARENT STEEL CONSUMPTION

Prompt scrap is generated when steel products (sheets, plates, bars, and wire, among others) are consumed in the production of end-use products.[25] Hence, the consumption of steel products is likely to affect the supply of total purchased scrap. We obtained a historical series of apparent steel consumptions, which equals production minus exports plus imports, from the USGS.[26]

3.3.4 FERROUS SCRAP TRADE

To control for the impact of U.S. exports of scrap on U.S. supply, we include the ratio of scrap exports[27] to domestic purchased scrap receipts in our supply function. USGS reports scrap exports and purchased scrap receipts on an annual basis. Again we used quarterly crude steel production data to convert annual scrap export ratios into a quarterly series.

3.3.5 ECONOMIC SHOCKS

There were several major economic shocks during the period 1985 through 2009 that affected ferrous scrap supply. The full impact of these shocks might not be captured by variables we include in our model. Hence, we introduced binary (dummy) variables to measure impacts of these events on the supply of ferrous scrap. A dummy variable is set equal to one for the quarters the event might have affected supply. It is set equal to zero for all other quarters.

Financial and Economic Crises in Asia and Brazil

Between 1998 and 2002, imports of iron and steel scrap into the United States increased rapidly due mainly to low prices and low demand in Asia and Brazil in the aftermath of their financial and economic crises. Average U.S. imports of iron and steel scrap were 852,000 net tons per quarter during the period. In contrast, average imports were only 589,000 net tons during the prior five years. Hence, between 1998 and 2002, the abnormally high volume of imports likely had a disproportionate effect on scrap receipts *vis-à-vis* other periods. To account for this possibility a dummy variable was included in our model. Its value was set equal to one for each quarter of 1998 through 2002 and zero during all other quarters.

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[25] Note that the use of apparent steel consumption as a supply factor is an improvement to our 1979 model. In the earlier model, we used steel mill and foundry shipments. However, foundry shipments are of finished products such as tubes and castings that are not re-shaped. No prompt scrap is generated when foundry products are consumed.

[26] See http://minerals.usgs.gov/ds/2005/140 and steel statistics on pages five through eight of http://minerals.usgs.gov/ds/2005/140/ironsteel.pdf.

[27] For 1985 to 2003, exports are reported by USGS in its *Open_file Report 01-006, Historical Statistics for Mineral and Material Commodities in the United States, Table: Iron and Steel Scrap Statistics*. For 2004-2008, the data are reported in USGS *Data Series 140, Historical Statistics for Mineral and Mineral Commodities in the United States, Table: Iron and Steel Scrap Statistics.* A value for 2009 is reported in the *Mineral Industry Survey of January 2010, Tables 7 and 9.*

U.S. Financial Crisis and Economic Recession

The steel and ferrous scrap industries were significantly affected by the severe U.S. recession from the fourth quarter of 2008 through 2009. The downturn in economic activity reduced scrap receipts and steel production. Hence, we included another dummy variable in our model. Its value equals one during the fourth quarter of 2008 and every quarter of 2009 and zero in all other quarters.

3.4 Factors Affecting Scrap Demand Other than Price

Factors that might affect scrap demand other than the price of scrap include the production of crude steel, consumption of iron ore, technological change, and the availability of other scrap that can substitute for obsolete ferrous scrap.

3.4.1 CONSUMPTION OF IRON ORE

Iron ore is the raw material used in crude steel production. In the form of pig iron, it substitutes for scrap. Hence, we include iron ore consumption at U.S plants[28] in our demand function to control for its impact on the demand for ferrous scrap.

3.4.2 CRUDE STEEL PRODUCTION

Crude steel production drives the demand for ferrous scrap. Hence, we included production in our demand function. We summed monthly crude steel production volumes reported by the World Steel Association to obtain quarterly production data.[29]

3.4.3 TECHNOLOGICAL CHANGE

Technological changes in steelmaking, particularly the increased utilization of the basic oxygen furnace (BOF) and the electric arc furnace (EAF), affect scrap demand. Of the metal materials used by BOF to make crude steel, 35 percent to 40 percent are ferrous scrap and the remaining 65 percent to 60 percent are pig iron. In the case of EAF, metal material inputs are almost entirely ferrous scrap. Therefore, the demand for scrap is likely to be highly influenced by the proportion of steel produced in BOFs and EAFs. Hence, we included in our demand function the proportion of total steel produced by the BOF technology as a factor affecting demand.[30] However, we did not include the proportion produced by EAF to avoid the statistical problem of co-linearity between explanatory factors. The EAF proportion is highly correlated with the BOF proportion. We converted reported annual BOF proportions into quarterly values using linear interpolation.

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[28] "Apparent consumption" in metric tons reported by USGS at http://minerals.usgs.gov/ds/2005/140/ironore.pdf.
[29] See http://www.worldsteel.org/?action=stats&type=steel&period=latest.
[30] Reported by USGS and available online at http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/

3.4.4 AVAILABILITY OF OTHER SCRAP

Finally, the quantity of purchased scrap demanded is at least partly influenced by the availability of home scrap.[31] Indeed, the quantity of obsolete scrap demanded is influenced by the availability of home and prompt scrap. Although home and prompt scrap supply are independent of price, they do affect market-clearing scrap prices. As additional volumes become available, the vertical supply curve (recall from Figure 3 above) shifts to the right. The shift pushes the total scrap supply curve to the right, which determines a new market-clearing scrap price-quantity combination.

To control for these effects, production volumes of home scrap are included in our demand function as ratios. In one case, we include the ratio of home scrap to home plus purchased scrap. In another case, we include the ratio of home plus prompt scrap to home plus purchased (prompt and obsolete) scrap.

While home scrap production figures are reported annually by the USGS, we estimated prompt scrap generated annually from shipments data, as discussed previously. Quarterly crude steel production figures were used to convert annual home scrap production into quarterly figures and data on quarterly apparent consumption (production plus imports minus exports) of iron and steel were used to convert estimated prompt scrap generated into a quarterly series.[32]

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[31] Reported by USGS and available online at http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/.

[32] Apparent consumption is calculated as shipments plus imports less exports of iron and steel. Monthly figures are reported by the American Iron and Steel Institute in its Annual Statistical Report, 2009, and were totaled to arrive at quarterly figures

4. Model

Having identified factors affecting the supply and demand of ferrous scrap, we now turn to specifying a model. We specify two. The first model is of total purchased ferrous scrap, which consists of prompt and obsolete scrap. The second is of purchased obsolete scrap only.

4.1 Total Prompt and Obsolete Scrap

For a reason that will soon become apparent, we begin by specifying the model in a multiplicative form as follows:

13. ${}_{Total}Q^{d}_{t} = A_0\,(Price_t^{A_1})\ (TSTL_t^{A_2})\ (OREC_t^{A_3})\ (BOP_t^{A_4})\ (C_t^{A_5})$

14. ${}_{Total}Q^{S}_{t} = B_0\,(Price_t^{B_1})\ (COST_t^{B_2})\ (FRTR_t^{B_3})\ (APC_t^{B_4})\ (XPRTR_t^{B_5})\ (DUMMY_t^{B_6})$

where Price is the producer price index for iron and steel scrap, TSTL is crude steel production, OREC is iron ore consumption, BOP is the BOF-produced share of total steel production, C is the home scrap production share of home and purchased scrap, COST is our index of ferrous scrap processing cost, FRTR is railroad revenue per ton-mile of waste and scrap, APC is apparent steel consumption, XPRTR is scrap exports as a share of net purchased scrap receipts, and DUMMY is a binary variable identifying quarters of economic shock.

We next transform the model's demand and supply functions by taking the natural logarithm (ln) of each. For simplicity, we drop the subscript for time (t), which is quarterly in our data.

15. $\ln({}_{Total}Q^{d}) = A_0 + A_1 \times \ln(Price) + A_2 \times \ln(TSTL) + A_3 \times \ln(OREC) + A_4 \times \ln(BOP) + A_5 \times \ln(C)$

16. $\ln({}_{Total}Q^{S}) = B_0 + B_1 \times \ln(Price) + B_2 \times \ln(COST) + B_3 \times \ln(FRTR) + B_4 \times \ln(APC) + B_5 \times \ln(XPRTR) + B_6 \times \ln(DUMMY)$

As expressed in equations 15 and 16 above, estimated values of A_1 and B_1 will be price demand and supply elasticities, respectively.

4.2 Obsolete Scrap

We begin with the following specification (again multiplicative) for our model of obsolete scrap:

17. $_{Obsolete}Q^{d}_{t} = C_0\,(Price_t^{C_1})\,(TSTL_t^{C_2})\,(OREC_t^{C_3})\,(BOP_t^{C_4})\,(B_t^{C_5})$

18. $_{Obsolete}Q^{S}_{t} = D_0\,(Price_t^{D_1})\,(COST_t^{D_2})\,(FRTR_t^{D_3})\,(XPRTR_t^{D_4})\,(DUMMY_t^{D_5})$

where all right-hand-side variables, but for B, are as defined above. In this model, B is home and prompt scrap as a share of home, prompt, and obsolete scrap. In the supply function, APC is not included. We are modeling purchased obsolete scrap, not total purchased scrap which includes prompt.

The logarithmic transformation of the above functions yields the following:

19. $\ln(_{Obsolete}Q^{d}) = C_0 + C_1 \times \ln(Price) + C_2 \times \ln(TSTL) + C_3 \times \ln(OREC) + C_4 \times \ln(BOP) + C_5 \times \ln(B)$

20. $\ln(_{Obsolete}Q^{S}) = D_0 + D_1 \times \ln(Price) + D_2 \times \ln(COST) + D_3 \times \ln(FRTR) + D_4 \times \ln(XPRTR) + D_5 \times \ln(DUMMY)$

Again, as expressed in equations 19 and 20 above, estimated values of C_1 and D_1 will be price demand and supply elasticities, respectively.

4.3 Estimation

A simple count of variables in each model reveals the supply and demand functions in each are over-specified. In both the total and the obsolete scrap models, m equals two. In the total scrap model, there are nine exogenous variables (four in the demand function and five in the supply function). In the demand function, the five exogenous variables of the supply function are missing, so k equals five, which is greater than m–1. Hence, the demand function is over-specified. In the supply function, k equals four, which exceeds m-1, so it too is over-specified. In the obsolete model, k equals four in both the demand and supply functions. Hence, both are over-specified (k > m-1).

Hence, 2SLS is the appropriate technique for estimating the parameters of the models. In the first stage, OLS is used to estimate a proxy for the endogenous price variable. In the second stage, OLS is used again to estimate the supply and demand functions when the estimated values of the proxy for price are used instead of actual prices.

The specification for estimating a price proxy in the first stage of 2SLS is as follows:[33]

21. $\ln(Price) = E_0 + E_1 \times \ln(TSTL) + E_2 \times \ln(OREC) + E_3 \times \ln(BOP) + E_4 \times \ln(B) +$
$E_5 \times \ln(COST) + E_6 \times \ln(FRTR) + E_7 \times \ln(XPRTR) + E_8 \times \ln(DUMMY$

The estimated parameters of equation 21 above, as well as statistical measures of the goodness of fit of the estimated equation are presented below (Table 2).

Table 2
Regression Results for Estimation of Price Proxy (first stage of 2SLS)

Parameter	Variable	Parameter Estimate	Standard Error	Calculated t-value /a	Significance /b
E_0	Constant	-5.70192	1.90497	-2.99	1 percent
E_1	TSTL	0.99191	0.47259	2.10	5 percent
E_2	OREC	-0.61115	0.44706	-1.37	> 10 percent
E_3	BOP	0.20812	0.62820	0.33	> 10 percent
E_4	B	-1.50185	0.31011	-4.84	1 percent
E_5	COST	1.51013	0.28108	5.37	1 percent
E_6	FRTR	0.38219	0.20493	1.86	10 percent
E_7	XPRTR	-0.06228	0.12989	-0.48	> 10 percent
E_8	DUMMY	-0.35586	0.07449	-4.78	1 percent

Note: 100 observations were used in the regression. The adjusted R-square statistic is 0.8901. The F value of the regression is 101.23 which is significant at one percent.

a. The t-value is the estimated value of the coefficient divided by its standard error. It measures the estimated coefficient's number of standard deviations from a value of zero. It is used to test the hypothesis that the true value of the coefficient is non-zero.

b. The probability of observing a t-statistic as large or larger in magnitude as the calculated t-value given that the true value of the coefficient is zero. A significance level of 5 percent indicates a 5 percent chance of rejecting the null hypothesis (true value of the coefficient is zero) when it is true.

Once the proxy function for price has been estimated, estimated quarterly values of $Price_t$ for 1985 through 2009 can be calculated from the actual values of the exogenous variables and the estimated coefficients of the equation. Estimated quarterly values of $Price_t$ are then used in the second stage of 2SLS to estimate the parameters of the supply and demand functions in both the total purchased scrap model and the obsolete scrap model.

[33] Notice that ln(C) is not included. Both ln(C) and ln(B) cannot be included because they are not independent. Home scrap as a share of home and purchased scrap (C) is correlated with home and prompt scrap as a share of home and purchased scrap (B).

5. Results

In this final chapter, we present our estimates of the supply function in both models and discuss the meaning of our results. Although our study focuses on supply elasticity and the supply function, we also estimated the demand functions of both models (see Appendix B).

The results of our study reveal that quantities of total prompt and obsolete ferrous scrap and of obsolete ferrous scrap supplied to the market are sensitive to changes in the price of scrap. More important, obsolete ferrous scrap supply is more sensitive to price changes. A 10 percent increase in scrap prices elicits an 8.85 percent increase in the quantity of obsolete ferrous scrap supplied to the market.

5.1 Total Prompt and Obsolete Scrap Supply

Beginning with our model of the supply of total prompt and obsolete scrap, all estimated coefficients were of their expected sign (positive denoting a positive effect on supply or negative denoting a negative effect) and, but for XPRTR (exports as a share of net purchased scrap receipts), all explanatory variables were statistically significant at the five percent level or better (Table 3).

The estimated price coefficient (0.589) represents the price elasticity of total prompt and obsolete scrap supply. Every 10 percent increase in price, holding constant the effects of all other supply-factors, elicited a 5.89 percent increase in the quantity of total purchased scrap supplied. A 10 percent increase in price increased the average quantity supplied from 13.161 million tons per quarter to 13.936 million tons per quarter, an increase of 775.2 thousand tons per quarter.

But price isn't the only supply factor that positively affects the quantity of purchased total scrap supplied to the market. Apparent steel consumption (APC) as well as the combined effects of the economic shocks (DUMMY) had positive effects on supply. Our results reveal that a 10 percent increase in apparent steel consumption increased the quantity of scrap supplied 3.26 percent. The positive effect of the shocks we included in our model indicates

Table 3
Regression Results for Supply of Total Prompt and Obsolete Ferrous Scrap

Parameter	Variable	Parameter Estimate	Standard Error	Calculated t-value /a	Significance /b
B_0	Constant	5.499	0.595	9.24	1 percent
B_1	Price	0.589	0.084	7.13	1 percent
B_2	COST	-0.826	0.208	-3.96	5 percent
B_3	FRTR	-0.405	0.098	-4.13	1 percent
B_4	APC	0.326	0.074	4.43	1 percent
B_5	XPRTR	-0.081	0.059	-1.36	> 10 percent
B_6	DUMMY	0.128	0.038	3.40	1 percent

Note: 100 observations were used in the regression. The R-square statistic is 0.79. The F value of the regression is 90.01.

a. The t-value is the estimated value of the coefficient divided by its standard error. It measures the estimated coefficient's number of standard deviations from a value of zero. It is used to test the hypothesis that the true value of the coefficient is non-zero.

b. The probability of observing a t-statistic as large or larger in magnitude as the calculated t-value given that the true value of the coefficient is zero. A significance level of 5 percent indicates a 5 percent chance of rejecting the null hypothesis (true value of the coefficient is zero) when it is true.

that the effects of the Asian and Brazilian crises, which led to increased imports and, hence, an increase in the supply of iron and steel scrap, exceeded the effect of the U.S recession, which led to lower domestic steel production.

Not surprisingly, scrap processing and transportation costs had negative effects on supply. Every 10 percent increase in processing cost (COST) reduced quantities of scrap supplied 8.26 percent. Every 10 percent increase in transportation cost (FRTR) reduced quantities supplied 4.05 percent. Higher costs of processing and transporting scrap reduce quantities supplied.

5.2 Obsolete Scrap Supply

The results of our obsolete scrap model are informative and, in relation to the total purchased scrap model, additionally enlightening (Table 4).

First and foremost, the price elasticity of obsolete scrap supply is greater than the elasticity of total prompt and obsolete scrap supply. Recall that a 10 percent increase in scrap prices elicited a 5.89 percent increase in the quantity of total scrap supplied to the market. In our obsolete model, we see that a 10 percent increase in scrap prices elicited an 8.85 percent increase in the quantity of obsolete scrap supplied to the market. A 10 percent increase in scrap prices increased the quantity of obsolete scrap supplied quarterly from 8.428 million tons to 9.174 million tons—an additional 746.0 thousand tons.

Table 4
Regression Results for Supply of Obsolete Ferrous Scrap

Parameter	Variable	Parameter Estimate	Standard Error	Calculated t-value /a	Significance /b
D_0	Constant	8.063	0.739	10.91	1 percent
D_1	Price	0.885	0.137	6.45	1 percent
D_2	COST	-1.235	0.303	-4.07	1 percent
D_3	FRTR	-0.619	0.449	-4.27	1 percent
D_4	XPRTR	-0.092	0.06	-1.51	> 10 percent
D_5	DUMMY	0.204	0.053	3.83	1 percent

Note: 100 observations were used in the regression. The R-square statistic is 0.594. The F value of the regression is 27.53.

a. The t-value is the estimated value of the coefficient divided by its standard error. It measures the estimated coefficient's number of standard deviations from a value of zero. It is used to test the hypothesis that the true value of the coefficient is non-zero.

b. The probability of observing a t-statistic as large or larger in magnitude as the calculated t-value given that the true value of the coefficient is zero. A significance level of 5 percent indicates a 5 percent chance of rejecting the null hypothesis (true value of the coefficient is zero) when it is true.

This result is not surprising. Total purchased scrap includes prompt and obsolete. Prompt scrap is, in effect, a by-product of the manufacturing process. Prompt scrap must be swept from the shop floor and disposed of. However, obsolete scrap exists in discarded end-use products that must be recovered and processed to obtain their ferrous material. Hence, quantities supplied of obsolete scrap are likely to be more sensitive to changes in scrap prices.

Also not surprising is our finding that scrap processing and transportation costs have greater effects on obsolete scrap supply than on total scrap supply. A 10 percent increase in processing cost reduced the quantity of obsolete scrap supplied to the market 12.35 percent; it reduced the quantity of total scrap supplied 6.19 percent. A 10 percent increase in transportation cost reduced the quantity of obsolete scrap supplied 6.19 percent; it reduced total scrap supplied 3.85 percent.

In conclusion, additional volumes of obsolete ferrous scrap will be recovered from the national inventory, supplied to the scrap market, and recycled by steel producers as the price paid for scrap increases.

Appendix A

Database

Table A

Database of Endogenous and Exogenous Variables Used in the Models

Year and Quarter	Purchased Prompt and Obsolete Scrap (1,000 tons)	Purchased Obsolete Scrap (1,000 tons)	Price (index)	TSTL (1,000 tons)	COST (index)	FRTR ($/ton-mile)	APC (1,000 tons)	XPRTR (ratio)	OREC (1,000 tons)	BOP (ratio)	C (ratio)	B (ratio)
1985:1	9,815.32	5,855.26	119.70	22,104.42	94.32	0.048	22,299.50	0.257	17,682.42	0.588	0.401	0.556
1985:2	10,209.83	6,090.60	112.63	22,992.88	94.99	0.048	23,191.48	0.257	18,393.14	0.588	0.401	0.547
1985:3	9,353.26	5,579.62	110.50	21,063.85	94.51	0.048	21,407.52	0.257	16,850.02	0.587	0.401	0.567
1985:4	9,414.45	5,616.12	107.60	21,201.64	94.84	0.048	21,407.52	0.257	16,960.24	0.587	0.401	0.565
1986:1	10,761.75	6,603.50	111.13	22,783.44	92.51	0.047	23,302.72	0.308	18,491.12	0.587	0.369	0.504
1986:2	10,454.03	6,414.68	108.43	22,131.98	89.80	0.047	23,302.72	0.308	17,962.40	0.587	0.369	0.510
1986:3	8,343.75	5,119.80	109.17	17,664.36	88.58	0.047	18,309.28	0.308	14,336.46	0.588	0.369	0.562
1986:4	8,419.25	5,166.12	109.77	17,824.19	88.92	0.047	18,309.28	0.308	14,466.18	0.589	0.369	0.560
1987:1	9,936.98	6,471.46	113.13	19,614.33	90.52	0.043	19,238.34	0.232	14,921.42	0.589	0.310	0.527
1987:2	11,344.26	7,387.96	112.80	22,392.12	91.69	0.043	21,861.75	0.232	17,034.60	0.589	0.310	0.495
1987:3	11,405.13	7,427.60	127.23	22,512.27	93.13	0.043	21,861.75	0.232	17,126.00	0.589	0.310	0.494
1987:4	12,092.58	7,875.30	160.47	23,869.20	93.64	0.043	23,610.69	0.232	18,158.28	0.588	0.310	0.481
1988:1	12,547.41	8,284.44	169.70	25,126.93	93.89	0.045	17,973.50	0.204	19,499.22	0.580	0.308	0.479
1988:2	12,614.56	8,328.77	171.87	25,261.41	95.25	0.045	17,973.50	0.204	19,603.58	0.590	0.308	0.478
1988:3	12,349.25	8,153.60	187.00	24,730.10	95.96	0.045	17,973.50	0.204	19,191.27	0.592	0.308	0.482
1988:4	12,069.62	7,968.98	180.00	24,170.13	96.48	0.045	17,254.56	0.204	18,756.71	0.594	0.308	0.487
1989:1	12,131.08	7,906.19	190.60	25,748.63	98.88	0.044	22,950.46	0.267	21,847.53	0.596	0.304	0.472
1989:2	12,033.96	7,842.90	182.87	25,542.50	101.04	0.044	22,950.46	0.267	21,672.63	0.597	0.304	0.474
1989:3	11,006.72	7,173.42	167.50	23,362.15	100.57	0.044	21,185.04	0.267	19,822.62	0.598	0.304	0.479
1989:4	10,733.03	6,995.04	153.90	22,781.23	100.89	0.044	20,302.33	0.267	19,329.72	0.599	0.304	0.477
1990:1	12,644.14	8,625.99	158.10	24,370.75	102.21	0.041	22,273.75	0.252	19,625.90	0.600	0.292	0.503
1990:2	12,908.36	8,806.25	169.73	24,880.01	101.70	0.041	22,273.75	0.252	20,036.01	0.600	0.292	0.514
1990:3	12,787.68	8,723.92	172.90	24,647.43	104.39	0.041	22,273.75	0.252	19,848.71	0.600	0.292	0.513
1990:4	12,365.62	8,435.99	163.40	23,833.93	109.16	0.041	21,382.80	0.252	19,193.60	0.600	0.292	0.513
1991:1	11,107.09	7,526.88	157.27	21,467.29	105.76	0.039	20,059.25	0.232	17,175.35	0.600	0.293	0.511
1991:2	10,959.37	7,426.78	146.37	21,181.80	104.15	0.039	19,256.88	0.232	16,946.93	0.605	0.293	0.517
1991:3	11,476.66	7,777.33	144.77	22,181.58	104.39	0.039	20,059.25	0.232	17,746.83	0.610	0.293	0.506
1991:4	11,651.18	7,895.59	142.10	22,518.89	104.62	0.039	20,861.62	0.232	18,016.70	0.615	0.293	0.510
1992:1	11,740.03	7,786.30	141.40	23,228.77	103.84	0.036	21,655.75	0.220	18,336.81	0.620	0.288	0.513
1992:2	11,839.75	7,852.44	141.43	23,426.08	105.26	0.036	22,521.98	0.220	18,492.57	0.615	0.288	0.518
1992:3	11,280.41	7,481.47	138.67	22,319.37	106.28	0.036	20,789.52	0.220	17,618.93	0.612	0.288	0.526
1992:4	11,436.40	7,584.93	135.13	22,628.01	106.13	0.036	21,655.75	0.220	17,862.57	0.609	0.288	0.521
1993:1	12,486.61	8,267.11	157.53	23,617.88	106.37	0.034	18,076.50	0.213	17,969.86	0.606	0.258	0.478
1993:2	12,763.43	8,450.39	162.57	24,141.47	107.35	0.034	18,076.50	0.213	18,368.24	0.606	0.258	0.486
1993:3	12,659.11	8,381.32	174.60	23,944.16	106.64	0.034	18,076.50	0.213	18,218.11	0.606	0.258	0.491
1993:4	12,796.65	8,472.38	195.40	24,204.30	106.28	0.034	18,076.50	0.213	18,416.05	0.607	0.258	0.501
1994:1	13,454.14	8,598.73	204.67	23,928.73	106.27	0.034	23,928.96	0.176	19,104.88	0.607	0.219	0.476
1994:2	13,808.03	8,824.91	184.10	24,558.14	107.29	0.034	24,926.00	0.176	19,607.41	0.606	0.219	0.484
1994:3	13,517.98	8,639.53	186.80	24,042.27	108.88	0.034	24,926.00	0.176	19,195.53	0.604	0.219	0.498
1994:4	14,334.85	9,161.60	196.03	25,495.10	109.33	0.034	25,923.04	0.176	20,355.48	0.602	0.219	0.488
1995:1	14,309.28	9,455.74	206.67	26,262.30	111.16	0.035	26,522.50	0.204	20,397.74	0.600	0.227	0.492
1995:2	13,918.89	9,197.76	202.13	25,545.80	112.99	0.035	26,522.50	0.204	19,841.24	0.593	0.227	0.488
1995:3	13,856.43	9,156.49	205.83	25,431.16	112.72	0.035	26,522.50	0.204	19,752.20	0.585	0.227	0.463
1995:4	14,132.70	9,339.05	196.07	25,938.22	112.27	0.035	26,522.50	0.204	20,146.03	0.570	0.227	0.458
1996:1	14,369.42	9,111.08	199.63	26,554.41	113.01	0.035	28,922.40	0.165	20,286.24	0.574	0.227	0.471
1996:2	14,095.04	8,937.11	197.37	26,047.35	113.96	0.035	27,810.00	0.165	19,898.87	0.571	0.227	0.497
1996:3	13,863.00	8,789.98	191.27	25,618.55	113.84	0.035	27,810.00	0.165	19,571.30	0.567	0.227	0.508
1996:4	13,889.84	8,807.00	176.00	25,668.16	114.84	0.035	27,810.00	0.165	19,609.19	0.564	0.227	0.510
1997:1	14,346.76	9,064.79	186.43	26,177.42	115.24	0.035	29,355.00	0.168	19,760.63	0.560	0.209	0.488
1997:2	14,573.31	9,207.93	184.03	26,590.78	113.25	0.035	29,355.00	0.168	20,072.67	0.558	0.209	0.497
1997:3	14,531.62	9,181.60	190.27	26,514.72	113.56	0.035	29,355.00	0.168	20,015.25	0.555	0.209	0.493
1997:4	14,970.22	9,458.72	194.77	27,314.99	113.87	0.035	30,529.20	0.168	20,619.35	0.553	0.209	0.477

(continued)

Table A (continued)

Year and Quarter	Purchased Prompt and Obsolete Scrap (1,000 tons)	Purchased Obsolete Scrap (1,000 tons)	Price (index)	TSTL (1,000 tons)	COST (index)	FRTR ($/ton-mile)	APC (1,000 tons)	XPRTR (ratio)	OREC (1,000 tons)	BOP (ratio)	C (ratio)	B (ratio)
1998:1	15,471.65	9,471.08	192.40	28,401.86	111.28	0.033	31,600.40	0.105	20,755.36	0.550	0.209	0.476
1998:2	15,181.02	9,293.17	183.53	27,868.35	111.10	0.033	31,600.40	0.105	20,365.49	0.544	0.209	0.508
1998:3	14,475.47	8,861.26	161.90	26,573.15	110.37	0.033	30,385.00	0.105	19,418.98	0.541	0.209	0.520
1998:4	13,293.75	8,137.86	122.27	24,403.82	109.41	0.033	27,954.20	0.105	17,833.70	0.540	0.209	0.517
1999:1	13,378.17	8,055.16	127.50	25,222.83	108.51	0.033	28,675.20	0.108	18,388.42	0.538	0.203	0.489
1999:2	13,775.15	8,294.19	132.93	25,971.29	110.95	0.033	29,870.00	0.108	18,934.08	0.536	0.203	0.505
1999:3	13,928.92	8,386.77	141.23	26,261.20	113.65	0.033	29,870.00	0.108	19,145.43	0.534	0.203	0.518
1999:4	15,135.07	9,113.01	155.20	28,535.24	114.80	0.033	32,259.60	0.108	20,803.30	0.532	0.203	0.491
2000:1	15,558.53	9,550.77	163.80	29,016.95	116.73	0.032	32,136.00	0.107	20,226.09	0.530	0.206	0.503
2000:2	15,834.54	9,720.20	148.50	29,531.72	119.08	0.032	33,372.00	0.107	20,584.91	0.528	0.206	0.505
2000:3	14,719.84	9,035.93	135.30	27,452.78	121.68	0.032	30,900.00	0.107	19,135.80	0.526	0.206	0.506
2000:4	13,411.28	8,232.66	120.97	25,012.29	123.48	0.032	28,428.00	0.107	17,434.67	0.524	0.206	0.494
2001:1	14,797.29	9,585.08	122.17	25,528.17	125.85	0.032	28,654.60	0.143	17,642.92	0.526	0.200	0.454
2001:2	15,109.73	9,787.47	120.03	26,067.19	123.29	0.032	28,654.60	0.143	18,015.45	0.515	0.200	0.465
2001:3	14,634.36	9,479.54	124.27	25,247.08	119.32	0.032	28,654.60	0.143	17,448.66	0.505	0.200	0.468
2001:4	12,778.23	8,277.22	113.57	22,044.90	114.97	0.032	24,246.20	0.143	15,235.58	0.500	0.200	0.495
2002:1	13,577.62	8,679.75	121.23	23,918.81	114.19	0.033	24,720.00	0.172	14,883.16	0.496	0.200	0.502
2002:2	14,207.73	9,203.19	144.50	25,028.82	116.95	0.033	25,750.00	0.172	15,573.85	0.495	0.200	0.485
2002:3	14,954.84	9,687.14	153.57	26,344.97	117.55	0.033	26,780.00	0.172	16,392.81	0.493	0.200	0.493
2002:4	14,579.41	9,443.95	146.13	25,683.59	119.13	0.033	25,750.00	0.172	15,981.27	0.492	0.200	0.482
2003:1	13,374.18	8,281.26	165.97	25,609.74	124.78	0.033	27,552.50	0.228	15,477.04	0.490	0.209	0.532
2003:2	13,325.25	8,250.96	169.07	25,516.04	123.05	0.033	27,552.50	0.228	15,420.42	0.488	0.209	0.520
2003:3	12,681.67	7,852.46	181.50	24,283.67	123.78	0.033	26,450.40	0.228	14,675.64	0.485	0.209	0.549
2003:4	13,198.61	8,172.55	213.70	25,273.53	123.63	0.033	27,552.50	0.228	15,273.86	0.483	0.209	0.540
2004:1	14,534.49	8,967.35	307.60	26,322.92	127.32	0.035	28,922.40	0.217	15,469.61	0.480	0.175	0.513
2004:2	14,947.15	9,221.95	269.53	27,070.28	130.79	0.035	30,127.50	0.217	15,908.83	0.472	0.175	0.524
2004:3	15,300.78	9,440.13	346.67	27,710.72	133.43	0.035	31,332.60	0.217	16,285.20	0.469	0.175	0.531
2004:4	15,182.70	9,367.28	370.83	27,496.87	137.03	0.035	30,127.50	0.217	16,159.53	0.460	0.175	0.516
2005:1	14,450.68	8,887.06	313.27	26,568.74	138.37	0.043	30,261.40	0.256	16,132.32	0.450	0.181	0.504
2005:2	13,672.48	8,408.47	267.03	25,137.95	141.43	0.043	27,933.60	0.256	15,263.56	0.440	0.181	0.508
2005:3	13,481.23	8,290.85	271.30	24,786.32	147.55	0.043	27,933.60	0.256	15,050.05	0.434	0.181	0.502
2005:4	14,282.21	8,783.45	307.47	26,258.99	154.40	0.043	30,261.40	0.256	15,944.25	0.427	0.181	0.498
2006:1	14,680.97	8,659.12	314.97	27,192.64	151.91	0.046	30,900.00	0.280	15,757.21	0.429	0.146	0.512
2006:2	15,467.72	9,123.15	356.80	28,649.88	155.01	0.046	32,136.00	0.280	16,601.63	0.427	0.146	0.505
2006:3	15,076.73	8,892.54	348.43	27,925.67	155.74	0.046	32,136.00	0.280	16,181.98	0.425	0.146	0.516
2006:4	13,416.94	7,913.57	320.80	24,851.35	151.29	0.046	28,428.00	0.280	14,400.51	0.423	0.146	0.501
2007:1	14,170.46	8,975.41	402.67	25,908.46	153.03	0.048	28,675.20	0.307	13,537.14	0.420	0.139	0.489
2007:2	15,057.32	9,537.13	415.23	27,529.94	160.06	0.048	29,870.00	0.307	14,384.37	0.422	0.139	0.476
2007:3	14,813.15	9,382.48	397.93	27,083.51	160.66	0.048	29,870.00	0.307	14,151.11	0.424	0.139	0.470
2007:4	15,152.58	9,597.47	411.23	27,704.11	164.67	0.048	31,064.80	0.307	14,475.37	0.425	0.139	0.448
2008:1	16,961.88	11,324.65	513.87	28,070.07	171.22	0.048	29,416.80	0.389	15,271.84	0.426	0.135	0.434
2008:2	16,973.20	11,332.21	738.27	28,088.81	186.60	0.048	29,416.80	0.389	15,282.03	0.410	0.135	0.435
2008:3	16,670.14	11,129.87	724.20	27,587.26	191.11	0.048	28,366.20	0.389	15,009.16	0.400	0.135	0.422
2008:4	10,241.74	6,837.93	291.03	16,948.96	162.58	0.048	17,860.20	0.389	9,221.28	0.390	0.135	0.468
2009:1	9,135.28	6,835.48	291.43	13,209.96	152.71	0.048	13,648.53	0.557	6,355.85	0.382	0.170	0.451
2009:2	9,363.20	7,006.03	277.97	13,539.55	154.77	0.048	13,648.53	0.557	6,514.43	0.380	0.170	0.407
2009:3	12,474.11	9,333.76	385.67	18,038.04	158.89	0.048	18,198.04	0.557	8,678.84	0.378	0.170	0.386
2009:4	13,388.86	10,018.22	397.43	19,360.80	162.02	0.048	19,497.90	0.557	9,315.27	0.376	0.170	0.393

Appendix B

Regression Results for the Demand Functions of Total Prompt and Obsolete Scrap and of Obsolete Scrap

Table B-1

Regression Results for Demand for Total Prompt and Obsolete Ferrous Scrap

Parameter	Variable	Parameter Estimate	Standard Error	Calculated t-value /a	Significance /b
A_0	Constant	2.142	0.393	5.46	1 percent
A_1	Price	-0.036	0.019	1.86	10 percent
A_2	TSTL	0.907	0.13	6.97	1 percent
A_3	OREC	-0.202	0.117	-1.72	10 percent
A_4	BOP	0.363	0.13	2.79	1 percent
A_5	C	-0.371	0.036	-10.12	1 percent

Note: 100 observations were used in the regression. The R-square statistic is 0.926. The F value of the regression is 234.08.

a. The t-value is the estimated value of the coefficient divided by its standard error. It measures the estimated coefficient's number of standard deviations from a value of zero. It is used to test the hypothesis that the true value of the coefficient is non-zero.

b. The probability of observing a t-statistic as large or larger in magnitude as the calculated t-value given that the true value of the coefficient is zero. A significance level of 5 percent indicates a 5 percent chance of rejecting the null hypothesis (true value of the coefficient is zero) when it is true.

Table B-2

Regression Results for Demand for Obsolete Ferrous Scrap

Parameter	Variable	Parameter Estimate	Standard Error	Calculated t-value /a	Significance /b
C_0	Constant	0.191	0.472	0.410	> 10 percent
C_1	Price	-0.030	0.029	-1.050	> 10 percent
C_2	TSTL	1.597	0.170	9.380	1 percent
C_3	OREC	-0.781	0.160	-4.870	1 percent
C_4	BOP	0.606	0.176	3.430	1 percent
C_5	B	-1.214	0.109	-11.060	1 percent

Note: 100 observations were used in the regression. The R-square statistic is 0.853. The F value of the regression is 108.87.

a. The t-value is the estimated value of the coefficient divided by its standard error. It measures the estimated coefficient's number of standard deviations from a value of zero. It is used to test the hypothesis that the true value of the coefficient is non-zero.

b. The probability of observing a t-statistic as large or larger in magnitude as the calculated t-value given that the true value of the coefficient is zero. A significance level of 5 percent indicates a 5 percent chance of rejecting the null hypothesis (true value of the coefficient is zero) when it is true.