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by

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October 1981

Institut für Weltwirtschaft an der Universität Kiel

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Abstract

This paper presents a practical model for the analysis of the price determination mechanism in raw materials markets that are characterized by the dominance of a large firm. The model takes explicit note of the influence of inventory adjustments; it is postulated that the dominant firm's decision on price and production levels is negatively related to the difference between actual and desired inventory levels. In a first empirical test, the model is applied to an analysis of the nickel industry. The empirical results support the hypothesized role of inventories and show the importance of inventory adjustments relative to the other factors determining price and production behavior.

PRICE DETERMINATION IN MONOPOLISTIC MARKETS WITH INVENTORY ADJUSTMENT: THE CASE OF NICKEL

I. Introduction

Price determination in markets characterized by the presence of one large firm and a few small firms has been widely discussed in the literature.[1] A plausible expectation is that the dominant firm sets the price at a level which maximizes its own profits, taking the supply of the other (small) producers as given.[2]

Under such a behavioral rule, the dominant firm obtains its demand curve by substracting the aggregate supply of the small competitors from the market demand. Given the resulting demand curve, the dominant producer acts like a pure monopolist and equates marginal revenue to marginal cost. The underlying assumptions of this model are:

(a) - small producers may sell as much as they want, and

(b) - market demand and the supply of other firms are correctly anticipated by the price setter.

This simple model implies that the market is cleared in each period and that there is no inventory accumulation or decumulation.

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1 Cf. the standard textbook treatments, such as James M. Henderson and R.E. Quandt, Microeconomic Theory, McGraw-Hill Co., 1971.

2 An alternative assumption is that the major producers collectively maximize industry profits. While not implausible on a priori ground, this assumption does not, as is generally recognized, provide an adequate description of producer behavior in the nickel industry. Cf. Charles River Associates, Inc., CRA Econometric Model of the World Nickel Industry, Boston, November 1976.

While the nickel industry is characterized by a large dominant firm (INCO - International Nickel Company) whose price leadership is evident[1], the above scenario would be too simplistic in the case of the nickel industry. During the time since World War II, the nickel industry has been experiencing shortages and periods of overproduction, the reasons being that either (a) market demand and the supply response of other firms are not perfectly anticipated by the price setter, and/or that (b) producers and consumers (who are, in turn, producers of a final product) hold inventories due to lags between production decisions and actual production and the uncertainty associated with future market conditions. Furthermore, the desired inventory holdings are not constant. Inventories are like any other asset: their desired level is determined by their expected capital gain, the opportunity cost of holding them and the expected future trading volume which determines precautionary inventory levels. Changes in these factors lead to changes in desired inventory holdings. However, due to adjustment costs, production and inventories will not adjust instantaneously. As a consequence, periods of shortages and overproduction will arise.

To illustrate the effect of inventory adjustments on market demand, production and price, assume that producers and concumers alike wish to reduce their nickel inventories.(Such a joint reduction of desired inventory levels may be caused by a rise in interest rates). The situation is illustrated in diagrams 1.a - 1.c. In figure 1.a, D shows market demand

[1] There have been occasional, though rarely succesful challenges to INCO's leadership role. For example, in 1979 S.L.N. announced $ 3.45 as its posted price per pound of nickel, but was forced to roll back its price after INCO announced a price of $ 3.20. On the other hand, INCO's dominance as expressed in market shares, has declined over time, from 2/3 of world production in 1948 to less than 1/4 in 1980. Nonetheless, INCO is still regarded as one dominant firm in the industry.

exclusive of any inventory adjustments. On the assumption that nickel consumers wish to reduce their inventories, the new market demand is

$$D' = D + \Delta IN_c^* \qquad (1)$$

where ΔIN_c^* is the consumers' desired change in inventory holdings, assumed to be negative in this example.

The original supply curve of small producers is represented by S. Since, by assumption, they also wish to reduce their inventories, their supply curve becomes

$$S' = S - \Delta IN_s^* \qquad (2)$$

where ΔIN_s^* stands for their desired change in inventories. The dominant firm's demand (figure 1.c.) appears as

$$ED' = D' - S' \qquad (3)$$

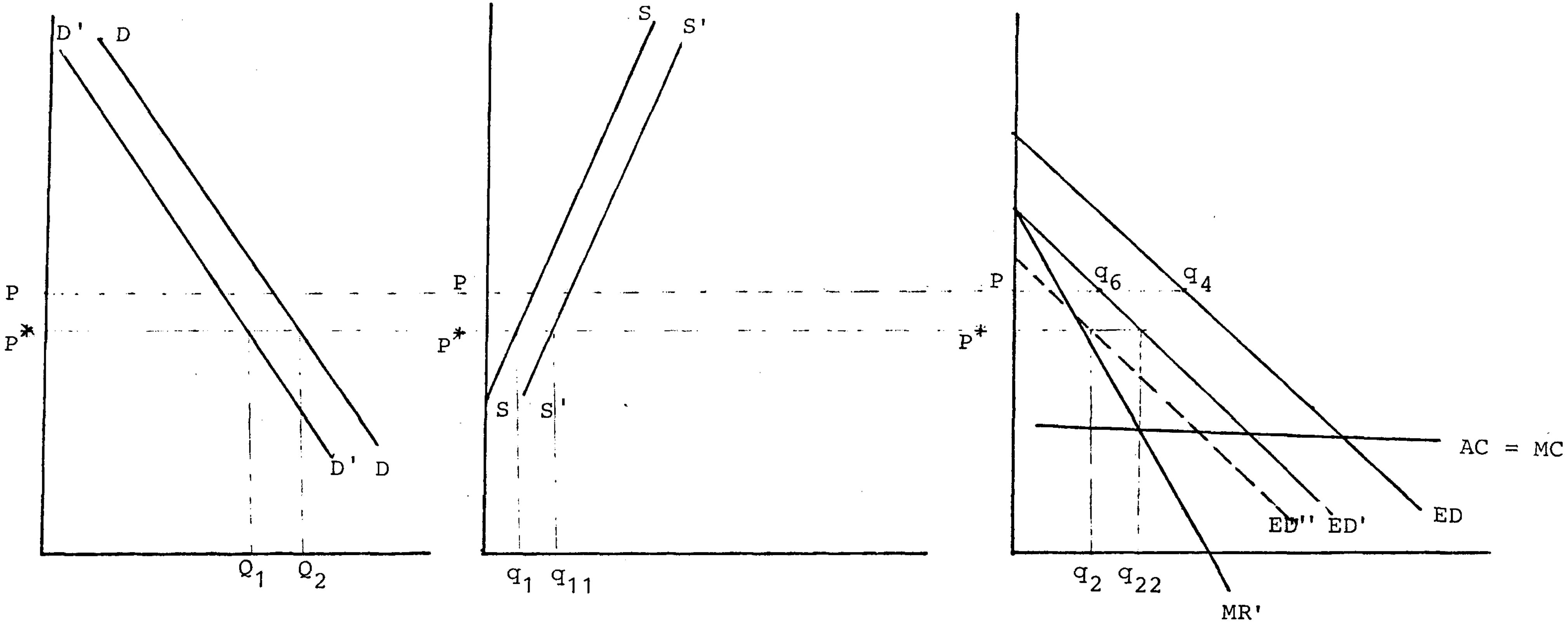
But, if - as assumed here - its inventory is also excessive, the effective demand to be filled by current production, will be

$$ED'' = ED' + \Delta IN_d^* \qquad (4)$$

where ΔIN_d^* is its desired change in inventory. Note that all desired inventory changes have been assumed to be negative, a situation similar to what prevailed from 1975 to 1979 in the nickel industry.
Given the dominant firm's marginal cost curve, price will be set at P^*. Nickel consumption will be Q_2, but the amount of nickel bought will only be Q_1. Small producers produce their profit maximizing output, q_1, but sell $q_{11} = q_1 - IN_s^*$. The price setter produces q_2, but expects to sell $q_{22} = q_2 - IN_d^*$.

So far, it has been assumed that the dominant firm takes into account the desire on the part of consumers and competing producers to reduce their inventories. Should the dominant firm ignore inventory adjustments, its perceived effective demand will

Diagram 1 - Price Setting with Inventory Adjustments



(1.a) (1.b) (1.c)

remain ED and it will set its price at P and produce q_4. However, due to this neglect it will actually only sell q_6 and will accumulate inventories by an amount equal to $(q_4 - q_6)$. Therefore, the rational dominant firm will consider inventory adjustments by other agents in its price setting and production decisions in order to avoid such frustration.

Previous studies of the nickel market have either ignored, or not fully considered, the role played by inventory adjustments. This paper tries to remedy that failure. Part II offers an empirical model which captures the effects of inventory adjustments on price setting and production of the dominant firm. Estimation procedure and empirical results for price and production equations are presented in Part III; there it is shown that the significance of inventory adjustments cannot be rejected. Part IV summarizes the findings.

II. The Model

It is generally acknowledged that the nickel market can be best described as a market in which the major producer, INCO, acts as a leader. Anticipating the supply response of the smaller competitors to various price levels, INCO sets its price at the profit-maximizing level on its perceived effective demand curve.[1]

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[1] A similar approach has been taken by Charles River Associates, op. cit., pp. 73 - 75. A different approach has been taken by Smithson et. al. who assume that price in period t is determinded by its lagged value and a measure of the stock-consumption ratio in period t or in period t-1. However, as mentioned by the authors (p. 20), this assumption is made only to simplify the model, rather than being based on some sort of maximization behaviours; cf. C.W. Smithson et. al., World Mineral Markets: An Econometric and Simulation Analysis, Ministry of Natural Resources, Ottawa, Canada, May 1979.

a) Market Demand

In the present study, the demand for nickel is

$$DD = \left[\alpha_0 + \alpha_1 \cdot Y + \alpha_2 \cdot \frac{P_S}{P_M} - \alpha_3 \frac{P}{P_M}\right] + \Delta IN_c^{*} + Z + \varepsilon_1 \qquad (5)$$

where $\left[\alpha_0 + \alpha_1 \cdot Y\ldots\ldots\right]$ is the derived demand for nickel in nickel-using industries (such as steel), ΔIN_c^{*} is the nickel users' desired change in inventories, Z is the change in the U.S. government strategic stockpile which is assumed to be exogenous, Y is the OECD index of industrial production, P_S is the U.S. price of steel, P is the U.S. price of nickel, P_M is the U.S. producer price index for metals and metal products, and ε_1 is the error term.

There are practical reasons for using U.S. prices in the demand function. First, the largest nickel consumers (and major INCO customers) are U.S. firms. Second, for the U.S. a deflator for metal prices is available, whereas a comparable deflator does not exist for the other major consumers.[1] As an alternative specification, an index of international inflation[2] was tried in place of the U.S. producer price index for metals and metal products. The empirical results were robust to this experiment.[3] For a measure of industrial production the OECD index appears to be appropriate, since the OECD countries are

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1 The alternative, the use of a wholesale price index, was considered as inferior.

2 The index of international inflation as computed by the World Bank is basically the index of the U.S.-dollar price of manufactured exports to developing countries by the U.S., U.K., France, Germany, Italy and Japan. For details of the construction method see Joseph Hilmy, "Old Nick", An Anatomy of the Nickel Industry and its Future, Commodity Note No. 13, World Bank, September 1979.

3 See Appendix II for estimation results concerning the international inflation index.

accounting for the major part (72 %) of nickel consumption.[1] Some studies, e.g., Smithson et al.[2], have used per-capita income in place of such a production index. Such a specification has the familiar weakness that the demand for nickel would be unaffected if income and population grow at the same rate.

The novelty of equation (5) is the inclusion of the inventory variable. Nickel purchases may differ from nickel consumption, depending on whether consumers' stocks exceed or fall short of their desired levels. In the present study, the desired changes in inventories are determined by the expected level of activity as well as by the expected capital gain and opportunity cost of holding inventories. This approach in modelling inventories is superior to the use of a stock-consumption ratio in the previous studies[3], where it is implicitly assumed that desired stocks are a constant fraction of world (or U.S.) consumption, irrespective of expectations concerning future market prices and the opportunity cost of holding inventories.[4]

b) Supply of small firms

The supply of nickel by small producers is formulated as

$$SS = (\beta_o + \beta_1 \cdot \frac{P}{P_M} + \beta_2 \cdot T) - \Delta IN_S^{*} + \varepsilon_2 \qquad (6)$$

where $(\beta_o + \dots)$ is their (aggregate) profit maximizing output and ΔIN_S^{*} is their desired change in stocks. The variable T stands for time and is introduced to capture the impact of improvements in technology and of new nickel discoveries; ε_2 is the error term.

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1 In non-Soviet-bloc world consumption, the OECD has a share of 95 %.

2 Op.cit., p. 136.

3 Cf. Charles River Associates, op.cit., p. 67 ; Smithson et.al., op.cit., p. 139.

4 In analyzing the pattern of change in consumer stocks, Hilmy notes that they have responded to the expected future price and high interest rates; cf. Hilmy, op.cit., pp. 45-48.

c) The dominant firm

Substracting equation (6) from equation (5) yields the dominant firm's perceived effective demand

$$ED = \gamma_o + \gamma_1 \cdot Y + \alpha_2 \cdot \frac{P_S}{P_M} - \gamma_3 \cdot \frac{P}{P_M} - \beta_2 \cdot T+Z+ \Delta IN^* + \varepsilon_3 \quad (7)$$

where

$$\Delta IN^* = \Delta IN_c{}^* + \Delta IN_s{}^*, \ \gamma_o = \alpha_o - \beta_o, \ \gamma_1 = \alpha_1, \ \gamma_3 = \alpha_3 + \beta_1$$

In the presence of inventory adjustments by the dominant firm, the profits-maximizing output level of the dominant firm is not determined in accordance with (7) alone. When the dominant firm considers changes in its desired inventory of nickel, $\Delta IN_d{}^*$, (7) is being modified to

$$ED^* = \gamma_o+\gamma_1 \cdot Y+\alpha_2 \cdot \frac{P_S}{P_M} -\gamma_3 \cdot \frac{P}{P_M} -\beta_2 \cdot T+Z+\Delta INT^* + \varepsilon_3 \qquad (8)$$

where $\Delta INT^* = \Delta IN_c{}^* + \Delta IN_s{}^* + \Delta IN_d{}^*$, or the cummulative change in desired inventory levels.

The dominant firm's expected profit, assuming constant average cost, can be written as

$$\pi = P\left[\gamma_o+\gamma_1 Y+ \ \ldots\ldots \ +\Delta IN^*\right] - AC\left[\gamma_o+\gamma_1 Y+ \ \ldots\ldots \ + \Delta INT^*\right] \quad (9)$$

where costs and revenues are expressed in U.S. dollars. The desired changes in inventories, ΔIN^* and ΔINT^*, are unobservable. To find a measure, it is assumed that the desired level of inventories can be written as

$$INT^* = c_o + c_1 \cdot E(Y) + c_2 \cdot E\ (P_t-P_{t-1}) - c_3 \cdot R \qquad (10)$$

In this relationship, the desired level of inventories depends on the expected level of economic activity, E(Y), the expected capital gain of holding inventories as expressed by the expected change in the price of nickel, $E(P_t - P_{t-1})$, and the opportunity cost of holding inventories represented by the short term U.S. interest rate, R.

d) Empirical specification

In recognition of the fact that actual adjustments will only be partial, the actual adjustments will be

$$\Delta INT_t = c_o.\theta + c_1.\theta.E(Y) + c_2.\theta.E(P_t - P_{t-1}) - c_3.\theta.R - \theta.INT_{t-1} + e,$$

where e is the error term and $o<\theta<1$. (11)

If expectations of future price and activity changes are assumed to be a first-order Markov process, then $E(P_t - P_{t-1})$ can be replaced by $(P_{t-1} - P_{t-2})$, and $E(Y)$ by Y_{t-1}. Thus,

$$\Delta INT = c^1{}_o + c^1{}_1 Y_{t-1} + c^1{}_2.(P_{t-1} - P_{t-2}) - c^1{}_3.R - \theta \cdot INT_{t-1} + e \quad (12)$$

Equation (12) can be estimated by ordinary least squares and the fitted value of ΔINT can be used as a proxy for the true, but unobserved desired change in inventory, ΔINT^*.

A further difficulty arises in measuring the cumulative inventory change of small (non-INCO) producers and consumers, ΔIN^*. Since there are no data on individual producer and consumer inventories[1], it is assumed that the change in inventories excluding INCO's, ΔIN^*, is proportional to the change in total inventories,

$$\Delta IN^* = \mu \cdot \Delta INT^*, \quad o<\mu<1 \quad (13)$$

[1] Consumer inventories are only available in the case of the U.S.

When all firms and consumers possess the same information, this assumption is not unreasonable. Obviously, however, this relationship cannot hold for 1979, when at the end of a 10-month strike INCO's inventories were at an extremely low level. To capture the effect of such a diversion, a dummy variable for 1979 was introduced.[1]

For the determination of the profit-maximizing price level of the dominant firm in accordance with (9), the fitted value of ΔINT, ΔINFIT, was inserted for ΔINT^* in equation (9). In the absence of average cost data for INCO, it was assumed that the average cost of nickel production is a linear function of the Canadian consumer price index.[2]

Equation (9) can therefore be rewritten as

$$\pi = P \left[\gamma_o+\gamma_1 \cdot Y \ldots\ldots - \gamma_3 \frac{P}{P_M} \ldots\ldots + \mu \cdot \Delta INFIT\right] - (-a_o+a_1\ ccp)$$
$$\left[\gamma_o+\gamma_1\ Y \ldots\ldots - \gamma_3 \frac{P}{P_M} \ldots\ldots + \Delta INFIT\right] \quad (14)$$

---

1 It could also be argued that expected change in price should not be the same for price takers and the price setter. For example, it can be argued that for the price setters the capital gain variable should either be the actual gain in this period, $P_t - P_{t-1}$, or the expected gain in the next period, i.e., $E(P_{t+1} - P_t)$. We entertained this idea which results in a slightly different price equation. But the empirical results were not encouraging and hence the latter approach was taken. Of course, we could substract IN_{t-1} from both sides of the equation (10) and insert the ensuing equation in equation (9). However, this will increase the number of independent variables in our final equation.

2 This formulation appears to be justified in the face of wage-determined price increases. In contrast to the mining of laterite nickel ores, mining of INCO's sulfide ores in Canada is relatively labor intensive. Indeed, announcements of price increases by INCO frequently allude to wage settlements, which in Canada have, in recent years, been predominantly oriented at the consumer price index.

where ccp is the Canadian consumer price index expressed in U.S. dollars. Maximizing profit with respect to P yields

$$\frac{P}{P_M} = \frac{\gamma_o}{2\gamma_3} + \frac{\gamma_1}{2\gamma_3} \cdot Y + \frac{\alpha_2}{2\gamma_3}\frac{P_S}{P_M} - \frac{\beta_2}{2\gamma_3} T + \frac{1}{2\gamma_3} \cdot Z - \frac{a_o}{2} \cdot \frac{1}{P_M}$$

$$+ \frac{a_1}{2} \cdot \frac{ccp}{P_M} + \frac{\mu}{2\gamma_3} \cdot \Delta INFIT \qquad (15)$$

From equation (15) it becomes apparent that the coefficient of Z (change in U.S. government stockpile) must be greater than the coefficient of ΔINFIT, because $o<\mu<1$. On a priori ground one can expect the value of μ to be around 0.5, since over the estimation period INCO accounted for roughly 50 % of total production in the market economies. Consequently, the coefficient of Z should be twice as large as the coefficient of ΔINFIT.

To determine INCO's production level, substitution of (15) into (8) yields a reduced form equation for the price setter's output.

$$ED^* = \frac{\gamma_o}{2} + \frac{\gamma_1}{2} \cdot Y - \frac{\beta_2}{2} \cdot T + \frac{\alpha_2}{2}\frac{P_S}{P_M} + \frac{1}{2} \cdot Z + \frac{a_o\ \gamma_3}{2} \cdot \frac{1}{P_M}$$

$$- \frac{a_1\ \gamma_3}{2} \quad \frac{ccp}{P_M} + (1-\frac{\mu}{2})\ \Delta INFIT \qquad (16)$$

Inspection of equation (16) reveals that the coefficient of Z must be 0.5 and the coefficient of the inventory changes should be close to 0.7, if the prior expectation on the magnitude of μ should be borne out.

Unfortunately, a direct test of (16) is impossible, since INCO production data are not available for the period before 1967. To obtain estimates for the coefficients of (16), Canadian nickel production was used instead of INCO's. With

INCO accounting for 75 % of the nickel production of Canada, the degree of bias in the results will be limited.

III. Estimation Procedure and Empirical Results

a) Inventories

Before estimating the central equations (15) and (16), a proxy value for the market's desired change in inventories, $\Delta INFIT$, was obtained by estimating equation (12):

$$\Delta INT = -\underset{(-.61)}{18.5} + \underset{(2.25)}{2.24}\, Y_{t-1} - \underset{(-2.68)}{24.4}\, R + \underset{(2.68)}{2.98}\, (P_{t-1} - P_{t-2}) - \underset{(-2.8)}{.32}\, INT_{t-1}$$

$$R^2 = .73 \qquad \bar{R}^2(\text{Adj.}) = .679 \qquad D.W. = 2.54$$

(Numbers in parantheses are t-values).

According to these results, an increase in the index of industrial activity by one unit raises desired inventories by 2,240 tons. In elasticity terms, the elasticity of the inventories with respect to industrial activity is 1.15, implying that inventories move roughly parallel with industrial activity.[1] A one-basis point increase in interest rates leads to a decrease in desired inventories by 24,400 tons. This implies an elasticity of inventories with respect to the interest rate of -.83, roughly implying inverse proportionality between the interest cost of holding inventories and their level.[2] A one cent increase in the expected future change in the price of one pound of nickel leads to an increase in desired inventories of about 3,000 tons, implying a price elasticity of inventories of 1.2.

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[1] The elasticity of inventory change with respect to industrial activity is 20, i.e., a one per cent increase in industrial activity raises the inventory increase by 20 % above the previously contemplated change.

[2] The inventory change elasticity is -13.

For illustration, in Table 1 the estimated values of the desired inventories are compared with actual nickel inventories for the estimation period 1961 - 1979. This comparison points to excess inventories for the early 1960's and late 1970's. Indeed, these were the periods during which the price of nickel fell in absolute terms. Table 1 also illustrates the prominent role of inventories: On average, inventories amount to roughly one third of world nickel consumption. The magnitude of this ratio underlines the importance of inventory adjustments for price determination and production behavior.

Table 1 - Actual versus Estimated Desired Inventory of Nickel

	Desired Inventory		Actual Inventory		Desired - Actual
	1000 t	As % of world consumption	1000 t	As % of world consumption	
1961	87.82	.27	70.56	.22	17.3
62	71.01	.22	114.8	.35	- 43.8
63	90.98	.26	133.4	.38	- 42.4
64	118.4	.36	134	.33	- 15.6
1965	134.2	.30	121.6	.28	12.7
66	176	.37	115	.24	61
67	177	.38	126	.26	50.6
68	126.8	.26	107.6	.218	19.2
69	120.6	.19	107.1	.213	13.5
1970	162.9	.26	71.99	.12	90.9
71	192.5	.35	105.5	.18	87
72	295.9	.44	197.9	.29	98.1
73	219.9	.31	200.5	.28	19.5
74	221.7	.37	193.7	.33	28.1
1975	260.4	.42	203.7	.34	56.6
76	199.8	.30	343.5	.51	-144
77	304.5	.45	383.3	.58	- 78.8
78	351.5	.49	466.6	.64	-115
1979	312.2	.39	347.1	.42	- 35
Average inventory/consumption ratio	-	.30	-	.32	-

b) Price equation

The estimation results for the price equation (15) and the Canadian nickel production equation (16) are presented in Tables 2a and 2b, respectively.[1] The price equation has an exceptionally good fit, considering that the dependent variable is the nickel price deflated by the metal price index.[2] All variables except for the time trend are significicently different from zero at the .05 level and have the expected signs.

The magnitude of the coefficient for U. S. government stockpile changes (Z) is, as had been postulated, almost twice as large as the coefficient for the desired change in inventory (Δ INFIT). The elasticity of the real price of nickel with respect to industrial activity is .75, with respect to U.S. stockpile changes .015, with respect to the real price of steel .48, with respect to the production cost proxy .95[3], and with respect to the desired change of inventory .005. These results are all plausible: Increases in production costs, expected demand and the price of the nickel-intensive commodities (steel) should, indeed, play the dominant roles in the price determination mechanism. On the basis of the production cost elasticity, the dominant firm appears to use mark-up pricing.

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[1] In the estimations, the expected price of steel and the level of economic activity have been specified by their lagged values in order to avoid simultaneity problems.

[2] Estimation of the price equation with an index of world inflation as an alternative deflator did not yield substantially different results; cf. Appendix II.

[3] The production cost elasticity is an approximative elasticity which has been calculated from the second price equation, since an elasticity cannot be obtained from the first equation which includes the two production cost terms $\frac{ccp}{p_M}$ and $\frac{1}{p_M}$,

Estimation of Price and Production Equations

Table 2a - Price equation (15)

Dependent Variable	C	Y_{t-1}	T	Z	$\frac{(P_{S,t-1})}{P_M}$	$\frac{ccp}{P_M}$	$\frac{1}{P_M}$	ΔINFIT	D 79	$R^2/\bar{R}^2$	D.W.	S.E.R.
$\frac{P}{P_M}$	-.56 (-2.01)	.0086 (2.33)	-.044 (-1.80)	.0016 (3.67)	5.59 (2.01)	3.16 (3.16)	-100.5 (-1.99)	.00087 (3.51)	.168 (3.44)	.96/.93	2.19	.033
$\frac{P}{P_M}$	-.57 (-2.3)	.0053 (10.57)	-	.0016 (4.12)	4.30 (1.99)	1.31 (4.70)	-	.0097 (4.05)	.144 (2.82)	.945/.91	2.06	.035

Table 2b - Production equation (16)

Dependent Variable	c	Y_{t-1}	T	Z	$\frac{P_s}{P_M}$	$\frac{ccp}{P_M}$	$\frac{1}{P_M}$	ΔINFIT	D 69	D 75	D 78	D 79	$R^2/\bar{R}^2$	D.W.
ED^*	147 (1.71)	3.15 (3.02)	-5.3 (-.63)	.54 (4.12)	-1845 (-2.3)	-58 (-.15)	11442 (.62)	.20 (2.27)	-47 (-4.2)	-26 (-1.87)	-76 (-3.38)	-71 (-2.80)	.978/.94	2.06
ED^*	157 (1.95)	3.41 (3.70)	-10.03 (-2.57)	.53 (4.2)	-1855 (-2.42)	164 (1.68)	-	.21 (2.45)	-48 (-4.4)	-28 (-2.28)	-70 (-3.62)	- 62 (-3.02)	.977/.94	1.99

The numbers in parantheses are t-statistics.

c) Production equation

Table 2b presents the estimation results on the determinants of dominant firm (Canadian) production. In this equation, apart from variables already familiar from the price equation, four dummy variables have been included to capture the effect of strikes in 1969, 1975, 1978 and 1979 in the Canadian nickel industry. Again, the fit of the model is very good; most of the coefficients are significantly different from zero and have the expected signs. The coefficient on U. S. stockpile changes (Z) is not significantly different from .5 - the value predicted by the model - and it is highly significant. The two reported regressions, which only differ by inclusion of the term $\frac{1}{P}$, confirm that inventory adjustments affect nickel production. However, the coefficient of the desired change in the inventory variable ΔINFIT (.2), is much smaller than the one predicted by the model (.7). This can perhaps be explained by consumers' loyalty to individual producers and by the size of other (non-INCO) firms. That is, it is quite likely that in quasi-monopolistic markets, where loyal customers are given preferential treatment during periods of excess demand, it is difficult to attract new customers for the purpose of reducing excess inventories in excess supply situations: This phenomenon maybe particularly important in the case of the nickel industry, where not only INCO, but also its competitors, such as S.L.N. or Falconbridge, aim at and appear to honor customer loyalty. In periods of excess supply, non-dominant firms are then also forced to reduce production.[1] If the supply of other (non-INCO) firms is specified as

$$SS = (\beta_0 + \beta_1 \cdot \frac{P}{P_M} + \beta_2 \cdot T + \beta_3 IN_S^*) - \Delta IN_S^* + \varepsilon_2, \qquad (17)$$

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[1] In support of this argument, a reduction in the output of such medium-sized firms as SLN and Falconbridge could be observed in 1977 and 1978.

it is recognized that the coefficient of ΔIN_S^* will no longer be equal to one. If we apply the same reformulation for consumers and the price setter, equation (16) will be derived as

$$ED^* = \frac{\gamma_o}{2} + \frac{\gamma_1}{2} \cdot Y - \frac{\beta_2}{2} \cdot T + \frac{\alpha_2}{2} \frac{P_S}{P_M} + \frac{1}{2} \cdot Z + \frac{a_o \gamma_3}{2} \cdot \frac{1}{P_M}$$

$$- \frac{a_1 \cdot \gamma_3}{2} \frac{ccp}{P_M} + (1 - \beta_3)(1 - \frac{\mu}{2}) \Delta INFIT \qquad (18)$$

If β_3 is somewhere close to .70, then the coefficient of ΔINFIT must be close to .20.[1]

The fact that steel prices have the wrong sign and the cost variable is insignificant should not be taken against the model's performance, because the dependent variable is only a proxy for INCO's nickel production. In fact, estimating the nickel production of Canada in this manner implies that all Canadian producers are acting collectively to maximize their profit,which is not true. However, to see the performance of the desired change in inventory variables, it was decided to estimate the nickel production of Canada in its present form.

In elasticity terms, the Canadian production responses to variable changes with significant and plausible coefficients are as follows: 1.2 with respect to industrial activity, -.15 with respect to unit cost increase, and .o56 with respect to inventory changes. With nickel demand being a derived demand, it is not surprising to obtain the near-proportional relationship between industrial activity and nickel production.

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[1] This implies that, in order to reduce inventories by 100 units, producing firms have to cut their production by 70 units. However, what they will sell is still 30 units more than if no reduction in inventories were desired.

IV. Conclusions

In this paper it was argued that the reason why previous studies have been unable to confirm the role of inventory adjustments on price setting and production decisions of the dominant firm in the nickel market is due to misspecification of desired changes in inventories. The alternative formulation proposed here, makes desired inventories a function of the expected volume of trading in the future, the expected change in the future price of nickel and the opportunity cost of holding inventories. It was demonstrated that the significance of the proposed variables in explaining past inventory changes cannot be rejected. The fitted values obtained from the proposed formulation for inventory change were subsequently used as a proxy for the desired changes in inventory, in the dominant firm's price setting equation and in the equation explaining the nickel production of Canada.

The results on price and production equations support the hypothesis that inventory adjustments have, along with the other variables, played an important role in influencing INCO's price setting. Inventory adjustments have, in turn, also influenced Canadian production decisions. Had other nickel models also included the effect of inventory adjustments, they might have been able to predict the actual price and production decrease that occurred in 1978 rather than, having overestimated production in 1980 by roughly 50 %.

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[1] The simulated value of Canadian nickel production in Charles River Study is 290 and it is approximately the same in Smithson et al. Study. However, the actual production is only 190 thousand metric tons. Needless to say, had not it been for the prolonged Canadian nickel strike in 1978 and 1979, the stocks of nickel would have been much larger and hence actual production would have been even less than 190 thousand metric tons. Due to the same reasoning none of these studies' simulations predicted the fall in the price of nickel which occurred in 1977 and 1978, when nickel stocks reached a record level; instead, they predicted a continuously rising price of nickel.

The model proposed here has two important applications. First, it can serve as the basis for projections and policy simulations. Second, models like this can be applied to an analysis of other raw material markets. Due to the geographic concentration of raw material deposits and economies of scale in mining and processing, many raw material markets share the major market characteristics featured in this paper.

Appendix I

Inventories of nickel were calculated using a formula which closely corresponds to the one used in the Charles River Study. Since production data measures the nickel mined in different countries at different stages of production, it was necessary to adjust these data when totaling world production. The following formula was used to calculate changes in the world's stock of nickel

$$\Delta INT = (CAN + NCL + SAF + USA + GRE + DRP + BUR) + .86\,[EBT] + .9\,(OWB) + .85\,(BOT) + .975\,(FIN + NOR + ZIM + AUS) - Z - CNW$$

where

Δ INT = estimated change in the world's stock of nickel
CAN = nickel production of Canada
NCL = nickel production of New Caledonia
SAF = nickel production of South Africa
USA = nickel production of U.S.A.
GRE = nickel production of Greece
DRP = nickel production of Dominican Republic
BUR = nickel production of Burma
EBT = nickel production of East Block countries
OWB = nickel production of the other western countries
BOT = nickel production of Botswana
FIN = nickel production of Finland
NOR = nickel production of Norway
ZIM = nickel production of Zimbabwe
Z = change in the U.S. government's nickel stockpile
CNW = world consumption of nickel
AUS = nickel production of Australia.

The world's estimated change in nickel stocks was also calculated without the abovementioned weights. The estimation were robust to this experiment. The weights were derived by considering the amount of nickel which will be lost in concentrating and smelting different sulfide and laterite ores.

All the data are from World Metal Statistics except nickel production of New Caledonia which was taken from Minerals Yearbook. Price data are weighted averages of the quoted range which are published in Metal Statistics.

To calculate the world inventories of nickels estimated changes in the world inventory of nickel were added to the estimated inventory of nickel in 1954, which according to the Charles River study was 29 thousand metric tons of nickel.

Appendix II

Table A.1 and A.2 present estimation results corresponding to Tables 2a and 2b, respectively, with the difference that the metal price index has been replaced by an index of world inflation as a deflator for the price and cost variables. A comparison of Table A.1 with Table 2a and Table A.2 with Table 2b reveals that estimation results are not substantially affected by the alternative deflator.

Estimation of Price and Production Equations

Table A.1 - Price Equation (15) with Index of World Inflation

Dependent Variable	C	Y_{t-1}	T	Z	$\frac{(P_{S,t-1})}{P_M}$	$\frac{ccp}{P_M}$	$\frac{1}{P_M}$	ΔINFIT	D 79	$R^2/\bar{R}^2$	D.W.	S.E.R.
$\frac{P}{P_M}$	-.97 (-1.52)	.02 (2.40)	- .145 (-1.82)	.0041 (3.55)	9.78 (2.06)	2.75 (2.67)	-129 (-1.77)	.0022 (3.43)	.335 (2.60)	.96/.93	2.24	.087
$\frac{P}{P_M}$	-1.18 (-2.72)	.012 (8.4)	-10.05 (- 2.57)	.004 (3.85)	4.06 (1.30)	1.22 (4.56)	-	.0023 (3.75)	.28 (2.20)	.95/.92	2.02	.092

The numbers in parantheses are t-statistics.

Table A.2 - Production equation (16) with Index of World Inflation

Dependent Variable	c	Y_{t-1}	T	Z	$\frac{P_s}{P_M}$	$\frac{ccp}{P_M}$	$\frac{1}{P_M}$	ΔINFIT	D 69	D 75	D 78	D 79	$R^2/\bar{R}^2$	D.W.
ED^*	84.5 (1.10)	3.34 (3.36)	- 5.11 (- .52)	.55 (3.99)	-868 (-1.90)	-10.5 (-.60)	6876 (.62)	.26 (2.03)	-39 (-2.11)	-31 (-1.95)	-75 (-3.25)	-68 (-2.69)	.978/.94	1.87
ED^*	113 (1.91)	3.52 (3.84)	-10.6 (-2.78)	.52 (4.16)	-753 (-1.87)	97 (2.64)	-	.22 (2.04)	-46.6 (-3.38)	-28.6 (-1.93)	-72.7 (-3.32)	-63.5 (-2.73)	.977/.94	1.87

The numbers in parantheses are t- statistics.