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THE EFFECT OF EXTERNAL ACCOUNTING ALTERNATIVES UPON MANAGEMENTS' INVESTMENT DECISIONS

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Accounting standards establish to a great extent the form and content of the financial reports that business managers distribute to external information users. There has been a growing concern that accounting standards for external reporting purposes might influence not only the behavior of external information users, but also the behavior of the business managers who communicate the external information (e.g., [Prakash and Rappaport, 1975 and 1977; Rappaport, 1977). With few exceptions (e.g., [Bruns, 1965]), there has been no empirical work directed toward answering the question: is the decision-making process of business management influenced by the information they communicate to external users? The present study is an attempt to fill this void.

The first section of the paper gives our reasons for selecting the external reporting of the investment tax credit/internal investment decision interface as the specific subject matter of this study. The first section also sets forth the primary null hypothesis of the study. The subsequent two sections describe the sample selection procedure, data collection mechanics and the statistical methodology utilized. The last two sections present the empirical results of the study and a summary.

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THE SPECIFIC QUESTION STUDIED

The first step in this study was to narrow the broad issue of the possible existence of an interface between external reporting and internal decisions to manageable proportions by selecting a specific item of information that managements communicate to external users. The criteria used to select this specific item of information included the availability of alternative external reporting methods and a potential link of the reporting alternative chosen by management to an internal management decision. Although many choices were considered for examination, the investment tax credit (ITC) emerged as a leading candidate. Alternative reporting methods for the ITC were clearly allowed: immediate flow-through of the credit to income or deferral of the tax savings, with periodic write-off. The second attribute, a potential link of the reporting alternative chosen to an internal decision, was also present. In fact, some have asserted the obvious existence of such a link. Possibly the most forceful sentiment of this nature was expressed by an Assistant Treasury Secretary [Walker, 1971]:

> The Treasury Department's overriding interest in seeking the credit is to create jobs both in the short and the long run by simulating purchase of new machinery and equipment...
>
> The vast majority of the companies have followed the former alternative...reflecting the benefit of the credit immediately in earnings. <u>It seems self-evident that... businessmen will have less motivation to purchase new equipment if the benefits of the credit are not reflected in operating results when realized</u>. (emphasis added)

To test for the existence of an external reporting/internal decision-making interface, the following study hypothesis was formulated: the ITC accounting method adopted by major companies in various industries did not affect those companies' acquisitions of plant and equipment. As demonstrated later, this hypothesis could not be rejected at the .05 level of significance. Accordingly, the results of this study are consistent with accepted cash flow theories of asset acquisition [Fama and Miller, 1972] and with the market association research which supports the hypothesis that investors are not influenced by managements' selection of different reporting methods [Gonedes and Dopuch, 1974].

Management was portrayed differently to the Congress in 1971. It was argued that a "self-evident" decrease in plant and equipment investment would result from required deferral accounting [Walker, 1971]. Congress accepted the assertion that the ITC accounting method would impact upon plant and equipment investment decisions without supportive empirical evidence. The 1971 Revenue Act included a provision stating that [Public Law 92-178, 1971, p. 547]:

> It was the intent of Congress in enacting, in the Revenue Act of 1962, the investment credit allowed by Section 38 of the Internal Revenue Code of 1954, and it is the intent of the Congress in restoring that credit in this Act, to provide an incentive for modernization and growth of private industry. Accordingly, notwithstanding any other provision of law,...
>
> (A) <u>No taxpayer shall be required to use, for purposes of financial reports subject to the jurisdiction of any Federal agency or reports made to any Federal agency, any particular method of accounting for the credit.</u> (emphasis added)

Although the Accounting Principles Board was opposed to Congressional involvement, it offered no empirical evidence to support its position. As indicated by the results of this study, an empirically supported argument can be made to advance the notion that Congress may not know what is best when it evaluates accounting standards.

SAMPLE SELECTION

The study sample consisted of two types of firms: those which have consistently utilized the flow-through method of accounting and those the deferred. This split-sample design was chosen so that tests could be performed to determine if the two types of firms differed in their plant and equipment investment behavior.

The firms comprising each sample subgroup were selected from a cross-section of industries. The largest eligible firm (of each accounting type) from each industry was selected for analysis. The size criterion was quarterly sales and Business Week [1974] was used as the source of this data. Eligibility was determined in light of: sufficient published data for the entire sample period and utilization of the same accounting method throughout the period. The two largest eligible firms of each accounting type were chosen from the automotive industry. The reason for inclusion of two firms was the degree of influence of firms in this industry on the macroeconomic investment structure.

The sample of firms chosen for this study is shown in Table 1.

Table 1

SAMPLE FIRMS

Industries	Flow-Through Firms	Deferred Firms
Aerospace	Northrop	Boeing
Automotive	International Harvester & TRW	Ford & General Motors
Chemical	Dow	Dupont
Electrical, Electronics	Westinghouse	General Electric
Food Processing	Kraft	Beatrice Foods
General Machinery	Babcock & Wilson	Combustion Engineering
Retailing (Food)	Safeway	Great Atlantic & Pacific Tea Company

METHODOLOGY AND DATA COLLECTION

The initial methodological step was to construct an appropriate model to explain managements' plant and equipment investment decisions. A review of the economic literature indicated wide acceptance of the basic flexible accelerator theory [Chenery, 1952; Koyck, 1954; Jorgenson and Siebert, 1968, a & b; Elliott, 1973]. This theory depicts net investment in plant and equipment as a function of changes in present and prior levels of desired capital (plant and equipment). The models springing from this theory are in the form of a distributed lag function:

$$
\begin{aligned}
N_t &= I_t - \delta K_t \\
&= u_0(K_t^* - K_{t-1}^*) + u_1(K_{t-1}^* - K_{t-2}^*) + u_2(K_{t-2}^* - K_{t-3}^*) + \ldots
\end{aligned} \tag{1}
$$

where, N_t = net (or expansion) investment in plant and equipment during period t,

I_t = gross investment during period t,

K_t = capital stock at the start of period t,

δ = constant of proportionality between replacement investment and beginning of period capital stock

u_1 = coefficients of the distributed lag function, and

K_t^* = level of desired capital at the start of period t.

As equation 1 is written, estimation of the unknown u_0, u_1,... sequence is not feasible because this parameter sequence is infinite in number, whereas the set of data observations is finite. To make it possible to estimate the parameters of the investment model via ordinary least-squares regression techniques, the condition was imposed that the function which is generating the u_0, u_1,... sequence is rational [Jorgenson, 1966]. By definition, if the generating function of the u_0, u_1,... sequence is rational, equation 1 may be written as,

$$
I_t - \delta K_t = [U(L)](K_t^* - K_{t-1}^*) = \left[\frac{Y(L)}{W(L)}\right](K_t^* - K_{t-1}^*) \tag{2}
$$

where, $[U(L)](K^*_t - K^*_{t-1}) = (u_0 + u_1 L + u_2 L^2 + \ldots)(K^*_t - K^*_{t-1})$

$$= u_0(K^*_t - K^*_{t-1}) + u_1(K^*_{t-1} - K^*_{t-2}) + u_2(K^*_{t-2} - K^*_{t-3}) + \ldots,$$

$$Y(L) = y_0 + y_1 L + y_2 L^2 + \ldots + y_n L^n,$$

$$W(L) = w_0 + w_1 L + w_2 L^2 + \ldots + w_m L^m, \text{ and}$$

$$L = \text{the lag operator.}$$

By normalizing the coefficient w_0 at unity and by multiplying both sides of equation 2 by W(L), the following rational distributed lag investment function results:

$$[W(L)](I_t - \delta K_t) = [Y(L)](K^*_t - K^*_{t-1})$$

or,

$$I_t = y_0(K^*_t - K^*_{t-1}) + y_1(K^*_{t-1} - K^*_{t-2}) + \ldots + y_n(K^*_{t-n} - K^*_{t-n-1}) - w_1(I_{t-1} - \delta K_{t-1}) - w_2(I_{t-2} - \delta K_{t-2}) - \ldots - w_m(I_{t-m} - \delta K_{t-m}) + \delta K_t \qquad (3)$$

where the y_i's represent the coefficients of the change in desired capital variables and the w_i's denote the coefficients of the net investment terms.

Empirical studies have been conducted by Jorgenson and Siebert (J&S) [1968, a & b] in an effort to determine the optimal proxy for the unmeasurable desired capital terms. Among the proxy measurements tested by J&S were,

$$\text{Output measurement of } K_t^* = \alpha Q_t$$

and, (4)

$$\text{Neoclassical measurement of } K_t^* = \alpha\left(\frac{P_t Q_t}{C_t}\right)$$

where α represents the coefficient that equates desired capital (K_t^*) with the proxy measurement, Q_t is total production in constant dollars and $P_t Q_t / C_t$ is defined as output in current dollars, divided by the cost of capital services. J&S [1968a] concluded that the neoclassical measurement of desired capital performed the best of the alternatives. The criteria for comparison included minimum regression standard error, accuracy in prediction of "peaks" and "valleys" of investment expenditures and number of desired capital terms which entered the regression models.

The J&S conclusion was challenged by Elliott [1973] who replicated the study using a different sample. His results indicated that, among other things, the output and neoclassical measurements were "virtually indistinguishable."

This study utilizes the output measurement of desired capital. Elliott's study suggests that either the output or the neoclassical measurement of desired capital would be appropriate; but since the cost of capital services (C_t) component of the neoclassical measurement contains the ITC, the output measurement was chosen for this study. The output measurement contains no cost of capital services term and therefore makes it easier to isolate the impact that different ITC accounting methods might have upon investment in plant and equipment.

Upon substitution of the proxy output measurement in period t (αQ_t) for desired capital in period t (K_t^*), equation 3 appears as follows:

$$I_t = \alpha y_0(Q_t - Q_{t-1}) + \alpha y_1(Q_{t-1} - Q_{t-2}) + \ldots + \alpha y_n(Q_{t-n} - Q_{t-n-1})$$
$$- w_1(I_{t-1} - \delta K_{t-1}) - w_2(I_{t-2} - \delta K_{t-2}) - \ldots - w_m(I_{t-m} - \delta K_{t-m}) \quad (5)$$
$$+ \delta K_t$$

where the terms are as defined at equations 1, 3 and 4.

Data Collection

Data for the fitting of the investment model set forth in equation 5 were obtained for each of the sixteen sample firms for the fifteen years beginning in 1959 and ending in 1973. The data gathered for each variable, unless otherwise stated, coincides in all material respects as to definition and measurement with those utilized by J&S [1968, a & b].

The variable I_t was defined as gross investment in plant and equipment, expressed in constant dollars. Investment in current dollars is presented in Moody's under "additions at cost." This figure was deflated by the investment goods price index defined as the wholesale price index applicable to machinery and equipment. This index is published in the Survey of Current Business.

Output in current dollars (P_tQ_t) was defined as recorded cost of goods sold plus (or minus) the change in inventory levels.[1] Moody's was the source for this information. This measure was deflated by the wholesale price index applicable to the firm's industry group (P_t) to derive Q_t (output in constant dollars) for use as the output measurement of desired capital. The index P_t is published in Wholesale Prices and Price Indexes.

To calculate the lagged replacement investment ($\delta K_{t-\ell}$) terms in constant dollars, the following relationship, which was assumed by Jorgenson and Stephenson [1967], was also utilized here,

$$K_{t-\ell+1} = I_{t-\ell} + (1 - \delta)K_{t-\ell}$$

or (6)

$$\delta K_{t-\ell} = I_{t-\ell} + K_{t-\ell} - K_{t-\ell+1}$$

The procedure used to obtain $K_{t-\ell}$ values for the fifteen years included in this study consisted of several steps. First, capital stock (net plant and equipment) at the beginning of 1959 was obtained from Moody's. Then, to restate the 1959 capital stock values in constant dollars, the historical cost numbers obtained in step one were deflated by the investment goods price index. The index used in this step was the index applicable to the year that preceded 1959 by life/2 years. This procedure assumes that firms purchase plant and equipment uniformly throughout the life cycle of aggregate plant and equipment and that the plant and equipment existing at the start of 1959 was half-way through its life cycle. Life was estimated via a cost/depreciation expense comparison. Step three was to calculate net capital stock at the start of 1974 in constant dollars. This was accomplished in a fashion that paralleled the procedure used to obtain the 1959 capital stock numbers. Then, to obtain capital stock values for each of the fifteen years included in this study, the difference between the beginning (1959) and ending (1974) capital stock values were interpolated by gross investment, in constant dollars. This approach appears algebraically as follows:

$$K_t = K_{1959} + \frac{\sum_{j=1}^{t} I_j}{\sum_{i=1}^{15} I_i}(K_{1974} - K_{1959}) \qquad (7)$$

Finally, the capital stock terms obtained via equation 7 were substituted into equation 6 to obtain measurements of the lagged replacement investment terms ($\delta K_{t-\ell}$).

Parameter Estimation

The covariance regression method was used in this study to estimate the coefficients of equation 5. Covariance regression is based on time series-cross section data and in this study it differs from ordinary regression analysis in that it isolates the specific investment characteristics of each of the sixteen firms and each of the time periods in addition to the explanatory variables enumerated in equation 5. The following specific equation was fitted to the sixteen-firm cross sectional data for fifteen years:

$$
\begin{aligned}
I_{jt} = {} & a_0 + a_1(Q_{jt} - Q_{jt-1}) + a_2(Q_{jt-1} - Q_{jt-2}) + \dots \\
& + a_{n+1}(Q_{jt-n} - Q_{jt-n-1}) - a_{n+2}(I_{jt-1} - \delta_j K_{jt-1}) \\
& - a_{n+3}(I_{jt-2} - \delta_j K_{jt-2}) - \dots - a_{n+m+1}(I_{jt-m} - \delta_j K_{jt-m}) \\
& + a_{n+m+2} K_{jt} + b_j + c_t + \varepsilon_{jt}
\end{aligned} \tag{8}
$$

where ε_{jt} is the regression residual, a_0 denotes an intercept and the remaining a_i's represent regression estimates of the coefficients of equation 5. In equation 8, the amount of gross investment for the j^{th} firm during period t (I_{jt}) depends not only on the values of the independent variables from equation 5, but also on a variable b_j, which is peculiar to firm j and on a variable c_t, which is specific to the t^{th} period. Equation 8 is structured to account not only for the effects that postulated explanatory variables have on investment, but also for the effects of variables that have been left out of the relation postulated in equation 5. The effect of non-postulated variables (b_j and c_t) on investment may vary between firms and between years. For any year t, c_t is the same for all 16 firms, but the b_j's differ among firms. Likewise, for any one firm j, b_j has the same value for all years, but the c_t's differ between years.

When fitting the data to equation 8, the average firm effect ($\bar{b}_j$) and the average year effect ($\bar{c}_t$) were constrained to have values of zero. This step means that, for the average year and for the average firm, equation 5 is assumed to be fully specified, but that gross investment can differ from this average specification for each firm and for each year. Therefore, the estimates of the b_j's that were obtained should be interpreted in relative terms. This characteristic of the unique firm effects (b_j's) on investment is important to this study because it permits a direct comparison of the b_j's for the two sub-samples of firms (flow-through firms and deferred firms) to test if one sub-sample of firms systematically differs in its unique investment behavior from the other sub-sample. As is pointed out more explicitly later in the results section, care must be exercised when interpreting systematic differences between sub-samples because a great many causes can be affecting the b_j's.

The constraining of the average b_j's and c_t's to zero values also aids in the estimation of the a_i regression coefficients of equation 8. By transforming the postulated variables [the $(Q_{jt-\ell} - Q_{jt-\ell-1})$'s, $(I_{jt-\ell} - \delta_j K_{jt-\ell-1})$'s, and the K_{jt}'s] into deviations from the variables' average values for each firm over all periods and from the variables' average values for each period over all firms, and adding the variables' grand means, we get a pure regression of investment on the variables that were postulated in equation 5.

That is, equation 8 becomes,

$$
\begin{aligned}
I'_{jt} = {} & a_1(Q_{jt} - Q_{jt-1})' + a_2(Q_{jt-1} - Q_{jt-2})' + \ldots \\
& + a_{n+1}(Q_{jt-n} - Q_{jt-n-1})' - a_{n+2}(I_{jt-1} - \delta_j K_{jt-1})' \\
& - a_{n+3}(I_{jt-2} - \delta_j K_{jt-2})' - \ldots - a_{n+m+1}(I_{jt-m} - \delta_j K_{jt-m})' \\
& + a_{n+m+2}K'_{jt} + \varepsilon_{jt}
\end{aligned}
\tag{9}
$$

where the prime sign (') indicates that the variables are transformed into deviations.[2]

EMPIRICAL RESULTS

The forward stepwise regression procedure (with a .05 inclusion/exclusion level) was used to obtain estimates of the a_i coefficients of equation 9 and to determine the appropriate number of lagged periods to include in the regression up to a predetermined maximum. The results of the regression are shown in Table 2.

Table 2

REGRESSION RESULTS

Variables	Estimated Coefficients (a_i's)	Standard Errors	t Values	Significance Levels
$(Q_t - Q_{t-1})'$	-.023	.009	-2.7	.0083
$(Q_{t-1} - Q_{t-2})'$	.075	.012	6.5	.0000
$(Q_{t-2} - Q_{t-3})'$	.080	.013	6.3	.0000
$(Q_{t-3} - Q_{t-4})'$	.063	.015	4.1	.0001
$(I_{t-1} - \delta K_{t-1})'$	2.661	.404	6.6	.0000
$(I_{t-2} - \delta K_{t-2})'$	-1.566	.409	-3.8	.0002
K'_t	.135	.033	4.0	.0001

Summary Statistics

Number of observations = 176

Standard error of the regression = 59.5 (in millions of dollars)

Coefficient of multiple determination (R^2) = .52

$\bar{R}^2 = R^2$ corrected for degrees of freedom = .50

The estimated coefficients (a_i) from Table 2 were used to calculate the 16 unique firm effects (b_j's) on gross investment. The computation for this purpose is described in footnote 2. Table 3 shows the 16 b_j's together with their ranks in terms of algebraic size. Recall

Table 3

UNIQUE FIRM EFFECTS ON GROSS INVESTMENT
(millions of dollars)

	Firm Effect Values (b_j's)			
	Flow-Through Firms		Deferred Firms	
Industries and firms	b_j's	Ranks	b_j's	Ranks
Aerospace:				
Northrop	-48.43	9		
Boeing			-23.80	11
Automotive:				
International Harvester	-58.28	7		
TRW	-72.38	3		
Ford			+37.49	15
General Motors			+740.39	16
Chemical:				
Dow	-54.55	8		
Dupont			-17.62	14
Electrical, Electronics:				
Westinghouse	-143.15	1		
General Electric			-25.36	10
Food Processing:				
Kraft	-71.99	4		
Beatrice Foods			-84.33	2
General machinery:				
Babcock & Wilson	-66.41	5		
Combustion engineering			-66.35	6
Retailing (Food):				
Safeway	-23.68	12		
Great Atlantic & Pacific Tea Co.			-21.55	13
Totals	-538.87		+538.87	

that each individual b_j represents the amount by which the particular firm's unique gross investment (that portion of the firm's non-random investment which remains unexplained after accounting for the effects of specific causal variables and for the effect of time) differs from the average unique gross investment of all 16 firms (assumed to be zero). Because the b_j's represent deviations from a mean value, the sum of the 16 b_j's equals zero.

The sign test was applied to the b_j's displayed in Table 3 to test this study's primary hypothesis that the method of accounting for the ITC does not affect managements' investment decisions. In statistical terms, the null and alternative hypotheses for the sign test can be stated as,

$$\begin{aligned} H_0&: \; P(b_j|FT > b_j|D) = P(b_j|FT < b_j|D) = 1/2 \\ H_A&: \; P(b_j|FT > b_j|D) \neq P(b_j|FT < b_j|D) \end{aligned} \tag{10}$$

where P denotes the probability of occurrence under the null hypothesis, FT signifies flow-through firms and D represents deferred firms.

The sign test was chosen in favor of alternatives because its results are not influenced by magnitudes. Any test that utilizes information about the size of the b_j's, as well as the direction of differences between b_j's within pairs, would yield results that were dominated by General Motors. The sign test utilizes only the direction (+ or -) of the differences between b_j values of matched firms.

Upon the application of the sign test, it was found that one of the eight pairs of firms (food processing) yielded a positive difference for the expression,

$$b_j|\text{flow-through} - b_j|\text{deferred} \tag{11}$$

If the null hypothesis were true, the probability of obtaining one positive difference is .07. Accordingly, the null hypothesis cannot be rejected at the .05 level of significance. In words, this means that, on the basis of the data gathered for this study, it cannot be said that the method of accounting for the investment tax credit (ITC) affected managements' internal investment decisions.

Since the alternative hypothesis (see equation 10) made no mention of which sign, positive or negative, would occur more frequently, the sign test that was performed was a two-tailed test. Had an advance prediction of the sign of unique investment effects (b_j's) been made, a one-tailed test of the null hypothesis from equation 10 would have been called for, and the alternative hypothesis would be either,

$$H_{A1}: \ P(b_j|FT > b_j|D) > 1/2$$

or (12)

$$H_{A2}: \ P(b_j|D > b_j|FT) > 1/2$$

where the terms are as defined at equation 10.

It is interesting to note that the application of a one-tailed sign test results in the rejection of the null hypothesis at the .05 level of significance and the acceptance of alternative hypothesis H_{A2} from equation 12. In words, this means that when the differential direction (flow-through versus deferred) of unique firm investment effects is taken into account, the data show that firms which utilize the deferred method to account for their investment tax credits invest more in plant and equipment than do their counterpart firms which use the flow-through method of accounting.

What the findings of the one-tailed test suggest from an accounting policy point of view is that the U.S. Congress may have acted, in 1971, under a false premise when it precluded the Accounting Principles Board from establishing an accounting standard for the ITC. The proponents of the 1971 Congressional action argue that because the deferred method of accounting for the ITC yields a smaller reported net income than the flow-through method in the year of investment, the deferred method is likely to dampen the investment stimulus produced by the ITC. If this argument were true, however, the predicted outcome of this study would have been that equation 11 would yield predominantly positive results. That is, the 1971 Congressional action was based upon the premise that H_{A1} from equation 12, and not H_{A2}, is the accepted hypothesis. The data utilized in this study, however, yield contrary results.

As pointed out earlier, the unique firm investment effects (b_j's) can be a function of a multitude of variables in addition to the method used to account for the ITC. A consequence of this fact is that the result obtained via the one-tailed sign test does not necessarily imply that the method used to account for the ITC caused flow-through firms to invest less than their matched deferred firms. It could be that some unknown variable is causing both the differences in the b_j's and in the methods used by firms to account for their ITC's. With this possibility in mind, a Spearman rank correlation test was performed to determine if the magnitude of investment in plant and equipment by the sixteen sample firms might be influencing the size of the respective firm's b_j. The result of this test was that we can be 98.5% confident that the average yearly investment in plant and equipment by each of the sixteen firms is positively correlated with the respective firm's unique investment effect (b_j).

Although there is strong evidence to indicate that size is a determinant of the b_j's, a further sign test indicated that firm size was not influencing the outcome of the conclusions drawn in this study. A one-tailed sign test of,

$$\begin{aligned} &H_0\text{:}\quad P(AI|FT > AI|D) = P(AI|FT < AI|D) = 1/2 \\ &H_A\text{:}\quad P(AI|D > AI|FT) > 1/2 \end{aligned} \tag{13}$$

where AI denotes average yearly investment, showed that the null hypothesis could not be rejected at any reasonable level of significance (significance level obtained was .363). Therefore, we can be quite confident that the sample selection process used in this study did not bias the sample of deferred firms with relatively large firms, as compared to their flow-through counterpart firms.

SUMMARY

This paper empirically examined the external reporting/internal decision-making interface. The reporting issue selected for analysis was accounting for the investment tax credit (ITC). Underscoring the significance of this study was the Congressional acceptance, in 1971, of the assertion that internal management actions were contingent upon externally reported numbers in the ITC situation.

The specific null hypothesis tested was that the ITC accounting method adopted by major companies in various industries did not affect those companies' acquisitions of plant and equipment. A split sample of firms representing each of the two generally accepted methods of accounting for the ITC (flow-through and deferred) was selected. The covariance regression method was used to isolate unique firm effects. A sign test applied to these unique effects resulted in the conclusion that the null hypothesis could not be rejected at the .05 level of significance.

FOOTNOTES

[1]The model as developed by J&S defined P_tQ_t as sales + or - the change in inventory. This definition compared a component (sales) containing a profit element with one valued at cost (inventory). To remove this measurement inconsistency, the P_tQ_t term was redefined as cost of goods sold + or - the change in inventory.

[2]In general terms, the covariance regression to be derived is,

$$x_{1jt} = a_1 + a_2x_{2jt} + \dots + a_nx_{njt} + b_j + c_t \tag{i}$$

where, x_1 = dependent variable

$x_2, \dots, x_n$ = independent variables

b_j = correlate of firm j

c_t = time intercept of year t.

We constrain the average firm effect $\bar{b}_j$ and the average year effect $\bar{c}_t$ to have zero values.

The regression equation for firm j at the average value of its variables over all the years will be,

$$\bar{x}_{1j} = a_1 + a_2\bar{x}_{2j} + \dots + a_n\bar{x}_{nj} + b_j + \bar{c}_t, \ (\bar{c}_t = 0) \tag{ii}$$

Subtracting (ii) from (i) we get,

$$x_{1jt} - \bar{x}_{1j} = a_2(x_{2jt} - \bar{x}_{2j}) + \dots + a_n(x_{njt} - \bar{x}_{nj}) + c_t \tag{iii}$$

Similarly, the regression equation for year t at the average value of the variables over all the firms will be,

$$\bar{x}_{1t} = a_1 + a_2\bar{x}_{2t} + \dots + a_n\bar{x}_{nt} + \bar{b}_j + c_t, \ (\bar{b}_j = 0) \tag{iv}$$

Subtracting (iv) from (i) we get,

$$x_{1jt} - \bar{x}_{1t} = a_2(x_{2jt} - \bar{x}_{2t}) + \dots + a_n(x_{njt} - \bar{x}_{nt}) + b_j \tag{v}$$

Finally, the regression equation for the average value of the variables over all firms and all years will be,

$$\bar{\bar{x}}_1 = a_1 + a_2\bar{\bar{x}}_2 + \ldots + a_n\bar{\bar{x}}_n + \bar{b}_j + \bar{c}_t, \ (\bar{b}_j = 0; \ \bar{c}_t = 0) \tag{vi}$$

Subtracting equations (ii) and (iv) from (i) and adding (vi) yields,

$$\begin{aligned}(x_{1jt} - \bar{x}_{1j} - \bar{x}_{1t} + \bar{\bar{x}}_1) &= a_2(x_{2jt} - \bar{x}_{2j} - \bar{x}_{2t} + \bar{\bar{x}}_2) + \ldots \\ &+ a_n(x_{njt} - \bar{x}_{nj} - \bar{x}_{nt} + \bar{\bar{x}}_n)\end{aligned} \tag{vii}$$

By designating capital x_{ijt} as the covariance variable $x_{ijt} - \bar{x}_{ij} - \bar{x}_{it} + \bar{\bar{x}}_i$, we get the covariance relation,

$$X_{1jt} = a_2X_{2jt} + \ldots + a_nX_{njt} \tag{viii}$$

which is a pure regression of the dependent variable on the explanatory variables after the constant term as well as the firm and year effects have been eliminated. Once the a_j's are estimated, the c_t's and the b_j's can be calculated from (iii) and (v), respectively. This procedure will, of course, produce j (number of firms) c_t's for each year and n (number of years) b_j's for each firm. But, since these computed c_t's and b_j's include the regression residual which has a mean of zero, unique c_t's and b_j's can be obtained by simple averaging.

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