Inventories and the Structure of Macro Models

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The message of this paper can be summed up in two words: *inventories matter*. They matter empirically, in the sense that inventory developments are of major importance in the propagation of business cycles; and they matter theoretically, in the sense that recognition of their existence changes the structure of a variety of theoretical macro models in some fairly important ways. This paper is mainly about the implications of inventories for the structure of theoretical macro models, but I begin by demonstrating the empirical importance of inventories in business fluctuations.

I. The Importance of Inventories in Business Cycles

Inventory investment is a tiny component of *GNP*, averaging only about 1 percent of the total, but its importance in business fluctuations is totally out of proportion to its size. As Table 1 shows, inventory investment typically accounts for about 70 percent of the peak-to-trough decline in real *GNP* during recessions.

Of course, recessions are rather special episodes. To get a broader perspective, note that real *GNP* (Y_t) is the sum of real final sales (X_t) and real inventory investment (ΔN_t, where N_t is the stock of inventories). After detrending each series and first differencing, we have $\Delta y_t = \Delta x_t + \Delta^2 n_t$, where lower case letters denote deviations from trend. It follows that the variance of changes in the deviations of *GNP* from trend can be decomposed as follows:

$$\underset{90.4}{Var(\Delta y)} = \underset{59.1}{Var(\Delta x)} + \underset{33.4}{Var(\Delta^2 n)} + \underset{-1.8}{2\,cov(\Delta x, \Delta^2 n)}$$

where the empirical magnitudes for the United States during 1959:1–1979:4 appear below each symbol. Changes in inventory investment account for 37 percent of the variance of changes in *GNP*. The importance of inventory fluctuations is not limited to cyclical downturns.

What types of inventories predominate in these inventory fluctuations? For the period 1959–76, unpublished quarterly data from the Bureau of Economic Analysis enable us to break down real nonfarm inventories into the six components listed in Table 2. The table shows that the predominant type of inventories accounting for variation in $\Delta^2 n$ are retail inventories, followed by manufacturers' inventories of raw materials and wholesalers inventories. Neither manufacturers' finished goods nor works in progress contribute much to the variance of $\Delta^2 n$. Note also in Table 2 that the correlations between Δx and the components of $\Delta^2 n$ are all pretty meager.

II. Microfoundations

The standard theory of the firm is based on nonstorable output. When output is storable, however, firms have an additional degree of freedom: they are able to make current production Y_t differ from current sales X_t, and often will find it advisable to do so. They may use inventories of finished goods to speculate on future price movements or to absorb short-run shocks to de-

*Princeton University and National Bureau of Economic Research. I thank the National Science Foundation for research support and David Ashmore for research assistance. A slightly longer version is available as National Bureau of Economic Research Working Paper No. 515.

TABLE 1—CHANGES IN *GNP* AND IN INVENTORY INVESTMENT IN THE POSTWAR RECESSIONS

Dates of Contraction Peak	Dates of Contraction Trough	Decline in Real *GNP*[a]	Decline in Inventory Investment[a]	Col. (3) as a Percentage of Col. (2)
(1)		(2)	(3)	(4)
1948:4	1949:4	$ 6.7	$13.0	194
1953:2	1954:2	20.6	10.2	50
1957:3	1958:1	22.2	10.5	47
1960:1	1960:4	8.8	10.5	119
1969:3	1970:4	12.0	10.1	84
1973:4	1975:1	71.0	44.8	63

Source: *The National Income and Product Accounts of the United States*, 1929-74, and *Survey of Current Business*.
[a] In billions of 1972 dollars.

TABLE 2—DECOMPOSITION OF THE VARIANCE OF $\Delta^2 n$, 1959:1–1976:4

Inventory Component	Variance	Percent of Total Variance	Correlation with Δx
Total Inventories ($\Delta^2 n$)	40.40	100	−.02
Manufacturer's Inventories:			
Finished Goods	2.15	5.3	−.05
Works in Progress	2.45	6.1	+.25
Materials and Supplies	5.20	12.9	−.09
Wholesale Inventories	4.77	11.8	−.07
Retail Inventories	14.18	35.1	+.18
Other[a]	4.13	10.2	−.11
All Covariance Terms	7.27	18.0	– –

[a] Includes other nonfarm inventories plus statistical discrepancies that arise because the disaggregated components of manufacturers' inventories have not been revised while the total has been revised.

mand; they may use inventories of raw materials to hedge against future price increases. Inventory holdings may be used to spur demand (by reducing delivery lags) or to reduce production costs (through improved scheduling).[1]

The first point is fairly obvious: the existence of inventories requires a new concept of market equilibrium. Since it may well be optimal for firms to set $Y_t \neq X_t$, there is no reason to think that "equilibrium" means that the market "clears" in the usual sense ($X_t = Y_t$). Instead, an appropriate definition of equilibrium seems to be a situation in which the quantity that suppliers desire to sell equals the quantity that customers desire to buy. Note that Y_t is not even involved in this definition: it can, in principle, be anything.

The second point is that profit maximization probably dictates that the beginning-of-period inventory stock N_t affects firms' decisions. Specifically, I wish to argue that output, sales, and inventory carryover depend on N_t as follows:

$$\text{(1a)} \quad Y_t = Y(N_t) \qquad -1 < Y'(\cdot) < 0$$

$$\text{(1b)} \quad X_t = X(N_t) \qquad 0 < X'(\cdot) < 1$$

$$\text{(1c)} \quad N_{t+1} = F(N_t) \qquad 0 < F'(\cdot) < 1$$

These equations have several obvious macro implications, and one that is not so

[1] The theoretical analysis of this paper pertains exclusively to inventories of finished goods. Different analyses would be necessary for inventories of inputs and works in progress.

obvious. Equation (1a) implies that models of aggregate supply—such as the celebrated Lucas supply function— should allow production to depend on inventory stocks. Equation (1b) implies (via the law of demand), that higher inventories lead to lower prices. Taken together, (1a) and (1b) imply that *GNP* and final sales may sometimes exhibit rather divergent behavior during short-run business fluctuations. Equation (1c) suggests that inventory investment equations should have a "partial adjustment" form, even in the absence of explicit costs of changing either production or inventory levels.

While it is possible to derive results like (1) rigorously in the context of specific micro models, I prefer to rely on an intuitive argument because it suggests that the equations are much more general than any specific model. The basic idea can be explained with the aid of Figure 1, which depicts (as point C) the equilibrium of the textbook firm with nonstorable output: optimal production (=sales) is determined by equating marginal revenue (MR) to marginal cost (MC). But when output is storable, the firm must operate simultaneously on *two* margins. To decide how many inputs to turn into inventories, it equates MC to the shadow value of inventories, which I call λ (point B). To decide how many inventories to withdraw for sale, it equates λ to MR (point A). Obviously, these separate decisions need not lead to $X=Y$.

The implications of equations (1) follow from Figure 1. So long as MC is an increasing function of Y and λ is a decreasing function of N,[2] it is clear that Y is a decreasing function of N, in accord with (1a). Similarly, so long as MR decreases with X, it is clear that X is an increasing function of N, in accord with (1b). Rising marginal costs also imply that it is optimal to rectify inventory imbalances gradually, in accord with (1c).

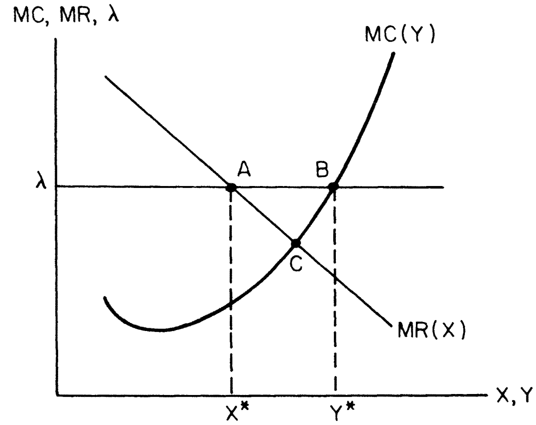

FIGURE 1

I now come to my third point, which is the nonobvious implication of (1): as compared to a world with nonstorable output, prices become "sticky" when output is storable.[3] The reason, of course, is the buffer-stock role of inventories. When there is a temporary surge in demand, the necessary price increase is moderated by the fact that firms disgorge inventories. In terms of Figure 1, the shadow value of inventories λ should be relatively insensitive to transitory shifts in demand (or cost) because it depends on *all* future demand and cost functions. Consequently, a shift in the MR schedule induces a larger sales response (a smaller price response) when output is storable than when it is not.

I close this section on microfoundations with a (loosely stated) general proposition about price rigidity that is prompted by these remarks:[4] Prices are more "rigid," that is, respond less to demand shocks, when the costs of varying inventory levels are lower and when demand shocks are less persistent.

The following sections use these microfoundations to develop the implications of inventories for the specification and logical structure of a variety of macro models.

[2]This negative relationship between inventories and their shadow value is slightly more subtle than might be expected. Under perfect competition, the shadow value of inventories can never diverge from the market price because firms can always sell *or buy* unlimited quantities at the going price. I therefore assume differentiated products with downward-sloping demand curves. For further details, see my 1978 paper.

[3]This implication is brought out by Louis Phlips, P. Reagan, and Y. Amihud and H. Mendelson.

[4]A more precise statement and a proof can be found in my 1980b paper.

III. Inventories and Old-Fashioned Keynesian Models

By including the stock of inventories in standard, old-fashioned Keynesian models, we simultaneously rid them of a serious logical flaw and of what is sometimes considered their most distressing empirical prediction—that real wages move countercyclically.

The logical flaw is quite general, but I will illustrate it with the simplest possible fixed-price model. The question is: what forces drive the economy toward an equilibrium where $Y=C+I+G$? A perfectly coherent answer is provided in most elementary textbooks. If Y, for example, exceeds $C+I+G$, inventories begin piling up, and this inventory disequilibrium signals firms to cut production. The problem is that this intuitive answer tends to get lost when models are formalized and mathematized. For example, a typical adjustment mechanism is (see, for example, Paul Samuelson, pp. 276–283):

$$\dot{Y}=\beta(X-Y), \quad \beta>0$$

where X is final sales. This tacitly defines equilibrium as any state in which inventories are *constant* ($X=Y$), regardless of the *level* of inventories—in stark contradiction to the intuitive story just related. In my 1977 article, I explore this problem and suggest a resolution based on (1a) which makes the planned level of production (not the change) depend on the level of inventories (not the change).

When this basic idea is embodied in a full-fledged Keynesian model with an endogenous price level (see my 1980a paper), a number of interesting results emerge. These may be listed briefly:

1) Instead of the countercyclical behavior of real wages predicted by standard Keynesian models, search-theoretic models, and "new classical" models with rational expectations, the Keynesian model with inventories predicts that real wages move procyclically. The reason is that inventory fluctuations cause the demand curve for labor to shift along a stable labor supply function during business fluctuations.

2) The dynamic adjustment path following an increase in aggregate demand includes a period during which inflation is accelerating while output is falling. Thus inventory adjustments offer yet another instance of stagflation of the "overshooting" variety.

3) The association between inventories and output is *countercyclical* in the very short run, but predominately *procyclical* over business fluctuations.

IV. Inventories and "Disequilibrium" Models

The existence of inventories has profound implications for the recent wave of so-called (and badly misnamed) "disequilibrium" macro models. Indeed, I would go so far as to say that it robs them of much of their interest.

Among the fundamental notions of these models are the "min condition" of voluntary exchange and the concept of "spillovers" from one market to another. But the existence of inventories undermines both of these. For example, in simple disequilibrium models such as Barro-Grossman, a firm facing a sales constraint due to a non-market-clearing price sells *and produces* the minimum of its notional supply and the constraint itself. If the constraint is binding, therefore, it cuts back on production, and hence on employment. So excess supply in the good market "spills over" into the labor market.

Now suppose that output is storable, so that production and sales can diverge. A firm confronted with a short-run sales constraint may find it optimal to produce more than it can sell, adding the unsold balance to its inventories. So output is not the minimum of "notional" supply and sales. To the extent that firms provide *more* than the "min condition" dictates, any spillover of excess supply of goods into excess supply of labor is curtailed. Thus inventories provide a buffer stock—or, as Axel Leijonhufvud put it, a "corridor" that limits the applicability of standard disequilibrium analysis to instances of truly severe shocks.

Recognition of the buffer-stock role of inventories also gets rid of the most embarrassing empirical prediction of the

Barro-Grossman model. Under conditions of excess demand in the goods market, Barro-Grossman workers, unable to purchase all the goods they want, curtail their supply of labor. Thus excess demand for goods spills over into excess demand for labor. Via this mechanism, an increase in aggregate demand, starting from a position of equilibrium, will actually *reduce* output. With buffer stocks of inventories, of course, only very extreme demand shocks will render workers unable to buy the goods they want. As long as we remain in Leijonhufvud's corridor, increases in aggregate demand increase output regardless of whether the economy is initially in a state of equilibrium, of excess demand, or of excess supply (see my 1980a paper).

V. Inventories and "New Classical" Models

Recent developments in macro theory have been dominated by the new classical models. The basic ingredients of these models are continuously clearing markets, rational expectations, and some variant of the Lucas supply function:

$$(2) \qquad Y_t = K_t + \gamma(p_t - {}_{t-1}p_t) + e_t$$

where p_t is (the *log* of) the price level, ${}_{t-1}p_t$ is its expectation formulated at time $t-1$, and e_t is a white noise disturbance. Such models do not exhibit serially correlated output disturbances unless we assume some sort of adjustment costs or accelerator mechanism for the capital stock, and they imply that fully anticipated monetary policy has no real effects.

I think it fair to say that these models have not paid much attention to the fact that many outputs are storable. Consider what happens if we maintain the assumption of continuous market clearance, but replace (2) by a supply function augmented along the lines of the microfoundations suggested in Section II:[5]

$$(3) \quad Y_t = K_t + \gamma(p_t - {}_{t-1}p_t) + \lambda(N^*_{t+1} - N_t) + e_t, \; 0 < \lambda < 1$$

where N^*_{t+1} connotes the desired level of inventories. Note that (3) obeys the principal implication of (1a). Similarly, assume that in accord with (1c):

$$(4) \quad N_{t+1} - N_t = \theta(N^*_{t+1} - N_t) - \phi(p_t - {}_{t-1}p_t) + v_t, \; 0 < \theta < 1$$

In this model, it is easy to see that unanticipated price-level shocks give rise to serially correlated output disturbances. A positive price surprise of one unit initially raises output by γ and reduces inventories by ϕ. If there are no further shocks, the resulting inventory shortage will be corrected gradually according to the adjustment parameter θ; and so long as inventories remain below N^* output will remain above its full-information (natural) level.

Anticipated monetary policy will have real effects *if* desired inventories are sensitive to real interest rates *and* real interest rates are sensitive to anticipated changes in money.

In addition to these theoretical propositions, (3) and (4) have implications for empirical work on the effects of unanticipated money. According to the model, the lagged effects of unanticipated money on output that Robert Barro has found are entirely due to inventory (and unfilled orders) discrepancies caused by past unanticipated money. Empirical evidence on this implication is mixed. (See William Haraf, Steven Sheffrin, and Robert Gordon.)

Finally, consider the possibility that markets do not clear because prices are "sticky" in some sense. A well-known paper by Bennett McCallum pointed out that some types of price rigidity leave intact the characteristic prediction of new classical models that only unanticipated money has real effects. However, R. Frydman has criticized McCallum's model for foundering on the logical pitfall mentioned at the start of Section III: it fails to take account of the effects of inventories on production decisions (in accord with (1a)). Frydman shows that a more appropriate treatment of inventories (along the lines of (3)) leads to the conclusion that anticipated monetary policy has real effects when prices are sticky.

[5]The following paragraphs summarize the findings of my forthcoming article with Stanley Fischer.

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