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Chapter Three

Inventory Investment

INTRODUCTION

Measured by its expected value or mean, the significance of inventory investment is easily underestimated. In a generally growing economy, with growing firms, inventory investment will usually be positive but small relative to capital expenditures over the long run. It becomes highly important for analysis of fluctuations in economic activity because of its considerable volatility; the standard deviation of inventory investment over time, as opposed to its mean, is comparable to that of capital expenditures.

Inventory investment, the rate of change of the inventory stock or the change from the end of one period to the end of another, has been usefully perceived as the sum of intended and unintended investment. Intended investment in inventory, in turn, may be related to the difference between the intended or desired stock of inventories—the product of a desired inventory-to-output or inventory-to-sales ratio and the expected level of output or sales—and the current stock. This leaves open one possibly critical element, the speed of adjustment from the actual to the desired stock of inventories, or the gap between desired and actual inventories which will be made up in any one period.

Unintended inventory investment stems in principle from unanticipated timing in the acquisition of materials used in sales or produc-

Note: A draft of this chapter was presented at meetings of the Econometric Society in New Delhi, India, in January 1975.

tion as well as from unanticipated sales or output. A reduction in the output rate tends to reduce inventories of goods in process and, to the extent that there is time for adjustment, the "raw materials" or stocks of inputs for the productive process. On the other hand, a reduction in sales below the anticipated level, and below the sales rate to which production had been geared, will entail investment in inventories of unsold final product. The amount of this unintended inventory investment should depend upon the length of time at the firms' disposal for adjusting the output rate to the actual sales rate, along with the speed, presumably related to cost, with which firms adjust their output rate.

Empirical implementation of our general model involves a number of further specifications. First, since the model makes sense in real or physical terms, price deflators have been applied to the inventory and actual sales variables. These, as indicated in Chapter 1, relate to the broad product or industry classes into which the McGraw-Hill firms could be categorized. To the extent that the indexes move differently from appropriately weighted averages of firms' prices, some bias, in the same direction for both inventory investment and actual sales changes, would be introduced.[1]

Second, we have to meet the questions of timing—when sales expectations are entertained and for what period. As will be recalled from Chapter 2, expected changes in the physical volume of sales are reported around March of each year as the percent difference between the sales of the previous year and those anticipated for the current year. These expectations, probably formulated some time before the reporting date, can be expected to influence output and inventory holdings during the current year. How much they affect intended inventory holdings at the end of the year, and hence intended investment, will presumably depend both on the length of the production process and on how relevant the sales expectations, formulated perhaps as much as twelve months earlier, prove to output and inventory behavior at the end of the year.

SPECIFIC MODELS OF INVENTORY INVESTMENT

Following upon earlier work by Lloyd B. Orr (1964, 1966, and 1967) and Jon M. Joyce (1967 and 1973), we are now able to utilize ten years of individual firm data—from 1959 through 1968—built

[1] A further error in our price deflation of inventories may arise from the varied timing of purchases of inventories in end of year stocks as well as the varied timing attributed by accountants employing FIFO or LIFO methods of inventory valuation. Except in periods of rapid price changes, however, most inventories are probably not held long enough to make this type of error serious.

around the McGraw-Hill surveys. Analysis of inventory investment along the lines laid out above requires information as to expected future sales changes. In many attempts at empirical implementation of investment theory, current and past values of variables are used as proxies for missing information on expectations of the future. The regressive components in the short-run relation between past and current sales changes and short-run expected sales changes, discussed in Chapter 2, indicate the futility of such extrapolations with regard to inventory investment.

Since the McGraw-Hill data include explicit responses regarding expected sales changes, it is possible to dispense with attempts to manufacture expectations by extrapolating the past. Utilizing (presumably) year end data on sales expectations, our basic general model may be written:

$$\Delta H_t = \alpha + \beta(k_t S^e_{t+1} - H_{t-1}) + \gamma(S_t - S^e_t) + u_t \tag{3.1}$$

where

$\Delta H_t = H_t - H_{t-1}$ = inventory investment in period t

H_{t-1} = the stock of inventories at the end of period $t-1$

k_t = the desired inventory-to-sales ratio in the period t

S^e_{t+1} = sales anticipated for period $t+1$

S^e_t = sales previously anticipated for period t

S_t = actual sales in period t

u_t = the ubiquitous disturbance.

In this general form, $k_t S^e_{t+1}$ represents desired inventories and β, the proportion of the gap to be bridged between desired inventories and the stocks brought over from the previous period. Thus, intended inventory investment related to sales expectations can be taken as $\beta(k_t S^e_{t+1} - H_{t-1})$. A nonzero value for α would reflect some unspecified change in inventory-sales ratios.

Unintended inventory investment, if there is no opportunity to adjust output within the period to the difference between actual and expected sales, might be just equal to that difference. If output were equal to previously expected sales, and actual sales coincidental with shipments, any excess of actual over expected sales would be met out of inventories. In this case, γ would equal -1 and unintended inventory investment would equal $-(S_t - S^e_t)$.

Aside from the problem of noncoincidence of sales and shipments, the assumption that firms have no opportunity to adjust output to the difference between the actual and the anticipated rate of sales is unrealistic to a varying degree, which increases with the length of the period to which sales and sales expectations refer. Certainly, over a period as long as the year relevant in the McGraw-Hill data, firms have substantial opportunity to revise the rate of output. If output were fully adjusted to current sales, we might take the values of both γ and unintended inventory investment to be zero.

But further, if current sales embody information as to expected future sales and output not reflected in previous or currently reported sales expectations, the difference between current sales and their previous anticipations will generate intended inventory investment, the upper bound of which might be given by a value of γ equal to the desired inventory-to-sales ratio, k. That would imply full adjustment of inventories within the period t to the difference between the stock of inventories held on the basis of sales expectations S_t^e and the stock held on the basis of the output and new expectations associated with the actual level of sales S_t. Then, however, recognizing the process of revision of earlier expectations, a more useful measure of expected sales change may be s_{t+1}^t, which probably best approximates expectations at the end of the year t of the rate of change of sales from the year t to the year $t + 1$.

Questions may arise in respect to both the accuracy of reported sales expectations (as noted in Chapter 2) and their relevance. Perhaps actual sales remain a better proxy for the expected sales which are operational in firm decisions. This may be tested empirically by introducing actual sales variables in our relation. A problem remains, however—the relative roles of actual sales (1) as the proxy for expected future demand, and hence a contributor to the demand for inventories and (2) in the shipment of the final product and consequent disinvestment in inventories.

There is also the question of estimating k_t or defining it precisely for our empirical investigation. Again, generally following Orr and Joyce, we have taken the simple average of the inventory-to-sales ratios over the previous three years as the desired inventory-to-sales ratio for future sales. Defined for each firm j in year t, this variable

$$k_{jt} = [(H_{t-1}/S_{t-1})_j + (H_{t-2}/S_{t-2})_j + (H_{t-3}/S_{t-3})_j]/3 \quad (3.2)$$

thus differs from firm to firm and changes over time. We have not undertaken, however, to make k_{jt} a function of such possible determinants as the cost of capital or liquidity.

As a final factor in intended inventory investment, we consider the rate of change in prices. Since information is not available on the expected rate of change, the actual rate, as measured by our broad price indexes, is used. To the extent that higher prices cause firms to economize in inventories, the price change will be negatively related to inventory investment. Errors in the price change variable, particularly any inappropriateness for deflating the year-end inventories of particular firms, may contribute even more to a negative relation between it and the change in price-deflated stocks of inventories, which we measure as inventory investment. To the extent that the current change in prices serves as a proxy for expected future changes we might expect a positive relation with inventory investment, as firms attempt to acquire inventories in anticipation of price increases. Conversely, however, price changes may be negatively related to unintended inventory investment: increases in prices may be most rapid when or where demand has outstripped supply and inventories are being drained down.

To capture directly a measure of unintended inventory investment, we also include a sales realization variable—that is, the difference between actual sales and the previously expressed anticipation of those sales.

For purposes of estimation we hence move from (3.1) to the following equation in expected sales, actual sales, and price changes:

$$\Delta h_{jt} = b_0 + b_1 h^t_{j,t+1} + b_2 h^{t-1}_{jt} + b_3 h^*_{jt} + b_4 h^*_{j,t-1} + b_5 e_{jt} + b_6 \Delta q_{jgt} + u_{jt} \tag{3.3}$$

where, with all variables except prices taken as ratios of previous inventory stocks,

$$\Delta h_{jt} = \left(\frac{H_t - H_{t-1}}{H_{t-1}}\right)_j$$ = inventory investment ratio of the jth firm in the year t

$$h^t_{j,t+1} = \left(\frac{k_t S^t_{t+1} - H_{t-1}}{H_{t-1}}\right)_j$$

$$h^{t-1}_{jt} = \left(\frac{k_t S^{t-1}_t - H_{t-1}}{H_{t-1}}\right)_j$$

$$h^*_{jt} = \left(\frac{k_t S_t - H_{t-1}}{H_{t-1}}\right)_j$$

$$h^*_{j,t-1} = \left(\frac{k_t S_{t-1} - H_{t-1}}{H_{t-1}}\right)_j$$

$$\Delta q_{jgt} = \left(\frac{Q_t - Q_{t-1}}{Q_{t-1}}\right)_{jg}$$ = the relative change in the price index for the group g containing the jth firm

$$e_{jt} = \left(\frac{S_t - S_t^{t-1}}{H_{t-1}}\right)_j$$

and, in turn,

S_t = sales of the year t

S_{t-1} = sales of the year $t - 1$

S^t_{t+1} = $(1 + s^t_{t+1})S_t$ = sales anticipated for the year $t + 1$ at the end of the year t and

S^{t-1}_t = $(1 + s^{t-1}_t)S_{t-1}$ = sales anticipated for the year t at the end of the year $t - 1$,

with all upper case symbols defined in millions of 1954 dollars.

Firm Time Series Estimates

Some firm time series estimates of equation (3.3) are presented in Table 3-1. With coefficients of the variables h^*_t and h^*_{t-1}, relating to actual sales, constrained to be zero, the substantial positive role of expected sales emerges clearly. In column (2), with all variables other than h^{t-1}_t and e_t deleted (that is, the coefficients constrained to be zero), one sees an adjustment of inventory in the year t of some 43 percent of the gap between desired and previous inventories. Here, desired inventories are projected as the product of sales expectations at the end of the previous year and the average of previous inventory-to-sales ratios. Further, the significant positive coefficient of e_t suggests that, given only these previous sales expectations, there

Table 3-1. Inventory Investment and Expected and Actual Sales, Firm Time Series, 1960-1968

$$\Delta h_t = b_0 + b_1 h^t_{t+1} + b_2 h^{t-1}_t + b_3 h^*_t + b_4 h^*_{t-1} + b_5 e_t + b_6 \Delta q_t + u_t$$

(1) Variable or Statistic	*(2)*	*(3)* Regression Coefficients and Standard Errors	*(4)*	*(5)*	*(6)* Means and Standard Deviations
Constant or Δh_t	.038 (.004)	.011 (.005)	.013 (.005)	.005 (.007)	.067 (.139)
h^t_{t+1}	– –	.364 (.043)	.367 (.043)	.439 (.053)	.133 (.139)
h^{t-1}_t	.427 (.036)	.104 (.052)	.104 (.052)	.270 (.088)	.067 (.107)
h^*_t	– –	– –	– –	–.186 (.092)	.066 (.121)
h^*_{t-1}	– –	– –	– –	–.083 (.064)	.002 (.096)
e_t	.062 (.007)	.012 (.009)	.012 (.009)	.027 (.012)	.003 (.577)
Δq_t	– –	– –	–.376 (.220)	–.364 (.220)	.007 (.017)
$\sum_{i=1}^{4} b_i$	.427 (.036)	.468 (.036)	.471 (.036)	.440 (.040)	
$n(-73)$[a]	1475	1475	1475	1475	
r.d.f.	1176	1175	1174	1172	
$\bar{R}^2$	.136	.185	.187	.189	
F	93.51	90.38	68.63	46.81	

[a]Acceptable intervals for the h variables were [0.7,-0.7], for e_t, [3.5,-3.5], and for Δq_t, [1,-1]. No additional effective bounds were put on transformations of these or other variables used in this chapter.

is a further adjustment of inventories to current sales. The positive relation of inventories to current output or to expected future sales and output appears to outweigh its buffer role.

When h^t_{t+1} is included in the regression, it apparently picks up the expectational element in current sales, as is indicated in column (3) by the much lower coefficient—virtually zero—of e_t. Sales expected for period $t+1$ show up as the prime determinant of inventories at the end of period t. It would appear that inventory investment in period t is initially shaped by the discrepancy between actual inventories and those desired on the basis of sales expectations at the end of year $t-1$. To the extent that sales during the year exceed those which had been expected, output adjusts just about enough, or shipments do not, so that inventory investment is little affected. But expectations of future sales, projected from current sales, then prove the prime determinant of inventory holdings at the end of the year. This is confirmed in column (4), where the relative price change variable shows a negative coefficient but, with little time series variance over this period, is not statistically significant and has little effect upon the regression.

Column (5) deals with all of the variables specified in equation (3.3) and appears to bring out all the more strongly the positive role of sales expectations, including those held at the end of the previous year. We do note, however, a curious melange of coefficients of the other variables, particularly negative coefficients for h_t^* and h_{t-1}^*, which takes some disentangling. The result of this disentangling and rearrangement is shown in the following equation:

$$\Delta h_{jt} = \underset{(0.007)}{0.005} + \underset{(0.053)}{0.439}\, h_{j,t+1}^{t} + 0.084(h_{jt}^{t-1} - h_{j,t-1}^{*}) \qquad (3.4)$$

$$+ (\underset{(0.012)}{0.027} - \underset{(0.092)}{0.186}\, k_{jt})e_{jt} - \underset{(0.220)}{0.364}\, \Delta q_{jgt} + u_t$$

where $h_{jt}^{t-1} - h_{j,t-1}^{*}$ may be more easily seen as $k_{jt}(S_{jt}^{t-1} - S_{j,t-1})/H_{j,t-1}$, the inventory investment related to the jth firm's expectations of relative sales growth in the year t.

Note first the substantial role once again of expected future sales, as seen in the coefficient of 0.439 of $h_{j,t+1}^{t}$, which we may take as an estimate of β in equation (3.1). (Alternative estimates may be seen in $\sum_{i=1}^{4} b_i$, ranging from 0.427 to 0.471, in Table 3-1.) The coefficient of 0.084 of the term $(h_{j,t}^{t-1} - h_{j,t-1}^{*})$ indicates that some inventory investment may be accounted for by the expected rate of increase in sales from year $t-1$ to year t.

Current sales seem to have no role except insofar as they are the base for projecting expected future sales or as they enter into the error in anticipations term e_{jt}. This last would appear to have a small but nonconstant parameter, corresponding to γ in equation (3.1), which varies with k_{jt}, the inventory-to-sales ratio of the firm—a ratio that has an overall average in the neighborhood of 0.2. Thus, when that ratio is at its mean value, the coefficient of e_{jt} is very slightly negative, about −0.01. Where the inventory-to-sales ratio is higher, the coefficient of e_{jt} is more negative; where it is lower, the coefficient may turn positive. While the absolute sizes of the coefficients are too small and their standard errors relatively too high to take this as more than vaguely suggestive, we might imagine that where inventory-to-sales ratios were low, there was little in the way of finished output to serve as a buffer. Sales higher than previously expected then tended to have a more immediate effect in increasing output and hence inventories in process, thus showing some positive relation with investment. Where the inventory-to-sales ratio was high, the buffer role of inventories could emerge and contribute to a negative coefficient of the error in anticipations variable, e_{jt}.

Firm Cross Section Estimates

The firm cross section regression should probably not be expected to offer a sharper focus on inventory investment. As in capital expenditure functions, cross-sectional differences should offer more in the way of "permanent" or long-run components of variance, but in the case of inventory investment it is not long-run changes in sales that are important. Rather, inventory considerations should relate more to short-run, even transitory, factors.

It is therefore not surprising that coefficients of determination ($\hat{R}^2$) are generally lower in Table 3-2, which presents the results of firm cross section regressions. We do note again the major role of expected sales for the subsequent year, as seen in the coefficients approaching 0.5 for h_{t+1}^{t}. Previously expected sales for the current year, as shown by coefficients of h_t^{t-1}, apparently have a lesser effect. Indeed, the sum of the h coefficients is quite generally smaller in the cross section than in the time series, suggesting that interfirm differences in the relation between sales and sales expectations and previous inventories have less to do with inventory investment than do intrafirm, intertemporal differences. This would be consistent with the hypothesis that the interfirm differences include more of the long-run, systematic elements that are less related to the short-run considerations affecting inventory investment. The greater absolute size of the negative coefficients of price changes are also noteworthy. They appear to differ significantly from zero, somewhat strengthening our notion that the price variable is picking up errors in our deflation procedure.

Table 3-2. Inventory Investment and Expected and Actual Sales, Firm Cross Section, 1960-1968

$$\Delta h_t = b_0 + b_1 h_{t+1}^t + b_2 h_t^{t-1} + b_3 h_t^* + b_4 h_{t-1}^* + b_5 e_t + b_6 \Delta q_t + u_t$$

(1) Variable or Statistic	(2)	(3)	(4)	(5)	(6) Means and Standard Deviations
	Regression Coefficients and Standard Errors				
Constant	.046	.019	.024	.009	.065
or Δh_t	(.004)	(.005)	(.005)	(.006)	(.144)
h_{t+1}^t	–	.420	.419	.474	.131
	–	(.038)	(.038)	(.045)	(.150)
h_t^{t-1}	.288	–.134	–.136	.124	.066
	(.031)	(.049)	(.049)	(.075)	(.114)
h_t^*	–	–	–	–.150	.065
	–	–	–	(.080)	(.125)
h_{t-1}^*	–	–	–	–.244	.002
	–	–	–	(.054)	(.102)
e_t	.061	.009	.007	.022	–.007
	(.006)	(.007)	(.007)	(.010)	(.599)
Δq_t	–	–	–.676	–.587	.007
	–	–	(.250)	(.249)	(.013)
$\sum_{i=1}^{4} b_i$	.288	.285	.283	.204	
	(.031)	(.030)	(.030)	(.034)	
$n(-73)$	1580	1580	1580	1580	
r.d.f.	1569	1568	1567	1565	
$\hat{R}^2$	.089	.155	.158	.171	
F	78.12	97.09	74.94	55.12	

Industry Time Series Estimates

Going back to time series, on the basis of industry observations that are the means of the individual firm observations within the industry, we note a stronger role for the inventory-to-sales relation. Coefficients of the variables built on sales expectations, h_{t+1}^t and h_t^{t-1}, are generally higher, and the sums of all of the h variables are uniformly higher, generally well over 0.5. Coefficients of determination are also greater, reflecting the tendency for "noise" (or errors and random variations) to wash out in the averaging process.

Columns (3) and (4) of Table 3-3 show that inventory investment tends to equal almost three-quarters of the amount that the sales expected for the current and next year would call for to maintain past inventory-sales ratios. Coefficients of determination, while higher than in the individual firm time series, are still modest, which

Table 3-3. Inventory Investment and Expected and Actual Sales, Industry Time Series, 1960-1968

$$\Delta h_t = b_0 + b_1 h_{t+1}^t + b_2 h_t^{t-1} + b_3 h_t^* + b_4 h_{t-1}^* + b_5 e_t + b_6 \Delta q_t + u_t$$

(1) Variable or Statistic	(2)	(3)	(4)	(5)	(6) Means and Standard Deviations
	Regression Coefficients and Standard Errors				
Constant or Δh_t	.034 (.013)	−.023 (.020)	−.025 (.020)	−.051 (.030)	.065 (.049)
h_{t+1}^t	–	.626 (.180)	.655 (.183)	.667 (.276)	.131 (.055)
h_t^{t-1}	.474 (.178)	.087 (.197)	.083 (.198)	.402 (.343)	.066 (.033)
h_t^*	–	–	–	.068 (.375)	.065 (.050)
h_{t-1}^*	–	–	–	−.540 (.285)	.002 (.030)
e_t	.055 (.023)	−.047 (.036)	−.052 (.037)	−.057 (.040)	−.007 (.252)
Δq_t	–	–	−.299 (.310)	−.345 (.307)	.007 (.018)
$\sum_{i=1}^{4} b_i$	.474 (.178)	.713 (.177)	.738 (.179)	.598 (.190)	
n(−73)	69	69	69	69	
r.d.f.	58	57	56	54	
$\hat{R}^2$	.154	.289	.288	.311	
F	6.44	9.14	7.08	5.51	
$F_{.01}$	5.00	4.16	3.69	3.17	
$F_{.001}$	7.81	6.23	5.39	4.48	

indicates that much remains to be explained in at least the timing if not the longer run determinants of inventory investment.

Industry Cross Section Estimates

The industry cross sections (Table M3-5) again show a major positive role for expected sales of the subsequent year, but the variable involving sales changes expected for the current year displays a sharply negative coefficient when both expectations variables are included. The role of all the sales variables, as measured in the sum of *h* coefficients, is again distinctly less important than in the time series.

Constrained Regressions

We have also constrained the inventory relation to the form indicated in equation (3.4). Regressions involving this equation are presented in Table 3-4 for the somewhat fewer observations available for our analysis of the role of profits (discussed below). For the firm time series shown in column (2), the results are, of course, similar to those reported in equation (3.4), although with lesser absolute values of coefficients of the error in anticipations term, e_t, thus lowering the tentative combination accelerator-buffer role that we suggested. The 0.603 sum of the coefficients of the sales anticipations variables, however, is fairly substantial and highly significant. The industry time series regression, shown in column (3), reveals a sum of sales anticipation variable coefficients of 1.039, suggesting that inventory investment tends within one year to be sufficient to maintain a ratio of inventories to expected sales about equal to average past inventory-sales ratios.

The cross section relations are again less sharp, with lower coefficients of determination and lower sums of coefficients of *h* variables. They appear relatively consistent, however, with what we have already observed, except for the additional absence of support for any significant role for the error in anticipations variables.

A brief look at the means and standard deviations shown in Table 3-4 helps reveal the substance of the relation between inventory investment and the sales anticipation variables. In the firm time series, of the mean inventory investment of 6.8 percent of previous inventory stock, some 6.3 percent can be accounted for by the product of b_1 and the mean value of h_{t+1}^t. All of that is wiped out on the average in the case of firms for which this desired inventory investment variable based on next year's sales anticipations is roughly one standard deviation below its mean value. The next sales change anticipation term accounts for a growth in inventories at the mean

Table 3-4. Inventory Investment and Expected and Actual Sales, Constrained Regressions, Time Series and Cross Sections, 1960-1968

$$\Delta h_t = b_0 + b_1 h^t_{t+1} + b_2 (h^{t-1}_t - h^*_{t-1}) + (b_3 + b_4 k_t)\, e_t + b_5\, \Delta q_t + u_t$$

(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
	Regression Coefficients and Standard Errors				*Means and Standard Deviations*			
Variable or Statistic	*Time Series*		*Cross Section*		*Time Series*		*Cross Section*	
	Firm	*Industry*	*Firm*	*Industry*	*Firm*	*Industry*	*Firm*	*Industry*
Constant	−.002 (.007)	−.041 (.023)	.014 (.006)	−.012 (.024)				
Δh_t					.068 (.137)	.066 (.052)	.066 (.141)	.066 (.049)
h^t_{t+1}	.463 (.034)	.615 (.161)	.321 (.029)	.495 (.170)	.136 (.134)	.134 (.056)	.134 (.146)	.134 (.048)
$h^{t-1}_t - h^*_{t-1}$	.139 (.067)	.424 (.250)	.193 (.062)	.263 (.320)	.064 (.060)	.065 (.022)	.065 (.063)	.065 (.020)
e_t	.012 (.013)	−.033 (.037)	.009 (.011)	−.047 (.034)	.016 (.560)	.010 (.250)	.010 (.581)	.010 (.262)
$k_t e_t$	−.083 (.092)	.099 (.275)	.127 (.080)	.224 (.312)	.001 (.086)	.001 (.039)	.001 (.087)	.001 (.033)
Δq_t	−.264 (.227)	−.329 (.304)	−.534 (.253)	−.628 (.403)	.007 (.017)	.007 (.018)	.007 (.014)	.007 (.015)
$b_1 + b_2$	.603 (.067)	1.039 (.254)	.514 (.057)	.758 (.290)				
$b_3 + b_4$	−.071 (.081)	.066 (.256)	.136 (.071)	.177 (.294)				
n (−64)	1285	69	1369	70				
r.d.f.	1014	55	1355	56				
$\hat{R}^2$	.208	.374	.176	.271				
F	54.46	8.16	59.28	5.53				

equal to 0.9 percent of previous stock, so that at their mean values, the two anticipations variables roughly account for all of the inventory investment.

In the case of the industry time series, the sales anticipation variables at their means appear to bring about more than mean inventory investment, the difference being picked up in a negative constant term. But standard deviations are, of course, much smaller in the industry variables, and their effects on inventory investment fluctuations are therefore of lesser importance. Standard errors are too great to pinpoint the industry relations, but coefficients of determination—considering the nature of the variance of the dependent variable, a first difference in ratio form—do not seem too disappointing.

THE ROLE OF PROFITS

Thus far we have assumed not only that firms endeavor to maintain a fixed inventory-to-sales ratio, but that they have a fixed lag structure of responses to changes in sales and expected sales and to disequilibria in their inventory situations. It may now be suggested, however, that the rate at which firms invest in inventories in order to maintain their accustomed inventory-to-sales ratio depends upon liquidity, profits, or "cash flow." In principle, indeed, the equilibrium inventory-to-sales ratio should itself depend upon the rental price of capital and the anticipated opportunity costs and returns of holding additional inventories.

With the available data, our most likely tests involve the role of gross profits or "cash flow." One might generally assume that firms would find it easier to finance holding additional inventories (where this seems desirable) when profits are relatively high. Higher profits may also conceivably lower the cost of capital to the firm and hence raise its desired inventory-to-sales ratio above its past level.

Given the changes in depreciation charges (and hence the measure of net profits) over recent years as a result of changing accounting practices (largely to conform with new tax provisions), as well as the greater relevance of gross profits as a measure of "cash flow" that might influence the cost of capital, we decided to work with a relative gross profits variable. This was defined as the difference between the sum of the current ratios of net profits and depreciation charges to immediately previous gross fixed assets and the mean of these sums for the previous three years; thus,

$$RGP_t = p_t^* + d_t^* - \sum_{j=1}^{3} (p_{t-j}^* + d_{t-j}^*)/3. \qquad (3.5)$$

It also seemed reasonable to assume that the effect of relative profits on the speed of inventory investment would be asymmetrical.

Higher relative profits might accelerate investment when desired inventory investment is positive because of higher expected sales; on the other hand, higher relative profits could make it easier to carry extra inventories and hence slow inventory disinvestment when expected sales call for lower inventories than the firm already holds. In order to isolate a positive role for relative profits in accelerating the rate of inventory investment in response to increases in desired inventories, we defined and introduced a set of dummy variables that generally took on the value of unity when positive desired inventory investment was indicated and was zero otherwise. These were defined specifically as follows:

$$X_i = 1 \text{ when } h_i \geqslant 0; X_i = 0 \text{ when } h_i < 0, \quad i = 1,\ldots,4, \tag{3.6}$$

where

$$h_1 = h_{t+1}^t,\ h_2 = h_t^{t-1},\ h_3 = h_t^{t-1} - h_{t-1}^*, \text{ and } h_4 = h_t^* - h_t^{t-1}.$$

By making use of these dummy variables in combination with relative gross profits, RGP, we were able to (1) examine the extent to which relative gross profits increased or reduced inventory investment and (2) measure any direct role of profits in inventory investment, distinguishing between the case where expected sales for next year indicated desired inventory investment and where it did not. The full general form for the assumed linear relation, with all possible variables included, may be written:

$$\Delta h_t = b_0 + \sum_{i=1}^{4} (b_{2i-1} + b_{2i} X_i RGP)h_i + (b_9 + b_{10} X_4 RGP)e_t$$
$$+ (b_{11} + b_{12} X_1)RGP + b_{13} \Delta q_t + u_t \tag{3.7}$$

Estimates of positive values of b_{2i}, $i = 1,\ldots,6$, would then suggest that current gross profits that are higher than their previous average would raise the positive effect (or decrease the negative effect) of the indicated variable on inventory investment. The magnitude of that effect would depend, however, on how much RGP exceeded its mean. The economic significance to be attached to any given value of b_{2i} would therefore depend upon the variance of RGP (and also the mean value of X_i, which would reveal the proportion of observations for which the variable X_iRGP h_i might be nonzero).

Table 3-6[2] introduces relative gross profits and accompanying

[2]Table M3-5 and Tables M3-7, M3-8, and M3-9 appear only in microfiche.

Table 3-6. The Role of Relative Gross Profits, Expected and Actual Sales, and Errors in Expectations, Time Series and Cross Sections, 1960-1968

$$\Delta h_t = b_0 + (b_1 + b_2 X_1 RGP) h^t_{t+1} + (b_3 + b_4 X_2 RGP) h^{t-1}_t + b_5 e_t + b_6 \Delta q_t + u_t$$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Regression Coefficients and Standard Errors				*Means and Standard Deviations*			
Variable or Statistic	*Time Series*		*Cross Section*		*Time Series*		*Cross Section*	
	Firm	*Industry*	*Firm*	*Industry*	*Firm*	*Industry*	*Firm*	*Industry*
Constant	.007 (.006)	−.017 (.019)	.019 (.005)	−.006 (.018)				
Δh_t					.068 (.137)	.066 (.052)	.066 (.141)	.066 (.049)
h^t_{t+1}	.405 (.049)	.523 (.205)	.457 (.042)	.815 (.201)	.136 (.134)	.134 (.056)	.134 (.146)	.134 (.048)
$X_1 \cdot RGP \cdot h^t_{t+1}$	.991 (.615)	1.898 (4.068)	.620 (.532)	3.732 (3.780)	.002 (.010)	.002 (.002)	.002 (.010)	.002 (.002)
h^{t-1}_t	.113 (.059)	.175 (.233)	−.157 (.055)	−.586 (.291)	.066 (.099)	.065 (.034)	.065 (.105)	.065 (.028)
$X_2 \cdot RGP \cdot h^{t-1}_t$	−2.227 (1.005)	5.177 (6.123)	−1.235 (.877)	.224 (5.980)	.001 (.006)	.000 (.001)	.000 (.006)	.000 (.001)
e_t	.010 (.010)	−.037 (.034)	.004 (.008)	−.066 (.027)	.016 (.560)	.010 (.250)	.010 (.581)	.010 (.262)
Δq_t	−.269 (.227)	−.504 (.331)	−.586 (.253)	−.671 (.382)	.007 (.017)	.007 (.018)	.007 (.014)	.007 (.015)
$b_1 + b_3$	.518 (.041)	.699 (.188)	.300 (.035)	.229 (.201)				
$b_2 + b_4$	−1.237 (.689)	7.075 (4.941)	−.615 (.614)	3.956 (4.589)				
n (−64)	1285	69	1369	70				
r.d.f.	1013	54	1354	55				
$\hat{R}^2$	.209	.356	.176	.330				
F	45.77	6.53	49.48	6.00				

Note: Table M3-5 appears only in microfiche.

dummy variables into the regressions otherwise analogous to those shown in column (4) of Tables 3-1, 3-2, 3-3, and 3-4. Coefficients of determination are raised somewhat, but standard errors are generally high, the estimated magnitude of profits effects small, and directions mixed. Noting the firm time series results in column (2), we find the coefficient of $X_1 \cdot RGP \cdot h_{t+1}^t$, relating to the relative profits-future sales expectations variable, to be 0.991, with a standard error of 0.615. Since the standard deviation of RGP (see Table M3-7) is only 0.047, this means that the effect of relative profits on a positive desired inventory investment component, h_{t+1}^t, was, for two-thirds of the observations, less than the standard error of 0.049 for the estimated parameter of h_{t+1}^t and not much more than 10 percent of the estimated parameter itself.

However, we should also note a significant negative coefficient of −2.227, with a standard error of 1.005, for $X_2 \cdot RGP \cdot h_t^{t-1}$. This would suggest that, if gross profits in the years $t-3$ to $t-1$ were less than subsequently, the inventory investment stemming from the increase in sales expected at the end of year $t-1$ would be less. But again, even with a coefficient considerably larger (in absolute size), the effect is moderate because of the low standard deviation of *RGP*. In this case, relative gross profits one standard deviation above the mean would be just about sufficient to reduce to zero the already small coefficient (0.113) of h_t^{t-1}.

The industry time series, as usual, have much higher standard errors of estimated parameters, but show large positive coefficients for both relative gross profits components, the coefficients summing to 7.075. Since the standard deviation of *RGP* in the industry time series is smaller than in the firm time series (0.016 as against 0.047), the effect of these higher coefficients is reduced. Still, we can estimate that in some 16 percent of the observations with positive sales change expectations the sum of the *h* coefficients, already approximately 0.7 for observations with average current relative gross profits, is raised by more than 0.1. Since the standard error of $b_2 + b_4$ is a whopping 4.941, however, we cannot reasonably call this effect statistically significant and must note that any substantial inferences are negated by the negative figure of −1.237 (standard error of 0.689) for the sum of b_2 and b_4 in the firm time series. The cross sections do little to render a clearer view.

A far more suggestive role, however, emerges for relative gross profits when treated together with virtually all combinations of *h* variables and the error in anticipations, e_t:

$$\Delta h_t = b_0 + (b_1 + b_2 X_1 RGP)h_{t+1}^{t} + (b_3 + b_4 X_2 RGP)h_t^{t-1}$$
$$+ (b_5 + b_6 X_3 RGP)(h_t^{t-1} - h_{t-1}^{*})$$
$$+ (b_7 + b_8 X_4 RGP)(h_t^{*} - h_t^{t-1}) + (b_9 + b_{10} X_4 RGP)e_t$$
$$+ (b_{11} + b_{12} X_1) RGP + b_{13} \Delta q_t + u_t \qquad (3.8)$$

We find that higher current relative profits contribute to the portion of inventory investment related to expectations of higher sales. Recalling that higher values of *RGP* imply that previous profits were lower, we can infer that lower profits induce more disinvestment when actual sales are high relative to previous inventories.

Starting with the time series results and adding terms (in which b_4, b_6, and b_8 specified in Table M3-7 are involved) for the more frequent observations where $X_2 = X_3 = X_4 = 1$, we raise the coefficient of RGP $\cdot\ h_t^{t-1}$ to 1.579. Similarly (when the terms associated with b_3, b_5, and b_7 are combined), the coefficient of h_t^{t-1} where RGP = 0 may be viewed as 0.035 + 0.109 + 0.072 = 0.216. This corresponds roughly to the positive coefficient of 0.270 for h_t^{t-1} observed in column (5) of Table 3-1. Then, for the situation $X_1 = X_2 = X_3 = X_4 = 1$, we can add terms to obtain

$$\Delta h_t = 0.002 + (0.441 + 1.898\, RGP)h_{t+1}^{t} + (0.216 + 1.579\, RGP)h_t^{t-1}$$
$$- (0.072 + 3.947\, RGP)h_t^{*} - (0.109 + 1.721\, RGP)h_{t-1}^{*}$$
$$+ (0.012 + 0.424\, RGP)e_t - 0.294\, \Delta q_t + u_t \qquad (3.9)$$

Thus, a higher *RGP* figure raises the positive coefficients of the sales expectation *h* terms—while sharply lowering the already negative h^* coefficients for inventory investment associated with current and previous actual sales.

Note that the relative gross profits term itself vanishes in the equation above where $X_1 = 1$. For, as shown in the time series regression results in Table M3-7, the positive coefficient of 0.411 of *RGP* is almost exactly balanced by the negative coefficient of −0.410 for X_1RGP, which applies to the bulk (some 85 percent) of the cases in which sales expected for the following year indicated that additional inventories were required to maintain the past inventory-sales ratio. The positive coefficient of 0.411 therefore only applies where expected sales indicated disinvestment. However, the standard deviation of only 0.047 for *RGP* suggests that its effect was minimal in any event.

The cross section results do not add particularly to the picture. Combination of terms for $X_1 = X_2 = X_3 = X_4 = 1$, as above, yields

$$\Delta h_t = 0.008 + (0.462 + 0.904\, RGP)h^t_{t+1} + (0.39 + 2.280\, RGP)h^{t-1}_t - (0.044 + 1.971\, RGP)h^*_t - (0.228 + 2.925\, RGP)h^*_{t-1} + (0.007 + 0.475\, RGP)e_t - 0.171\, RGP - 0.521\, \Delta q_t + u_t \quad (3.10)$$

The coefficients have the same signs as in the time series, but are somewhat different in magnitude.

In general, it may be observed that higher relative gross profits seem to contribute to the inventory investment called for in order to keep the inventory-sales ratio constant in the face of expected growth in sales. They seem, however, to increase the disinvestment associated with high current and previous actual sales.

These observations are borne out by direct estimation of equation (3.11), which is much like equation (3.9):

$$\Delta h_t = b_0 + (b_1 + b_2 X_1\, RGP)h^t_{t+1} + (b_3 + b_4 X_2 RGP)h^{t-1}_t + (b_5 + b_6 X_5\, RGP)h^*_t + (b_7 + b_8 X_6\, RGP)h^*_{t-1} + (b_9 + b_{10} X_4\, RGP)e_t + (b_{11} + b_{12} X_1)RGP + b_{13}\, \Delta q_t + u_t \quad (3.11)$$

The sum of the direct coefficients of the *h* variables is a substantial and significant 0.663 in the firm time series (Table M3-8). Relative profits seem to have a significant positive effect on h^t_{t+1}, as indicated by the apparently significant value of $b_2 = 2.992$. The coefficients of the relative profits interaction variables involving current sales and lagged sales and sales expectations are all negative, and their sum appears clearly significant.

These results appear to support the hypothesis that the effect of higher relative profits is to speed or increase the investment in inventories designed to maintain the firm's inventory-sales ratio. Inventory investment related to previous sales and sales expectations is apparently reduced or retarded by higher current relative profits, which may be to say, by lower relative profits at the time of development of these sales and sales expectations. The current relative profits variable also appears to contribute negatively to inventory investment related to current sales. This, conceivably, might also reflect the lagged role of previously lower profits in affecting the inventory response to increased sales as they occur during the year.

Relative gross profits have very little direct effect on inventory investment. For the great bulk of cases in which sales were expected to increase ($X_1 = 1$), the coefficient of RGP is virtually zero (precisely, 0.392 – 0.434 = –0.042). In the relatively small number of cases where the inventory investment indicated by expected sales for the subsequent year was negative, the applicable positive coefficient of 0.392 came with a standard error of 0.246.

While the coefficient of determination of the industry time series was 0.325, as against only 0.213 in the firm time series, standard errors of the coefficients involving the relative profits variable were generally very high, so that little in the way of reliable inference appears feasible. The firm cross section results again seem somewhat less clear than the time series and add little to what we already know. The industry cross sections once more have standard errors so high as to prevent reliable inference as to the role of variables involving relative profits.

The results are not overwhelmingly different (Table M3-9) when we abandon the assumption that the role of the relative profits variable is asymmetric between situations calling for both positive and negative investment:

$$\Delta h_t = b_0 + (b_1 + b_2 RGP)h_{t+1}^t + (b_3 + b_4 RGP)h_t^{t-1} + (b_5 + b_6 RGP)h_t^* + (b_7 + b_8 RGP)h_{t-1}^* + (b_9 + b_{10} RGP)e_t + b_{11} RGP + b_{12} \Delta q_t + u_t \qquad (3.12)$$

The suggestion of an asymmetric role, however, is supported. For without the assumption of symmetry, the coefficients of $RGP \cdot h_{t+1}^t$ are lowered, at least in the individual firm regressions. Similarly, the sum of $b_4 + b_6 + b_8$ is lowered in absolute value—that is, has some of its effects apparently washed out in cases of inventory disinvestment.

SUMMARY AND CONCLUSIONS

Inventory investment is viewed as the sum of intended and unintended investment. Intended investment relates to the effort, in the face of changing sales, to keep a constant ratio of inventory to sales. Unintended investment stems from the discrepancy between sales and shipments and the anticipated sales to which inventories had been geared.

With each firm's past three year average inventory-sales ratio taken as "equilibrium," intended inventory investment is well accounted for in time series regressions by the excess of expected future sales over current sales. This appears to offer a substantial explanation for the sharpness of inventory cycles. When real sales expectations turn down, inventory disinvestment can be large. When they turn down for an entire industry group, the effect appears all the greater. The relation is somewhat less clear in cross sections, however, where interfirm variance in sales expectations may be viewed as more permanent in character and less likely to relate immediately to inventory investment.

Unintended investment in inventories does not bulk large in our data, perhaps because of their annual character. There is a suggestion of a buffer role, in which the relation of investment to unanticipated sales changes is the more negative the greater the past inventory-sales ratio.

An attempt to discern a role for relative gross profits in the speed of inventory investment was generally inconclusive. Some slight evidence can be found, however, that higher current relative profits may accelerate investment based upon the expectation of higher sales. Lower previous profits tended to increase the disinvestment associated with current and previous actual sales that were high relative to previous inventories. Relative gross profits do not appear to have any role in inventory investment independent of their possible interaction with sales expectations. The expectation-based accelerator, reinforced by the role of profits, is consistent, however, with the frequently perceived significant role of inventory investment in cyclical fluctuations.