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MARKET STRUCTURE, MARKETING METHOD, AND PRICE INSTABILITY*

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Data for metals sold on commodity exchanges and at prices set by producers are used to test the relationship between the organization of markets and the behavior of prices. On the production side the question is whether prices are more stable in concentrated industries. And on the sales side the question is whether markets where buyers are consumers have more stable prices than those with consumers and speculators. The recent increase in metal-price instability is explained by changes in the market-structure and organization variables. Foremost is increased reliance on commodity exchanges. Declines in concentration are of less importance.

I. INTRODUCTION

Data on metal prices sold on commodity exchanges and under a system of producer pricing are used to test the relationship between the organization of markets and the behavior of prices. Market organization is considered at two levels: production and sales. And two aspects of price behavior are assessed: level and variability. The emphasis, however, is on the determinants of price instability, not level.

On the production side of the market, the question of interest is whether prices are more stable in concentrated industries. This question has been debated at least since the time of Berle and Means [1932]. Recently, the issue has received considerable attention in the macroeconomic literature. Fixed or menu costs of price adjustment [Barro, 1972; Sheshinski and Weiss, 1977; Akerlof and Yellen, 1985; Mankiw, 1985] and variable-adjustment costs [Rotemberg, 1982] have been proposed to explain sticky prices in concentrated industries. The empirical literature, although unable to discriminate among theories, supports the notion that prices are more stable in oligopolies [Carlton, 1986; Wilder, Williams, and Singh, 1977].

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At the level of sales the question of interest is whether markets where all buyers are consumers have more stable prices than those with consumers, hedgers, and speculators. This question is even older, dating back to Adam Smith [1789], who emphasized the stabilizing effects of speculative activity. More recently, however, models have been developed in which hedging and speculation can destabilize prices [Newbery, 1984b, 1987; Hart and Kreps, 1986; Stein, 1987]. Nevertheless, the empirical evidence summarized by Cox [1976] tends to confirm the hypothesis that speculation is a stabilizing influence.

Metal-price data are used to test the two questions simultaneously. Traditionally, nonferrous metals were sold under two pricing systems: prices set by the major firms in the industry, and prices determined on metal exchanges such as the London Metal Exchange. In the 1970s producer prices were dominant in North America, whereas exchange-based prices prevailed in the rest of the western world. Recently, however, a combination of factors has weakened the North American producer-pricing system and has led to increased reliance on metal exchanges. Both horizontal concentration and vertical integration have declined in many markets. In addition, recycling has grown, and the extent of both international integration and government participation has risen. As a consequence, price volatility has increased.

Increased price instability must be considered a problem in industries already noted for chronic gluts and shortages. In addition, the recent stock market crash has focused attention on commodity markets, where margins are smaller and manipulation is easier.[1]

The problem is to untangle and measure the strengths of the various determinants of price instability. The data used for this purpose pertain to six commodities sold under two arrangements (producer and exchange) in two time periods (the 1970s and the 1980s). The variable that is analyzed is the variance of the rate of change of price. Both regression and analysis-of-variance techniques are used in an attempt to decompose the variation in this measure of price volatility into components that are related to familiar economic and institutional factors.

A distinction is made between significant and important determinants of volatility.[2] A *significant* factor is one whose effect

1. The silver crisis of 1980 and the tin crisis of 1985 are evidence that price manipulation may be possible in these markets.
2. This distinction is made by Schmalensee [1985].

can be measured with *statistical accuracy*. An *important* factor, in contrast, is one whose contribution to the variance of the dependent variable is *large*. To anticipate results, both horizontal-market structure and contractual arrangement are found to be significant determinants of price volatility but only the latter is important. The evidence, therefore, is consistent with the idea that prices in markets with hedgers and speculators are less stable than prices in markets where all buyers are consumers.

The organization of the paper is as follows. The next section analyzes the factors that can contribute to price instability. Section III discusses the two pricing systems in the nonferrous-metal industries; Section IV describes the statistical model and the data; and Section V presents the empirical results. Finally, the last section concludes with a discussion of the consequences of increased price volatility.

II. Factors Affecting Price Stability

In this section I analyze the principal determinants of price volatility in metal markets. Primary attention is given to the two factors of interest: horizontal-market structure and commodity-marketing arrangement. Because it is necessary to control for other factors in the empirical work, however, other determinants are briefly discussed.

The choice of metals was motivated by several considerations. First, all are homogeneous commodities and thus have "a price." Second, all are industrial goods, and therefore their prices are affected by fluctuations in industrial activity. Third, all are durable goods, and therefore their prices are affected by inventory swings. And finally, all are capital intensive and subject to long delays in expanding capacity. It is therefore unnecessary to correct for differences in these factors across markets. Only factors that differ by commodity or time period are discussed here.

IIa. Horizontal-Market Structure

There are several reasons why prices might be more stable in concentrated industries. In a competitive market firms are price takers. Oligopolists, in contrast, have more control over price. They therefore must weigh the costs and benefits of price changes. Economists have focused on two costs that might cause managers not to adjust prices continuously and fully: fixed and variable costs.

Fixed costs are independent of the size of a price change [Barro, 1972; Sheshinski and Weiss, 1977; Akerlof and Yellen, 1985; Mankiw, 1985]. For example, when a price schedule must be printed, a fixed cost is incurred. With fixed costs there is an incentive to adjust prices infrequently but by large amounts. Variable costs, in contrast, increase with the size of the change [Rotemberg, 1982]. If it is costly to stay informed of relative prices of inputs, consumers may prefer frequent, small price changes.

Inventories can also play a role in stabilizing prices. Newbery [1984a] notes that the benefits of price stabilization accrue to the industry as a whole, whereas the costs are private.[3] Price stabilization is therefore to some extent a public good. Only firms with large market shares can capture a sufficient fraction of the benefits to warrant engaging in private stabilizing activities.

Considerable effort has been devoted to testing the relationship between horizontal-market structure and price stability [Wilder, Williams, and Sing, 1977; Carlton, 1986; Cecchetti, 1986; Dahlby, 1988]. The evidence tends to confirm the predictions of the theoretical models.[4]

IIb. Marketing Method

When commodity prices are set by producers, all purchasers of the good are consumers. When they are sold on exchanges, in contrast, new actors are introduced: brokers and speculators. Differences in motives across agents can lead to differences in price behavior.

Do speculators destabilize prices? Perhaps the first to ask this question was Adam Smith [1789]. The conventional wisdom says that speculation stabilizes prices. Speculators, if they are to realize a profit, must buy cheap and sell dear. It would thus seem that speculation can destabilize prices only if speculators on average lose money.

The question, however, is not quite so simple. Hart and Kreps [1986], who demonstrate that optimizing behavior on the part of rational agents can destabilize prices, point out that speculators do not buy when the price is low; they buy when the chance of price appreciation is high and sell when the chance is low. In addition,

3. There has been much discussion in the literature about whether price stability is desirable (see, for example Oi [1961]). Nevertheless, all producers and consumers interviewed stated that they preferred stable prices.

4. The evidence, however, is not unanimous. For example, Domberger [1979] finds that in the United Kingdom, the speed of price adjustment is higher in concentrated industries.

Hart [1977] notes that sophisticated speculators can earn a profit by exploiting the naive forecasting rules of others. And Newbery [1984b] shows that it may pay a dominant producer to speculate with the intent of destabilizing the spot market. Finally, Newbery [1987] notes that futures markets, by introducing hedging and thus providing participants with insurance, can encourage them to engage in more risky activities.

These studies demonstrate that speculation and hedging *can* destabilize prices, not that they do. Because the theoretical results are ambiguous, we turn to empirical evidence. I have been unable to uncover recent tests of the relationship between speculation and price stability. Cox [1976], who finds that the introduction of a futures market reduces autocorrelation of price changes, concludes that speculation leads to increased information in the market and greater price stability.

IIc. Supply Factors

Factors affecting price stability on the supply side of the market include cost stability, recycling activity, and by-production. Cost is clearly an important determinant of price. Unfortunately, it was not possible to obtain data on relative-cost stability across markets. For this reason, cost variability is not considered in the empirical analysis.

Secondary production is often an important source of metal supply. When recycling costs are sensitive to the quality of material processed, the recycler is the marginal producer. If there is little secondary supply when prices are low, coupled with heavy production when they are high, recycling stabilizes prices. If, on the other hand, there is a large recycling sector processing low-cost material, prices may have far to fall to clear the market in a downturn. The effect of recycling is therefore ambiguous.

Joint production is common in mining. When metals occur in ores in roughly fixed proportions, it is difficult to vary relative-metal-recovery rates. In addition, a by-product is often more sensitive to the price of the primary commodity than to its own price. We therefore expect unstable prices in markets where by-products are important.

IId. Demand Factors

The structure of demand is also important in determining price stability. Two factors are considered: the stability of the output of the using sectors and the ease of substitution in downstream production.

If production in the using sectors is unstable, derived demand for metal is unstable. For example, when metal is combined with other inputs in fixed proportions, fluctuations in metal use are entirely determined by fluctuations in output downstream. We therefore expect prices to be more volatile when user markets are unstable.

Metal, however, is rarely combined with other inputs in fixed proportions. When substitution is easy, a high metal price triggers a switch to another material, which has a stabilizing effect. On the other hand, variations in price of the substitute material can lead to changes in metal use, which have the opposite result. For this reason, the net effect of flexibility in downstream production is ambiguous.

IIe. Time-Period Factors

Two important determinants of price stability vary by period but not by commodity: exchange and inflation rates. As metals are traded in international markets, both the dollar price of metals quoted in pounds and the pound price quoted in dollars fluctuate with changes in the dollar/pound exchange rate. In addition, mining costs are paid in many currencies. As the pound and dollar fluctuate with respect to these currencies, metal prices vary. Periods of exchange-rate volatility are therefore expected to be associated with metal-price instability.

Within a country, as the overall price level moves, firms adjust prices to reflect changes in input costs. And, as the nature of adjustment to inflation varies from industry to industry, price volatility is often associated with high inflation rates. Empirical studies that examine the relationship between relative-price variability and inflation confirm the positive association [Parks, 1978; Fischer, 1981; Domberger, 1987].

III. THE TWO PRICING SYSTEMS

Nonferrous-metal sales in North America have traditionally been conducted under a system known as producer pricing, whereas sales in the rest of the western world have generally relied on commodity exchanges. Producer prices are set by the major firms in the industry. Exchange prices, in contrast, are related to price quotations on metal exchanges, principally the London Metal Exchange (LME).

In the late 1970s and early 1980s, radical changes occurred in the pricing of many metals. This period saw the virtual demise of the producer price of copper and the introduction of aluminum and nickel contracts on the LME. Even those industries where producer prices remained relatively strong were affected. The producer price of lead showed a tendency to follow exchange prices more closely, and more recently, producers began discounting the price of zinc. This section describes the two pricing systems as they existed in the 1970s.

IIa. Exchange Prices

Many commodity exchanges exist throughout the world. By far the most important for metal pricing, however, is the London Metal Exchange.[5] This market dates back to the middle of the nineteenth century, when a need for forward dealing and hedging developed. It was at this time that the practice of trading in a ring began. It was the custom for some member to draw a large chalk circle on the floor of the coffee house where traders met and to call "ring, ring." Members then stood in their recognized places and cried their bids and offers across the floor.

Superficially, the LME today closely resembles its nineteenth century ancestor. Membership in the Exchange is still limited to 36, the number of seats in the curved wooden benches that form the modern "Ring." Dealings in each commodity are still limited to two five-minute intervals in the morning and two in the afternoon. Members still transact business by means of open outcry across the floor. And an official price is still established for each commodity every morning.

In spite of the superficial similarities with the past, the LME underwent a fundamental reorganization in 1987. This reorganization was due to general misgivings about the nature of regulation of investment business in the United Kingdom. It was further aggravated by the tin crisis of 1985, when LME tin trading was suspended indefinitely.[6]

Three major changes were instituted in 1987. The first was the switch from a principals' market (a market where members act as principals for the transactions that they conclude across the Ring

5. For a history of the LME, see Slade [1988].
6. For an analysis of the tin-market crisis, see Anderson and Gilbert [1988].

and with their clients) to a clearinghouse system. A clearinghouse is an independent body that clears and guarantees business transacted between brokers. The second was the introduction of margins. The LME system of margins is unusual, however, in that it applies only to the net position of brokers. As the clearinghouse looks at a member's total exposure when calculating margins, in-credit positions can compensate losses on risk positions. The final innovation was the introduction of formal options.

The only real competitor to the LME in terms of metal trading is the Commodity Exchange of New York (COMEX) and, with the exception of copper, it is clearly of secondary importance. Nevertheless, a brief description of COMEX is in order. Membership in COMEX is without formal limit and usually numbers in the hundreds. COMEX has always required margins and its clearinghouse system was established over 50 years ago. Finally, the volume of speculative activity is greater on COMEX than on the LME, where "legitimate" trade dominates.

IIIb. Producer Prices

Producer prices are set by the major North American firms in the primary industry.[7] These prices change only at discrete intervals. Most often, the producer price is for refined ingot. Other products and shapes may sell at premiums and discounts, but their prices will usually be tied to this price.

The exact method of producer-price determination varies by commodity. There are, however, broad similarities. The producer price of copper is discussed here to give a feel for the general class of pricing. As this price is no longer predominant in North America, the period of the 1970s is described.

The producer price was the price at which most domestic refineries sold copper metal to affiliated and independent fabricators. In the mid-1970s about 75 percent of U. S. refined copper was sold at this price. The producer price, which represented a common set of price quotations for delivery, was based to a large extent on production cost and was moderately stable. Some refinery shapes sold at discounts and others at premiums, but the prices of all shapes were tied to the producer price. It therefore seems reasonable to speak about *the* producer price.

It is important to note that the producer price is announced by the companies for current sales. It is not a long-term-contract

7. The one exception is zinc, which also has a European-producer price.

price. Moreover, contracts can be based on either a producer or an exchange price. The producer price guarantees neither security of supply nor stable future prices. Nevertheless, the practice of the leading firms in times of scarce supplies has been to serve existing contracts and regular customers first.

IV. The Empirical Model and the Data

IVa. The Model

There are several candidates for a measure of price instability: the variance of price, the coefficient of variation of price, and the variance of percent changes in price. Each has its strengths and its weaknesses. For example, the variance of price depends on units of measurement and is therefore inappropriate for making comparisons across commodities. This difficulty can be remedied by using the coefficient of variation. The coefficient of variation, however, like the variance, cannot distinguish between random price movements and systematic trends. Because random fluctuations are apt to be more problematic than predictable trends, the variance of percent changes in price is perhaps the best measure of instability.

Our proxy for price instability, the variance of percent changes in commodity price, is defined by

$$VPDP_{ijT} = \text{var}\,[(\dot{p}/p)_{ijT}], \tag{1}$$

where a dot over a variable denotes its time derivative, i stands for commodity i, j for price system j, and T for time period T. The variance is taken over all observations t in time period T. $(\dot{p}/p)_{ijt}$ is approximated by

$$(\dot{p}/p)_{ijt} = \ln(p_{ijt}) - \ln(p_{ijt-1}), \qquad t \in T. \tag{2}$$

Economic theory often gives guidance for the construction of structural models for means of economic variables. It seldom has much to say about higher-order moments. For this reason, a simple atheoretical framework is adopted here. The strength of a descriptive approach is that conclusions reached concerning the effects of interest will not be conditioned by maintained hypotheses regarding determinants of these effects.

The question addressed is the relationship between the dependent variable *VPDP* and two factors: (1) horizontal concentration in commodity market i and (2) marketing method j. Both factors deserve clarification. First, a distinction must be made between rigidity (infrequent price change) and stability (small variation in percent changes). Price changes are more frequent on exchanges, where a new price is established daily. Nevertheless, if changes are large, producer prices can have higher variances.[8] Stability is assessed here.

We must also make a distinction with respect to the second factor of interest. It is often asked if the introduction of a futures market destabilizes the spot price of a commodity [Newbery, 1987; Stein, 1987]. The question addressed here, however, corresponds more closely to one asked by Hart and Kreps [1986]: are prices in markets where all purchasers are consumers more stable than prices in markets that also have hedgers and speculators? Hedging and speculation, which are common on exchanges, are impossible under a system of producer prices.

The analysis is performed in two stages. First, ordinary least squares (fixed-effects estimation) is applied to an equation of the following form:[9]

$$(3)\quad VPDP_{ijT} = a + b\,PS_j + c\,HC_{iT} + d\,DT_T + \Sigma_k\, e^k\, Y_{iT} + \Sigma_h\, f^h\, Z_{it} + u_{ijT},$$

where

- PS_j is a dummy variable that equals one if this price is a producer price and zero otherwise,
- HC_{iT} is a variable that measures horizontal concentration in market i in period T,
- DT_T is a dummy variable that assumes the value zero in the first period and one in the second,
- Y_{iT} is a vector of demand variables that affect price in market i in period T, and
- Z_{iT} is a vector of supply variables that affect price in market i in period T.

Equation (3) is used to test for *significant* effects.

The second stage consists of decomposing the variation in the dependent variable into components attributable to the economic factors of interest. To do this, we write equation (3) in matrix

8. Monthly exchange prices are averages of some twenty prices, whereas monthly producer prices are averages of approximately two or three prices. Averaging generally has the effect of reducing variability. If it is found that exchange prices are more volatile, the finding will therefore be conservative.

9. The possible endogeneity of PS and HC is discussed in Section V.

notation as

$$v = X\beta + u. \tag{4}$$

Taking the variance of both sides of (4) yields

$$\sigma_v^2 = \beta' \operatorname{cov} X\beta + \sigma_u^2. \tag{5}$$

The fraction of the variation in v that is explained is therefore

$$(\beta' \operatorname{cov} X\beta)/\sigma_v^2 = (\Sigma_i \Sigma_j \beta_i\beta_j\sigma_{ij})/\sigma_v^2, \tag{6}$$

where $\sigma_{ij} = \operatorname{cov}(x_i, x_j)$.

Define the gross effect of factor x_i to be

$$GE_i = (\beta_i^2\sigma_i^2)/\sigma_v^2 \tag{7}$$

and the net or marginal effect to be

$$NE_i = (\Sigma_j \beta_i\beta_j\sigma_{ij})/\sigma_v^2. \tag{8}$$

When the explanatory variables are orthogonal, the gross effect is an accurate measure of the fraction of the variation in *VPDP* (across commodities, time periods, and pricing systems) that is explained by economic factor x_i. Economic variables, however, are rarely orthogonal. The net effect, which corrects for covariation in the explanatory variables, is therefore a better measure of *importance.*

IVb. The Data

The analysis pertains to the 1970–1986 period. This seventeen-year interval is split into two subperiods: the 1970s and the 1980s. Several important events occurred at the end of the decade that make this a natural division. These include the introduction of aluminum and nickel contracts on the LME and the silver-market bubble of 1980. It is therefore of interest to test whether the periods are noticeably different and, if so, whether the difference can be explained by changes in underlying economic factors.

All commodities that were traded on the LME in 1986 are considered in the analysis. These are aluminum, copper, lead, nickel, silver, and zinc.[10] Price data are monthly. A detailed description of the data is contained in the Appendix. In particular, it should be noted that *all data used are representative of actual transactions.* Because discounting off list price has been prevalent in the aluminum market since 1960, it was necessary to construct a

10. Since 1986, the silver contract has been dropped, and a tin contract has been reinstated.

measure of a transactions price for the aluminum producers (see the Appendix).

Prices used in the analysis are nominal. Deflating would make little difference since both numerator and denominator would be divided by an overall price index. In addition, one test of interest is whether inflation or exchange-rate volatility is a stronger determinant of metal-price instability.

Figures I–VI are plots of the price series. Aluminum and nickel were not traded on the LME until the late 1970s. In addition, producer prices for nickel were not published in the second period. The producer price of copper ceased to be important in the late seventies and is now no longer published. Silver has never been traded on a producer-price basis. And finally zinc, unlike the other commodities, has a European-producer price. There are thus twenty price series. Tables I and II contain summary statistics for levels and rates of change of these prices.

Figures VII–X, which contain histograms for percent changes in producer and LME-zinc prices in the two periods, illustrate differences in the behavior of prices over time and across pricing system. The histograms for the 1970s show that variability was

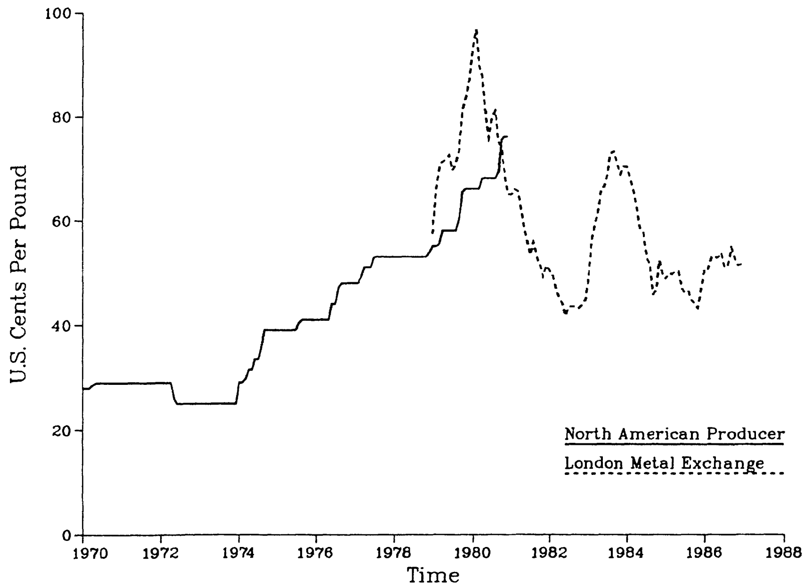

FIGURE I
Aluminum Prices, Monthly, 1970–1986

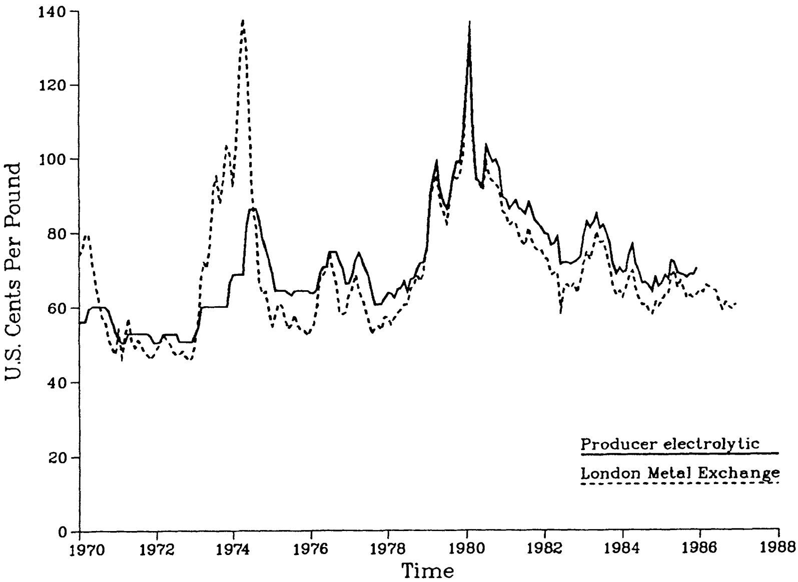

FIGURE II
Copper Prices, Monthly, 1970–1986

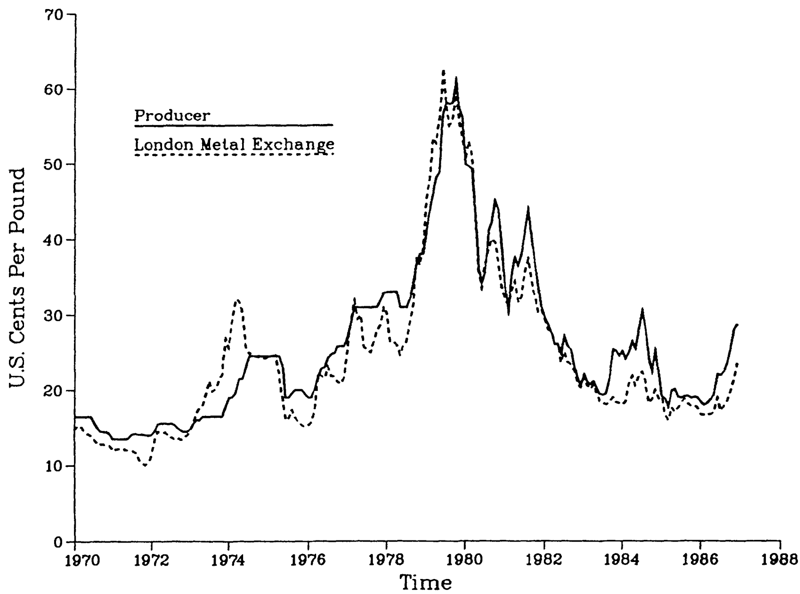

FIGURE III
Lead Prices, Monthly, 1970–1986

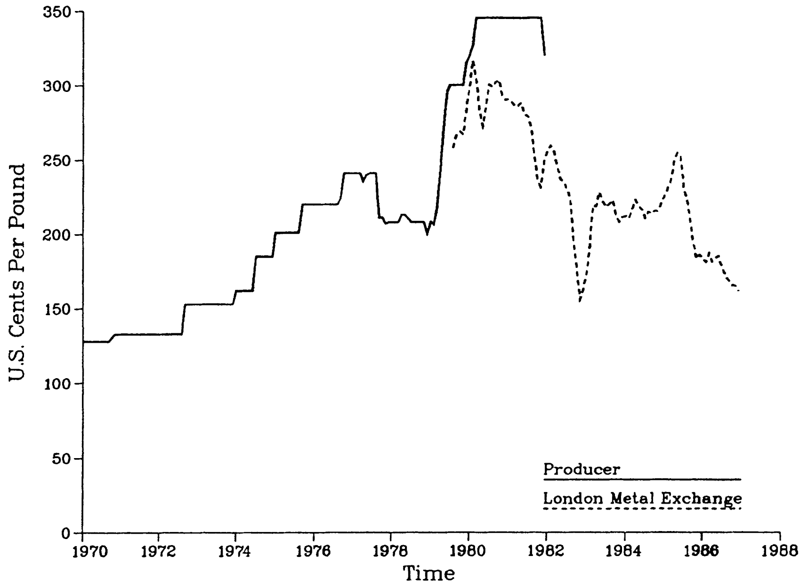

FIGURE IV
Nickel Prices, Monthly, 1970–1986

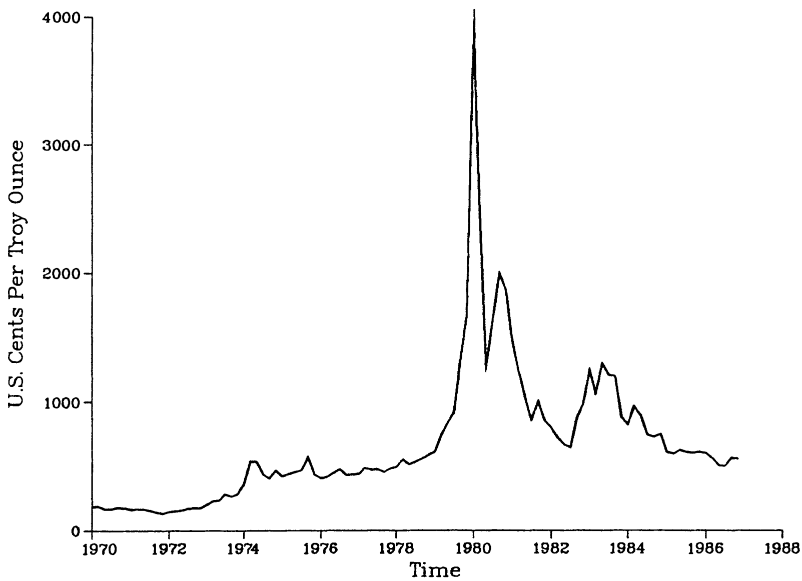

FIGURE V
Silver Prices, Monthly, 1970–1986

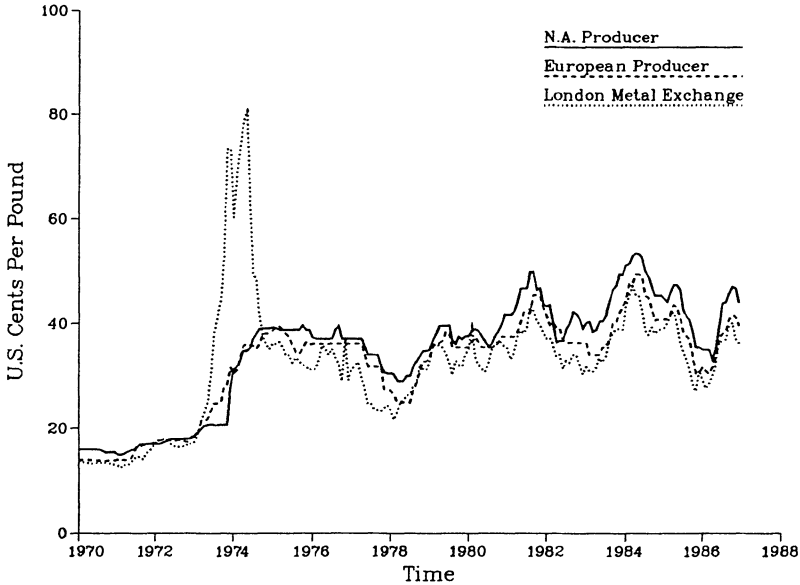

FIGURE VI
Zinc Prices, Monthly, 1970–1986

greater on the LME (the LME histogram is flatter). Most striking is the fact that the producer price did not change in 44 percent of the months considered, as indicated by the circled dot. In addition, changes in the producer price are asymmetric, with price increases more frequent than price cuts. Finally, the LME histogram shows many large outliers with $|\dot{p}/p|$ greater than 15 percent.

In the 1980s both markets show signs of increased variability (flatter histograms). In addition, there is less difference between the two pricing systems; extreme outliers are less prevalent in the LME-price series; and the producer-price histogram is no longer noticeably asymmetric.

We now turn to the explanatory variables. Two measures of horizontal concentration are used. The first is the Hirschman-Herfindahl concentration index (HHI) for North American (U. S. plus Canadian) markets. These indices were calculated using data on firm shares of primary production, which can be found in the American Bureau of Metal Statistics' *Non-Ferrous-Metal Data*. To obtain a value that represents the period, averages of each index in two years from each decade were computed. The years chosen are 1972, 1977, 1982, and 1985. North American markets are considered due to lack of data for other countries.

TABLE I
SUMMARY STATISTICS FOR PRICE LEVELS

Price	Units	Period	Mean	Variance	Minimum	Maximum
Aluminum	¢/lb					
Producer		I	39.4	79.8	24.4	53.9
Producer		II	58.8	94.1	44.1	82.0
LME		II	59.6	176.5	41.7	96.6
Copper	¢/lb					
Producer		I	62.9	76.4	50.4	86.3
LME		I	64.1	327.6	45.6	137.6
LME		II	74.5	203.1	57.7	132.4
Lead	¢/lb					
Producer		I	21.4	47.9	13.5	38.0
LME		I	20.3	48.6	10.0	38.9
Producer		II	30.7	140.6	17.7	61.1
LME		II	28.6	167.9	16.0	62.6
Nickel	¢/lb					
Producer		I	183.5	1933.4	128.0	300.0
LME		II	232.0	1764.4	155.8	316.6
Silver	¢/troy oz					
LME		I	34.7	223.9	13.1	59.3
LME		II	101.8	3247.6	50.2	392.5
Zinc	¢/lb					
NA producer		I	27.7	88.1	15.0	39.7
EU producer		I	26.7	80.1	13.8	39.5
LME		I	29.0	239.1	12.4	80.6
NA producer		II	42.1	25.3	33.1	53.4
EU producer		II	38.5	18.2	30.4	49.4
LME		II	35.8	18.2	27.1	47.2

The second measure of horizontal concentration attempts to correct for the problems associated with the use of local concentration measures when markets are in fact worldwide. HCW measures the degree of horizontal concentration in western-world-commodity markets. This increased generality, however, is not obtained without cost. Only qualitative estimates are available. Concentration in commodity markets is classified as being low (L), medium (M), high (H), or very high (VH). This procedure may seem somewhat arbitrary. Each classification, however, represents a consensus of opinion of at least three commodity specialists for each market. The specialists consulted are marketing managers and vice presidents of mining companies.[11]

11. In the interviews specialists were shown a table similar to Table III and asked to comment. Revised tables were produced until there was no major disagreement.

TABLE II
SUMMARY STATISTICS FOR RATES OF MONTHLY PRICE CHANGES

Price	Period	Mean	Variance	Minimum	Maximum
Aluminum					
Producer	I	0.906	7.8	−9.2	7.4
Producer	II	−0.061	14.4	−7.4	9.6
LME	II	−0.115	24.8	−11.8	13.3
Copper					
Producer	I	0.233	11.9	−6.8	16.7
LME	I	−0.055	54.1	−24.0	19.4
LME	II	−0.144	31.8	−23.5	16.1
Lead					
Producer	I	0.780	12.8	−20.6	9.6
LME	I	0.909	49.0	−17.8	24.2
Producer	II	−0.293	54.4	−20.1	15.7
LME	II	−0.527	43.0	−21.2	14.4
Nickel					
Producer	I	0.741	9.9	−13.3	14.0
LME	II	−0.530	19.8	−13.9	13.3
Silver					
LME	I	1.804	50.5	−27.4	37.8
LME	II	−0.105	199.5	−49.9	65.1
Zinc					
NA producer	I	0.725	13.2	−6.9	28.6
EU producer	I	0.800	12.9	−14.9	11.7
LME	I	0.767	71.9	−25.1	33.0
NA producer	II	0.246	15.7	−9.7	11.8
EU producer	II	0.197	13.5	−11.5	10.5
LME	II	0.156	30.0	−15.8	13.7

The measure of recycling activity (RECY) is secondary recovery from new and old scrap divided by total production. Due to data constraints, U. S. recovery rates are used.[12] The raw data are taken from the U. S. Bureau of Mines' *Minerals Yearbooks*. Again, averages were taken over two years in each decade. The years chosen are the same as those used in the calculation of the concentration indices.

The two remaining variables are qualitative. Both the degree of substitutability in downstream production (SUB) and the importance of by-product production (BYP) were obtained through consensus in the manner described above.

12. Only *relative* (across commodities) recycling rates matter. Use of U. S. data therefore does not pose problems if recycling *levels* differ in the rest of the world.

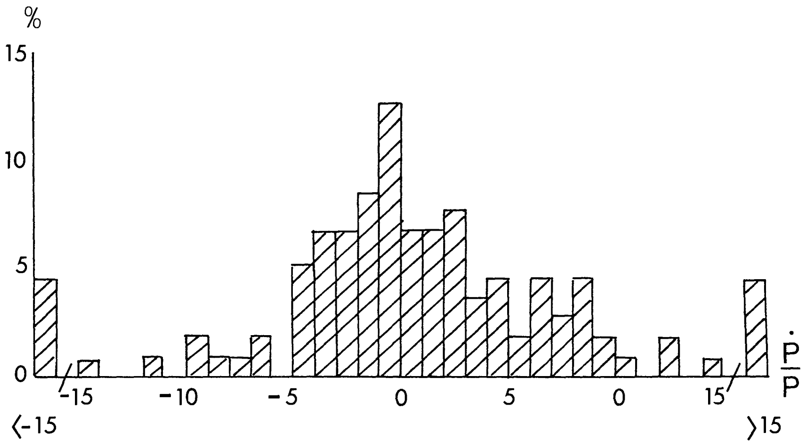

FIGURE VII
Histogram of Percent Changes in Zinc Prices: LME 1970s

Table III shows values of the variables by commodity and time period. We see that the principal differences between the two measures of horizontal concentration are that the North American measure overestimates (underestimates) concentration in silver (lead) markets.

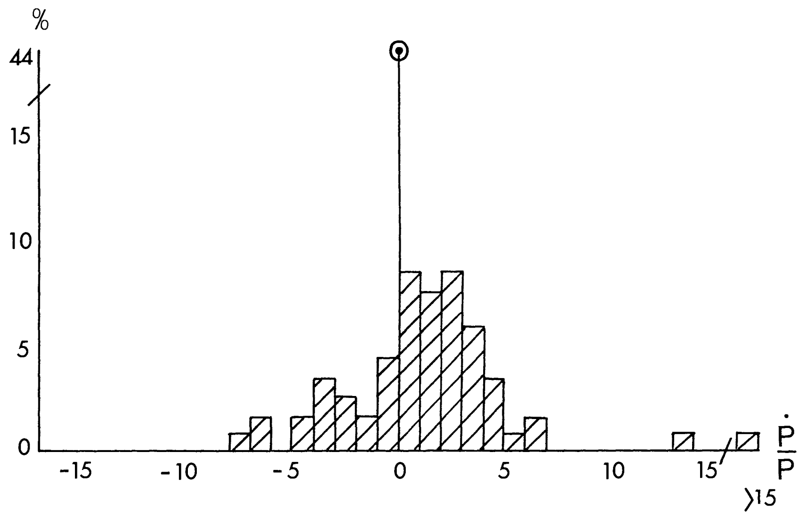

FIGURE VIII
Histogram of Percent Changes in Zinc Prices: Producer 1970s

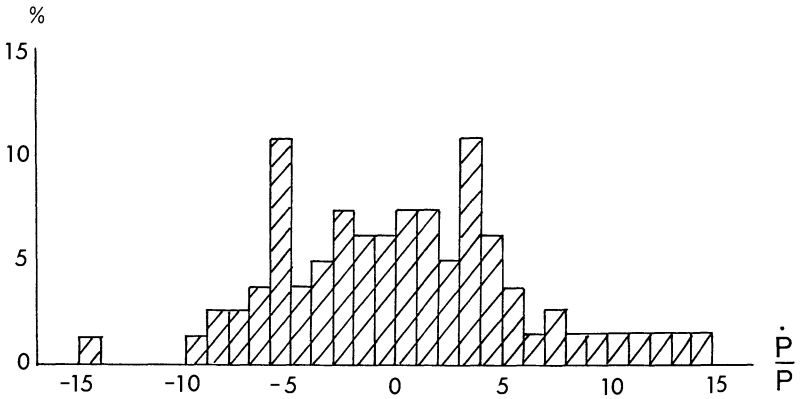

FIGURE IX
Histogram of Percent Changes in Zinc Prices: LME 1980s

V. EMPIRICAL RESULTS

Va. *Preliminary Analysis*

The first task is to uncover the stylized facts. In particular, we examine the *unconditional* mean of $VPDP_{yT}$ by time period and pricing system. A priori, we expect producer prices to be more stable. Because inflation (exchange) rates were more variable in the 1970s (1980s), it is not clear what to expect concerning the time-period effect.

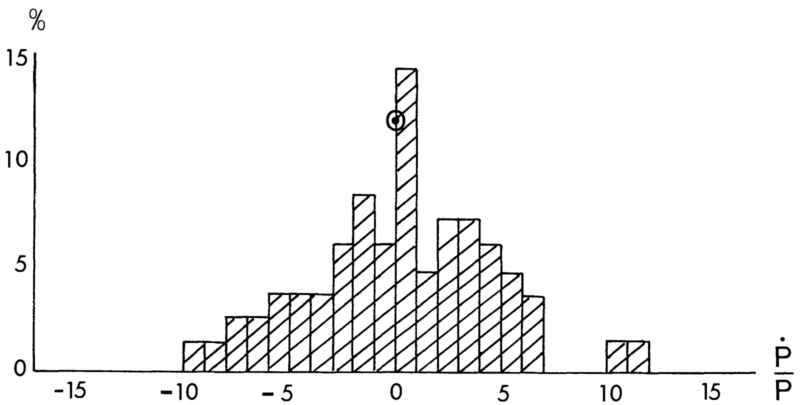

FIGURE X
Histogram of Percent Changes in Zinc Prices: Producer 1980s

TABLE III
MEASURES OF MARKET STRUCTURE, SUPPLY, AND DEMAND FACTORS

Commodity	HHI	HCW	RECY	SUB	BYP	VI
Aluminum						
70–79	0.142	VH	0.194	H	L	VH
80–86	0.134	H	0.281	H	L	VH
Copper						
70–79	0.071	M	0.437	H	M	M
80–86	0.076	M	0.500	H	M	M
Lead						
70–79	0.098	H	0.520	M	VH	M
80–86	0.113	H	0.550	M	VH	M
Nickel						
70–79	0.529	VH	0.127	L	M	M
80–86	0.442	VH	0.186	L	M	M
Silver						
70–79	0.089	L	0.564	M	VH	M
80–86	0.117	L	0.626	M	VH	M
Zinc						
70–79	0.120	H	0.391	M	H	L
80–86	0.177	VH	0.552	M	H	L

Tables I and II suggest two conclusions. First, on average, producer prices were more stable. And second, both sets of prices were more volatile in the second period. It is possible to test these hypotheses statistically. The Mann-Whitney-Wilcoxin (MWW) nonparametric test for a difference in means is used for this purpose.[13] The advantage of a nonparametric test is that its validity does not depend on underlying distributional assumptions. In particular, no appeal is made to large-sample theory.

Table IV shows averages of VPDP by commodity, time period, and pricing mechanism. It also contains values of the MWW test statistic and their corresponding P values. We see that on average period-1 and producer prices were more stable. The price-system effect is highly significant, whereas the time-period effect is significant only at the 90 percent level of confidence.

Both conjectures are thus verified. We do not know, however, what caused the differences in variability. It is possible, for example, that the difference in marketing system is responsible for the observed difference in average variance that the second half of Table IV confirms. On the other hand, it is also possible that

13. For descriptions of the nonparametric tests, see Gibbons [1976].

TABLE IV
TESTS FOR DIFFERENCES IN UNCONDITIONAL MEAN VARIABILITY

Variability by period:	
Average value of VPDP	
Period 1 (1970–1979)	29.4
Period 2 (1980–1986)	44.7
Test statistic	88.0[a]
P value	0.10
Variability by pricing mechanism:	
Average value of VPDP	
Producer	16.7
Exchange	57.4
Test statistic	63.0[a]
P value	0.00**

a. The Mann-Whitney-Wilcoxin test is used.
**Denotes statistical significance at the 99 percent confidence level.

changes in the underlying structural variables are responsible, and that the correlation between pricing system and price variability is spurious.

To investigate this possibility, paired samples are considered. That is, we investigate the six pairs of prices (producer and exchange) that exist for a particular commodity in a given period.[14] The paired samples have two advantages. First, the calculated means are conditional on common demand, supply, and time-period factors. And second, it is now possible to consider differences in price levels across marketing arrangement.

Table V shows tests for differences in means of the paired samples. The tests make use of the Wilcoxin-signed-rank nonparametric statistic. The first half of the table assesses levels, whereas the second half assesses variability. We see that it is not possible to reject the hypothesis that price level is unaffected by marketing method. Price variability, in contrast, is higher when commodities are sold on exchanges.

The fact that price levels are unaffected by marketing arrangement is interesting in itself.[15] Underlying this regularity is the fact

14. The pairs are aluminum II, copper I, lead I and II, and zinc I and II.
15. The coexistence of two pricing systems implies that producer prices should not exceed exchange prices by more than the costs of transporting metal. Table I, however, shows that often the average producer price is *lower* than the average exchange price.

TABLE V
TESTS FOR DIFFERENCES IN MEANS OF PAIRED SAMPLES

Price level:	
Average value of P	
Producer	40.6
Exchange	39.6
Test statistic	8.0[a]
P value	0.344
Price variability:	
Average value of VPDP	
Producer	20.4
Exchange	45.5
Test statistic	45.5[a]
P value	0.05*

a. The Wilcoxin-Signed-Rank test is used.
*Denotes statistical significance at the 95 percent level of confidence.

that, in periods of high demand, producers often ration their customers.[16]

The paired-sample tests give support to the idea that prices are more volatile on exchanges, even after we account for differences in economic conditions. However, they do not allow us to assess market-structure effects. For this reason, we turn to the regression analysis.

Vb. Regression Analysis

The regression equation is

$$(9)\quad VPDP_{ijT} = a + b\,PS_j + c\,HC_{iT} + d\,DT_T + e\,SUB_{iT} + f^1\,\mathrm{CBY}_{iT} + f^2\,\mathrm{RECY}_{iT} + g\,DS_{iT} + u_{ijT}.$$

Equation (9) contains one variable that has not yet been defined, DS. As the silver-market bubble of 1980 caused the period 2 silver variance to be an extreme outlier in the data, DS, a dummy variable that equals one for silver in period 2 and zero otherwise, was added to the equation.

Three of the explanatory variables in equation (9) are qualitative. These ordinal variables were converted to cardinal measures using a technique due to Terza [1987].[17]

16. The subject of rationing is beyond the scope of this paper. Interested readers are referred to Slade [1991].
17. An appendix with the details of this conversion can be obtained from the author.

Table VI shows the results from the regression analysis. Equations with unprimed numbers (1, 2, and 3) use the North American-concentration measure (HHI), whereas their primed counterparts (1′, 2′, and 3′) use the world measure (HCW). The first part of the table (A) contains OLS estimates, whereas the second part (B) reports equations corrected for possible bias due to simultaneity.

With respect to statistical inference we must take into account possible misspecification. Not only are the models very simple, but also it is not possible for all specifications to be correct. For example, if the system is simultaneous, the first set is incorrectly specified and vice versa. For this reason, I report White [1982] robust t-statistics, which can be used to make inference in the presence of misspecification of an unknown form.

The coefficient of the time-period-dummy variable was small and insignificant in all versions of the model estimated. In addition, the coefficients of the remaining variables were virtually unchanged by the exclusion of DT. For this reason, the equations shown do not contain DT.

Let us discuss the OLS estimates first. The first two equations in Table VI contain all of the relevant variables. Unfortunately, with this specification the only economic variable that is consistently significant is PS. Equations were therefore estimated which contain demand but not supply factors (2 and 2′) and supply but not demand factors (3 and 3′).[18] In these equations market-structure and pricing-system effects are always significant. In addition, the substitution and by-product factors are usually significant and have reasonable signs. The recycling effect, whose sign was ambiguous a priori, is only marginally significant.

Our principal concern is with the impact of the price system, as measured by the coefficient of PS, and of horizontal concentration, as measured by the coefficient of HC. The coefficient of PS is highly significant and very stable across specifications. The same is not true of the coefficient of HC, which varies in both magnitude and significance as the specification changes.[19] Nevertheless, market-structure factors are frequently significant. All else equal, there-

18. Separating demand and supply effects is valid as long as they are uncorrelated. Given that one set is determined by the technology of mining and the other by the technologies of the using sectors, this seems reasonable.

19. Clearly when different concentration measures are used, we expect differences in magnitude. Here, however, the magnitude changes even when the same measure is used.

TABLE VI
REGRESSION RESULTS FOR VPDP

A. OLS estimates

#	CON a	PS b	HC c	SUB e	BPY f^1	RECY f^2	DS g	R^2	$\bar{R}^2$	F
1	62.6	−23.6	−19.9	−7.5	14.4	−45.6	151	0.93	0.90	28.6
	(2.2)*	(−4.2)**	(−0.2)	(−0.4)	(1.4)	(−1.8)	(31)**			
1′	59.6	−23.0	−1.2	−9.8	15.3	−42.0	154	0.92	0.89	43.8
	(4.9)**	(−4.0)**	(−0.5)	(−1.9)	(2.2)*	(−1.5)	(35)**			
2	57.3	−23.4	−88.3	−10.5			152	0.92	0.90	43.8
	(8.1)**	(−4.1)**	(−2.7)*	(−2.2)*			(33)**			
2′	56.5	−21.1	−7.7	−4.4			143	0.91	0.88	35.9
	(8.8)**	(−3.0)**	(−2.8)*	(−1.6)			(22)**			
3	67.2	−23.7	−55.5		9.9	−39.7	152	0.93	0.90	36.4
	(3.5)*	(−4.2)**	(−2.2)*		(2.3)*	(−1.3)	(38)**			
3′	51.3	−21.4	−4.7		7.1	−33.4	142	0.92	0.90	34.0
	(4.4)*	(−3.5)**	(−2.1)*		(2.0)*	(−1.7)	(22)**			

B. Estimates with selection-bias correction

#	CON a	PS b	HC c	SUB e	BPY f^1	RECY f^2	DS g^1	IMR g^2	R^2	$\bar{R}^2$	F
1*	69.8	−18.8	−49.2	−3.0	13.4	−53.8	147	−5.2	0.93	0.89	23.7
	(2.2)*	(−6.7)**	(−0.4)	(−0.2)	(1.2)	(−2.0)*	(27)**	(−0.8)			
2*	71.9	−18.7	−97.1	−12.0			148	−4.9	0.92	0.90	34.2
	(8.5)**	(−4.1)**	(−3.6)**	(−2.7)*			(23)**	(−1.0)			
3*	71.9	−18.5	−63.9		11.7	−52.2	148	−5.5	0.93	0.90	29.9
	(3.7)**	(−6.4)**	(−2.7)		(2.6)*	(−1.6)	(27)**	(−1.3)			

C. Estimates corrected for the existence of both pricing systems

#	CON a	PS b	HC c	SUB e	BPY f^1	RECY f^2	DS g^1	DPE g^2	R^2	$\bar{R}^2$	F
1°	55.0	−18.6	−13.4	−7.5	14.1	−41.9	156	7.5	0.93	0.88	23.7
	(2.3)*	(−4.8)**	(−0.2)	(−0.4)	(1.3)	(−1.6)	(28)**	(1.3)			
2°	51.1	−18.1	−83.1	−10.5			158	8.2	0.92	0.90	34.5
	(7.3)**	(−3.7)**	(−2.7)*	(−2.2)*			(38)**	(1.3)			
3°	59.5	−18.7	−48.4		9.7	−36.0	157	7.6	0.93	0.90	29.5
	(3.5)**	(−4.5)**	(−2.1)*		(2.3)*	(−1.2)	(37)**	(1.3)			

TABLE VI
(CONTINUED)

D. Estimates with rationing periods removed

#	CON a	PS b	HC c	SUB e	BPY f^1	RECY f^2	DS g^1	R^2	$\overline{R}^2$	F
1#	26.6	−22.4	−15.0	−11.6	15.1	−53.8	151	0.93	0.89	23.8
	(0.4)	(−4.0)**	(−0.1)	(−0.5)	(1.4)	(−1.9)	(33)**			
2#	71.2	−21.3	−97.0	−12.6			152	0.92	0.90	34.5
	(5.9)**	(−3.4)**	(−2.8)*	(−2.3)*			(38)**			
3#	53.6	−22.0	−63.2		9.5	−44.4	153	0.93	0.90	29.6
	(3.5)**	(−3.6)**	(−2.2)*		(2.3)*	(−1.3)	(40)**			

E. Two-stage-least-squares estimates

#	CON a	PS b	HC c	SUB e	BPY f^1	RECY f^2	DS g^1	R^2	$\overline{R}^2$
1•	74.7	−23.7	−80.3	−3.0	8.8	−46.5	153	0.93	0.89
	(2.1)*	(−3.7)**	(−0.6)	(−0.1)	(0.6)	(−0.9)	(9.5)**		
2•	59.2	−23.2	−99.3	−11.7			152	0.92	0.90
	(7.3)**	(−3.7)**	(−2.6)*	(−1.9)			(10.5)**		
3•	72.0	−23.7	−64.4		10.5	−47.5	157	0.93	0.90
	(2.8)*	(−3.8)**	(−1.6)		(2.0)	(−1.0)	(10.3)**		

*Denotes statistical significance at the 95 percent level of confidence.
**Denotes statistical significance at the 99 percent level of confidence.

fore, prices are more stable in concentrated industries and under a producer-pricing system.

The fact that the time-period effect is never significant deserves further comment. The unconditional mean of VPDP was higher in the 1980s. Conditioning on the economic variables, however, completely removes the temporal difference in means. This implies that the increase in instability is entirely explained by changes in the economic variables. This finding is in sharp contrast to the comparable result for price system, where the difference in means remains even after conditioning.

Vc. Alternative Explanations

With the regressions in part A of Table VI, PS is treated as an exogenous variable—the causality is assumed to run from pricing system to variability. However, reverse causality is often claimed [Telser, 1981]. According to this theory, increased variability leads to increased demand for insurance which in turn makes hedging on

TABLE VII
PROBIT EQUATION FOR PS

Independent variable	Coefficient	t statistic
CON	1.67	0.46
HHI	4.81	0.39
DT	−0.27	−0.68
SUB	1.49	0.56
BYP	0.62	0.32
RECY	−4.64	−0.49
VI	−0.55	−0.68
	Percentage of Correct Predictions: 55	
	Likelihood-Ratio Test: 2.2*	

*Denotes statistical significance at the 90 percent level of confidence.

commodity exchanges more attractive. Under this scenario, the fact that silver does not trade at producer prices or that the nickel-pricing system changed between time periods is endogenous. If this is the case, simultaneity will lead to a bias in the coefficients of equation (9) when estimated by OLS.

To remedy this potential problem, equation (9) was reestimated with Heckman's [1979] correction for sample-selection bias. This procedure, which is well-known, involves two steps. In the first step an equation that explains the choice of pricing system is estimated. In this equation, PS is the dependent variable. The independent variables are the exogenous factors in equation (9) plus an additional instrument. The instrument used is the degree of vertical integration in the industry, which can be found in Table III under the heading VI. For each observation, the inverse Mill's ratio (IMR) is then obtained from the Probit regression.[20] In the second step equation (9) is reestimated with IMR included as an explanatory variable. If PS is endogenous, the addition of IMR will correct for the simultaneity bias. If PS is not endogenous, however, the correction can make matters worse.

The Probit regression, which is shown in Table VII, performs poorly, an indication that PS may be exogenous as initially specified. Nevertheless, we can tentatively interpret the coefficients. We see that firms in concentrated industries are more apt to

20. The inverse Mill's ratio is calculated as $f(X\beta)/F(X\beta)$ if $PS = 1$ and $f(X\beta)/[F(X\beta) - 1]$ if $PS = 0$, where f (F) is the density (cumulative density) for the standard normal.

chose a producer-pricing system. The use of producer prices, however, has fallen over time and is less likely when there is a strong recycling sector.

On the other hand, although the estimated coefficients of IMR shown in part B of Table VI are not significant, they have their expected signs, an indication that PS may be endogenous. To conserve on space, only those regressions with HHI are shown. Fortunately, including IMR does not change our initial conclusions. As before, both PS and HC are significant determinants of price variability.

A second alternative theory emphasizes that the *coexistence* of producer and exchange prices can increase the volatility of spot-market prices [Hubbard and Weiner, 1988, 1989]. According to this reasoning, rationing by producers leads to excess demand in the spot market which causes spot prices to rise. The opposite occurs in a downturn.

To test this alternative, a dummy variable DPE was added to the regression equations. DPE equals one if this is an exchange price *and* if a producer price exists for the commodity at the time. Part C of Table VI shows the equations estimated with DPE. It can be seen that the estimated coefficients of DPE have their expected signs but are never significant. In addition, the inclusion of DPE does not alter our initial conclusions.

Since rationing is an important issue, a second method of purging its influence is considered. Here, the dependent variable VPDP is recalculated omitting months when rationing occurred.[21] The regressions using the new dependent variable, which are displayed in part D of the table, show that HC and PS are still significant.

Finally, consider the possibility that the causality runs from price variability to market structure. High prices can cause entry, whereas low prices can cause bankruptcy and exit. Under this alternative, HC is endogenous. To correct for endogeneity, the equations were reestimated using an instrumental-variable technique.[22] Section E of Table VI shows that this correction lessens the explanatory power of HC but does not alter the main conclusions.

The additional regressions do not cast doubt on the alternative

21. Periods when the exchange price exceeds the producer price by more than transport cost are considered rationing periods—a procedure used by McKinnon and Olewiler [1980].

22. The instruments for HC are the exogenous variables in the system plus VI, our measure of vertical integration.

TABLE VIII
ANALYSIS-OF-VARIANCE MEASURES OF IMPORTANCE

	Effect									
	PS		HC		SUB		BPY		RECY	
Eqn	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
2	8.0	8.6*	6.0	3.8	3.1	0.0				
3	8.1	8.8*	2.3	2.4			5.5	5.0*	1.9	0.0
Average		8.7*		3.1						

*Denotes an important effect.

theories. They do, however, indicate that the increased volatility which has been found to be associated with exchange markets is not spurious.

Vd. Analysis of Variance

Table VIII shows the results of the analysis of variance.[23] Table entries are the net and gross effects discussed in subsection IVa. For the analysis of variance, estimates of the coefficients β were obtained from the regressions indicated in the table. The estimates of the variances and covariances are their sample values.

In Table VIII an effect that contributes more than 5 percent to the total variation in VPDP is (somewhat arbitrarily) denoted important. The analysis-of-variance estimates show that the price-system component is always important. It accounts for, on average, more than 8.5 percent of the total variation in VPDP across markets, pricing systems, and time periods. Horizontal concentration, in contrast, explains a much smaller fraction of the variation in our measure of price volatility, approximately 3 percent.

When coefficient estimates from equation (2) are used, the gross effect of HC is 6 percent. The net effect, in contrast, is only 3.8 percent. This difference is explained by the fact that the covariance between HC and RECY is negative. The implication is that when there is a strong recycling sector, horizontal concentration in the primary industry overestimates the degree of horizontal-market power. This consideration reemphasizes the superiority of

23. The simultaneous-equation estimates are not shown, as the analysis-of-variance framework makes less sense in this context.

the net effects as measures of importance. Using the net effect, we conclude that horizontal concentration is not an important factor.

VI. Conclusions

Metal markets have always been unstable. For example, the U. S. Nonfuel Minerals' Policy Review [1979] found metal prices to be four times more volatile than prices in the economy as a whole. And the gluts and shortages that result from severe price fluctuations cause concern to producers and consumers alike.

The increase in metal-price instability that has occurred in the last decade is entirely explained by changes in underlying market-structure and organization variables considered here.[24] Foremost among these is increased reliance on commodity exchanges, which accounts for a significant fraction of the systematic variation across markets. The decline in horizontal concentration that has taken place in some markets, although a contributing factor, is of less importance.

A fundamental difference between markets where prices are set by producers and those with commodity exchanges is the scope for speculation that exchanges introduce. The tests conducted here show that exchange prices are inherently more unstable than producer prices. Although not a direct test of the effects of speculation, the evidence is consistent with destabilizing speculation in the markets studied, a finding that is probably more surprising to economists than to commodity specialists.[25] For example, Simon Strauss, Vice Chairman of ASARCO, notes that *"The classic theory is that speculators help to stabilize markets by purchasing commodities when demand slumps and by selling when demand revives. Long observation of mineral markets appears to warrant the opposite conclusion. Speculative buying interest is greatest when concrete evidence develops that an economic upturn is in the making, with expectations of a revival of industrial purchasing. In periods of economic downturn, speculators are disinclined to buy industrial commodities. They wait for positive signs of recovery before re-entering the market"* [Strauss, 1986, p. 105].

24. The increase in variability (the time-period effect) is entirely explained, not variability itself.

25. Some experimental evidence [Smith, Suchanek, and Williams, 1988], however, supports the existence of bubbles and crashes in asset markets.

One reason why speculation in commodities has become so active appears to be the low margin requirements. Margins on the LME, which are between 5 and 10 percent of the value of a contract, apply only to the net position of brokers. This contrasts with margins of 50 percent or more on security transactions. Brokerage firms are clearly aware of the greater leverage obtained for a given amount of funds when commodities are traded rather than securities.

The recent reorganization of the LME is a step toward making metal trading more secure. In particular, the clearinghouse provides greater insurance than was available at the time of the tin crisis. Nevertheless, even without a collapse, the price instability that is associated with exchanges is a cost that must be balanced against the considerable benefits of well-organized futures markets.

Appendix: The Price Data

Abbreviations and Sources

MS: *Metal Statistics*
MW: *Metals Week, Annual Price Handbook*
NFMD: *Non-Ferrous Metal Data*

The Data

Aluminum Prices, 1970–1986, monthly, U. S. cents/lb
- LME prices, 1979–1986, 99.5 percent ingots, Source: NFMD
- North American producer prices, Source: NFMD

Copper prices, 1970–1986, monthly, U. S. cents/lb
- LME Prices, Source: NFMD
- Producer Prices of electrolytic copper, Source: MS

Lead prices, 1970–1986, monthly, U. S. cents/lb
- LME prices, Source: NFMD
- U. S. Producer Lead Prices, Source: NFMD

Nickel Prices, 1970–1986, monthly, U. S. cents/lb
- LME Prices, August 1979–December 1986, Source: MW
- Producer prices, Source: NFMD

Silver Prices, 1970–1986, monthly, U. S. cents/troy ounce
- LME Prices, Source: 1970–1985, MS, 1986 MW86, p. 215

Zinc prices, 1970–1986, monthly, U. S. cents/lb
- LME prices, Source: NFMD
- Prime Western Zinc prices in New York, Source: MS

Transactions Prices

Producers have always discounted the published producer price of aluminum. It therefore cannot be considered a true transactions price. The following procedure was adopted to overcome this difficulty. More details can be found in Slade [1988].

Metals Week publishes both monthly and yearly-average prices for aluminum which are estimates of the prices at which merchants and traders sell aluminum ingot. In addition, Alcan's annual reports give figures for annual ingot sales and ingot revenues.[26] An estimate of Alcan's average realized ingot price can thus be obtained by dividing ingot revenues by sales. The seventeen yearly observations on the two prices (1970–1986) were used in a regression analysis. That is, Alcan's realized price was regressed on the *Metals Week* price. The fitted equation, together with the monthly *Metals Week* data, was then used for interpolation purposes. That is, an estimate of Alcan's realized price in each month was constructed from the estimated equation. This "producer" price is less volatile than the *Metals Week* price: it is smoother and has lower peaks and higher troughs. In addition, it lags somewhat behind the *Metals Week* price. Statistics for the producer price of aluminum shown in Table I and used in the statistical analysis refer to the estimated realized price and not to the published producer price.

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26. Alcan is the world's largest producer of aluminum ingot.

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