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INVENTORIES AND THE STRUCTURE OF MACRO MODELS

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ABSTRACT

This short paper briefly documents the empirical importance of inventory movements in business cycles, and then reviews some of the implications of inventories and storable output for theoretical models. Attention is paid, first, to the effects of inventories on the micro-foundations of macroeconomics, and then to the implications of inventories for the workings of macro models. Models of the "old-fashioned Keynesian," "disequilibrium," and "new classical" schools are considered, and it is shown that adding inventories changes each in important ways.

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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. While most of this paper is about the implications of inventories for the structure of theoretical macro models, I think it important to begin by making the case for the empirical importance of inventories in business fluctuations.

1. The Importance of Inventories in Business Cycles

Inventory investment is a tiny component of GNP, averaging only about 1% of the total. Yet inventory investment assumes an importance in business fluctuations totally out of proportion to its size. As Table 1 shows, inventory investment typically has accounted for about 70% of the peak-to-trough decline in real GNP during postwar 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:[1]

$$\Delta y_t = \Delta x_t + \Delta^2 n_t ,$$

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:[2]

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

where the empirical magnitudes for the U.S. during the 1959-1979 period appear below each symbol. The variance of changes in inventory investment account for 37% of the variance of changes in GNP.[3] In other words, 1% of GNP accounts for 37% of its variance. The importance of inventory fluctuations is not limited to cyclical downturns.

What types of inventories predominate in these inventory fluctuations? For the period 1959-1976, 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 $\Delta^2 n$ was retailer inventories, followed by manufacturers' inventories of raw materials and wholesalers inventories.[4] Neither manufacturers' finished goods nor works in progress contribute much to the variance of $\Delta^2 n$. We note also in Table 2 that the correlations between Δx and the components of $\Delta^2 n$ are all pretty meager. It thus seems fair to say that, at least where fluctuations in Δy are concerned, finished goods inventories are the major source of variation, but that manufacturers' finished goods inventories are of minor importance.

2. 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 can make current production, Y_t, differ from current sales, X_t. It will not be considered earth-shattering to suggest that firms often find it advisable to use this ability. They may use inventories of finished goods to speculate on future price movements or to absorb short-run shocks to demand; 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).[5]

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, be an argument of firms' behavior functions. More specifically, I wish to argue that output, sales, and inventory carryover depend on N_t as follows:

(1a) $Y_t = Y(N_t), \quad -1 < Y'(\cdot) < 0$

(1b) $X_t = X(N_t), \quad 0 < X'(\cdot) < 1$

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

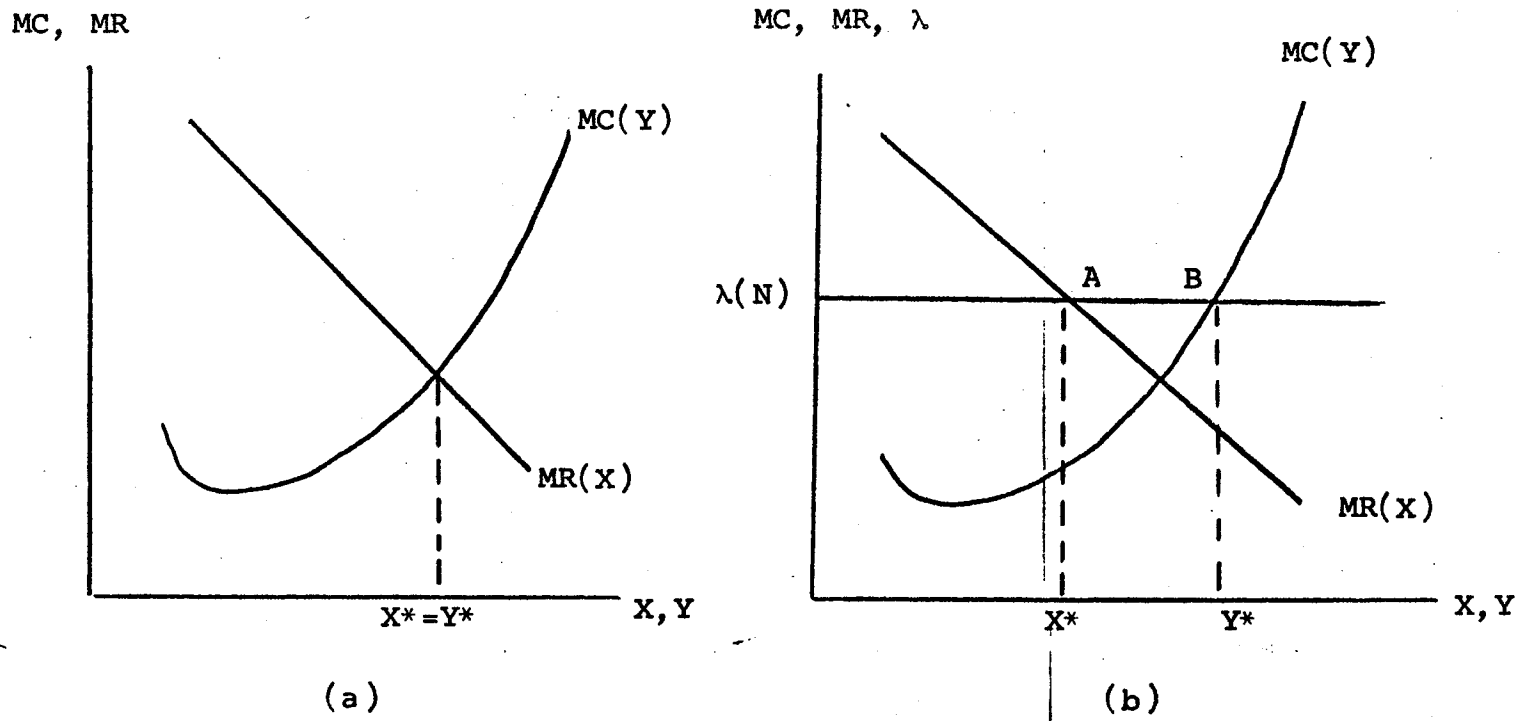

Figure 1

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

3. Inventories and Old-fashioned Keynesian Models

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

The logical flaw is in fact quite general, but I will illustrate it in the context of 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 many elementary textbooks. If Y, for example, exceeds C + I + G, inventories begin piling up, and this inventory disequilibrium serves as a signal to 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, Samuelson (1947), pp. 276-283):

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

where X is final sales. This tacitly defines equilibrium as any state in which inventories are <u>constant</u> (X=Y), regardless of the <u>level</u> of inventories--in stark contradiction to the

4. 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 most fundamental notions of these models are the "min condition" of voluntary exchange and the concept of "spillover effects" from one market to another. But the existence of inventories undermines both of these. For example, in simple disequilibrium models such as Barro-Grossman (1976), a firm facing a sales constraint due to a non-market-clearing price sells and produces the minimum of the quantity it would produce in the absence of any constraint, and the constraint itself. If the constraint is binding, therefore, it cuts back on production, and hence on employment. These layoffs cause excess supply in the goods market to "spill 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 well 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" output and actual 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.[13] Thus inventories provide a buffer stock--or, as Leijonhufvud (1973) put it, a "corridor"--that limits the applicability of standard disequilibrium analysis to instances of truly severe shocks.

noise disturbance. Such models do not exhibit business cycles (i.e. serially correlated output disturbances) unless we assume some sort of adjustment costs (Sargent, 1979, Ch. 16) or accelerator mechanism for the capital stock (Lucas, 1975),[14] and they imply that fully anticipated monetary policy has no real effect.

I think it fair to say that these models have not paid much attention to the fact that many outputs are storable.[15] Consider first 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 2:[16]

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

where N^*_{t+1} connotes the desired level of inventories. Note that with $0 < \lambda < 1$, (3) obeys the principal implication of (1a). Similarly, assume that in accord with (1c):

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

with $0 < \Theta < 1$.[17] In this model, it is easy to see that unanticipated price-level shocks give rise to serially-correlated output disturbances. Suppose N^* is constant. A positive price surprise of one unit initially raises output by γ and reduces inventories to $N^* - \phi$. 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.

6. Conclusion

Since this whole paper is a summary, it seems unnecessary to summarize its conclusions. There are both persuasive empirical and theoretical reasons to suspect that inventory developments play a major role in the propagation of fluctuations in economic activity. Improving our understanding of inventory movements should therefore be high on the research agenda of empirical macroeconomics.

[8]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 Blinder (1978).

[9]This implication is mentioned in passing by Zabel (1972) and brought out by Phlips (1980), Reagan (1980), and Amihud and Mendelson (1980).

[10]A more precise statement and a proof can be found in Blinder (1980c).

[11]The model in Blinder (1980a) treats inflationary expectations as adaptive. In Blinder (1980b), I show that the implications of the model are unchanged by adopting instead an extreme form of rational expectations--perfect foresight. Maccini's (1976) model has similar implications.

[12]The wording here suggests that the procyclical behavior of real wages depends on the assumption that the labor market clears continuously. However, it is shown in Blinder (1980a) that a version of the same result emerges in a non-clearing labor market of the Barro-Grossman (1976) variety.

[13]This is recognized in a recent paper by Green and Laffont (1980) who, however, take a more sanguine view of its implications for disequilibrium theory.

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