

Inventory Investment, Goods  
Output, and Price

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## Inventory Investment, Goods Output, and Price\*

This paper presents and estimates a monetarist model of the business cycle with price-setting firms. The properties of the model are illustrated by simulations using the point estimates of the model.

Five properties of the estimated model deserve special attention. The real goods market is found to be stable even though subject to sharp changes in output. Secondly, a procyclical interest rate is explained by a second transmission mechanism, not by anticipated inflation. Although this model is consistent with rational expectations, monetary policy can have a lasting impact, and the simulations show this to be the case. Fiscal policy too is found to influence the business cycle, but in the simulations its short-run effects are substantially smaller than its impact effects. Lastly, the model suggests that prices do not adjust in the short run because output does adjust; the reverse of the usually assumed causal flow. These properties are discussed in greater detail in the following paragraphs.

Inventory investment is the most volatile major component of GNP. As such it is of concern to forecasters. There are, however, additional reasons for the attention paid to the inventory cycle. The economy is usually characterized by fairly steady growth punctuated by short periods of rapid recession and recovery. This pattern presents problems for most models of the economy, which tend to project sinusoidal behavior. One way to generate the observed pattern is to assume that the real goods market is unstable, as in the "razor's edge" models.

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With such a view of the real goods market inventory fluctuations can take on added importance. A decision by firms that stocks are excessive could trigger a recession, while the decision to replenish could end the recession and start the recovery. This approach to inventory investment is supported by the general practice of treating inventory investment like other forms of investment and assuming that it is a decision variable of the firm.

This paper presents an alternative approach to the inventory cycle. The adjustment process of inventories is found to be stable. Nevertheless, sharp changes in output are generated in simulations. These sharp fluctuations are not explained by instability in the output market, but, on the contrary, by quick adjustments of inventory stock to new equilibrium levels. In the model the stock adjustments which occur are not the source of fluctuations, but the result of external disturbances. This explains the observed lag of inventories behind output, an observation which is hard to reconcile with the theory that inventory cycles are the cause of fluctuations in the economy.

As the inventory adjustment process is not the cause of fluctuations in the real goods market, the source of these fluctuations must be identified. The model used in this paper is derived from the Karl Brunner-Allan Meltzer three-market model.<sup>1/</sup> Following the Brunner-Meltzer approach it is assumed that fluctuations are introduced to the real goods market from the financial markets. Interest rate and price of existing assets are determined proximately in the credit and money markets. These two variables affect the real goods market.

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<sup>1/</sup> Brunner, Karl and Allan H. Meltzer, "Money, Debt and Economic Activity," Journal of Political Economy, September-October 1972.

In the standard IS-LM framework if cycles are caused by monetary disturbances, then interest rates should be countercyclical. Interest rates are observed to be procyclical. This paradox is usually explained by monetarists by changes in anticipated inflation affecting interest rates. The model in this paper presents an alternative explanation for the procyclical behavior of interest rates, namely, changes in the price of existing assets. Unlike in the IS-LM framework, in this model there are two rates of return which affect the real goods market. In simulations when interest rate and price of existing assets move together, as they have during the most of the postwar period, interest rates are procyclical. Simultaneous increases or decreases in both money and debt can yield a procyclical interest rate. In the short term, at least, bonds should not be treated as a close substitute for money or for equity.

Showing that there is a monetarist explanation for a procyclical interest rate does not prove that the asset markets are the only source of variation in the economy. Indeed, fiscal policy plays an integral role in the short-run behavior of the Brunner-Meltzer model. Government expenditures are added to the model in this paper, yielding substantial improvement in the estimated equations. Impact and short-run (after inventory adjustment) multipliers for sustained changes in government expenditures are estimated. The short-run multipliers are much smaller than the impact multipliers. Much of the reaction to a sustained change in government expenditures is a short rapid adjustment of stocks to a new equilibrium level.

In most models of the real goods market output and price are treated asymmetrically. Prices are assumed to adjust to equate supply

and demand. In this paper firms are assumed to be price setters. Prices are determined by the same state variables and parameters as determine other firm decisions. Within a period supply and demand are not necessarily equated. Unintended inventory accumulations and liquidations can and do occur. Disequilibrium is signaled by unintended inventory change, not by unanticipated change in inflation.

A major problem for economists has been the empirical observation that output adjusts in the short run, while price adjusts only in the long run. Typically this problem is treated by assuming that rigid prices are the cause, and the phenomenon to be explained. The results in this paper suggest that the causation may run in the opposite direction; prices do not adjust because output does. The phenomenon to be explained is the adjustment of output. As rigid prices have proven difficult to justify, this distinction may prove to be important.

This paper is an extension of previous work by the author.<sup>2/</sup> While the basic model has been presented before, herein is a detailed discussion of the theoretical framework of the individual firm. Estimation is performed on the durable and nondurable goods producing sectors separately, yielding a substantial improvement in results. In particular, durable and nondurable goods price equations are presented. More extensive simulation results are obtained, most notably with regard to the effects of interest rate and equity price on the real goods market. Lastly, government expenditure is explicitly introduced, yielding substantial further improvement in the empirical results, particularly in the output equations.

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<sup>2/</sup>Bryant, John, "Relative Prices and Inventory Investment," Journal of Monetary Economics, January 1978, pp. 85-102.

The paper is divided into six sections. The next section presents the model of the real goods market. The third section includes empirical estimation of that model and analysis of the estimated coefficients. In the fourth section the important properties of the estimated structure are illustrated using simulations. The fifth section introduces fiscal policy to the model and presents reestimated equations and revised simulations. The paper ends with a summary and concluding comments.

#### The Model

In the model of the real goods market the problems of undesired inventory accumulation and undesired savings, as well as of speculative inventory holdings, are explicitly treated.

Firms are assumed to make output, price, and minimum inventory (maximal sales) decisions at the beginning of each period, before the demand schedule is observed. Firms can sell at most output plus initial inventory stock. However, at the beginning of the period a firm can decide to maintain a minimum inventory level. This restricts sales to be less than output plus initial inventory stock. These decisions are binding for the period. Initial inventory stock, anticipated demand, the rate of discount of the future, and the marginal cost function determine the firm's decisions.

Firm decisions and demand jointly determine inventory investment. Price has a negative impact upon demand, which is stochastic. If a high level of demand is not realized and firms do not stock out, inventory investment is output minus demand. If firms do stock out (sell less than possible given their price and the demand curve), end of period inventory equals minimum inventory. Therefore, stocking out yields

inventory investment equal to minimum inventory minus beginning of period inventory. A low level of demand relative to anticipations results in undesired inventory accumulation. A high level of demand results in undesired inventory decumulation, and undesired saving if stocking out occurs.

The firm's inventory problem differs from the usual inventory problem in two ways.<sup>3/</sup> First, demand is stochastic and nonstationary. Second, the firm can speculate in inventories by withholding them from sale.

The firm's maximization problem is presented below.<sup>4/</sup> The assumptions used are:

1. The firm is risk neutral and maximizes its discounted infinite horizon expected profit stream using discount rate  $\beta$ .
2. A cost function of output with  $c(X)$ ,  $c_X(X)$ ,  $c_{XX}(X) > 0$ .
3. Demand =  $d = d(P, U)$  is a function decreasing in price ( $P$ ) and increasing in the stochastic term ( $U$ ).
4.  $U$  is a random variable of a particular form,  $U \in [0,1]$ .

Let  $I_{t-1}$  be the information available to the firm at the beginning of period  $t$ . It is assumed that there exists a real valued informational variable  $N_t$  such that  $F(U_{t+i} | N_t) = F(U_{t+i} | I_{t-1})$  for  $i = 0, 1, 2, \dots$ . Further,  $N_{t+1} = h(U_t, N_t)$  for some real valued increasing function  $h$ .

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<sup>3/</sup> See Zabel, Edward, "Multi-Period Monopoly Under Uncertainty," Journal of Economic Theory, December 1972, pp. 524-536.

<sup>4/</sup> For a fuller discussion see Bryant, John, "Demand Anticipation and Speculation in Inventories: The Decisions of a Price Setting Firm," mimeographed.

Lastly,  $N'' > N'$  implies  $F(U_{t+i} | N_t = N'')$  is stochastically larger than  $F(U_{t+i} | N_t = N')$  for all  $i = 0, 1, 2, \dots$

The corresponding density functions are assumed to exist.

These assumptions require further elaboration.

### $\beta$

In a model omitting claims to existing capital,  $\beta$  is  $1/(1+i)$  where  $i$  is the interest rate on bonds. To determine the rate of discount in this more complex model we turn to the conventional capital asset pricing model. Letting  $i_m$  be the rate of return on the market portfolio of claims to existing capital and  $i_j$  be the rate of return of firm  $j$  we have:

$$1/\beta_j = 1 + i + E(i_m - i) [\text{COV}(i_j, i_m) / \sigma_m^2].^{5/}$$

We assume that  $[\text{COV}(i_j, i_m) / \sigma_m^2]$  can be treated as a constant, so that  $\beta_j$  is increasing in  $i$  and  $E(i_m)$ . The interest rate and rate of return on capital are assumed to be martingales and their expected values (the previous observations) are used. Further, at each point in time all future  $\beta_j$ 's are assumed to equal the current  $\beta_j$ .<sup>6/</sup>

Equity price, as a measure of price of existing assets, is assumed to be an inverse measure of the rate of return on existing

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<sup>5/</sup>See, for example, Klein, Michael A., "The Economics of Security Divisibility and Financial Intermediations," Journal of Finance, September 1973, pp. 923-931.

<sup>6/</sup>The role of anticipated inflation is downplayed in this paper. However, all the equations have been estimated with nominal interest rate and inflation rate or real interest rate as independent variables. Current inflation rate and various measures of anticipated inflation rate were used. These measures of inflation all have insignificant coefficients, and real interest rates perform similarly to nominal interest rate. Only the results using nominal interest rate alone are reported.



capital. In contrast to the Keynes-Wichsell approach, fluctuations in the anticipated return on capital per unit of real capital play no role in the model. The horizon for most capital investments is long. Current economic conditions have little influence on long-term return, just as they have little influence on permanent income. In the short term, changes in the rate of return on existing capital are assumed to be due to changes in the price of existing capital.

c(X)

The cost function is taken as a given in this model. This reflects the belief of the author that demand fluctuations play a more important role in the inventory cycle than do fluctuations in production costs. In the analysis presented the cost function is treated as constant, but it can equally as well be assumed to follow a known deterministic path through time. Capital stock and the position of the labor supply curve determine the marginal cost curves of firms. By assumption, increases in capital stock and outward shifts of the labor supply curve decrease marginal cost at all levels of production.

The firm investment decision is not modeled. Instead, capital stock present and future is treated as given, with last period capital being the state variable for capital stock. Capital stock is, then, assumed constant, or more generally, growing at a constant rate.

Previous quarter compensation ("wage") and man-hours of production workers ("labor") are used as proxies for the position of the labor supply curve. From one point, the whole labor supply curve is assumed to be extrapolated. Moreover, each firm assumes that the labor supply curve, as a function of nominal wage, will be unchanged (or changing at a constant rate) in the coming periods. As the model describes

short-run behavior and is estimated on quarterly data, hopefully this assumption introduces little error. Anticipations of future shifts of the labor supply function play no role in the model. For a longer-run model more sophisticated modeling of the labor market may be necessary. Both previous quarter labor and wage are included as firms are assumed to have some monopsony power.

Materials and work-in-process inventories can be included in the model. A simple way of doing this is to make minimum inventory an argument of the cost function. However, a random cost function is not considered. Therefore, speculation in materials inventories is not treated.

There is no cost to holding inventories in the model. However, such a cost function can be added without changing the qualitative results as long as the cost is convex. Storage costs are in general higher for nondurable than durable goods producers. If these costs are included in the model, one finds the anticipated result that higher marginal storage cost implies greater sensitivity of firm decisions to initial inventory stock. There also is no cost to stocking out, except, of course, for the cost of foregone sales. An ad hoc cost of stocking out also can be added without changing the results. A much more satisfactory way to handle stock-out costs is to explicitly model the effects of stock outs on future demand. However, such an approach would greatly complicate the model, probably without introducing new implications testable on the aggregate data studied in this paper.

#### Demand

The demand functions assumed for durable and nondurable goods are a modified version of the Brunner-Meltzer demand function.

The variables determining demand must be specified. Demand is a decreasing function of price. Of course, the prices of all available goods should be included in the demand function. At the level of aggregation of this paper, durable goods, nondurable goods, structures, and services price indexes should be included. However, because of problems of multicollinearity, only own price is included in the equations.<sup>7/</sup>

The stochastic term,  $U_t$ , is nonstationary and is determined by several variables. Capital stock is a measure of wealth, and demand is increasing in wealth. Purchasers have the option of holding bonds and claims to real capital. As with firms, the rates of return of both these assets are important. The Modigliani-Miller theorem is not assumed to apply, at least not to the issuance of government securities. The rate of return on bonds and existing capital both influence the tradeoff between current and future consumption and current and future investment. Demand is decreasing in interest rate and increasing in equity price because the substitution effect is assumed to dominate the income effect.<sup>8/</sup> The effect of equity price upon durable goods purchasing is particularly strong. Existing capital goods are a close substitute for newly produced capital goods.

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<sup>7/</sup>This may bias the coefficient of wage in the estimated equations.

<sup>8/</sup>In the Brunner-Meltzer model there are both real balance and real debt effects, and real money stock and real debt are productive assets. However, these effects seem unlikely to be significant contributory factors in short-run fluctuations in the economy. The direct effects of real balance and real debt upon demand and output are ignored in this paper. Fluctuations in the asset markets are transmitted to the real market only via the effects of interest rate and equity price.

Durable goods purchases may also be affected by current receipts.<sup>9/</sup> Much of the variation in current receipts results from variation in durable goods output. Therefore, it is assumed that current durable goods output has a positive effect upon current durable goods demand with "multiplier" less than one. Unfortunately, this effect of receipts upon durable goods purchasing is not identified in the equations.

$N_t$  and  $I_{t-1}$

Fluctuations in demand play an important role in fluctuations in the real goods market. Firms' decisions depend upon their anticipated demand. The firm's knowledge of the stochastic element of the current and all future demand curves can be summarized by a single statistic,  $N_t$ . An increase in this statistic implies that the distribution of the current and all future demand schedules are shifted "outward." An increase in  $N_t$  can unambiguously be taken as an increase in anticipated demand, and  $N_t$  will be referred to as anticipated demand.

Firms may not follow rational expectations in the Muth sense when they form anticipations of demand. However, it is assumed that they use the variables determining  $U_t$  in the demand function in this model to predict the demand schedule. Therefore,  $I_{t-1}$  consists of last period capital stock, interest rate, and equity price. The interest rate and equity price of the coming period are unknown to the firms when they make their decisions, and previous period values are used. Further, whether or not they use these variables optimally, it is assumed that

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<sup>9/</sup>Meltzer, Allan, H., "Anticipated Inflation and Unanticipated Price Changes: Some Theoretical and Empirical Differences," Journal of Money, Credit, and Banking, February 1977.

they at least get the signs right. Anticipated demand is increasing in capital stock and equity price and decreasing in interest rate. To be consistent with the definition of  $N_t$  and  $h$ , these latter two variables are assumed to be generalized random walks.

Firms

The firms' problem can be written as

$$\begin{aligned} \max & \quad \sum_{t=0}^{\infty} \beta^t E\{P_t S_t - c(X_t)\} \\ 0 & \leq P(H, N) \\ 0 & \leq X(H, N) \\ 0 & \leq H^m(H, N) \leq X + H \end{aligned}$$

subject to:

$$\begin{aligned} S_t &= \min\{d(P_t, U_t), X_t + H_{t-1} - H_t^m\} \\ H_t &= X_t + H_{t-1} - S_t \\ &= \max\{X_t + H_{t-1} - d(P_t, U_t), H_t^m\} \end{aligned}$$

where  $X$  = output,  $P$  = price,  $H^m$  = minimum inventory,  $H$  = end of period inventory, and  $S$  = sales.

In principle, properties of the decision functions can be solved for using dynamic programming. However, doing so is not straightforward. Strict concavity of the objective function implies continuous decision functions if the constraint set is convex. Strict concavity of the current period return function does hold if  $Pd(P, U)$  is strictly concave in  $P$ , for example, if  $d$  is linear in  $P$ . Unfortunately, the function  $\max\{X + H - d, H^m\}$  is not concave. Therefore, the constraint set is not convex.

In order to get results, we assume that in practice decisions lie within a convex set so that the objective function is strictly concave.<sup>10/</sup> This implies that the decision functions are continuous.

We now examine the solution to the firms' problem. Let  $g(X,P)$  be such that  $d[P,g(Z,P)] = Z$ . Then  $F[g(X+H-H^m),P] | N$  is the probability that the firm does not stock out. By the principle of optimality the value of the firm can be defined by the recursion relation:

$$v[H,N] = \max_{\substack{X,P,H^m \geq 0 \\ H^m < X+H}} \left\{ \int_0^g [Pd + \beta v(X+H-d, N')] f(U) | N \right\} dU \\ + \int_g^1 [P(X+H-H^m) + \beta v(H^m, N')] f(U | N) dU - c(X)$$

where  $N' = h(U,N)$ . The first integral is price times expected sales plus expected discounted next period value of the firm for the firm not stocking out, while the second integral is price times expected sales plus expected discounted next period value of the firm for the firm stocking out. By standard dynamic programming procedures it can be shown that  $v[H,N]$  is unique, continuous, and increasing in its arguments. While  $v$  may not be differentiable, for simplicity we will treat it as if it were two smooth. The results hang on concavity not on differentiability, and the same results can be rigorously derived using small finite differences.

The first-order conditions required for maximization are:

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<sup>10/</sup> This problem of nonconcavity does not appear in the problem with no uncertainty in the current period, but uncertainty in the future. Therefore, this assumption does not seem unreasonable if the uncertainty for the current period is not too "large" in some sense.

$$\int_0^g \beta v_H f(U|N) dU + P \int_g^1 f(U|N) dU + \lambda \leq c_X(X), = \text{if } X > 0$$

$$\int_0^g [(P - \beta v_H) d_p + d] f(U|N) dU + (X + H - H^m) \int_g^1 f(U|N) dU \leq 0, = \text{if } P > 0$$

$$\int_g^1 \beta v_H f(U|N) dU - P \int_g^1 f(U|N) dU - \lambda \leq 0, = \text{if } H^m > 0$$

$$X + H - H^m \geq 0, = \text{if } \lambda > 0$$

where  $v_H = \frac{\partial v[\max(X+H-d, H^m), N']}{\partial \max(X+H-d, H^m)}$ ,  $d_p = \frac{\partial d}{\partial P}(P, U)$ , and  $\lambda$  is a Lagrangian multiplier

These first-order conditions can be rearranged to yield some simple interpretations which increase their intuitive appeal. Adding the first-order conditions of  $X$  and  $H^m$  yields:

$$c_X(X) \geq \int_0^1 \beta v_H f(U|N) dU, = \text{if } X, H^m > 0.$$

Marginal cost is greater than or equal to discounted expected marginal worth of inventories next period, with equality if output and speculative inventory holdings are positive. Assume for the moment that  $d$  is additive in  $U$  so that  $d_p$  is independent of  $U$ . Substituting the first-order condition of  $X$  into the first-order condition of  $P$  and rearranging yields, for  $X, P, X+H-H^m > 0$ :

$$c_X(X) = \frac{P d_p + \int_0^1 \min[d, X+H-H^m] f(U|N) dU}{d_p}.$$

Notice that in the simple conventional monopoly model marginal cost equals marginal revenue can be written as  $c_X(X) = \frac{P d_p + d}{d_p} = \frac{P d_p + X}{d_p}$ . Also, these expressions together imply that price exceeds discounted expected marginal worth of inventories unless maximal sales are zero. You don't sell goods for less than their worth to you as inventories!

Using the implicit function theorem one can derive the effects of changes in state variables and parameters on decision variables. In doing so, we use the assumption that the objective function is strictly jointly concave in  $X$ ,  $P$ ,  $H^m$ , and  $H$ . This is not sufficient, however, to "sign" several of the decisions of interest. The addition of the assumption that  $d(P,U)$  is linear in  $P$  and additive in  $U$  is sufficient for these results, and is imposed.

With these assumptions, totally differentiating these first-order conditions and solving simultaneously using Cramer's rule yields:

$$-1 < dX/dH \leq 0, \quad dP/dH \leq 0, \quad dX/dH + 1 \geq dH^m/dH \geq 0$$

with strict inequality when the respective decision variable is positive. Further, if, counter to our assumptions,  $c_{XX}(X) = 0$ , then  $dX/dH = -1$ . If  $dX/dH = -1$ , then  $dP/dH = dH^m/dH = 0$ . Inventories are a substitute for output and influence  $P$  and  $H^m$  only by their effect on goods on hand,  $X + H$  (this also follows immediately from observation of the first-order conditions).

Using this procedure, one also finds that:

$$dX/dN \geq 0, \quad dP/dN \geq 0, \quad \text{but } dH^m/dN \text{ is of ambiguous sign.}$$

Minimum inventory is speculative holdings of inventories. The relative increases in current and future anticipated demands and the rate of discount of the future have to be known in order to predict if minimum inventory is increasing in anticipated demand.

This procedure also shows that:

$$dX/d\beta \geq 0, \quad dH^m/d\beta \geq 0, \quad \text{but } dP/d\beta \text{ is of ambiguous sign.}$$



Intuitively, decreased  $\beta$  can be interpreted not only as increased discounting of future profits, but as increased marginal financing cost as well. These two effects are reinforcing in the expressions for  $dX/d\beta$  and  $dH^m/d\beta$ , but are offsetting terms in the expression for  $dP/d\beta$ . Similarly, one can show that uniform increases in  $C_X(X)$  decrease output and minimum inventory and increase price.<sup>11/12/</sup>

$$dP/dc_X > 0 > dX/dc_X, dH^m/dc_X.$$

### The Market

Now let us turn to the market as a whole. For the individual ( $i^{\text{th}}$ ) firm:

$$\Delta H_i = X_i - d_i, d_i \leq X_i + H_i - H_{m_i} \text{ (not stocking out)}$$

$$= H_{m_i} - H_i, d_i > X_i + H_i - H_{m_i} \text{ (stocking out)}$$

$$H_i' = H_i + \Delta H_i$$

where  $\Delta H$  is inventory investment,  $H$  is initial inventory stock, and  $H'$  is end-of-period inventory stock. Unfortunately, it is impossible to determine which firms in the sector stock out, the number of firms stocking out, or the amount of unsatisfied demand.

An additional assumption on stocking out is necessary to make the model operational. Define excess demand as demand minus maximal sales,  $d^e = d - (X+H-H^m)$ . Assume that unsatisfied demand ( $d^u$ ) can be

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<sup>11/</sup>This can be done, for example, by replacing  $c_X(X)$  by  $(1+\alpha)c_X(X)$  in the first-order condition of  $X$  and considering changes in  $\alpha$ .

<sup>12/</sup>In these experiments we are holding the  $v$  function constant. Therefore, only one-period changes in parameters are imposed. However, using the usual iterative procedure starting at  $v$  equals the zero function, one can show these signs hold for a permanent change.

approximated as a linear function of total excess demand in the sector.

$d^u = \alpha d^e + \gamma$ ,  $\alpha, \gamma > 0$ ,  $\alpha < 1$ . This is only an approximation as excess demand can be either positive or negative. Unsatisfied demand, the difference between demand and sales (S), is nonnegative. With this assumption  $\Delta H = X - S = X - (d - d^u) = X - \{d - \alpha[d - (X + H - H_m)] - \gamma\} = (1 - \alpha)(X - d) + \alpha(H_m - H) + \gamma$ , where the variables have been summed over all firms in the industry.  $\alpha$  is the proportion of an increase in excess demand that is unsatisfied.  $\gamma$  is unsatisfied demand when excess demand is zero.  $\alpha$  and  $\gamma$  are determined by such factors as the distribution of inventories across firms, the distribution of demand, the amount of search, and the substitutability of goods produced. The assumption that such factors are constant is a strong one.

Aggregation of output is by sum. In order to extend the results of the firm problem to aggregate output, identical linear output functions are assumed as an approximation. Minimum inventory is treated in the same manner. Aggregation of price is by weighted sum, not by sum. This problem is ignored and the price function of the individual firm is assumed linear and used for the aggregate.

Summary

Summarizing, the three equations in the model are:

$$(1) \quad X = X(K_{-1}, L_{-1}, W_{-1}, i_{-1}, Pe_{-1}, H_{-1})$$

$$X_1, X_2, X_5 > 0 > X_3, X_4, X_6; X_6 > -1$$

$$(2) \quad P = P(K_{-1}, L_{-1}, W_{-1}, i_{-1}, Pe_{-1}, H_{-1})$$

$$P_3 > 0 > P_2, P_6$$

$$(3) \quad \Delta H = (1-\alpha)[X-d(K_{-1}, i_{-1}, Pe_{-1}, P, X)]$$

$$+ \alpha[Hm(K_{-1}, L_{-1}, W_{-1}, i_{-1}, Pe_{-1}, H_{-1})-H_{-1}] + \gamma$$

$$= h(K_{-1}, L_{-1}, W_{-1}, i_{-1}, Pe_{-1}, H_{-1}, P, X)$$

$$h_2, h_7, h_8 > 0 > h_3, h_6; h_6 > -1; h_8 < 1. \frac{13}{14}$$

Variables are defined in the appendix.

That  $0 > X_6 > -1$ ;  $P_6 < 0$ ;  $h_6 > -1$  follow directly from the result of the firm maximization problem that  $-1 < dX/dH < 0 < dH^m/dH$ ,  $dP/dH < 0$ .  $h_6 < 0$  follows from the firm maximization problem,  $dH^m/dH < 1$ , together with the assumption that some firms stock out.  $X_1, X_2 > 0 > X_3$ ;

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<sup>13/</sup>The lag in adjustment of output and price to interest and equity price, assumed in the Brunner-Meltzer model, allows the use of partial equilibrium analysis. To avoid simultaneous equation error, last period interest rate and equity price are included in the demand function as well. However, including current values does not substantially affect the results.

<sup>14/</sup>Real output is written as a function of nominal wage, not real wage. Real wage equal to marginal product of labor is not, in general, optimal policy in this model. Because firms are price setters, and prices are not necessarily equilibrium prices, ceteris paribus higher price means not only lower real wage, but lower expected sales as well.

$P_3 > 0 > P_2$ ;  $h_2 > 0 > h_3$  follow from the firm maximizations problem, specifically  $dP/dC_X > 0 > dX/dC_X$ ,  $dH^m/dC_X$ , and  $dX/dN$ ,  $dP/dN > 0$ , and the assumptions that (a) capital, labor, and wage determine marginal cost, and (b) that capital affects anticipated demand.  $X_5 > 0 > X_4$  follows from the firm maximization problem,  $dX/dN$ ,  $dX/d\beta > 0$ , and the assumptions that (a) the rate of discount of the future is determined by interest rate and equity price, and (b) that these variables affect anticipated demand as predicted.  $h_7 > 0$  results from the assumption that demand is decreasing in price. That some firms stock out and that the marginal propensity to purchase is greater than zero each imply  $h_8 < 1$ . The marginal propensity to purchase being less than one implies  $h_8 > 0$ .

$P_1$  is less than zero if the effect of capital on marginal cost outweighs its effect on anticipated demand.  $P_4$  is less than zero and  $P_5$  greater than zero if the interest rate and equity price effects on the rate of discount of the future and on anticipated demand are as predicted, and outweigh their effects upon financing costs.  $h_4$  is positive and  $h_5$  is negative if the effects of interest rate and equity price on demand are as predicted and are larger than or reinforce their effects on minimum inventory.  $h_1$  is negative if the effect of capital stock on demand is larger than the effect of capital stock on minimum inventory.

#### Empirical Estimation

The three equations of the model are estimated for durable and nondurable goods sectors in this section. The aggregation of firms assumes identical decision functions. Historical experience and economic theory indicate that the durable and nondurable goods sectors differ substantially. There may also be significant differences within the

sectors. The following empirical results are a joint test of the model and of the aggregation to the level of durable and nondurable goods producers.

The functional form assumed for all equations is linear.<sup>15/</sup> The equations are estimated as a block recursive system.<sup>16/</sup> First-order serially correlated error terms are assumed. The Hildreth-Liu search routine with a grid of .05 over [0, 1) is used to estimate the coefficients and the degrees of serial correlation. t statistics are provided in parenthesis. For a description of the data see the appendix. The estimation period is 1952I-1975IV.

The model implies thirty-four restrictions on the coefficients of the estimated model. Twenty-six of the estimated coefficients meet these restrictions with statistical significance.<sup>17/</sup> Two coefficients violate the restrictions, with one of these almost statistically significant.

Two sets of coefficients are of particular interest warranting discussion: (a) the coefficients of inventory stock in the six equations and the coefficients of output and price in the inventory investment equations, and (b) the coefficients of interest rate and equity price in

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<sup>15/</sup> In any case, log linear output and price functions and log difference inventory equations do not outperform linear ones, and yield similar results.

<sup>16/</sup> This requires for identification that the error terms in the output and price equations be independent of those in the inventory investment equation. Use of the durable and nondurable manufacturing industrial production indexes as instrumental variables for output has little effect upon the inventory investment equations. This procedure does reduce the autocorrelation of the nondurable equation almost to zero. Instrumental variables for price are unnecessary as goods and inventory investment deflators are very different.

<sup>17/</sup> A result will be referred to as significant if the null hypothesis is rejected at the 95 percent level of confidence with a two-tailed t test.

the six equations. These coefficients determine the inventory adjustment process and the impact of financial markets on the business cycle, respectively. In the following section of this paper the point estimates of these coefficients will be used in simulation of the model.

(1) Output

Inventory stock has a highly significant negative coefficient between zero and minus one in both regressions, as predicted. Both coefficients are close to minus one, showing that substantial adjustment of output to inventory stock occurs within a quarter. The durable coefficient is closer to minus one, indicating that the output adjustment of durable goods producers is somewhat larger than that of non-durable goods producers. This result is a bit surprising given the facts that durable goods producers have smaller storage costs and durable goods inventories dominate the inventory cycle.

Equity price has the predicted positive coefficients in the regressions. The durable coefficient is twice as large as and more significant than the nondurable coefficient.<sup>18/</sup> This differential is consistent with durable goods being a closer substitute for existing capital stock than are nondurable goods. The interest rate coefficients are small and insignificant.

(2) Price

Inventory stock has a significant negative impact upon nondurable goods price but no significant effect upon durable goods price. This is consistent with the observations that durable goods producers have smaller

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<sup>18/</sup>As nondurable output exceeds durable output, the elasticity is larger in the durable equation as well.

(1) Output

$$\begin{aligned} \text{XD} = & .940\text{K}_{-1} + .402\text{LD}_{-1} - 4.22\text{W}_{-1} - .206\text{i}_{-1} \\ & (6.8) \quad (5.7) \quad (-4.3) \quad (-.068) \end{aligned}$$

$$\begin{aligned} & + .369\text{Pe}_{-1} - .953\text{HD}_{-1} - 615 \\ & (3.0) \quad (-6.2) \quad (-6.8) \end{aligned}$$

$$\rho = .95, R^2 = .988, \text{DW} = 2.29, \text{DF} = 88$$

$$\begin{aligned} \text{XN} = & .607\text{K}_{-1} + .337\text{LN}_{-1} - 2.26\text{W}_{-1} - .207\text{i}_{-1} \\ & (7.7) \quad (3.4) \quad (-4.2) \quad (-.11) \end{aligned}$$

$$\begin{aligned} & + .164\text{Pe}_{-1} - .784\text{HN}_{-1} - 236 \\ & (2.2) \quad (-5.7) \quad (-4.7) \end{aligned}$$

$$\rho = .90, R^2 = .996, \text{DW} = 1.86, \text{DF} = 88$$

storage costs and that the inventory cycle is dominated by durable goods. The greater the price flexibility, the smaller the inventory adjustment.

In the firm maximization problem, initial inventory stock influences price by its effect upon goods on hand, output plus inventory stock. Because of the large adjustment of output for inventory stock, inventory stock has a small effect upon goods on hand. In addition, the firm maximization problem shows that the factors determining marginal cost influence price by their effects upon the output decision, and thereby upon goods on hand. This suggests the dropping of capital, labor, and wage from the price equations, and the replacement of inventory stock by goods on hand,  $X + H$ . When this is done, goods on hand has a highly significant negative coefficient in both durable and non-durable price regressions.<sup>19/</sup> Prices are sensitive to goods on hand.

The signs of the coefficients of equity price and interest rate in the price equations were not predicted. A positive equity price coefficient and a negative interest rate coefficient indicate that the effects of these variables on the rate of discount of the future and on anticipated demand are more important than their effects upon the marginal financing cost of output. In both regressions equity price has a negative coefficient, implying that goods producers treat increases in equity price as decreasing financing cost. The coefficient in the nondurable equation is three times as large in absolute value and much more significant. This result is consistent with a larger positive anticipated demand effect of equity price for durable goods. Once again, neither of the interest rate coefficients is significant.

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<sup>19/</sup>This holds true if the output component of goods on hand is replaced by an instrumental variable formed from the industrial production index.



(2) Price

$$PD = -.0471K_{-1} - .0263LD_{-1} + .972W_{-1} + .719i_{-1}$$

(-2.3)            (-2.5)            (6.7)            (1.6)

$$- .0184Pe_{-1} + .0130HD_{-1} + 77.3$$

(-1.0)            (.57)            (5.7)

$$\rho = .95, R^2 = .998, DW = 1.76, DF = 88$$

$$PN = -.00574K_{-1} + .0382LN_{-1} + 1.01W_{-1} - .0934i_{-1}$$

(-.37)            (1.9)            (10)            (-.24)

$$- .0560Pe_{-1} - .0643HN_{-1} + 27.4$$

(-3.8)            (-2.3)            (2.9)

$$\rho = .85, R^2 = .994, DW = 1.99, DF = 88$$

### (3) Inventory Investment

Output has highly significant positive coefficients less than one, as predicted, in both regressions. Price has significant positive coefficients in both inventory investment regressions. The higher price, the lower demand and the more inventories are accumulated.

Interest rate has a highly significant positive coefficient and equity price a negative coefficient in the durable equation. The effects of these variables upon demand are larger than their effects upon minimum inventory. In the nondurable equation, interest rate has a positive coefficient, although it is much smaller than in the durable equation. For nondurable goods, as well as for durable goods, demand is decreasing in interest rate, and this effect upon demand is larger than the effect upon minimum inventory. In contrast, the equity price coefficient is positive and significant in the nondurable equation. Equity price has a smaller effect upon nondurable goods demand than upon nondurable goods minimum inventory. Once again, these equity price coefficients are consistent with durable goods being a close substitute for existing capital stock, while nondurable goods are not.<sup>20/</sup>

Unlike in the output and price regressions, both interest rate and equity price have significant coefficients in the inventory investment regressions. Therefore, we can reject the hypothesis that interest rate and equity price are two measures of the same rate of return.

### Stability of Coefficients

An important test of estimated coefficients is whether they are sensitive to the estimation period. Of greatest interest is whether

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<sup>20/</sup>When the industrial production indexes are used as instrumental variables for output, equity price has a negative coefficient in both equations. The negative coefficient in the nondurable inventory investment equation is smaller in absolute value.

(3) Inventory Investment

$$\Delta HD = .0710K_{-1} + .0185LD_{-1} - 1.14W_{-1} + 3.13i_{-1}$$

(1.8)            (.55)            (-3.5)            (2.8)

$$- .0993Pe_{-1} - .204HD_{-1} + .489PD + .493XD - 90.2$$

(-1.9)            (-4.2)            (2.1)            (10.)            (-3.3)

$$\rho = .3, R^2 = .839, DW = 1.96, DF = 86$$

$$\Delta HN = .0942K_{-1} + .00910LN_{-1} - 1.53W_{-1} + 1.19i_{-1}$$

(1.7)            (.14)            (-3.7)            (1.1)

$$+ .102Pe_{-1} - .346HN_{-1} + 1.19PN + .407XN - 164$$

(2.2)            (-3.6)            (3.8)            (6.6)            (-5.2)

$$\rho = .85, R^2 = .641, DW = 2.08, DF = 86$$

the coefficients are constant over the business cycle or whether there is asymmetry in the behavior of the dependent variables. To test for this the durable and nondurable equations were each run on two sub-periods; quarters when the respective output rose and quarters when it fell. F statistics were calculated to determine whether the change in coefficients over the two periods was significant. The null hypothesis of no change of coefficients is rejected at the 95 percent level of confidence for the durable and nondurable output, durable price, and durable inventory investment equations.<sup>21/</sup>

The apparent change in coefficients is most significant in the two output equations. In both equations in both subperiods most of the estimated coefficients are smaller in magnitude and less significant. The most notable changes of coefficients in the output equations are in the inventory coefficients. Seemingly, inventory stock is important in determining whether output will rise or fall but is less important (although still significant) in determining the rate of output given that a rise or fall is occurring.

We can test this explanation of the instability of the coefficients in the output equations. The variables are all first differenced. Then the equations are estimated with a dummy variable equal to one in quarters when output rose and zero otherwise. The dummies are very highly significant in both durable and nondurable output equations (but not in price or inventory investment equations). Moreover, although the changes in intercept and slopes are significant at the 99.9 percent level for both output regressions, the changes in slopes alone are not significant at the 90 percent level in either equation. Most of the

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<sup>21/</sup>This is true for the log linear functional form as well.

coefficients, including the inventory coefficients, are smaller in magnitude and less significant when the dummy variable is included.

We conclude that the instability of the coefficients in the output equations over the cycle does not represent asymmetry in the behavior of output. Rather, there is less variance to be explained given the output is rising or falling. The independent variables, notably inventory stock, have a large role in determining whether output will rise or fall but have a smaller impact upon the rate of rise or fall. The problem has been moved back one step. The question remains why the rate of rise or fall of output should be relatively insensitive to the independent variables.

#### Simulation

By simulation some of the properties of the estimated coefficients can be illustrated.<sup>22/</sup> The output, price, and inventory investment equations together with the identity  $H_t = H_{t-1} + \Delta H_t$  generate difference equations in inventories. Using the estimated coefficients these difference equations are very stable. Holding all independent variables constant, an imposed drop in inventory stock results in a rapid, smooth return of inventory stock to the equilibrium level determined by the independent variables. At the same time, output jumps up and returns smoothly to its equilibrium level. Nondurable goods price also rises rapidly and returns smoothly to its equilibrium level. Durable price is

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<sup>22/</sup> These simulations do not take into account the effect of the real goods market on the labor and asset markets, and the resulting feedback effect on the real goods market. Use of the instrumental variable coefficients of the inventory investment equations changes none of the results in this section.

unaffected. Suppose the predetermined variables undergo a permanent shift increasing equilibrium output and inventory stocks. Inventory adjusts smoothly to the new equilibrium level. Output jumps above its new higher equilibrium level, and then adjusts smoothly downward to that level. Shocks introduced to the real goods market can yield the pattern of sharp, short-lived reductions in output that are observed.

The question remains whether shocks from the asset markets can explain the procyclical interest rate. Sequences of interest rate and price of assets are imposed on the equations, other predetermined variables held fixed. Interest rate is countercyclical when interest rate and equity price move in opposite directions, and procyclical when they move together. In most of the postwar period, interest rate and price of assets have actually moved together; bond and equity price have been inversely related. When the observed sequence of interest rate and equity price are imposed, interest rate is procyclical through the 1960's.

We cannot infer from the model what monetary and fiscal policy could generate such a pattern of interest rate and equity price. In the Brunner-Meltzer model price of equity is determined proximately in the money market and interest rate proximately in the credit market. If this holds, then simultaneous increases or decreases in money and debt can yield a procyclical interest rate.

For the two recent downturns and recoveries a countercyclical interest rate appears in the simulations, as observed. In these cycles interest rate and equity price have been negatively related. This causes larger and longer adjustments of goods output in the simulations. An increase in interest rate and a decrease in equity price decreases

equilibrium goods output but increases equilibrium inventory. As a result, output is sharply decreased and then continues to fall to its equilibrium level. In contrast, when interest rate and equity price fall together, both equilibrium goods output and inventory fall. In this case output is sharply decreased and then rises to its only slightly reduced equilibrium level.

When interest rate and equity price are negatively related they have substantial impact upon equilibrium output. When interest rate and equity price are positively related most output change is temporary as an adjustment of inventories. Assume again that equity price and interest rate are determined proximately in the money and credit markets respectively. This implies that deficits financed by debt and money have a sharp but short-lived effect on output, whereas open market operations have a sharp and lasting effect.

Durable goods dominate the inventory cycle in the simulations as they do in reality. The simulations do show a larger nondurable cycle in 1974-1975 than in earlier recessions, also as observed.<sup>23/</sup>

#### Government Expenditures

It has been shown that a procyclical interest rate may be explained without appealing to fiscal policy or to the unobservable anticipated inflation rate. This does not prove that all disturbances

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<sup>23/</sup> The simulated fluctuations are of somewhat smaller magnitude than have actually occurred. Presumably shifts in the labor market tend to dampen the cycles, so one cannot appeal to the feedback from the labor market. There are likely to be short-run costs to adjusting labor which are reflected in the coefficients of labor in the output equations. By holding labor fixed the short-run nature of these adjustment costs are ignored and the adjustment of output over the cycle understated. The smaller variation in the simulations was to be expected as regression is a smoothing technique and the errors are autocorrelated.

are monetary. The estimated interest rate coefficients in the output equations are small and insignificant, contrary to prediction. Exclusion of important explanatory variables could have forced this result. The estimation procedure has to reconcile the observed output and interest rate sequences. The empirical results could be interpreted to mean that a procyclical interest rate can be generated only if interest rate has a small effect upon output.

The output and price equations are highly autocorrelated, and first difference stationarity cannot be ruled out. While first difference stationarity is well accepted for prices, it is less acceptable in a real output equation. Indeed, this high degree of autocorrelation can be taken as evidence of important excluded variables. In addition, the instability of the coefficients in the estimated output equations suggests an excluded variable correlated with both the explanatory variables and the dummy variable on rising output.

An obvious candidate for excluded variable is fiscal policy. In not explicitly treating the government, it is implicitly assumed that fiscal policy is an endogenous variable. How the government finances its expenditures is important, but the expenditures themselves contain no independent information. The government is a purchasing agent for the public.

As Carl Christ has noted, given the government's budget constraint, three of the four variables government expenditure, tax, change in base money, and change in government debt can be taken as independent variables.<sup>24/</sup> In the model in this paper, which does not

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<sup>24/</sup>Christ, Carl, "A Simple Macroeconomic Model with a Government Budget Constraint," Journal of Political Economy, January 1968.



include the credit and money markets, three of the four variables government expenditure, tax, interest rate, and equity price can be taken as independent. The Christ example is followed, and tax is dropped. Therefore, we are studying the effect of government expenditure financed in a manner that leaves interest rate and equity price unchanged. The proportions of tax, debt, and money financing this requires is not examined.

There are several econometric problems involved in the inclusion of government expenditures as explanatory variables. Government expenditures is a component of real output. Therefore, it is likely to be correlated with the error terms in the output equations. Secondly, government expenditure may be the result of countercyclical policy, which introduces simultaneous equation error.<sup>25/</sup> Lastly, government expenditure this quarter is a good substitute for government expenditure next quarter. This too may bias downward the estimated multiplier. To avoid these problems a reaction function is specified. This reaction function is used to form instrumental variables for government expenditures.

The variables in the reaction function are: armed forces employment (ARM), time trend (T), the gap between the average growth path of real potential GNP and real potential GNP itself (Gappot), the gap between real potential GNP and an instrumental variable for actual real GNP (Gap), that instrumental variable for real GNP (X), and inflation rate lagged ( $\Delta p/p_{-1}$ ). The gap between potential GNP and its growth path is used on the assumption that the government may try to use expenditure

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<sup>25/</sup> See Goldfeld, Stephen M., and Alan S. Blinder, "Some Implications of Endogenous Stabilization Policy," Brookings Papers on Economic Activity, 3, 1972.

policy to stimulate capital accumulation or productivity. Inclusion of the gap between potential GNP and the instrumental variable for actual GNP allows for countercyclical policy. The instrumental variable for actual GNP is used as the government may tend to spend a constant proportion of output.<sup>26/</sup> Lastly, inflation rate is included because expenditure policy may be used to (or act as if it is used to) fight inflation.

The determination of correct fiscal policy indicator variables has proven to be a thorny problem. However, the problem is thought to be less severe for government purchases than other elements of the budget.<sup>27/</sup> In this paper federal government expenditures for durable (GD) and nondurable (GN) goods are considered. The distribution of government expenditure within these categories probably has less importance at the aggregate level than, say, the distribution of government expenditure between transfers and goods purchasing.

The approach has an obvious drawback. Revenue generated in the durable goods industries by government expenditure may not be spent only on durable goods. Revenue generated in other sectors by government expenditure may be spent on durable goods. Clearly to study the traditional multipliers instrumental variables for other forms of government

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<sup>26/</sup>The instrumental variable for real GNP is derived using the estimated coefficients of a Hildreth-Liu regression. Real GNP is regressed on lagged capital, man-hours of production workers in manufacturing, compensation per man-hour, interest rate, equity price, business inventory stock, and inflation, and current armed forces employment, time trend, gap between potential real GNP and its growth path, and potential real GNP. This equation is the output equation with the other variables of the reaction function added as independent variables.

<sup>27/</sup>Blinder, Alan S., and Robert M. Solow, "Analytic Foundations of Fiscal Policy," in The Economics of Public Finance, Washington, D. C., The Brookings Institution, c. 1974.

expenditure must be included in the equations. Unfortunately, multicollinearity prohibits doing so. Government expenditure, except in so far as it influences capital formation, is assumed not to affect wealth and private demand for nondurables. While increased revenues from government expenditure may increase purchases of durables, it is hoped that government durable expenditure adequately captures this effect.

The government expenditure term in the output and price equations is assumed to be anticipated government demand. In the inventory investment equation the government expenditure term is both actual and anticipated government demand.

There may be many trends influencing the economy which are not included in the model. To capture the effects of such trends time is entered into the equations as an independent variable. The coefficients of time trend reflect the effects of any excluded variable which has changed at a fairly constant rate over time.<sup>28/</sup>

#### Reaction Functions

The estimated reaction functions for federal government expenditure on durable and nondurable goods are presented below.

For nondurable goods all the coefficients are significant except inflation rate. Nondurable expenditure rises with the size of the armed forces. Nondurable expenditure apparently is used to try to stimulate or retard the growth of potential GNP, a somewhat surprising result. The government's nondurable expenditure has a significant countercyclical component but at the same time it is increasing in real

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<sup>28/</sup> Variables that have been changing at a constant rate in the past may stop doing so. A significant coefficient on time trend is a warning that errors may not be stationary in the future.

Reaction Functions

$$\text{GD} = .00192 \text{ ARM} - .979\text{T} + .446 \text{ Gappot} + .113 \text{ Gap}$$

(1.3)                    (-.96)    (.77)                    (.90)

$$+ .112\hat{\text{X}} - .508 \Delta\text{p}/_{\text{p-1}} - 24.3$$

(.90)    (-3.5)                    (-.59)

$$\rho = .8, R^2 = .956, \text{DW} = 1.67, \text{DF} = 88$$

$$\text{GN} = .00717 \text{ ARM} - 3.90\text{T} + 2.23 \text{ Gappot} + .503 \text{ Gap}$$

(2.4)                    (-2.2)    (2.1)                    (2.3)

$$+ .482\hat{\text{X}} + .126 \Delta\text{p}/_{\text{p-1}} - 184$$

(2.2)    (.43)                    (-2.5)

$$\rho = .75, R^2 = .902, \text{DW} = 1.70, \text{DF} = 88$$

GNP. The net effect of a change in real GNP upon nondurable government expenditure is close to zero. Holding these other factors constant, nondurable expenditure has been decreasing over time.

In contrast with nondurables, in the durable equation only inflation rate has a significant coefficient. While the other variables all have the same signs as in the nondurable equation, they are all smaller and less significant. Durable expenditure is not used in a large way to stimulate growth or to stabilize the economy. There appears to be a policy dichotomy that output targets are to be hit by the non-durable purchasing instrument, and inflation targets are to be hit by durable goods purchasing. Interestingly, the coefficient on armed forces employment is not large in the durable equation. Perhaps there is truth to Defense Department statements that many (durable) weapons system programs are postponed during wartime.

#### Model Estimates

Provided below are the reestimated durable and nondurable output equations. Time trend and the instrumental variable for government expenditures are included as independent variables. The other reestimated equations of the model are unremarkable, except the durable price equation. In that equation government expenditure has a significant negative coefficient. One explanation is that large expenditure occurred before 1972 (the base year) and the durable goods purchased by the government have had higher inflation than other durable goods. Unlike for output and inventories, aggregation of prices is by weighted sum. The reestimated price and inventory investment equations pass the test for stability of coefficients.

Output

$$\text{XD} = .661\text{K}_{-1} + .520\text{LD}_{-1} - 1.16\text{W}_{-1} - 7.63\text{i}_{-1}$$

(8.8)      (10.4)      (-3.0)      (-4.4)

$$+ .324\text{Pe}_{-1} - .569\text{HD}_{-1} + 2.45 \hat{\text{GD}} - 1.60\text{T} - 482$$

(3.5)      (-5.9)      (4.5)      (-5.9)      (-9.7)

$$\rho = .2, R^2 = .990, \text{DW} = 2.04, \text{DF} = 86$$

$$\text{XN} = .431\text{K}_{-1} + .421\text{LN}_{-1} - 1.14\text{W}_{-1} - 3.96\text{i}_{-1}$$

(6.2)      (4.3)      (-3.0)      (-2.3)

$$+ .127\text{Pe}_{-1} - .658\text{HN}_{-1} + 1.08\hat{\text{GN}} + .644\text{T} - 189$$

(1.6)      (-5.2)      (5.3)      (2.0)      (-4.6)

$$\rho = .65, R^2 = .997, \text{DW} = 1.89, \text{DF} = 86$$

In general, the inclusions of government expenditure and time substantially improve the properties of the output equations.

In both output equations interest rate has the predicted negative coefficients. These coefficients are highly significant, and the durable coefficient is larger in absolute value. The degree of autocorrelation, as measured by  $\rho$ , is much reduced by the introduction of time and government expenditure, particularly for the durable output equation. The coefficient of inventory stock is reduced in absolute value in both output equations, most notably in the durable equation, although it remains highly significant. In these equations it appears that durable goods producers are slower to adjust inventories than are nondurable goods producers. This result is consistent with higher durable storage costs and with a larger durable inventory cycle. The tests for stability of coefficients are performed. Once again, these show that there is a significant difference in intercept when output is rising or falling, but not a significant difference in slopes. The dummy variable for output rising is included as an explanatory variable. Contrary to the previous finding, the sizes of the remaining coefficients are not greatly reduced.

The coefficients of durable and nondurable government expenditures in the output equations are 2.4 and 1.1, respectively. These can be interpreted as "un-crowded out" impact multipliers. They are "un-crowded out" because interest rate and equity price are held fixed. They are impact multipliers because the nominal labor supply curve, capital stock, and inventory stock (but not revenue!), are held fixed.

Short-run multipliers can easily be obtained. The estimated model equations are used to simulate a maintained increase in government expenditure. We thereby derive the maintained increase in output after

inventory stock adjustment but before adjustment of the nominal labor supply curve and capital stock. The resulting "uncrowded out" short-run multipliers for durable and nondurable goods are 1.4 and .3, respectively.<sup>29/</sup> In the short run, even without the potentially large crowding out effects, there is substantial substitution of government for private nondurable demand. This may be true for durable goods as well. One explanation for the larger durable multiplier is that nondurable demand is not sensitive to current revenue while durable demand is. The multiplier for nondurable goods is very robust to changes in sample and specification, while that for durable goods is not.

Interest rate has large negative coefficients in both output equations. Simulations with equal percentage changes in interest rate and equity price are performed. In these simulations interest rate is only slightly procyclical. However, equity price is more volatile than interest rate. The actual interest rate and equity price sequences also are imposed. A strongly procyclical interest rate appears in these simulations in much of the period before 1969. After 1969 the interest rate is usually countercyclical, as observed in reality. While government expenditure is significant in the model, a monetarist explanation of a procyclical interest rate can still be made and without appealing to anticipated inflation.

#### Summary and Concluding Comments

The real goods market is stable. After a one-period shock to demand (or any variable in the system) output, price, and inventories

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<sup>29/</sup> These simulations take the questionable estimated durable price equation as given. Holding prices fixed the short-run multipliers are 1.3 and .3 for durables and nondurables, respectively.



return quickly and smoothly to their equilibrium levels. If there is a maintained shift in a predetermined variable, inventory stock adjusts quickly and smoothly to its new equilibrium. This smooth adjustment of inventories is achieved by output moving quickly to a point close to or beyond its new equilibrium level and then smoothly approaching this new equilibrium level.

The implied sharp adjustment of output is important. The economy is characterized by occasional sharp changes in output. Such behavior is not generated by the usual lagged partial adjustment models. Moreover, these sharp movements in output are often taken as evidence of the instability of the real goods market. However, the simulations using this inventory model show a stable real goods market generating sharp changes in output with fluctuations in interest rate, price of assets, or other predetermined variables.

On the average, a substantial adjustment of output to inventory stock occurs within a quarter. As a result, there is little sensitivity of price to initial inventory stock. The question remains why output adjustment is used more than price adjustment in the short run. This behavior can be explained in this model by nearly constant marginal costs.

Inclusion of government expenditures as independent variables improves the estimated output equations in terms of autocorrelation, stability of coefficients, fit, and estimated interest rate coefficients. However, the impact multipliers of government expenditure greatly exceed the short-run multipliers calculated after allowing for stock adjustment. The estimated "un-crowded out" short-run multipliers are 1.4 and .3 for durable and nondurable goods expenditures, respectively. This

raises the possibility that previous studies of multipliers of government expenditure have exaggerated their magnitude by ignoring the transient nature of inventory adjustment.

Interest rate and equity price influence the adjustment process of inventories, and, therefore, of the real goods market by influencing firms' decisions and demand. The significance of both interest rate and equity price has important implications. Interest rate and equity price are not two measures of the same thing. This need not imply that interest rate is a measure of real interest rate rather than of anticipated inflation over the sample period. It can only be noted that the estimated coefficients are as predicted under the assumption that nominal interest rate measures real interest rate. These coefficients may also be consistent with some models with the traditional transmission mechanism. Nevertheless, the results do lend support to the position that bonds and money or bonds and equity cannot be treated as close substitutes in the short run. If this holds, then the money and credit markets cannot be collapsed into a single market. The transmission mechanism does not work solely through one rate of return. Monetary policy can have a lasting impact, and the simulations indicate that it may.

The simulations in this paper show that if disturbances in the asset markets cause the fluctuations in the output market, and if interest rate and equity price move together, interest rate should be procyclical. We need not use anticipated inflation as an explanation for this phenomena.

The estimated coefficients in the inventory investment equations show that inventory investment is not a decision variable of the firm. Rather inventory investment is a residual determined by the firms'

output, price, and minimum inventory decisions and the realized demand schedule. The significant coefficients of inventory stock in the inventory investment equations show that stocking out, and, therefore, undesired saving, plays a significant role in the behavior of the real goods market. During disequilibrium undesired investment does occur in the form of undesired inventory accumulation, and undesired saving does result from firms stocking out.

## Appendix: Description of Data

- HD = (four times) Durable Business Inventory stocks, billions of 1972 dollars, end of period, calculated by summing inventory investment back to 1947-I.
- HN = (four times) Nondurable Business Inventory stocks, billions of 1972 dollars end of period, calculated by summing inventory investment back to 1947-I.
- XD = Durable Goods Output, billions of 1972 dollars, at annual rates.
- XN = Nondurable Goods Output, billions of 1972 dollars, at annual rates.
- PD = Durable Goods GNP Implicit Price Deflator, 1972 = 100.
- PN = Nondurable Goods GNP Implicit Price Deflator, 1972 = 100.
- Pe = Equity Price, Standard and Poor's Index of Stock Prices, months averaged, divided by K, 1972 = 100.
- i = Interest rate, Moody's AAA bond rate (mean  $\approx 4.0$ ), months averaged.
- W = Wage, compensation per man-hour in the private nonfarm economy, 1972=100.
- LD = Labor, millions of man-hours of production workers on durable manufacturing payrolls per week.
- LN = Labor millions of man-hours of production workers on nondurable manufacturing payrolls per week.
- K = Capital, gross business structures and equipment in \$1972. Quarterly figures derived by assuming constant growth throughout the year.
- Hm = Minimum inventory.
- Goods on hand =  $X + H_{-1}$ .
- Goods available for sale =  $X + H_{-1} - H^m$  = maximal sales.
- GD = Federal government expenditure for durable goods, billions of 1972 dollars.
- GN = Federal government expenditure for nondurable goods, billions of 1972 dollars.
- ARM = Armed Forces Employment.

T = Time trend.

Gap<sub>pot</sub> = Gap between growth rate of potential GNP \$1972 and potential GNP \$1972.

Gap = Gap between potential GNP \$1972 and an instrumental variable for GNP \$1972.

$\hat{X}$  = Instrumental variable for GNP \$1972.

$\Delta p / p_{-1}$  = Lagged year-over-year inflation rate of the GNP deflator.

Capital Stock is measured by total business structures and equipment. Series on the capital stocks of durable and nondurable goods producers are not available.

Wage is measured by compensation per man-hour. Compensation also is not available on a durable and nondurable goods producers basis. Average hourly earnings are available at a disaggregated level, but average hourly earnings exclude a major portion of the true wage. As a result, compensation significantly outperforms average hourly earnings in the regressions reported in this paper. Labor is measured by man-hours of production or nonsupervisory workers on durable and nondurable manufacturers payrolls. Of course, much of goods producing employment is not at manufacturers, and the manufacturing man-hours are proxies for total man-hours in durable and nondurable goods producing industries.

All variables except capital are seasonally adjusted. Interest rates and stock prices can be found in the Federal Reserve Bulletin Compensation, Manhours and Employment in Bureau of Labor Statistics publications, and all other variables in the Survey of Current Business.

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