archive

SOME EVIDENCE ON DIFFERENTIAL INVENTORY BEHAVIOR IN COMPETITIVE AND NON-COMPETITIVE MARKET SETTINGS

by

Raymond S. Hartman*

Working Paper No. MIT-EL 79-025WP

April, 1979

*The author is an assistant professor of economics at Boston University and a member of The Research Staff, Massachusetts Institute of Technology Energy Laboratory.

INTRODUCTION

Inventory behavior has long been analyzed as important in explaining economic cycles at the macro level, the industry level and the firm level.[1] At the firm and industry levels, inventory behavior is frequently hypothesized to be motivated by the desire to maintain a constant inventory/sales or inventory/production ratio for transactions purposes. Some version of an accelerator model is utilized to model such transactions motives.[2]

While the desire to maintain a constant inventory/sales ratio can characterize most firms or groups of firms, whether oligopolistic or competitive, the inventory behavior of an oligopoly may be expected to be more complicated than a competitive firm's behavior because oligopoly behavior in general is more complicated. Inventory behavior is one of several tools used by oligopolists in pursuing pricing and production goals. For example, in an oligopolistic industry, the participants may set a common price reflecting their joint short-run and/or long-run goals[3] while taking into account their short-run (several months) and long-run (up to several years) perceptions regarding demand conditions, cost conditions and potential entry. Because the group of interdependent producers tacitly or overtly accepts the common price and because each

---

1 See for examples [1, 4, 6, 7, 14, 15, 16, 17, 18]

2 See for examples [11, 13, 14, 17]

3 The richness of potential goals and behavior in oligopolistic industries is well known and not explored here. See [21] for greater discussion.

member realizes in a working oligopoly that output/price decisions governed by narrow self-interest may be destructive, each member of the oligopoly will defend the group price by passive output adjustment. As a result, production is adjusted where possible to demand levels at the accepted price to avoid upsetting the group price. When production is not entirely flexible and when the quantity of output collectively supplied by members of an oligopoly does not clear the market at the established group price, inventories (and order backlogs) can be used to defend the common price. Thus, when demand pressures are high enough to render a maintained group price too low for short-run equilibrium, inventories may be drawn down to support that given price, until rationing or a price change is required. Likewise, when oligopolists hope to maintain short-run administered prices above the equilibrium levels, additions to inventories can be a useful technique for helping maintain a given price structure in the face of short-run market conditions. Such behavior is documented by Kaplan, Dirlam, and Lanzilotti[1] and O'Hanlon [19] for the U.S. primary copper producers and by Peck[2] for the U.S. aluminum producers. Furthermore, Scherer[3] documents a positive relationship between the variability of inventory/sales ratios and the levels of concentration (C_4) for 23 U.S. industry groups, thereby suggesting a more active use of inventories as an economic tool in more concentrated (hence, potentially more oligopolistic) industries.

---

1 [12], pp. 176-181

2 [20], pp. 88

3 [21], Chapter 5

The purpose of this paper is to report econometric results that confirm the transactions motives of competitive and non-competitive firms[1] for holding inventories (the accelerator model with its desired inventory sales ratio) and furthermore indicate the greater reliance of oligopolistic firms upon inventories for other reasons. To accomplish this, the paper develops a model of inventory behavior that incorporates a wide array of motivations for holding and using inventories. The transactions motive and the price maintainance motive of oligopolists mentioned above are two of many possible motivations for holding inventories. There exist other precautionary and speculative motives. While these motives can be and have been worked into a number of models which include rigid and flexible accelerator models, buffer stock models and supply of storage models [13], Section 1 incorporates them into a "remodified" flexible accelerator model to be applied to the inventory behavior to three groups of producers within the U.S. copper industry. These groups and their respective inventories are

- Primary copper producers' inventories of refined copper output
- Fabricators' and semi-fabricators' inventories of scrap and refined copper inputs
- Secondary copper refiners' and smelters' inventories of scrap inputs

The primary producers can be characterized as an oligopoly; the fabricators/semi-fabricators and secondary refiners can be characterized as competitive.[2] Section 2 reports the results of applying the model to all three groups. Section 3 discusses the conclusions to be drawn.

---

[1] The results reported here hold for groups of competitive or oligopolistic firms. However I feel there is little aggregation problem in deducing behavioral conclusions for individual firms from the group results.

[2] See [2, 3, 8, 10]. For an identification of the corporate members of each group, see [8], Chapter 1, and [2].

1. THE MODEL

A variant of the accelerator model is used here for both competitive and non-competitive groups for both product and factor inventories. A brief discussion of the forms of the accelerator is useful to indicate how this version differs from others.

The strict accelerator assumes that inventories (I) vary directly with output (Q), i.e., $I_t = \alpha Q_t + \mu_t$, where α is the inventory/sales ratio. The theory applies to factor and product inventories and incorporates the insight that stocks are held as precautionary reserves to meet production and/or sales goals.[1]

This specification of inventory behavior is clearly too rigid. It does not differentiate between desired and actual inventories nor between planned and actual production/sales. It does not take into account lags between inventory changes and changes in sales or production levels. The existence of such a time lag implies that for various reasons (which should be made explicit)[2] producers and consumers will adjust actual inventories only partially to their equilibrium (or desired) level. Furthermore, if firms make errors in their sales/production forecasts, discrepancies between actual and planned inventories will occur.[3] Finally, the simple rigid accelerator above fails to explicitly take into account speculative price expectations, the costs of holding inventories, and the use of inventories

---

[1] See [13], Chapter 4; [1]; [8].

[2] And are not made explicit by many straightforward partial adjustment formulations.

[3] See [15], [16], and [17] .

by oligopolists for price maintainance. Thus, although desired inventories may be some relatively constant proportion of forecasted output, that proportion will be sensitive to inventory price expectations, strike expectations, the costs of holding inventories and oligopolistic price maintainance motives.

To take account of not only time lags, but also the ex post differences between output expectations and realizations and the influence of other speculative and expectational variables upon the assumed proportionality between inventories and production, several other models have been introduced. One improvement is a simplistic flexible accelerator combining a simple accelerator hypothesis (1a) with a simple partial adjustment model (1b)[1] as follows:

$$I_t^* = \alpha_0 + \alpha_1 Q_t \qquad (1a)$$

$$I_t - I_{t-1} = \lambda(I_t^* - I_{t-1}) \qquad (1b)$$

$$\text{or, } I_t = \lambda\alpha_0 + \lambda\alpha_1 Q_t + (1-\lambda) I_{t-1}$$

where I_t^* is the desired stocks at the beginning of period t; I_t is actual stocks; and Q_t is the output in the period t (or expected output under certainty). With stochastic specification, we obtain:

$$I_t = \lambda\alpha_0 + \lambda\alpha_1 Q_t + (1-\lambda) I_{t-1} + \varepsilon_t$$

---

1 See [13], pp. 64-65; [14], [5].

Lundberg and Metzler [15-17] have developed an alternative approach which focuses upon the use of inventories as a buffer between production and sales. Accordingly, planned inventories are related to planned sales and the difference between actual and planned inventories is determined by the difference between actual and planned sales.[1] If data on sales expectations[2] were available, this modelling approach could be useful for the copper industry. They are not available. Furthermore, the more sophisticated versions of the buffer stock model do not lend acceptable behavioral specifications. For example, Lovell [14] combines the buffer stock model and the flexible accelerator which he reduces to a behavioral relationship between actual stocks and expected sales, actual sales and lagged stocks. Not only does this specification require sales expectations data, but it appears to suffer from a weak assumption. A major weakness is that the model assumes that the partial adjustment specification operates between <u>planned</u> and <u>desired</u> inventories. Thus, Equation 1b) becomes:

$$I_t^p - I_{t-1} = \lambda(I_t^* - I_{t-1}) \qquad 2)$$

where I_t^p is planned inventories, and the other variables are defined as in Equation 1b). While there are reasons why actual stocks can only adjust partially to desired levels (as is discussed below), I see little reason

---

[1] For a good summary of the full equational specification, see [13], pp. 65-67.

[2] Such as that completed by the Office of Business Economics (OBE) quarterly surveys. For a critical discussion of this data, see [11], Chapters 1 and 2.

why plans do not adjust to desires quickly enough to render this specification inappropriate. It implies a lack of rational planning, particularly for annual data. Clearly, actual inventories will not meet planned levels always. However, Equation 2 is mute as to reasons why plans cannot at least approximate "desires" ($\lambda \approx 1$)or what causes this consistent inability to plan.

In light of these considerations, the form of the modified flexible accelerator seems most appropriate. However, it requires remodifications.[1] The "remodified flexible accelerator" to be used here combines a specification of desired inventories plus a partial adjustment specification of the relationship between actual inventory changes and desired changes as follows:

$$I^*_t = \alpha_0 + \alpha_1 Q^e_t + \alpha_2 \, DSTE2_t + \alpha_3 \left(\frac{P^e_{t+1} - P_t}{P_t}\right) \tag{3a}$$

$$I_t - I_{t-1} = \lambda(I^*_t - I_{t-1}) + F(X,Y,Z) \tag{3b}$$

$$\text{or } (I_t - I_{t-1}) - \lambda(I^*_t - I_{t-1}) = F(X,Y,Z)$$

Equation (3a) relates desired inventories in year t to expected production in year t, to strike activity expected in year t to take place in year t+1 (i.e., DSTE2, an expected strike dummy), and to expected price changes (capital gains) of the inventoried commodity from t to t+1. For both producers'inventories of final product and consumers'inventories of factor inputs, the priors are $\alpha_1 > 0, \alpha_2 > 0, \alpha_3 > 0$. Equation 3a) identifies a mix of precautionary, transactions and speculative motives for inventory demand.

---

[1] A number of interesting modifications have been pursued and tested in [11], Chapter 6.

Equation 3b) is the usual partial adjustment specification with the additional identification of factors affecting actual inventory behavior and its relation to desired inventory behavior. F is a function of market conditions, current strike activity, and costs of holding inventories -- all of which will affect the hypothesized relation between actual and desired inventory behavior.

Linearizing F and incorporating proxies for these factors for the U.S. copper industry, we obtain:

$$I_t - I_{t-1} = \lambda(I_t^* - I_{t-1}) + \lambda_1 (RPLME_t - RPEMJ_t) + \lambda_2 \, DUMST2_t + \lambda_3 \, ACCEP_t \qquad (3b)$$

(RPLME - RPEMJ) is the difference in year t between the real price (RP) of copper on the London Metals Exchange (LME) and the real price (RP) of copper quoted in the copper trade journal, Engineering and Mining Journal (EMJ). RPLME is a short-run competitive price reflecting world supply and demand; RPEMJ is the primary producers' group price determined by the goals of the oligopolistic primary producers.[1] The difference reflects the extent of excess demand in the U.S. copper market in a given year. Thus when (RPLME-RPEMJ) is great, U.S. markets are in disequilibrium since RPEMJ is maintained well below international market clearing prices.[2] DUMST2 is a strike dummy indicating the number of months of strike in the U.S. copper industry (at the smelting and refining stages) in year t. $ACCEP_t$ is the annual average 90-day bankers acceptance rate, which is felt to reflect the non-warehousing costs of holding inventories.

---

[1] See [2,3,8] for much greater clarification of the structure of the industry.

[2] I do not discuss why the primary producers would maintain desired prices below world market levels. See [8] chapter 1, and its footnotes for discussion, speculation and relevant sources. My interest here is the effects of those desires on inventory behavior. Of course, such price maintainance motives are assumed only for the period of estimation.

The priors for 3b are: $\lambda_1 < 0$, $\lambda_2 < 0$, $\lambda_3 < 0$. For example, in a "demand crunch" period (world copper prices well above U.S. primary producer price) when primary producers are disgorging stocks to help maintain an oligopolistic price below short-run competitive levels and/or when strike activity limits production and necessitates sales from inventory and/or when the costs of holding inventories are high, ceteris paribus, the actual inventory increases on the part of those primary producers will be less than desired.

Combining 3a) and 3b) and introducing a disturbance term,[1] we obtain:

$$I_t - I_{t-1} = \lambda\alpha_0 + \lambda\alpha_1 Q_t^e + \lambda\alpha_2 \, DSTE2 + \lambda\alpha_3\left(\frac{P_{t+1}^e - P_t}{P_t}\right) - \lambda I_{t-1} + \lambda_1 (RPLME_t - RPEMJ_t) + \lambda_2 \, DUMST2_t + \lambda_3 \, ACCEP_t + \varepsilon_t \qquad (4a)$$

or,

$$I_t = \lambda\alpha_0 + \lambda\alpha_1 Q_t^e + \lambda\alpha_2 \, DSTE2_t + \lambda\alpha_3 \left(\frac{P_{t+1}^e - P_t}{P_t}\right) + \lambda_1 (RPLME_t - RPEMJ_t) + \lambda_2 \, DUMST2_t + \lambda_3 \, ACCEP_t + (1-\lambda) I_{t-1} + \varepsilon_t \qquad (4b)$$

---

[1] The stochastic assumptions merit some discussion. If Equations 3a) and 3b) both have disturbance terms ε_1 and ε_2, respectively, then $\varepsilon = \varepsilon_1 + \varepsilon_2$ and the distribution of ε is determined by assumptions regarding ε_1 and ε_2. Thus, if $\varepsilon_1 \sim N(0, \sigma_1^2)$, $\varepsilon_2 \sim N(0, \sigma_2^2)$; $\varepsilon \sim N(0, \sigma_1^2 + \sigma_2^2)$ if $cov(\varepsilon_1 \varepsilon_2) = 0$. Many analysts treat 3a) as a non-stochastic equation, making $\varepsilon = \varepsilon_2$. In any case, Equations 3a) and 3b) are estimated as part of a larger system determining both actual and expectational variables. As discussed below, 2SLS techniques were used to insure consistent estimates.

2. RESULTS

The estimation results for 4b) for the oligopolistic primary producers and the competitive secondary refiners and fabricators/semi-fabricators are given in Table 1. The estimates come from a simultaneous econometric model of the U.S. copper industry [8]; 2SLS/Hildeth-Lu and/or 2SLS/Cochrane-Orcutt techniques were used. The variables are defined fully in Appendix A.

A number of alternative expectational price variables have been utilized. P^e_{t+1} is proxied by simple averages of future prices. Two alternatives for P^e_{t+1} tried were copper futures contracts prices PFUT1 and PFUT7, which differ only in timing of delivery of the futures contracts (see Appendix A). Alternative forms of the expectational price variables include a non-linear[1] form $\left(\frac{RPFUT1 - RPPR}{RPPR}\right)$ and a linear form (RPFUT1 - RPEMJ). Q^e_t is usually proxied by actual Q_t (production level of the group being analyzed). Some empirical work suggests this is a good approach: for example, actual sales realizations have been shown to be decent proxy for sales anticipations.[2] Furthermore, the use of actual realizations for expectations is a "rational expectations" formulation.

Using the data [5], Equation 4b) is estimated on an annual basis. However, the various models can be formulated in terms of end-of-year, beginning-of-year, or monthly average inventory positions. The specification

---

[1] RPPR is the real primary producers price while RPEMJ is the real Engineering and Mining Journal (EMJ) primary producer price. The prices are almost identical. See [2, 8] and Appendix A.

[2] See an excellent discussion and empirical test of alternative sales expectations models including the Ferber Law of Expectations, the adaptive expectations model and rational expectations models in Hirsch and Lovell, [11], Chapter 5.

in Equations 3a and 3b) for the copper industry are most relevant for analyzing the behavior of average monthly inventory positions in a given year. However, the consistent body of data available [5], for all three producer groups quantifies only year-end inventory positions. Thus, most estimates of the inventory equation in Table 1 utilize I_t as end-of-year inventory levels in year t. However, to assess the sensitivity of the behavioral specification, I have also used as I_t the simple annual average end-of-month inventory position (IRRAV) for year t. This has been estimated for primary refiners alone.

The results are discussed for the three producer groups. Only a few specifications are detailed which represent those judged best.

- Primary Refiners' Inventories of Refined Copper

Equations Ai, Aii and Aiii) examine the hypothesized model for the oligopolistic producers when inventories are defined on a monthly average basis for the year ($IRRAV_t$). Aiv) and Av) use end-of-year inventory estimates. My intent here is to examine only the sign and statistical significance of the estimated coefficients; therefore, direct hypotheses regarding the α_0, α_1, α_2 and α_3 are not examined and these parameters are not separately estimated here (which would have required maximum likelihood assumptions).[1]

In Equation Ai) all coefficients are the correct sign except $\lambda\alpha_1$ (the coefficient of QPR) and λ_3. Neither are significantly different

---

[1] In 4b), the signs of $\lambda\alpha_1$, $\lambda\alpha_2$ and $\lambda\alpha_3$ should be the same as α_1, α_2, α_3 because $\lambda > 0$.

from zero; likewise, $\lambda\alpha_0$ is not significantly different from zero. Equation Aii) is identical except the constant has been dropped. A Fisher-Chow[1] test reveals that one cannot reject $H_0: \lambda\alpha_0 = 0$, while Equation Aiii) furhter indicates that one cannot reject $H_0: \lambda\alpha_3 = 0$. In Equation Aii), all coefficients are the correct sign: $\hat{\lambda\alpha}_1$, $\hat{\lambda}_1$, and $(1-\hat{\lambda})$ are all significant at the 99% level, while $\hat{\lambda\alpha}_2$ and $\hat{\lambda}_2$ are significant at the 80-90% level. $\hat{\lambda}$ is between 0 and 1, as expected. The results suggest that an accelerator relation to QPR is operative. Likewise, strike and price expectations do affect desired inventory levels. The price expectation coefficient is not significant, however. Furthermore, while the hypothesized determinants of desired stocks appear operative, actual stocks are adjusted to desired levels in light of market conditions (λ_1) and actual strike[2] conditions (λ_2). Apparently, costs of holding inventories as proxied by the cost of money (ACCEP) has little effect upon the relation of actual inventory changes to desired changes.

Finally, Equation Aiii) suggests (as do all others) that active inventory policy characterizes the oligopoly,as has been hypothesized earlier. That discretionary inventory policy is utilized for price expectation and strike reasons. Furthermore, inventory policy is also utilized as an

---

1 Asymptotically, an F test or likelihood ratio test. This is the usual test utilizing the sum of squared residuals of an unconstrained and constrained coefficient vectors. That is, $\frac{(E^{*\prime}E^{*} - E'E)/r}{E'E/n-K} \sim F(r, n-K)$.

2 The strike dummy used by CRA [3] was also used and compared with my strike dummy. The results were similar.

alternative to pricing policy. The sign and significance of $\hat{\lambda}_1$ suggest the primary producers do use inventories to help support the "administered" EMJ price. Thus, when (RPLME - RPEMJ) is large and positive, and pressure is exerted upon the EMJ price, inventories are drawn down (relative to levels determined by the other inventory motives) in order to support the group price. If the price difference is negative and downward pressure is exerted on the EMJ price, inventories are built up to support that price.

Equations Aiv) and Av) utilize the same equational specification, but use the end-of-year inventory variable (IRR). Notice, as a result, the coefficient of DSTE2 is insignificant in Aiv) and H_0: $\lambda\alpha_2 = 0$ cannot be rejected using a Fisher-Chow test. Thus, Equation Aiii) indicates that expectations of strikes in year t+1 affect monthly average inventory positions in year t[1] positively. However, the use of year-end inventory estimates in the equations Aiv) and Av) masks any build-up that would have occurred in expectation of a strike if that build-up starts to be drawn down near the end of the year.[2] That build-up would be reflected in monthly average inventory numbers, but is lost in the difference between year-end levels.

In any case, the use of a consistent body of data for the analysis of competitive and non-competitive segments of the domestic copper industry has argued for the use of year-end estimates[3]. On the whole,

---

[1] Incidentally, in light of a continually recurrent three-year contract pattern, these strike expectations are generally relatively good.

[2] For example, during the severe 1967/1968 strike.

[3] The differences in results from the alternative inventory data should be most pronounced for the oligopolists, since they have more complicated inventory behavior. However, as noted in the text, the empirical results are fairly similar for the oligopoly.

TABLE 1: INVENTORY EQUATION

DEPENDENT	CONSTANT	Accelerator Term QPR	Accelerator Term QSR	QFAB	DSTE2	Price Expectations RPFUT1-RPPR / RPPR	Price Expectations RPFUT1-RPEMJ	RPLME-RPEMJ	DUMST2	ACCEP
A) Oligopolistic Primary Producers										
i) IRRAV =	86.55 (.82)	-.02095 (-.266)			7.77 (1.81)	26.36 (1.0)		-236.37 (2.18)	-10.07 (-1.28)	4.71 (.72)
ii) IRRAV =		.0431 (2.06)			8.74 (2.28)	27.09 (1.07)		-272.62 (-2.80)	-4.74 (-1.02)	1.63 (.28)
iii) IRRAV =		.0443976 (4.09)			6.8496 (1.69)	70.3516 (1.31)		-2.29042 (-3.55)	-6.1793 (-1.54)	
iv) IRR =		.096933 5.70			2.00331 (.34)	140.967 (2.43)		-3.39123 (4.84)	-5.4979 (-1.34)	-1.31714 (- .28)
v) IRR =		.0917137 (7.81)					2.60096 (2.67)	-3.2435 (-5.52)	-5.53 (-1.47)	
B) Competitive Secondary Refiners										
i) IRS =			.196385 (3.50)					-.326789 (-1.75)		
C) Competitive Fabricators/Semi-Fabricators										
i) IF =				.0207 (1.21)	5.12715 (1.22)	5.32439 (.12)			-6.36184 (1.54)	2.71931 (.54)
ii) IF =				.02745 (2.48)	5.1806 (1.50)				-6.1446 (-1.68)	
iii) IF =				.02682 (2.35)					-6.2789 (-1.66)	

NOTE: t Statistics for H_0: Parameter = 0 in parentheses below parameter estimate

ESTIMATES

LAGGED DEPENDENT	$\hat{\lambda}$	R^2	$\hat{\rho}$	F	SAMPLE	PRICE DEFLATOR
.364 (1.64)	.636	.74	.152	4.08	1952-1970	PUWD; 1967 = 100
.354 (1.60)	.646	.72	.232		1952-1970	PUWD; 1967 = 100
.4381 2.22	.562	.73	.193		1951-1973	PUWD74; 1974 = 100
-.2892 (1.30)	1.289	.67	.04		1951-1973	PUWD74; 1974 = 100
-.261623 (-1.6)	1.262	.65	-.001		1951-1973	PUWD74; 1974 = 100
.118702 .50	.8813	.01	-.19		1953-1973	PUWD74; 1974 = 100
.609738 (2.94)	.3903	.39	.10		1953-1973	PUWD74; 1974 = 100
.57142 (3.19)	.43	.37	.08		1953-1973	PUWD74; 1974 = 100
.6112 (3.33)	.39	.29	.05		1953-1973	PUWD74; 1974 = 100

the results are still quite good. In spite of the use of IRR for Equation Aiv) $\hat{\lambda}\alpha_1$, $\hat{\lambda}\alpha_3$ and $\hat{\lambda}_1$ are significant at the 99% level. $\hat{\lambda}_3$ is still insignificant although now of the correct sign. Strike activity is diminished in its impacts, both in expectational and actual form. $\hat{\lambda}$ is now insignificant but greater than 1, which does not accord with the model in Equation 3b. Of course, it could happen if market conditions consistently forced actual inventory changes to be greater than desired changes. Given the relative insignificance of $(1-\hat{\lambda})$, however, the fact that $\hat{\lambda} > 1$ has not been analyzed deeply. However, the general insignificance of $(1-\hat{\lambda})$ in Ai) - Av) indicates that one cannot generally reject the hypothesis that $\lambda = 1$. This implies that not only do the primary producers have fairly sophisticated inventory behavior but also that the adjustment of actual inventory to desired levels occurs quickly. This interpretation further emphasizes the oligopolistic use of inventories as an active tool.

In Equation Av), $\hat{\lambda}\alpha_1$, $\hat{\lambda}\alpha_3$ and $\hat{\lambda}_1$ are again all significant at the 99% level and $\hat{\lambda}_2$ and $\hat{\lambda}$ are significant at between the 80% and 90% level (i.e., insignificant by normal rules of thumb). Fisher-Chow tests could not reject the null hypothesis that the other coefficients were zero. The signs of the coefficients are as expected.

Aiv) and Av) suggest that not only is there an accelerator effect operative, but also that price expectations are insignificant but actual strikes and market conditions (RPLME - RPEMJ) do limit the ability of the oligopolistic primary producers to adjust actual inventories to desired levels (as seen in all A) equations).

- <u>Secondary and Custom Refiners' and Smelters' Inventories of Scrap</u>

The secondary refiners are "workably" competitive in both the product and factor markets [2, 8]. While competitive producers will also have a mix of transactions and speculative motives for holding inventories, it is the hypothesis of this paper[1] that the importance and use of inventory policy will be less pronounced for such competitive groups. This hypothesis is borne out by initial econometric estimation of Equation 4b) in its complete form. The only parameter estimate significantly different from zero in such a complete specification is $\hat{\lambda\alpha}_1$, the accelerator term.

Upon reflection, it is not surprising that many of the parameter estimates are not significantly different from zero. Actual and expected strike activity at the smelting and refining stage of production do not affect factor supply from the scrap market in any substantial fashion.[2] Hence, stockpiling scrap in expectation of a strike and/or drawing down inventories of scrap during an actual strike is not expected or hypothesized; thus, it is expected that $\lambda\alpha_2$ and λ_2 are never significantly different from zero. Furthermore, $\hat{\lambda}_3$ is never significantly different from zero.[3] The price expectation variable (RPFUT1 - RPEMJ) is not significant.[4]

---

[1] And others; see [21], Chap. 5.

[2] If factor prices rise, competitive product prices will also rise.

[3] Which coincides with the results for the primary refiners.

[4] A proper speculative price expectation variable would have dealt with the expected changes in the real price of scrap (e.g., $(RPS^e - RPS)/RPS$), where RPS^e would be a futures price or an expected futures price of scrap. However, an easily accessible future price series does not exist; furthermore, RPFUT1 should be a workable proxy for RPS^e. The sign of the estimated coefficient of (RPFUT1 - RPEMJ) is generally the opposite of that hypothesized. However, the estimate is never significant at acceptable levels.

It appears therefore that desired stocks are basically driven by a simple accelerator model ($\lambda\alpha_1 > 0$) and that market conditions [as reflected by (RPLME - RPEMJ)] may affect the partial adjustment of actual to desired inventory levels ($\lambda_1 > 0$). Actual strikes and costs of holding inventories have no reasonable effect upon the partial adjustment process. Speculative price and strike expectations do not affect desired inventory levels.

- Fabricators and Semi-Fabricators Inventories of Scrap and Refined Copper

Three equations are presented for the inventory behavior of the fabricators and semi-fabricators. Although the motives for holding inventories can differ for a consuming and producing group, it is again felt that Equation 4b is an adequate general behavioral representation for the fabricators' demand for scrap and refined copper (i.e., material input inventories). Initial tests indicated that one could not reject the hypothesis that the constant term and the coefficient of (RPLME - RPEMJ) were zero. Hence, the first equation listed, Equation Ci) does not include those terms. Thus, while the market condition proxy had a strong effect upon the inventory behavior of the primary refiners (leading to inventory behavior to defend the group price), it has little effect upon fabricators' inventory behavior. This is further indication that inventory policy is a more active price maintenance tool of the oligopolistic primary producers, as hypothesized. While some of the fabricators (about 1/3 by production capacity) are extensions of the vertically-integrated primary producers, there exist many other independent fabricators and semi-fabricators. In light of the non-oligopolistic character of the fabricators/semi-fabricators and their lack of desire to defend RPEMJ, it is not surprising that inventory behavior is not affected by (RPLME - RPEMJ).[1]

The signs of the coefficients in Equation Ci) are as expected, except for $\hat{\lambda}_3$. However, only $\hat{\lambda\alpha}_1$ and $(1-\hat{\lambda})$ are significant at the 99% level. In fact, a Fisher-Chow test indicates that one cannot reject $H_0: \lambda\alpha_2 = \lambda\alpha_3 = \lambda_1$ $\lambda_3 = \lambda\alpha_0 = 0$, at any reasonable level. Equation Ciii) embodies this conclusion, relating IF to production (QFAB), actual strikes and lagged inventory

---

[1] Although their inventories could have been drawn down in the face of the general excess demand proxied by (RPLME - RPEMJ); apparently, they weren't.

levels. Thus, little discretionary activity is reflected in the fabricators/ semi-fabricators inventory behavior: an accelerator formulation is successful in explaining desired inventory levels and actual strike activity is almost successful (almost at the 90% level) in helping explain the difference between actual and desired inventory changes.

3. CONCLUSION - INTERPRETATION OF RESULTS

The conclusions of this paper are easily summarized in Table 2; the hypotheses that, first, a desired inventory/sales ratio characterize most producers and second, that differential inventory behavior exists in competitive and non-competitive market settings have been supported. A model of inventory behavior permitting a fairly rich examination of potential motives for holding inventories has been specified and estimated for an oligopolistic group of refined copper producers and for two competitive groups of copper producers. The results suggest that oligopolistic inventory behavior is substantially more complicated and sophisticated than that of competitive producers. The parameter estimates for the oligopolistic group are uniformly more significant and the residual variance of the estimated equations is uniformly less.

Estimates for the competitive groups indicate that <u>only</u> a transactions motive is a statistically significant (at usual levels) explanatory factor for desired inventory. Using estimates of $\lambda\alpha_1$ and λ in equations Bi) and Ciii), the estimate of α_1 can be easily obtained.[1] α_1 is the estimate the desired inventory/production ratio for the competitive groups. For the secondary refiners we have $\hat{\alpha}_1$ = .22 and for the fabricators/semi-fabricators we have $\hat{\alpha}_1$ = .069.

For the oligopolistic primary producers, a much wider range of inventory motives and uses are evidenced. Using somewhat relaxed statistical significance criteria (at the 80-90% level) the results suggest transactions motives ($\lambda\alpha_1$); strike ($\lambda\alpha_2$) and price ($\lambda\alpha_3$) expectational motives; and price stabilization motives in response to short-run market conditions (λ_1)

---

[1] Given the necessary assumptions to make $\hat{\lambda\alpha_1}$ and $\hat{\lambda}$ maximum likelihood estimates.

explain primary producer inventory behavior. Applying the usual significance criteria in Aiii) and Av), we find that the primary producers have a desired inventory/production ratio (.079 in Aiii) and .073 in Av)). However, in Av) the primary producers hold inventories for expected capital gains ($\hat{\alpha}_3$ = 2.60) and they lower inventory holdings (from average) in the face of short-run market price disequilibrium given their group price ($\hat{\lambda}_1$ = -3.2435). Thus, using the estimates in Av), if price expectations suggested a 5¢ rise in the copper prices in t+1 (i.e., RPFUT1 - RPEMJ were expected to rise by 5¢), the change in primary producer inventory levels in t ($IRR_t - IRR_{t-1}$) would be increased 13000 short tons. If at the same time, short-run market disequilibria increased excess demand, given the fixed primary producers price (e.g., RPLME - RPEMJ = 5¢), the primary producers would draw down inventories 16,220 short-tons to help meet that excess demand while maintaining their fixed price. Finally in 4 of the 5 equations in A) the hypothesis that $\lambda = 1$ cannot be rejected. This suggests that not only do the primary producers have a wider range of factors affecting their inventory behavior but also that they react quickly to adjust actual inventory to desired levels.

TABLE 2: SUMMARY OF DIFFERENTIAL INVENTORY BEHAVIOR

Producer Group	Transactions Motives: Desired Inventory/ Production Ratio	Other motives, suggested to be statistically significant*	Speed of adjustment of actual inventory levels to desired levels**
Oligopolistic Primary Producers	Yes, statistically significant*	Oligopolistic Price maintainance (Ai-Av) Price Expectations (Aiv-Av) Strike Expectations (Aii)	Immediate
Competitive Secondary Refiners	Yes, statistically significant	None	Immediate
Competitive Fabricators/semi-fabricators	Yes, statistically significant	None	Lagged

* At the 95% level

** H_0: $(1 - \hat{\lambda}) = 0$ cannot be rejected; hence H_0: $\hat{\lambda} = 1$ cannot be rejected

APPENDIX A

VARIABLE[1] DEFINITIONS AND THEIR SOURCES

1. ACCEP — Annual average, 90-day bankers' acceptances. Source: Federal Reserve Board of Governors, Federal Resource Bulletin.

2. DSTE2 — Dummy variable indicating whether a strike is expected next year and how many months it is expected to last. For example, if a 2-1/2 month strike is expected to affect between 75-100% of production next year, DSTE2 = 2.5. DSTE2 = 0 if no strike is expected. (DSTE2(t) = DUMST2(t+1)).

3. DUMST2 — Dummy variable for strikes affecting the smelting and refining stages of copper production. Dummy estimates number of months a major strike affected more than 75% of the production workers in the industry; 0.0 when no strike. Source: Interviews with Asarco, Phelps Dodge, Kennecott and Anaconda.

4. IF — Fabricators stocks of copper, both scrap and refined (IF = IFS + IFR). $\Delta IF = IF(t) - IF(t-1)$.

5. IFR — Refined copper stocks held by wire mills, brass mills and other fabricators and semi-fabricators, end of year. Source: CDA, Table 1, Item 16.

6. IFS — Scrap stocks held by brass mills, foundries and other fabricators and semi-fabricators, end of year. Source: CDA, Table 2, Item 3.

7. IRR — Refined copper stocks held at refineries, end of year. Source: CDA, Table 1, Item 16. $\Delta IRR = IRR(t) - IRR(t-1)$.

8. IRRAV — Stocks of refined copper in the United States at refinery on consignment at the end of each month. Figures include refined copper in United States regardless of origin. ABMS figures in Metal Statistics.

---

[1] All quantity series in 1,000 short tons. Variables in alphabetical order.

9. IRS — Scrap stocks held by smelters and refineries, end of year. Source: CDA, Table 2, Item 3. ΔIRS = IRS(t) - IRS(t-1).

10. PEMJ — Metals Week (formerly E&MJ Metal and Mining Markets) average domestic refinery price of electrolytic copper wire bars and ingot bars, FOB refinery; also tabulated in the Yearbook of the American Bureau of Metal Statistics (ABMS) as monthly average prices of copper, domestic refinery--New York--¢/lb.

11. PFUT1 — Simple average of Closing Future Price (¢/lb) of copper for all of the next 12 months reported starting in January of the year. Source: Wall Street Journal.

12. PFUT7 — Simple average of Closing Future Prices (¢/lb) of copper for all of the next 12 months reported starting in July of year. Source: Wall Street Journal.

13. PLME — The London Metals Exchange Price of Copper: electrolytic, delivered for 1946 to 1953; electrolytic wire bars monthly average settlement price for 1953 to 1974. Asked quotation for spot is converted to ¢/lb by the annual average exchange rate for sterling. Both series found in ABMS Yearbook--"Average Prices of Principal Metals," (p. 147 in the 1973 Yearbook).

14. PPR — Producers' prices of electrolytic copper delivered United States destinations. Averaged from quotations published daily in American Metal Market, in ¢/lb. Source: Metal Statistics.

15. PS — From 1956 on, dealers' buying price for No. 2 heavy copper scrap; before 1956, dealers' buying price for No. 1 heavy copper scrap. ¢/lb--Metal Statistics.

16. PUWD — Wholesale price index of durable manufacturing, 1967 = 100. Source: Bureau of Labor Statistics (BLS).

17. PUWD74 — Wholesale price index of durable manufacturing, 1974 = 100. Source: BLS.

18. QFAB — Supply of mill, foundry and power products to domestic market - total. Source: CDA, Table 4.

19. QPR Total production of refined copper from Primary Sources. Source: Copper Development Association (CDA), Table 1, Item 13. Series is adjusted to include refined copper produced from scrap and sold at the primary producers' price and to exclude copper produced from ore yet sold in the secondary market.

20. QSR Production of refined copper in the United States produced from scrap. Source: CDA, Table 1, Item 13. Series is adjusted to include copper produced from ore and sold in the outside market and to exclude copper produced from scrap and sold at the primary producers' price.

21. RPEMJ Deflated PEMJ. Deflator is alternatively PUWD or PUWD74.

22. RPFUT1 PFUT1 deflated by PUWD or PUWD74.

23. RPFUT7 PFUT7 deflated by PUWD or PUWD74.

24. RPLME Deflated LME price of copper (PLME deflated by PUWD or PUWD74) in ¢/lb.

25. RPS The real price of scrap, PS, deflated by PUWD or PUWD74.

References

1) Abramovitz, M., Inventories and Business Cycles (New York; National Bureau of Economic Research, 1950).

2) Arthur D. Little, Inc., Economic Impact of Environmental Regulations on the United States Copper Industry, (Cambridge, January, 1978).

3) Charles River Associates, Economic Analysis of the Copper Industry, (Cambridge; March, 1970).

4) Clark, J.M., "Business Acceleration and the Law of Demand: A Technical Factor in Economic Cycles," Journal of Political Economy 25 (1947), pp. 217-235.

5) Copper Development Association, Inc., Annual Data, selected years.

6) Goodwin, R., "Secular and Cyclical Aspects of the Multiplier and Accelerator" in Income, Employment and Public Policy: Essays in Honor of Alvin H. Hansen. (New York; W. W. Norton & Co., 1948).

7) Hansen, A., Fiscal Policy and Business Cycles, (New York, 1941).

8) Hartman, R. S., "An Oligopolistic Pricing Model of the U.S. Copper Industry," unpublished Ph.D. dissertation, Massachusetts Institute of Technology, (Feb. 1977).

9) Hartman, R.S., "A Probability Model of Oligopoly Pricing," MIT Energy Laboratory Working Paper # MIT-EL 77-037WP, October, 1977.

10) Hartman, R.S., Bozdogan, K., and Nadkarni, R., "An Analysis of the Economic Impacts of Alternative Pollution Abatement Legislation in the U.S. Copper Industry," mimeo, 1978.

11) Hirsh, A. and Lovell, M., Sales Anticipations and Inventory Behavior (New York; Wiley and Sons, 1969).

12) Kaplan, A.D.H., Dirlam, J.B., Lanzilotti, R.F., Pricing in Big Business (Washington; Brookings, 1958).

13) Labys, W., Dynamic Commodity Models: Specification, Estimation and Simulation.

14) Lovell, M., "Manufacturers' Inventories, Sales Expectations and the Acceleration Principle," Econometrica 29 (1961), pp. 293-314.

15) Lundberg, E., Studies in the Theory of Economic Expansion, (London; P.S. King & Sons, 1937).

16) Metzler, L., "Factors Governing the Length of Inventory Cycles", Review of Economics and Statistics 29 (February, 1947).

17) Metzler, L., "The Nature and Stability of Inventory Cycles," The Review of Economic Statistics, 23, (Aug. 1941).

18) Mills, E.S., Price Output and Inventory Policy, (New York; Wiley and Sons, 1962).

19) O Hanlon, T., "The Perilous Prosperity of Anaconda", Future (May, 1966) pp. 121 and 235.

20) Peck, M.J., Competition in the Aluminum Industry, (Cambridge, Harvard University Press, 1961).

21) Scherer, F.M., Industrial Market Structure and Economic Performance (Chicago; Rand McNally, 1970).