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Inventories and the Business Cycle: An Overview

by Terry J. Fitzgerald

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Introduction

Investment in business inventories has averaged roughly one-half of 1 percent of real GDP in the United States over the post–World War II period. Given its relatively minor role as a component of output, it might seem curious that inventory investment has traditionally drawn a great deal of interest from macroeconomists and policymakers. One reason is that although the level of inventory investment is quite small relative to GDP, fluctuations in inventory investment are not so small relative to the fluctuations in GDP. For example, changes in inventory investment are, on average, more than one-third the size of quarterly changes in real GDP over the postwar period.[1]

Perhaps more strikingly, table 1 shows the peak-to-trough decline in GDP and the associated decline in inventory investment during postwar recessions. The fall in inventory investment for most of these periods is generally substantial relative to the fall in real GDP, and sometimes even exceeds it. Using similar data, Blinder and Maccini (1991a, p. 291) report that "the drop in inventory investment has accounted for 87 percent of the drop in GNP during the average postwar recession in the U.S."

Movements in inventory levels over the business cycle are also closely associated with movements in output during the postwar period, with output leading inventories slightly (see figure 1).[2] Furthermore, changes in inventory holdings are, on average, roughly 60 percent the size of quarterly changes in output.[3]

Such observations about the behavior of inventories over the business cycle, long familiar to economists, have led some to speculate that understanding the reason for inventory fluctuations may provide the key to understanding the

1 Following Christiano (1988), I define the volatility of a variable, say x, as the time average of absolute changes in x, expressed as a percentage of gross output, $v_x \equiv 100 * \frac{1}{T} \sum_{t=1}^{T} \frac{|\Delta x_t|}{y_t}$. From 1947:IQ through 1997:IQ, the ratio of v_{di} to v_y (using the time series for real inventory investment and real GDP) is 0.36.

2 The correlation between the cyclical component of inventories and the cyclical component of output is 0.54 and peaks at 0.83 when output is lagged by two quarters. This lagged response of inventory levels is consistent with the fact that cyclical inventory investment is most highly correlated with contemporaneous cyclical output.

3 Using the measure discussed in footnote 1, the ratio of the volatility of inventory levels to output from 1947:IQ through 1997:IQ is 0.605.

TABLE 1

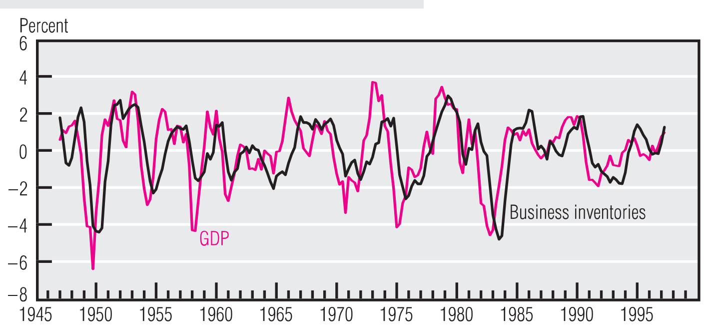
Inventory Investment and Postwar Recessions

GDP Peak to Trough	Change in GDP	Change in Inventory Investment
1948:IVQ–1949:IVQ	–24.4	–33.3
1953:IIQ–1954:IIQ	–48.8	–20.0
1957:IIIQ–1958:IQ	–81.4	–18.4
1960:IQ–1960:IVQ	–40.7	–47.9
1969:IIIQ–1970:IVQ	–20.3	–38.4
1973:IVQ–1975:IQ	–146.2	–77.0
1980:IQ–1980:IIIQ	–116.7	–52.7
1981:IIIQ–1982:IIIQ	–140.9	–43.4
1990:IIQ–1991:IQ	–124.1	–60.7

NOTE: Dates correspond to the largest peak-to-trough decline in GDP associated with each postwar recession. Each date is within one quarter of the quarter containing the peak or trough month as defined by the National Bureau of Economic Research. Data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

FIGURE 1

Deviations from Trend of Real GDP and Inventory Holdings



NOTE: Quarterly data have been logged and detrended using the Hodrick–Prescott filter (λ =1,600). Raw data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

business cycle itself.[4] For example, Blinder (1990, p. viii) states that “business cycles are, to a surprisingly large degree, inventory cycles.”

The present article reviews the literature on the relationship between inventory investment and business cycle fluctuations, focusing on developments over the past 15 years. This literature provides a good example of how theory and data interact in the ongoing process of research, and the discussion will be organized around this interaction.

Beginning in the early 1980s, economists began to point out that the standard theoretical model of inventory behavior, the production smoothing model, was not consistent with key features of U.S. data regarding production, inventories, and sales. This inconsistency led to a sizable body of research showing how to modify the standard model to make it accord better with the empirical observations. At the same time, other researchers were developing alternative models of inventory behavior that could also be consistent with the data.

This literature has been largely motivated by two overriding questions. First, does inventory investment play a key role in amplifying and propagating exogenous shocks to the economy? More than 50 years ago, Metzler (1941) provided a model demonstrating that exogenous, uncorrelated shocks, combined with a certain structure of inventory investment, could produce serially correlated movements in GDP that resemble the business cycle. Much of the subsequent work has been motivated by the desire to know whether the process of adjusting inventory holdings in response to exogenous shocks may help explain the magnitude and persistence of changes in real output growth over the cycle.

The second overriding question is, does inventory behavior illuminate the underlying source of the shocks that give rise to business cycle fluctuations? That is, does the statistical relationship between inventory investment and other economic variables provide information on the nature of the shocks that lead to aggregate fluctuations? The answers to these two questions are particularly important to policymakers because they are likely to provide information on the nature of optimal policies, both fiscal and monetary.

I begin this article by briefly presenting what was considered, at least through the early 1980s, the standard model of inventory behavior—the production smoothing model. Next, I discuss some of this model's empirical predictions and review some facts about inventories that are at odds with the simplest version of the model. I then provide an overview of how economists have responded to the discrepancy between theory and data and examine how the interaction between theory development and data has continued to evolve.

4 Abramovitz (1950) provides early documentation on the importance of inventories in aggregate fluctuations during the interwar period.

This review is intended to introduce readers who are unfamiliar with the literature on inventory behavior and cyclical fluctuations to its central issues and developments. Accordingly, the discussion provides a general background, without the more technical details that underlie the research. Readers interested in these details should consult the references given throughout this article.

I. Theory: A Production Smoothing Model

The production smoothing model has provided the microeconomic foundation for most research on the behavior of inventories over the business cycle. The key assumptions of this model are straightforward: Firms face variable demand for their goods, the cost of production is convex, and goods are storable. Loosely speaking, these assumptions imply that a profit-maximizing firm will have an incentive to use inventories to smooth production through time in the face of fluctuating sales.

In examining how the literature on inventories has evolved, it will be useful to have a simple version of the production smoothing model in hand.[5] Consider an individual firm that produces a single storable good. Let the total sales and the price of its good at each date t be given by S_t and p_t, respectively, where these variables may vary through time. The model is silent as to how sales and prices are determined.[6]

The firm faces the following current-period cost function:

$$(1)\qquad C_t = \gamma_1 Y_t + \gamma_2 Y_t^{\,2} + \gamma_3 I_t^{\,2},$$

where $\gamma_1, \gamma_2 > 0$, $\gamma_3 \geq 0$, Y_t is production during period t, and I_t is the stock of inventories at the end of period t. The first two terms reflect the current costs of production, and the assumption that γ_2 is strictly positive implies that marginal costs are increasing in output. The last term represents the cost of holding inventories (such as handling and storage costs), which is assumed to be an increasing function of inventory holdings.

The link between inventory accumulation, production, and sales is given by

$$(2)\qquad I_t - I_{t-1} = Y_t - S_t,$$

with inventory holdings subject to the nonnegativity constraint

$$(3)\qquad I_t \geq 0.$$

Inventory investment is equal to current output minus current sales. Current sales can be met through current output and previously accumulated inventory holdings.

In this environment, a firm's decision problem is to organize its production schedule through time, given the processes for sales and prices, by choosing output and inventory holdings so as to maximize the expected discounted value of its profits

$$(4)\qquad E_0 \sum_{t=0}^{\infty} \beta^t (p_t S_t - C_t),$$

subject to constraints (1), (2), and (3), where E_0 denotes the expectation conditional on information known at time 0. The parameter β is a discount factor implied by a constant real rate of interest, where $\beta = 1/(1 + r)$, and is between 0 and 1.

Since prices and sales are determined outside the model, this problem can be written more succinctly as the firm choosing production and inventories in a way that minimizes the expected discounted present value of costs

$$(5)\qquad E_0 \sum_{t=0}^{\infty} \beta^t C_t,$$

subject to constraints (1), (2), and (3).

It follows immediately from this setup that the firm will have an incentive to smooth the flow of production through time by holding inventories in order to minimize cost. To state it differently, the variance of output will be lower if firms can accumulate inventories than if they cannot, assuming inventories are sometimes held in the solution to the problem. Given that sales vary through time, inventories will be held by the firm as long as the cost of holding them is not too large, the discount factor β is not too small, and the cost of production is sufficiently convex.

For example, suppose that sales alternated predictably between 1,000 and 2,000 units each period. If the cost of production is linear in output ($\gamma_2 = 0$), then the firm would have no

5 This model is a simple version of the linear quadratic model of optimal inventory behavior introduced by Holt et al. (1960).

6 The firm's decision problem can be thought of as a subproblem in a more general model where a profit-maximizing monopolistic firm also chooses production levels and prices.

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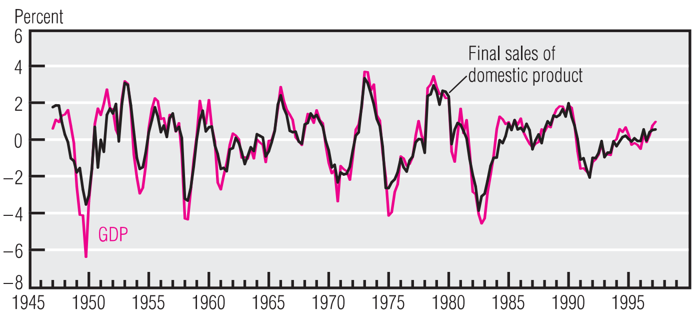
FIGURE 2

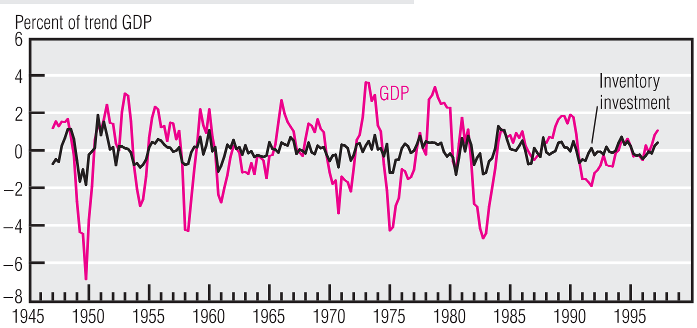
Deviations from Trend of Real GDP and Final Sales of Domestic Product



NOTE: Quarterly data have been logged and detrended using the Hodrick–Prescott filter (λ = 1,600). Raw data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

FIGURE 3

Deviations from Trend of Real GDP and Inventory Investment



NOTE: Because inventory investment is sometimes negative, the levels of the quarterly data have been detrended using the Hodrick–Prescott filter (λ = 1,600), and both series are expressed as a percentage of the trend in GDP. Raw data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

incentive to accumulate inventories, since the marginal cost of production would be the same in all periods. In that case, the firm would simply match output with sales, period by period. If, on the other hand, the cost of production is convex, firms will have an incentive to produce a surplus when sales are low, and to use this surplus to reduce output when sales are high. Consider the case where $\gamma_3 = 0$ and $\beta = 1$.[7] Then, inventories are costless to hold, and the firm minimizes costs by producing 1,500 units each period. This is the basic intuition of production smoothing.

In addition, if sales are stochastic, inventories may also play what is commonly called a buffer-stock role in production. The intuition here is that firms will respond to unexpected increases in sales by reducing inventory holdings and increasing production, with production increasing less than sales. If the firm must make its production decision before observing the sales shock, then the increase in sales will come entirely out of inventories.

II. Inconsistencies between Theory and Data

Two empirical predictions of the production smoothing model follow directly from the discussion above. The first is that the variance of sales exceeds the variance of production. The second is that inventory investment and output move in opposite directions. It is natural to ask (as economists began doing in the early 1980s) how well these predictions accord with the data.

Let's begin our exploration of the facts by looking at aggregate data on inventories, output, and sales. Figure 2 shows postwar data on the cyclical components of real GDP and real final sales of domestic product, defined as GDP minus inventory investment. This figure shows that at the aggregate level, output is *more* variable than sales—just the opposite of what the production smoothing model predicts. The standard deviation of cyclical real GDP over the postwar period is 1.81 percent, compared to 1.44 percent for final sales.

In addition, figure 3 shows that output and inventory investment tend to move in the *same* direction over the business cycle, rather than in opposite directions. In fact, the correlation between cyclical inventory investment and cyclical output is strongly positive (0.57).

The empirical findings that output is more variable than sales and that output and inventory investment are positively correlated have also been found to hold when less aggregated data are used. Papers by Blanchard (1983), Blinder (1981, 1986), Blinder and Maccini (l991a, b), and West (1986) reported that these findings held when industry-level data were used. These results were judged to cast a large shadow over the production smoothing model,

■ 7 Strictly speaking, I am referring to the properties of the solution as β approaches 1.

a view expressed in the title of Blinder's 1986 paper, "Can the Production Smoothing Model of Inventory Behavior Be Saved?"

These empirical findings led to a series of papers seeking to modify the existing theory or to develop other theories that could explain them. The next section will summarize this research. Before proceeding, though, I note several challenges to the finding that production is typically more variable than sales. A number of papers, including Lai (1991), Miron and Zeldes (1989), Fair (1989), Krane and Braun (1991), and Krane (1994), present evidence that this finding, at least for some industries, may result from measurement problems with the data or from aggregation biases. While this research suggests that the empirical findings may not be as striking or as prevalent as earlier work reports, it does not entirely resolve the issue, and I will proceed under the assumption that a basic inconsistency remains between the theory and the data for at least some industries.

III. Theory Responses

I have noted that the discrepancy between the predictions of the standard production smoothing model and the properties of the data led to a new burst of research aimed at reducing the discrepancy. This section provides an overview of several approaches that have been taken, some of which can be viewed as modifications of the production smoothing model. After outlining these strategies, I will briefly discuss some other approaches.

Modifications of the Production Smoothing Model

Modifications of the model in response to the empirical findings can be broadly classified into three groups: adding cost shocks, adding a target inventory level, and adding nonconvexities in technology.

Adding Cost Shocks

One approach to resolving the discrepancy between the theory and the facts (arguably the most obvious one) is to add shocks to the firm's production costs. Cost shocks can be introduced by replacing equation (1) in the production smoothing model with

$$(6) \quad C_t = (\gamma_1 + \tau_t)Y_t + \gamma_2 Y_t^{\,2} + \gamma_3 I_t^{\,2},$$

where τ_t is a shock that varies through time.

Adding cost shocks to the model provides, at least theoretically, a straightforward explanation of the facts. This can be seen most readily in a version of the model with constant sales. In that case, production varies as costs change, with production being high when costs are low (and vice versa), and inventory investment covering the gap between sales and output. Clearly, output will be more variable than sales in this example, and inventory investment will be procyclical. Furthermore, this suggests that a model with both sales and cost shocks may also be consistent with the facts.[8]

Early research that added cost shocks to the production smoothing model included Blanchard (1983), Eichenbaum (1984, 1989), Maccini and Rossana (1984), Blinder (1986), and Christiano and Eichenbaum (1989). Empirical results from these papers were mixed, but generally indicated that cost shocks play an important, if limited, role in explaining inventory behavior. All of these papers invoke unobserved cost shocks to make their point, that is, they do not use cost shocks that are directly measured from data. More recently, West (1990) found that unobserved cost shocks appear to be a dominant source of fluctuations in aggregate inventory holdings, and Kollintzas (1995) reported further evidence that such shocks are an important factor for understanding inventory behavior.

In a separate branch of the literature that developed during the same period, Kydland and Prescott (1982) found that the cyclical fluctuations in aggregate data were surprisingly consistent with a general equilibrium model driven exclusively by unobserved productivity shocks. They introduced inventories as a factor of production and found that cyclical fluctuations in the inventory stock and the correlation of cyclical movement in inventories and output in their model were roughly consistent with the data. Christiano (1988) demonstrated that, by modifying the Kydland–Prescott framework so that inventories buffer unexpected shocks to preferences and technology, the volatility of inventories and the correlation of inventory investment with output could be largely explained. From the viewpoint of this theory, the apparent inconsistency between theory and data discussed in the previous section is not an inconsistency

8 Blinder (1986) argues that highly serially correlated sales shocks combined with relatively small cost shocks can lead the variance of production to exceed the variance of sales.

at all. The patterns in the data are what this theory would predict. Furthermore, the explanation of inventory investment as a residual component contrasts sharply with the prominent role that some economists envisioned for inventories as a central means of propagating exogenous shocks.

While it had become clear that introducing cost shocks could successfully resolve at least some of the discrepancies between theory and data, many economists were troubled by the unobserved nature of the cost shocks. Researchers asked whether the unobserved shocks that were being invoked corresponded to actual, measurable movements in observed price and cost data. Initially, work that attempted to locate the cost shocks in the data was unsuccessful. Miron and Zeldes (1988) found little evidence that observed cost shocks in the form of raw material, energy, and wage prices helped to save the production smoothing model. More recently, Durlauf and Maccini (1995) reported evidence that observed cost shocks in the form of material and energy prices and wage rates do contribute significantly to explaining inventory movement at the industry level. This issue continues to be a subject of active research, but a consensus finding has yet to emerge.

Adding a Target Inventory Level

While adding cost shocks to the production smoothing model provides one possible explanation of the data, other researchers have found that they can explain the facts using only sales (or demand) shocks. A second modification that is capable, at least in theory, of reconciling the model with the data is to assume that firms have a strictly positive inventory-to-sales ratio from which it is costly to deviate, and that shocks to sales are persistent.[9] The assumption of a target inventory level is incorporated into the model by replacing equation (1) with

$$(7) \qquad C_t = \gamma_1 Y_t + \gamma_2 Y_t^{\,2} + \gamma_3 (I_t - \alpha S_t)^2,$$

where $\alpha > 0$. Thus, inventory costs are minimized by setting inventories at a fixed fraction of sales. This assumption is motivated by the observation that the cost of carrying inventories, which increases with inventory holdings, must be balanced against the cost of stocking out or backlogging orders, which falls with inventory holdings.

That the assumption of a target inventory level and persistent sales shocks can make the variance of output exceed the variance of sales was shown by Blanchard (1983) and West (1986), among others. The intuition for this result is as follows: Suppose an unexpected increase in sales occurs in period *t*. Further assume that the firm's production decision is made before the current-period shock is realized. The firm will respond this period by lowering its inventory holdings by the amount of the shock. In the next period, the firm will increase production not only to meet the expected higher level of sales, but also because its target level of inventory holdings has increased along with sales. This creates a so-called accelerator effect, leading production to increase by more than the unexpected increase in sales. Furthermore, it suggests an avenue by which output and inventory investment may be positively correlated.

Kahn (1987) provides a theoretical basis for a target inventory level by explicitly modeling a stockout avoidance motive for inventory accumulation. Maccini and Zabel (1996) extend to a more general environment Kahn's finding that production is more volatile than sales in a stockout avoidance model. Bils and Kahn (1996) have recently put forth a model in which sales are simply assumed to be an increasing function of inventory holdings.

Empirical results in West (1986), Eichenbaum (1989), and Miron and Zeldes (1988) are unfavorable to early specifications of target inventory models. More recently, Kahn (1992) reports that a stockout avoidance motive in the face of fluctuating demand largely suffices to explain inventory behavior in the automobile industry, while Durlauf and Maccini (1995) find that the stockout avoidance motive helps explain inventory behavior, but does not provide a complete solution. This issue is the subject of continuing research.

Adding Nonconvexities in Technology

A third approach to modifying the production smoothing model in order to reconcile it with the data is to assume that the marginal cost of production is decreasing, rather than increasing, over a relevant range of firm output. This amounts to assuming that γ_2 is less than zero in the cost function given by equation (1).

9 Some versions of the model use expected next-period sales instead of current-period sales.

In an output range with decreasing marginal costs, firms would generally lower their costs by producing high output in some periods, resulting in low marginal costs, and less output in other periods, resulting in high marginal costs. Thus, firms would minimize costs by "bunching" rather than "smoothing" production.

Exploring this possibility, Ramey (1991) finds evidence of declining marginal costs in several manufacturing industries. She also demonstrates that decreasing costs imply that the variance of production exceeds the variance of sales in a model with demand shocks only. Looking at the same industries, Durlauf and Maccini (1995) report evidence of rising marginal costs. The prevalence of declining marginal costs remains an open issue.

Another Approach

While some economists were at work modifying the production smoothing model to bring it into line with the data, others were developing alternative approaches to explain inventory behavior.

(S,s) Models

The production smoothing model is often thought to apply most naturally to manufacturers' inventories of finished goods. Most of the empirical work already mentioned looks at precisely these data. Yet, Blinder and Maccini (1991a, b) report that manufacturers' inventories of finished goods account, on average, for less than 15 percent of inventory investment in the manufacturing and trade industries. Furthermore, they find that this component of inventory investment is the least volatile, with the most volatile being retail inventories and manufacturers' inventories of raw materials and supplies. They argue that these facts suggest that a disproportionate emphasis has been placed on manufacturers' finished goods inventories.

An alternative theory of inventory behavior is provided by the so-called (S,s) model, which focuses attention on the timing of deliveries rather than the timing of production. Because it concentrates on deliveries, this model is commonly viewed as a theory of retail inventories and manufacturers' raw materials and supplies.

In an (S,s) model, a firm's decision rule about inventories has the following characteristics: The firm optimally picks some number, *s*, below which it does not let inventories fall. When inventory stocks reach that level, the firm orders a new batch, increasing the stocks to an optimally chosen level, *S*. The quantity *S* minus *s* is referred to as the optimal lot size. The firm orders more inventories only when the stock again falls to *s*.

One assumption that leads to (S,s) inventory behavior is that the cost of acquiring goods includes a fixed cost plus a constant marginal cost. Reinterpreting the cost function in the production smoothing model as the cost of acquiring goods, an (S,s) model firm faces the cost function

$$(8) \quad C_t = \begin{cases} \gamma_0 + \gamma_1 * [I_t - (I_{t-1} - S_t)] & \\ \quad \text{if } I_t > I_{t-1} - S_t \text{ and} & \\ 0 \quad \text{if } I_t = I_{t-1} - S_t, & \end{cases}$$

where γ_0 reflects the fixed cost of placing and processing an order, γ_1 is the constant marginal cost, and S_t is current-period sales.[10] Notice that costs are incurred only when goods are acquired, which is indicated by end-of-period inventories (I_t) exceeding beginning-of-period inventories minus current-period sales ($I_{t-1} - S_t$). Here, the costs of holding inventories are set to zero.

A justification for this cost function is that marginal costs represent shipping costs, which are assumed to be a constant function of the quantity ordered, and ordering a shipment requires paying a fixed cost per order. If relatively large fixed costs exist, firms will order infrequently and will bring in large shipments when they do order (that is, the optimal lot size, *S* – *s*, will be large).

The intuition as to why the variance of shipments (production) can exceed the variance of sales in this setup is clearly illustrated when sales are constant. In that case, shipments will alternate between zero and the optimal lot size, while sales will not vary. This suggests that shipments may also vary more than sales when sales are not constant, at least in cases where the variance of sales is not too large.

Comparing the properties of aggregated data at the industry- or economywide level with the predictions of an (S,s) model is greatly complicated by the difficulties associated with aggregating across firms. There is no representative firm in this model. Instead, one must keep track of the distribution of inventory holdings across firms, since firms will behave differently in response to shocks, depending on their inventory holdings.

10 Scarf (1960) showed that the (S,s) behavior of inventories is optimal given this cost structure.

Early work examining the implications of (S,s) inventory behavior in partial equilibrium models includes Blinder (1981) and Caplin (1985), who provide evidence that (S,s) models are consistent with the facts discussed in section II. Caballero and Engel (1991) present a more sophisticated framework for exploring the aggregate dynamics of (S,s) inventory behavior.

The recent work of Fisher and Hornstein (1997) develops a dynamic general-equilibrium framework with a retail sector in which the aggregate implication of (S,s) inventory policies can be studied. Their model economy replicates salient features of the business cycle and is consistent with the data observations in section II. In addition, they are able to examine quantitatively the effect of (S,s) policies on business cycle shocks. They find that the policies have little effect on the propagation and amplification of productivity disturbances, but contribute substantially to the amplification of a type of demand shock.[11]

Other Research

While the approaches already discussed broadly characterize the bulk of research on the cyclical behavior of inventories, several alternative theories have been developed. Bental and Eden (1993) present a general equilibrium model of sequential trade in which buyers for a product arrive in batches. Demand uncertainty arises from uncertainty about whether a batch will show up for a given product. Inventories accumulate whenever a batch does not arrive. The authors show that this approach provides, at least theoretically, a model that is consistent with the empirical observations discussed earlier. While the specifics of the model differ substantially from the work of Kahn (1987, 1992), this paper can be viewed as providing an alternative theoretical basis for target inventory behavior.

Kashyap, Lamont, and Stein (1994) argue that financial constraints may play a crucial role in understanding inventory behavior during recessions associated with restrictive monetary policy. They find that the inventory investment of firms with no access to public bond markets was significantly liquidity constrained during 1974–75 and 1981–82, recessions in which restrictive monetary policy is thought to have played a large role. They report some evidence suggesting that financial constraints may explain a substantial fraction of inventory movements during these downturns.

Other approaches may also help increase our understanding of inventory behavior. Haltiwanger and Maccini (1990) show that allowing multiperiod labor contracts and a distinction between temporary and permanent adjustments to the workforce can bring theory more into line with the data. Rotemberg and Saloner (1989) demonstrate that strategic behavior by duopolists leads them to accumulate inventories when demand is high so as to deter cheating from an implicitly collusive arrangement. This strategy results in a positive correlation between inventories and sales.

IV. Data Responses

The basic production smoothing model may be inconsistent with certain properties of the data, but we have seen that there are a handful of modifications that may, at least in theory, resolve this inconsistency. To the extent that the alternative models which underlie these explanations have different implications for the two overriding questions posed in the introduction—Does inventory investment play a key role in the amplification and propagation of shocks? What does inventory behavior tell us about the underlying source of the shocks?—it is important to know how much each of these explanations contributes to reconciling theory with the data. This is a quantitative issue.

One procedure to separate out the more plausible alternatives is to compare their predictions with a broader set of facts that characterize the relationship between inventories and variables at the aggregate and industry levels. For example, which alternatives are consistent with the behavior of inventory-to-sales ratios? More generally, since we are ultimately interested in the aggregate implications of inventory behavior, which alternatives are consistent with the aggregate behavior of output, inventories, investment, consumption, and productivity?

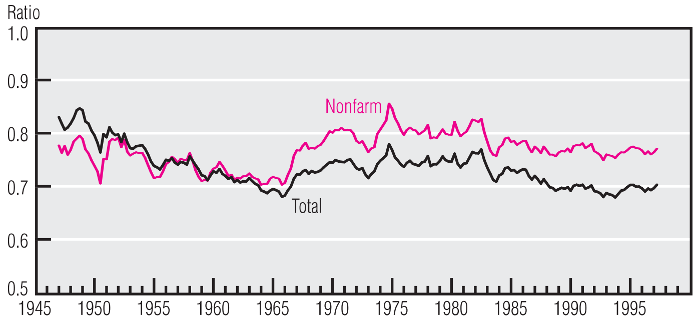
Figure 4 shows that the ratio of inventories to final sales of domestic product declined from the late 1940s through the mid-1960s and has leveled off since then.[12] The ratio of nonfarm inventories to final sales of nonfarm business has shown no decline over this period. This may surprise some, given the extensive reporting in recent years on changes in inventory management practices, such as just-in-time and

11 The authors consider discount rate shocks.

12 The ratio of inventories to final sales of domestic business displays a similar pattern, except that it has fallen relatively more over the past 15 years.

FIGURE 4

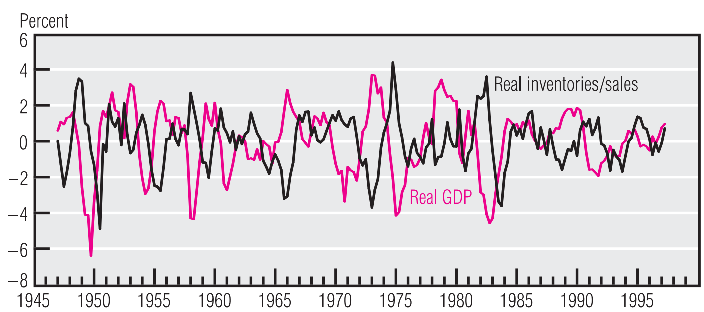
Inventory-to-Sales Ratios



NOTE: *Total* represents total business inventories divided by final sales of domestic product. *Nonfarm* represents nonfarm business inventories divided by final sales of nonfarm domestic business, which is defined as final sales of domestic product less gross product of households and institutions, general government, and farm business. Final sales are at a quarterly rate. Raw data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

FIGURE 5

Deviations from Trend of Real GDP and Inventory-to-Sales Ratio



NOTE: Quarterly data have been logged and detrended using the Hodrick–Prescott filter (λ = 1,600). Raw data are in billions of chained 1992 dollars.
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

lean production strategies. Figure 5 shows that the ratio of inventories to final sales is countercyclical. The correlation between the cyclical component of this ratio and output is –0.34. An obvious question is, which alternative theories are consistent with these observations on the trend and cyclical behavior of inventory-to-sales ratios?[13]

In addition, it has been shown that different components of inventories behave in substantially different ways over the business cycle. Work by Reagan and Sheehan (1985) and Blinder and Maccini (1991a, b) describes some of these differences. Their findings lead one to ask whether understanding the differences in the behavior of inventory components is crucial for understanding the implications of inventory behavior for business cycle fluctuations.[14]

V. Will Theory Respond?

Given that the issues of interest are the macroeconomic implications of inventory behavior, general equilibrium models of inventory behavior are essential tools. Furthermore, general equilibrium models allow the predictions of alternative inventory models to be compared across a broader set of relevant facts, such as those commonly used in the equilibrium business-cycle literature (see Cooley [1995, table 1.1]).

At this time, however, many of the alternative inventory theories have been offered only in partial equilibrium contexts. Although these models provide possible explanations of industry- and plant-level data, they are of limited use in analyzing the economywide implications of inventory behavior.

Exceptions to this shortcoming include the general equilibrium business-cycle theory put forth by Kydland and Prescott (1982) and modified by Christiano (1988) and a host of others, who model inventories as a factor of production. Fisher and Hornstein (1997) have taken a first step in embedding (S,s) inventory behavior in a general equilibrium framework and analyzing its aggregate implications. Bental and Eden (1993) develop an alternative approach with sequential trade. Other general equilibrium studies of inventory behavior include Christiano and Fitzgerald (1989) and Chatterjee and Ravikumar (1993).

The next step in evaluating the quantitative significance and implications of other inventory theories is to embed those theories in general equilibrium frameworks, so that their aggregate quantitative implications can be compared with data and with other models.

13 Bils and Kahn (1996) argue that the countercyclical behavior of the inventory-to-sales ratio poses a major puzzle to business cycle theories that rely on productivity shocks as the source of uncertainty. They also argue that this behavior supports their own model, in which sales are assumed to be an increasing function of inventories and are subject to stochastic demand shocks.

14 Recent research by Humphreys, Maccini, and Schuh (1997) takes a step toward incorporating input inventories (materials and works in process) and finished goods inventories separately in an otherwise standard inventory framework.

VI. Concluding Remarks

Prior to the 1980s, the predominant view of the business cycle was that fluctuations were driven by demand shocks, which were conceived of as aggregate disturbances to components such as consumer durables and investment. This view was commonly part of a broader vision in which business cycle fluctuations were considered inefficient; therefore, it was thought, they should be actively mitigated by the central government (one possible interpretation of sunspot models is that they provide a modern formalization of this perspective). This vision generated a vast body of research on ways the government could intervene to improve the economy's performance.

Data on inventory behavior over the business cycle initially seemed to pose a serious challenge to the demand-shock view, since they appeared to show that cost or technology shocks, originating on the production side of the economy, were the major source of economic disturbances. A broader vision of many proponents of the cost-shock view of business cycle fluctuations was that the economy reacted efficiently to such shocks (the modern formalization of this vision appears in real business cycle models). This vision carried with it the notion that government attempts to improve the performance of the economy would frequently be counterproductive.

The facts about inventory investment brought the conflict between the demand- and cost-shock views of business cycle fluctuations into sharp focus. While the initial impression was that the evidence supported the cost-shock view and conflicted with the demand-shock view, demand-shock proponents responded with revised theories of inventory investment that were consistent with empirical observations. Advocates of the cost-shock view had little need to revise their theory, since it was consistent with the inventory observations from the beginning.

The underlying source of the shocks that drive business cycle fluctuations continues to be a matter of considerable debate. The next step in advancing this debate is to formulate general equilibrium models that allow us to explore the broader implications of the two views. The real business-cycle literature supplies one set of such models. Research on inventory behavior, which provides one of many avenues for this exploration, is currently in progress.

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