

IT, Inventories and the Business Cycle

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Abstract

Recent years have witnessed an explosion in the power of computer processing. The primary gain to computerization is the ability to manipulate large volumes of digital information very rapidly. This paper focuses on the increased ability of manufacturing firms to track production and sales data through computerization. A two sector dynamic general equilibrium model is constructed with firms using inventories to buffer differences in sales and production to avoid stockouts. The model will then be used to examine the changes in aggregate dynamics when firms lower their inventories due to better tracking of sales/production data through computerization.

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1 Introduction

”As has often been the case in the past, the behavior of inventories provided substantial impetus for the initial strengthening of the economy. Manufacturers, wholesalers, and retailers took vigorous steps throughout 2001 to eliminate an unwanted buildup of stocks that emerged when final demand slowed late in 2000”¹.

Aggregate inventory investment represents a rather small fraction of the US economy (approximately 1% of GDP), but investment in inventories is also perhaps the most volatile of the macroeconomic time series (approximately six times that of GDP). This has led researchers as well as policymakers to believe that understanding the behavior of investment behavior is important for understanding business cycles. Further, recent development and rapid innovation of information technologies has allowed for dramatic improvements in inventory control mechanisms.

”Innovations, such as more advanced supply-chain management and flexible manufacturing technologies, have enabled firms to adjust production levels more rapidly to changes in sales. But these improvements apparently have not solved the thornier problem of correctly anticipating demand.”²

Therefore, the goals of this project are twofold:

1) To examine the determinants of inventory investment at the the firm level and the resulting dynamics of the major aggregates.

¹Testimony of Chairman Alan Greenspan before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, July 16, 2002

²Testimony of Chairman Alan Greenspan before the Committee on Financial Services, U.S. House of Representatives , July 18, 2001

2) To examine the effects on these decisions and resulting dynamics of an improvement in inventory control methods brought on through IT.

The relationship between inventories and business cycles has been largely ignored by researchers. However, the last 15 years has seen a renewed interest in the role that inventories play on the aggregate economy. A central issue underlying the literature is the relative importance of demand and supply shocks as a source of business cycle fluctuations - a question that still plagues researchers today. Traditional Keynesian arguments for recessions rely on declines in consumption demand brought on by demand shocks or shifts in consumer confidence. This drop in consumer demand forces firms to scale back production and employment. However, the conventional neoclassical attack on this hypothesis is that consumer demand is only one component of aggregate demand. A drop in consumer demand (hence, by definition, a rise in saving) would lower interest rates. This decrease in the cost of capital investment would raise investment demand by the private sector. The increase in investment should offset the drop in consumption leaving aggregate output unchanged. The neoclassical model relies on economy wide shocks to multifactor productivity to generate recessions rather than demand shocks. However, the neoclassical model has a weakness in that it is assumed that firms can quickly and costlessly shift from producing consumption goods to producing capital goods. In a world with inventories, there would most likely be a lengthy transition while the stock of inventories in one sector are built up and the stock of inventories in the other sector are decreased. This is the view taken here.

Why do firms hold inventories? The two conventional arguments are as follows. First, if firms have convex costs associated with adjusting production levels and there exists constant

fluctuations in demand, inventories would be the solution to the firm's cost minimization problem (assuming that the holding cost of inventories is less than the adjustment costs in production). The firm would operate at a constant production level and use inventories to buffer changes in sales demand. Models of this form - notably Fisher/Hornstein (1995), Ramey (1991), Thomas (2002) - result in an (S,s) policy for inventory investment. As long as inventories stay within a defined range (where the range depends on the convexity of costs), no investment is needed. When stocks drop below (rise above), inventory investment will be positive (negative). These models are able to reconcile the salient business cycle properties of inventories (production is more volatile than sales and inventory investment is positively correlated with sales). The second class of models are known collectively as "stock avoidance" frameworks. Here, the purpose of inventories is to provide insurance to the firm against unexpected shocks to demand. The resulting level of inventories depends on the volatility of supply and demand. This class of model also does well explaining business cycle features of inventories and will be used here.

As documented by Blanchard (2001), the last two expansions in the US have been unusually long. Blanchard attributes this increased duration to a large underlying decline in the volatility of GDP, not just the fortunate absence of adverse shocks. He shows that the decline in volatility began in the 1950's, was interrupted in the 1970's and then returned to trend in the 1980's. In fact, the standard deviation in output growth has decreased by a factor of three over the period. He argues that this decline has several proximate causes: a decline in the volatility of government purchases early on, decreased consumption and investment volatility later on, and finally, a change in the behavior of inventory investment in the 90's. Specifically, a reversal of the correlation between inventory investment and sales. Could this change in behavior be a

result of improved inventory management efficiency brought on by the heavy investment in IT throughout the 90's? This question will be addressed in this project.

The paper will proceed as follows. Section 2 will define the model. Most of the framework is an entirely standard neoclassical model with two exceptions. First, production will be divided into two sectors (standard models consist of one sector producing consumption and investment goods at a constant relative price of one) - one for investment and one for consumption. Second, inventories will be used by firms to buffer changes in demand. Section 3 will analyze the implication of the model. Section 4 will provide some conclusions and directions for further research.

2 The Model

2.1 Consumption Goods Production

There exists a representative firm that produces consumer goods. It has at its disposal k units of capital and employs l units of labor. It produces output according to the following technology.

$$y = Ak^{\alpha}l^{\omega} \quad \alpha + \omega = 1 \tag{1}$$

The productivity term, A , can be thought of as a random shock to multifactor productivity. This productivity term follows an $AR(1)$ process given by:

$$A_t = A + \rho A_{t-1} + v_t \quad (2)$$

$$v_t \sim N(0, \sigma_v^2) \quad (3)$$

where $0 \leq \rho \leq 1$.

Capital used in the production of consumer goods depreciated at the constant rate δ . The firm can add to its existing capital stock by purchasing capital goods from the capital goods sector.

$$k_{t+1} = (1 - \delta) k_t + q_t I_t \quad (4)$$

Where I_t represents purchases of new capital goods and q_t is the relative price of capital (consumption is chosen to be numeraire). Due to the fact that the firm faces consumer demand that will be subject to preference shocks, the firm carries inventories to buffer against the possibility of stockouts. The maximum amount of consumer goods the firm can sell in period t is its inventory at the end of period $t - 1$ denoted V_{t-1} , plus any production during period t . Therefore, sales in time t will be

$$C_t = \min [V_{t-1} + y_t, c_t] \quad (5)$$

where C_t denotes actual sales at time t . Given k units of capital and taking the real wage rate w and the price of capital q_t as given, the plant manager maximizes profits.

$$\Pi_t(k, w) = \max_{l_t, I_t, V_t} \{C_t - w_l l_t - q_t I_t\} \quad (6)$$

2.2 Capital Goods Production

There exists a representative firm that produces capital goods. For simplicity, assume that capital goods are produced using only labor. It produces output according to the following technology.

$$K = B \tilde{l}^\omega \quad (7)$$

The productivity term, B , is again a productivity term. This productivity term follows an $AR(1)$ process given by:

$$B_t = B + \xi B_{t-1} + \epsilon_t \quad (8)$$

$$\epsilon_t \sim N(0, \sigma_\epsilon^2) \quad (9)$$

where $0 \leq \xi \leq 1$. Initially, the model will be used to examine the impact of demand shocks, so it will be assumed that $\xi = \rho$ and $\epsilon = v$. However, later on, the parameters will be varied to examine the importance of sectoral shocks.

The capital goods firm will also hold inventories as insurance against uncertain demand. The maximum amount of capital goods the firm can sell in period t is its inventory at the end of period $t - 1$ denoted \tilde{V}_{t-1} , plus any production during period t . Therefore, sales in time t will be

$$S_t = \min \left[\tilde{V}_{t-1} + K_t, I_t \right] \quad (10)$$

where C_t denotes actual sales at time t . Given k units of capital and taking the real wage rate w and the price of capital q_t as given, the plant manager maximizes profits.

$$\Pi_t(k, w) = \max_{l_t, \tilde{V}_t} \left\{ q_t S_t - w_t \tilde{l}_t \right\} \quad (11)$$

2.3 Consumers

Consumers have preferences defined over random streams of consumption represented by the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t W(c_t) \quad (12)$$

$$W(c) = \phi \ln(c)$$

where c represents consumption, l represents labor, $\beta < 1$ is the discount rate and E_0 represents the conditional expectation based on information available at time 0. One unit of labor is supplied exogenously. The term ϕ represents a preference shock. This shock is governed by an $AR(1)$ process.

$$\phi_t = \phi + \alpha\phi_{t-1} + \mu_t \quad (13)$$

$$\mu_t \sim N(0, \sigma_\mu^2) \quad (14)$$

with $0 \preceq \alpha \preceq 1$. Income comes from three sources. As wages paid out by the production firms as well as any profits.

$$y_t = w_t + \Pi_t^c + \Pi_t^k \quad (15)$$

Income can be allocated for consumption purposes or can be saved. Savings earns the real rate of interest. Therefore, consumers face the following budget constraint.

$$c_t + s_{t+1} = w + (1 + r_t) s_t + \Pi_t^c + \Pi_t^k \quad (16)$$

the household's decision problem is to choose a contingency plan for

$\{c_t, l_t, s_{t+1}\}_{t=0}^{\infty}$ that maximizes expected lifetime utility subject to the budget constraint.

The consumers problem can be written in the following recursive formulation. Note that to save on notation, time subscripts have been left out. Primed variables indicate their t+1 values. s represents the state of the world which will be defined later.

$$J(s) = \underset{c, s'}{Max} \left\{ \begin{array}{l} W(c) + \beta E_t J(s') \\ + \lambda_1 (w + (1 + r) s + \Pi_t^c + \Pi_t^k - c - s') \end{array} \right\} \quad (17)$$

The upshot of the dynamic programming problem are the following first order conditions

$$W'(c) = \lambda_1 \quad (18)$$

$$\beta E J'(s'; e') = \lambda_1 \quad (19)$$

Along with the following envelope condition

$$J'(s; e) = \lambda_1 (1 + r) \tag{20}$$

Equation (18) is the efficiency condition for consumption. The multiplier represents the marginal utility of wealth. Equation (19) is the efficiency condition for savings.

3 Equilibrium

The competitive equilibrium can be defined as a set of decision rules $\{c, s, l, \tilde{l}, V, \tilde{V}, \tilde{I}\}$ and a set of pricing functions $\{r, w, q\}$ such that

- 1) Consumers optimize, taking interest rates, wages, and prices as given.
- 2) The representative firms and all plants maximize profits taking interest rates, wages, and prices as given.
- 3) Given the behavior of consumers and producers, prices adjust such that markets clear, as represented by the following conditions

$$I_t + \tilde{V}_t = B_t \tilde{l}^\omega \tag{21}$$

$$c_t + V_t = A_t k_t^\alpha l_t^\omega \tag{22}$$

$$l_t + \tilde{l}_t = 1 \tag{23}$$

4 Analysis

5 References

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