Are Inventories Sensitive To Interest Rates?

by Dan M. Bechter and Stephen H. Pollock

Are business inventories sensitive to interest rates? Common sense suggests they ought to be. After all, the pressures of competition and the opportunities for higher profits encourage businesses to control all costs, and the cost of carrying inventories is surely no exception. But is the interest expense of inventories significant enough to be of much consequence? Yes, it is.

During 1979, for example, the average book value of inventories held by all businesses exceeded $400 billion. With the rate of interest on commercial paper averaging over 10 per cent in 1979, the interest cost of carrying these inventories can be conservatively estimated to have been $40 billion. While $40 billion was only 1.16 per cent of the value of total business sales in 1979, it was close to 13.0 per cent of the net income of business (before-tax profits of corporate and noncorporate businesses).

The implication of these percentages is that while a change in the rate of interest on inventory loans probably has very little effect on prices of goods, the effect on business profits is, at least potentially, quite significant. Logically, therefore, one would expect businesses to reduce their stocks of materials and finished goods when, other things equal, interest rates rise.

Why, then, have most studies of inventory fluctuations failed to confirm the relationship between changes in inventories and changes in interest rates? Part of the answer is that short-term interest rates are not the only variable that businesses consider in adjusting inventories, and the influences of these other variables may statistically hide the effect of interest rates. In particular, businesses stock up on inventories when sales are strong. Yet, when sales are strong, the demand for credit, including the demand for inventory loans, is also strong. Consequently, when business is brisk, interest rates tend to be higher because of the strength in the demand for credit. It sometimes happens, therefore, that inventories rise when interest rates rise. Because sales, interest rates, and inventories are all moving in the same direction, it is difficult to determine by how much the sales-induced increase in inventories has been reduced by the rise in interest rates.

The lack of success in showing interest rate sensitivity in several empirical studies of inventory adjustments also can be attributed to other factors, such as the poor quality of data used, omitted variables, and the way certain included variables are defined and measured. For example, there is a wide variation among

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studies in the way in which inflation is taken into account, both as an explanatory variable and in the conversion of observed dollar values of inventories and sales to constant dollar measures.

This article presents a new approach to measuring the sensitivity of inventories to interest rates. The primary distinguishing feature of this approach is its focus on the inventory-sales ratio, rather than on the inventory stock, as the variable businesses seek to control. The empirical results of applying this interpretation of business inventory behavior to the retail and wholesale trade sectors are also reported. These empirical results support the view that inventory fluctuations, which figure so importantly in business cycles, are indeed affected by interest rates.

BACKGROUND

In an important paper that appeared in 1976, Martin Feldstein and Alan Auerbach took a detailed and systematic look at the traditional stock-adjustment models of inventory fluctuations.[1] Such models reflect the assumption that businesses only partially adjust their stocks of inventories to desired levels and to unanticipated sales from one period to the next. Symbolically, a partial stock-adjustment model may be given as,

$$(1)\ I_t - I_{t-1} = \lambda(I_t^* - I_{t-1}) + \delta(S_t^e - S_t)$$

where I_t denotes the actual stock of inventories at the end of period t,

I_{t-1} denotes the actual stock of inventories at the end of the preceding period t-1,

I_t^* denotes the desired stock of inventories at the end of period t,

S_t^e denotes expected sales during period t,

S_t denotes actual sales during period t,

and where λ and δ are speed-of-adjustment coefficients to be estimated.

Equation (1) states that the one-period change in the inventory stock, $I_t - I_{t-1}$, is a fraction, λ, of the desired change, $I_t^* - I_{t-1}$, plus a fraction, δ, of the difference between expected sales and actual sales, $S_t^e - S_t$. For estimation purposes, the desired stock is assumed to be a function of expected sales, the rate of interest on inventory loans, the anticipated rate of inflation, and certain other variables, depending on the type of inventory adjustments being studied. Expected sales are sometimes available from survey data, but usually must be assumed to be a function of past sales.

After studying all the literature, Feldstein and Auerbach concluded that there were several bothersome features about the results obtained by other researchers who used the stock-adjustment model. Specifically, the rate of interest was virtually never shown to affect inventory adjustments, and the estimated speed-of-adjustment to desired stocks was unbelievably slow in light of overwhelming evidence to the contrary.

In the hope that the stock-adjustment model might be capable of better performance, Feldstein and Auerbach tried using it with better data, more elaborate sets of variables, and more sophisticated methods of estimation. However, they were unsuccessful in improving the model's performance, and finally concluded that the conventional stock-adjustment model should be considered an inappropriate theoretical specification for application to inventory investment. They rejected the model of partial adjustment in favor of one in which

[1] Martin Feldstein and Alan Auerbach, "Inventory Behavior in Durable-Goods Manufacturing: The Target-Adjustment Model," *Brookings Papers on Economic Activity*, Vol. 2, 1976, pp. 351-396. Comments by Robert E. Hall and Michael C. Lovell, pp. 397-405.

inventories adjust completely within one quarter to targeted levels. Besides offering an alternative model of their own, Feldstein and Auerbach opened the door for others to suggest new specifications.

Since the publication of the Feldstein and Auerbach arguments against using the stock-adjustment model to explain inventory fluctuations, three researchers have reported finding evidence of the interest rate sensitivity of inventories.

In a study of monthly inventory changes in retail trade, F. Owen Irvine, Jr., used a stock-adjustment model and obtained good results, including acceptable estimates for the speed-of-adjustment coefficients. In a second paper, Charles Lieberman assumed complete within-period adjustment of inventories to desired levels, and found businesses sensitive to inventory carrying costs. In a third recent paper, Laura Rubin used a stock-adjustment model to demonstrate the effects of interest rates and uncertainty on quarterly changes in aggregate inventories.[2] Lieberman's work dealt with annual adjustments in inventories, but annual adjustments are too far apart to be very useful in business cycle analysis. The results of Irvine and Rubin did not hold up on reestimation with more recent quarterly data. Their interest rate variables, in particular, lost their significance and no longer showed inventory sensitivity.

THE INVENTORY-SALES RATIO MODEL

The model presented in this article not only overcomes the principal objections raised by Feldstein and Auerbach, but also the problems of the three papers just cited. The inventory-sales ratio model summarized below is specified in a way different from the stock-adjustment model and avoids the problems inherent in the traditional specification.

The inventory-sales ratio model is expressed in equation (2),

$$(2)\ (I/S)_t = (I/S)^*_t + \sigma(S^e_t - S_t)$$

which states that, in period t, the actual ratio of inventories to sales, $(I/S)_t$, equals the desired ratio of inventories to sales, $(I/S)^*_t$, plus some fraction, σ, of the difference between expected sales, S^e_t, and actual sales, S_t.

The inventory-sales ratio model expressed by equation (2) differs from the partial stock-adjustment model of equation (1) in two important ways. First, in the inventory-sales ratio model, the focus is on the ratio of inventories to sales instead of on inventory levels alone. This focus reflects the judgment that businesses exercise control over both inventories and sales, and that this joint control is best captured by the ratio of inventories to sales.[3] Second, the inventory-sales ratio model reflects the assumption introduced by Feldstein and Auerbach that complete adjustment to the desired inventory-sales ratio is achieved within the period, instead of the assumption of partial adjustment that is characteristic of stock-adjustment models. By permitting a deviation

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2 See F. Owen Irvine, "Retail Inventory Investment and the Cost of Capital," and Charles Lieberman, "Inventory Demand and Cost of Capital Effects," unpublished papers presented to the August 1978 meeting of the Econometric Society (Chicago). Also, see Laura Rubin, "Aggregate Inventory Behavior: Reponse to Uncertainty and Interest Rates," *Journal of Post Keynesian Economics*, Vol. 2, No. 2 (Winter 1979-80), pp. 201-211.

3 Even a casual observation of the trade sector, the sector examined empirically in this article, suggests that the main concern of business managers is how large their inventories are relative to their sales. Inventory levels are controlled by two processes: additions to stock of new inventory-goods, and the sale of inventory-goods from stock. Both of these processes are under the control of the business. Sales control is achieved primarily through pricing, such as clearance or stock reduction sales, rebates, and other sales promotions. Businesses cannot control sales as completely as they can additions to stock (through orders), but they can influence sales significantly.

between the actual and the desired inventory-sales ratio, however, recognition is made of the fact that businesses cannot fully control sales.

A first step in putting equation (2) into a form which can be estimated is to specify a functional relationship for the desired inventory-sales ratio, $(I/S)^*_t$. Accordingly, it is assumed that businesses want a higher inventory-sales ratio, (1) the lower the cost of carrying their inventories, (2) the greater the expected growth in sales, and (3) the lower the degree of uncertainty regarding sales.[4] This relationship is presented as,

$$(3)\ (I/S)^*_t = \alpha - \beta \bullet C_t + \gamma(S^e_{t+1} - S_t) - \mu U_t$$

Equation (3) states that the desired inventory-sales ratio in period t, $(I/S)^*_t$, is assumed to be some constant, α, which captures the impact of excluded determinants; minus some fraction, β, of a variable measuring the cost of carrying inventories, C_t; plus some fraction, γ, of the expected growth in sales, as measured by the difference between expected sales in the next period, S^e_{t+1}, and current sales, S_t. The desired inventory-sales ratio is also assumed to be the negative of a fraction, μ, of the uncertainty in sales in period t, denoted by U_t.

The next step in putting equation (2) into estimable form is to combine equations (2) and (3) so as to eliminate the desired ratio term, $(I/S)^*_t$, which is not observable. Replacing $(I/S)^*_t$ in equation (2) with its determinants, which are defined by the right side of equation (3), yields

$$(4)\ (I/S)_t = \alpha - \beta C_t + \gamma(S^e_{t+1} - S_t) - \mu U_t + \sigma(S^e_t - S_t)$$

Equation (4) says that the actual inventory-sales ratio, $(I/S)_t$, will be higher when businesses face lower inventory carrying costs, C_t; when they expect sales in the next period, S^e_{t+1}, to be stronger than sales in the current period, S_t; when they regard future sales with less uncertainty, U_t; and when they are surprised by the extent to which they have overestimated sales in the current period, as given by the difference between expected sales, S^e_t, and actual sales, S_t. The coefficients α, β, γ, μ, and σ are all assumed positive, as in equations (2) and (3).

The final step required to get the inventory-sales ratio model ready for estimation is to define the variables in equation (4), using definitions that permit measurement of these variables. Measuring the expected sales variables, S^e_{t+1} and S^e_t, proves to be a problem, since there are no survey data available on the sales expectations of retailers and wholesalers, the sectors under study. Expected sales are assumed to be a function, therefore, of past sales adjusted for trend.[5] The effect of this assumption is to make next period's expected sales, S^e_{t+1}, dependent on expected

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4 The hypothesis that businesses will want a higher current ratio of inventories to sales when sales growth is expected to accelerate follows from the fundamental rationale for holding inventories. That is, the receipt of goods is not likely to be perfectly synchronized with their (use and) sale, therefore a firm will want to maintain stocks of finished goods in order to facilitate smooth continuous business activity, which is more conducive to profitability. The assumption that a higher desired ratio of inventory to sales accompanies the expectation of an acceleration of sales is also consistent with the idea that businesses will want to plan ahead to compensate for the slower deliveries to them that come with an increased pace of business activity. Conversely, when sales are expected to slow, new orders will be filled more quickly so a lower inventory-sales ratio is required to maintain smooth selling. The hypothesis that the desired inventory-sales ratio depends inversely on the degree of sales uncertainty follows from the current view that business investment is depressed by increased uncertainty. This hypothesis might be considered competitive with the hypothesis that sales uncertainty prompts businesses to add "buffer stocks" of inventories.

5 See the Appendix for a more complete description of how the expected sales variable was constructed.

Table 1
THE VARIABLES IN THE INVENTORY-SALES RATIO MODEL

Variable	
I/S	Inventories in constant dollars divided by sales in constant dollars.
C	The four- to six-month rate on prime commercial paper minus the per cent change from a year earlier in the producer price index for finished consumer goods.
S^e	Expected sales in the current period, where expected sales equal trend sales adjusted for deviations from trend in the previous period. All sales in constant dollars.
S	Actual sales in constant dollars.
U	Uncertainty in sales measured by the volatility of sales around trend.

sales this period, S^e_t. The estimable form of the model, therefore, reduces to equation (5).

$$(5)\ (I/S)_t = a - \beta C_t + \omega S^e_t - \epsilon S_t - \mu U_t$$

Equation (5) says that the inventory-sales ratio will be higher with decreases in inventory carrying costs, with increases in expected sales, with decreases in actual sales, and with decreases in uncertainty. The coefficients ω and ϵ in equation (5) reflect the combined influences of γ and σ from equation (4), as well as a trend factor arising from the assumption that expected sales are defined as past sales adjusted for trend.[6]

The cost variable, C_t, is worthy of special attention, for it is where the interest rate enters. An interest rate adjusted for inflation seems the most appropriate way to include a variable measuring the real financial cost of carrying inventories.[7] The cost variable and the other variables appearing in the estimable form of the inventory-sales ratio model, equation (5), are defined in Table 1.[8]

With the variables of equation (5) now defined in measurable form, the inventory-sales ratio model can be estimated. The results of such empirical estimates are reported in the next section of the article.

APPLICATIONS TO RETAIL AND WHOLESALE TRADE

During the period from 1967 through 1979, the value of the inventory-sales ratio in the retail trade sector has varied from a high of 1.49 during the recession year of 1974, to a post-recession low of 1.32 in 1976 (Chart 1, top). Many ups and downs of significant size occurred within this range, but no trend is evident. The wholesale trade sector has seen its inventory-sales ratio range from 1.17 to 1.34 over this same period (Chart 1, bottom). Again, fluctuations are the rule. Although no continuing trend is evident, it is clear that,

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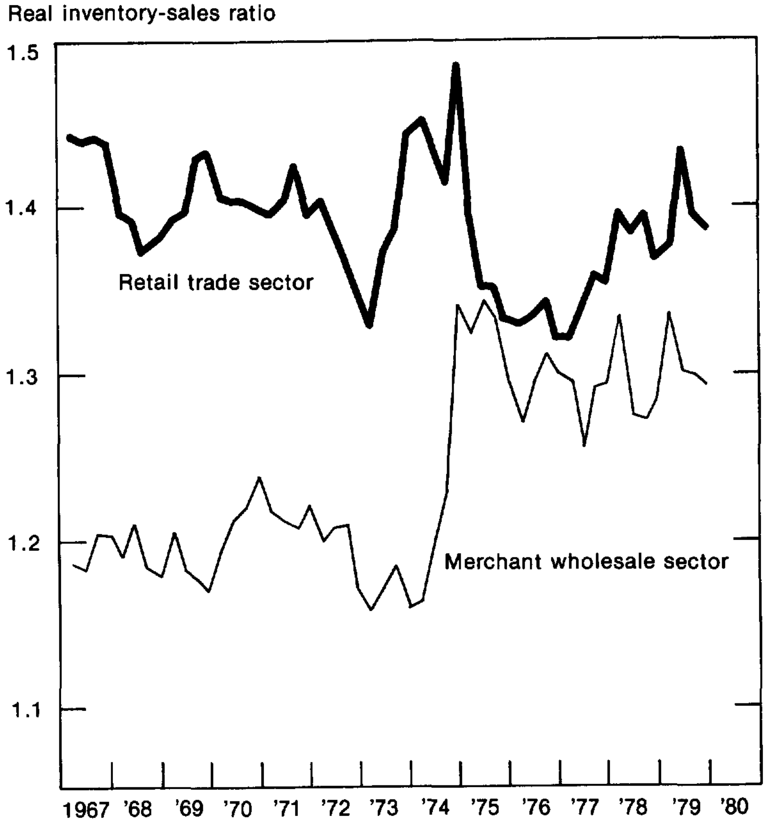
[6] If it is assumed that $S^e_{t+1} = \phi \bullet S^e_t$, where ϕ is some positive constant, the relationships between the actual and expected sales coefficients in (5) and those in (4) are $\omega = \gamma - \sigma$, and $\epsilon = \gamma\phi - \sigma$.

[7] The cost variable, C, does not include the cost of inventory storage and the like. Such costs can be considered reasonably constant in real terms over the period studied, so including them would not affect the results.

[8] For more detailed (mathematical) definitions of the expected sales and uncertainty variables, see the Appendix.

Chart 1
INVENTORY-SALES RATIOS
(1972 Dollars)



since mid-1974, the inventory-sales ratio in wholesale trade has averaged substantially higher than it did during the late 1960s and early 1970s.

Quarterly data covering the period from 1967:IV to 1979:IV were used to estimate the parameters of equation (5) for the retail and the wholesale trade sectors.[9] Aside from defining sales and inventories appropriately to fit the sector studied, the variables in the wholesale trade equation were constructed identically to those in the retail trade equation. The results are summarized in Table 2 and discussed below.

In the retail trade equation, the estimate of the coefficient of the real interest rate, C, is negative and significant. This result supports the hypothesis that the real interest cost of holding inventories does indeed affect the inventory-sales ratio. The coefficient's size implies that for every percentage point change in the rate of interest charged on inventory

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9 Some data series are considered unreliable for periods before 1967.

loans, the retail inventory-sales ratio would move .0041 points in the opposite direction, other things being equal. At the current level of sales, that amount of change in the inventory-sales ratio means that a one percentage point change in the real rate of interest would bring a change in retail inventories of almost $200 million in 1972 dollars. As indicated in Table 2, the results for the real interest rate, C, in the wholesale trade sector are virtually as strong statistically.

The other estimated coefficients can be interpreted in a similar fashion. For example, the coefficient of expected sales, S^e, in the retail equation indicates that by itself, a constant dollar increase of $1 billion of sales expectations would prompt retailers, in the aggregate, to raise their inventory-sales ratio by .017 points. According to the estimate of the coefficient for current retail sales, S, an increase in actual sales of $1 billion in constant dollars by itself draws down the retail inventory-sales ratio by .0216. The dummy variable, DUM, which appears in the wholesale trade equation, captures the apparently permanent jump in the inventory-sales ratio that occurred in the wholesale trade sector early in the recession of 1974-75. The estimation results for the uncertainty variable, U, suggest that firms maintain tighter control over inventories when sales are fluctuating. Specifically, an increase of .01 in the measure of sales volatility would cause the retail inventory-sales ratio to decrease by .00277.

To summarize, the model presented here—which was fit with the inventory-sales ratio as the variable whose fluctuations were to be explained—demonstrates a sensitivity of inventories to interest rates. The estimated coefficients for the real interest rate variable as

Table 2

ESTIMATION RESULTS FOR INVENTORY-SALES RATIO EQUATIONS

Retail Sector

$$I/S = \underset{(22.3)}{1.589} - \underset{(-2.3)}{.4098} \bullet C + \underset{(4.3)}{.0170} \bullet S^e - \underset{(-5.7)}{.0216} \bullet S - \underset{(-3.1)}{.2770} \bullet U$$

corrected R^2 = .55 D.W. = 1.99 Rho = .7593

Estimation period 1967:IV - 1979:IV

Wholesale Sector

$$I/S = \underset{(19.6)}{1.269} - \underset{(-2.2)}{.3615} \bullet C + \underset{(5.7)}{.0215} \bullet S^e - \underset{(-6.5)}{.0227} \bullet S - \underset{(-2.4)}{.2552} \bullet U + \underset{(4.8)}{.0734} \bullet DUM$$

corrected R^2 = .71 D.W. = 1.91 Rho_1 = 1.0955 Rho_2 = -.4921

Estimation period 1967:IV - 1979:IV

$$DUM = \begin{cases} 0, & 1967{:}IV - 1974{:}I \\ 1, & 1974{:}II - 1979{:}IV \end{cases}$$

NOTES: The numbers in parentheses are the t-ratios associated with each coefficient estimate. The retail equation was estimated with a correction for first order serial correlation. The wholesale equation was estimated with a correction for second order serial correlation. The original Durbin-Watson Statistics (D. W.) for the retail and wholesale equations were 0.57 and 1.12, respectively. The R^2's are the multiple correlation coefficients and the Rho's are the serial correlation coefficients.

well as the estimated coefficients for the other variables turned out significant and exhibited the proper signs.[10]

Simulation Experiments

Using the estimated coefficients of the inventory-sales ratio model, inventory investment in the trade sector can also be simulated. Simulation is a process in which the explanatory variables in a relationship are assumed to take on certain values in order to determine what effects these hypothetical values have on the variable under study. Simulations are not forecasts or predictions, although it is common to use them to "look ahead" to see what might happen in response to different economic scenarios.

Three alternative sets of assumptions are made about the behavior of sales, interest rates, and prices in the four quarters of 1980. The results of the simulation experiments clearly imply that inventories are sensitive to interest rates as well as to sales. Chart 2 summarizes the simulation results, which are discussed below.

In the first of the simulation experiments, Case 1, the interest rate on commercial paper is assumed to decline 1.0 percentage point per quarter, while the other variables are assumed to remain at their 1979:IV levels through 1980. The effect of the assumed decline in the interest rate is that the real rate of interest variable falls, exerting upward pressure on the inventory-sales ratio. Chart 2 shows the results of transposing the simulated inventory-sales ratios into changes in the levels of inventories. As can be seen from the first frame of Chart 2, the Case 1 assumptions result in continued accumulation of inventories during 1980. That is, if the rate of interest on inventory loans declines, retailers and wholesalers can be expected to add to their inventories even if sales do not increase.

In Case 2, sales are assumed to decline 1.0 per cent each quarter, while all other variables, including the rate of interest, are assumed to remain constant. The second frame of Chart 2 shows that substantial inventory decumulation (reduction in stocks) would likely accompany a recession (continued decline in sales), other things equal.

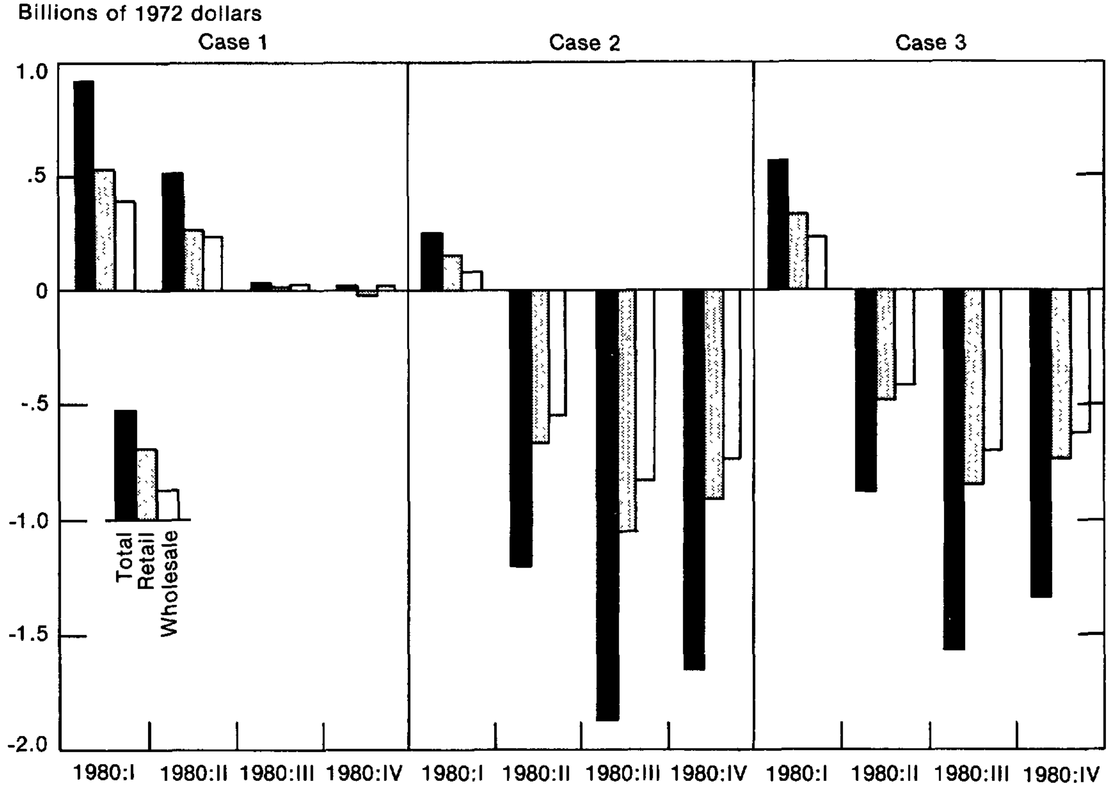
Case 3 combines the assumed decline in the interest rate of Case 1 with the assumed decline in sales of Case 2. The third frame of Chart 2 shows that if a decline in sales is accompanied by a decline in interest rates, the likely decumulation in inventories would be buffered somewhat. Needless to say, a rapid increase in interest rates along with a decline in sales (not shown) would accentuate the likely reduction in inventory levels.

SUMMARY AND CONCLUSIONS

The traditional partial stock-adjustment model has yielded mixed results in explaining inventory fluctuations, particularly with respect to interest rate sensitivity. This article offers an alternative model, together with some encouraging results from its use. The model presented reflects recognition of the fact that sales as well as inventories are partly under the control of firms. The ratio of inventories to sales is chosen, therefore, as the variable that best captures the concept of this joint control.

10 The equations were also estimated with all terms multiplied through by sales, leaving only a variable measuring inventory levels on the left hand side. Estimating this altered form of the equations did not significantly change the values of the estimated coefficients or their standard errors, but it did add considerably to the values of R^2, bringing them up to levels reported in earlier studies. If one is interested in focusing on inventory levels, therefore, and likes the better fit resulting from the introduction of the strong trend relationships between inventory levels and sales levels, the inventory-sales ratio model is easily adapted to those needs.

Chart 2
SIMULATED CHANGES IN TRADE INVENTORIES



Using quarterly data for retailers and for wholesalers, the inventory-sales ratio model produced a significant inverse relationship between inventories and the real rate of interest. That is, when there is a rise in the real rate of interest—the rate of interest adjusted for inflation—then there is a decline in the level of inventories relative to sales; or, looking at movements in the other direction alternatively, when the inflation-adjusted rate of interest declines, businesses increase the quantities of inventories held for any volume of sales. Although the findings must be considered preliminary, they suggest that the sensitivity of inventories to interest rates is economically as well as statistically significant. The empirical evidence gives support to the view that monetary policy does influence inventory investment, the most volatile component of aggregate demand over most business cycles.

Appendix

The inventory-sales ratios used in this study were constructed from U.S. Department of Commerce, Bureau of Economic Analysis data for end-of-quarter, seasonally adjusted inventories in constant 1972 dollars for retail trade and merchant wholesalers, and data on quarterly sales in constant 1972 dollars, seasonally adjusted at monthly rates, of the same retailers and wholesalers.

The variable C, the real cost of carrying inventories, is composed of a nominal interest rate and a measure of inflation. The four- to six-month prime rate on commercial paper is the nominal interest rate used. Although obviously not the rate all businesses pay on inventory loans, the commercial paper rate is probably as good a measure as any to capture changes in commercial loan rates. The other component in the real interest rate variable C, the producer price index for finished consumer goods, is considered appropriate as a measure of the inflation experienced by retailers and wholesalers.

The variable for expected sales, S^e, was constructed by first fitting an exponential trend to actual sales data, S_t,

$$\text{(A.1)} \qquad S_t = \eta\psi^t$$

where η and ψ are the coefficients to be estimated, and where t indexes time. Then the fitted time trend for sales is given by

$$\text{(A.2)} \qquad S_t^T = \hat{\eta}\hat{\psi}^t$$

where S_t^T denotes trend-fitted sales, and where $\hat{\eta}$ and $\hat{\psi}$ are the estimated coefficients for the exponential time trend. In the case of retail trade, for example, $\hat{\eta} = 28.5054$ and $\hat{\psi} = 1.00869$. The second step along the path toward finding values for expected sales was to determine by how much, on the average, actual sales, S_t, differed from trend sales, S_t^T, adjusted for the deviation of sales from trend in previous period, $S_{t-1} - S_{t-1}^T$. This step was accomplished by using linear regression to estimate the coefficient § in equation (A.3).

$$\text{(A.3)} \qquad S_t = S_t^T + \S(S_{t-1} - S_{t-1}^T)$$

Expected sales, S_t^e, were then defined by equation (A.4).

$$\text{(A.4)} \qquad S_t^e = S_t^T + \hat{\S}(S_{t-1} - S_{t-1}^T)$$

where $\hat{\S}$ is the estimated value of the coefficient § in equation (A.3). In the case of retail trade, $\hat{\S} = 0.85$. As it turns out, the expected sales variable closely follows the value of actual sales lagged one period, S_{t-1}, with the growth trend imposed.

The sales uncertainty variable, U_t, was designed to reflect the deviations of sales from trend as well as the volatility of sales. Sales uncertainty in the current period, then, is defined as the sum of the absolute values of the two prior periods' percentage deviations of sales from trend plus the sum of the absolute values of the two prior periods' percentage changes in sales. Sales uncertainty, U_t, is therefore a sum of four absolute values of percentages. Symbolically

$$\text{(A.5)} \quad U_t = \left|(S_{t-1} - S_{t-1}^T)/S_{t-1}^T\right| + \left|(S_{t-2} - S_{t-2}^T)/S_{t-2}^T\right| + \left|(S_{t-1} - S_{t-2})/S_{t-2}\right| + \left|(S_{t-2} - S_{t-3})/S_{t-3}\right|$$