STOCK AND FLOW VARIABLES AND THE DYNAMICS OF SUPPLY AND DEMAND

by

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ABSTRACT

This paper contrasts two viewpoints for analyzing the concepts of supply and demand. The first viewpoint, which dominates most economic thinking, treats supply and demand as rates of flow. For example, supply in economic models tends to be measured by a rate of production, while demand is measured by a flow of consumption or purchases. The second viewpoint sees supply and demand primarily as stock variables or integrations. According to this viewpoint, for example, supply would be measured by the available inventory of a commodity while demand would be measured by a backlog of unfilled orders.

The central point of the paper is that stock-variable concepts of supply and demand must be incorporated explicitly in economic models in order to capture the full range of disequilibrium behaviour characteristics of real socio-economic systems. More specifically, the paper shows that consideration of stock-variable measures of supply and demand is necessary to describe the price- and quantity-adjustment mechanisms linking supply and demand; to analyze properly the stability characteristics of an economic system; to analyze short-run and long-run disequilibrium behaviour; and to assess the desirability of economic policies intended to influence such disequilibrium modes of behaviour as economic growth and fluctuation.

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I. INTRODUCTION

Supply and demand are the two central concepts in both classical and modern economic analysis. Models of economic process can be divided into two broad categories: equilibrium theories, which analyze the outcome of market transactions once supply and demand for a particular commodity have settled into balance in equilibrium; and disequilibrium theories, which treat the behavior of the economy when supply and demand are not necessarily equal, and where discrepancies between supply and demand are assumed to generate pressures for change.

In both equilibrium and disequilibrium models, the question arises of how to measure or represent the concepts of supply and demand. This paper contrasts two particular viewpoints on analyzing supply and demand. The first viewpoint, which dominates economic thinking, treats supply and demand as rates of flow. For example, John Maynard Keynes' General Theory popularized the concept of aggregate demand, which is the sum of planned consumption, investment, and government expenditures. These three forms of expenditures are all rates of flow, measured in goods units (or dollars) per unit time. Even long predating Keynes, however, the static theory of the firm regarded supply as a flow of production determined by the equalization of price and marginal cost. Analogously, the theory of the household treated demand as a flow of consumption governed by relative prices and marginal utilities.

An alternative perspective to the rate-of-flow viewpoint concerning supply and demand sees supply and demand primarily as stock variables or integrations. According to the stock-variable viewpoint, supply, for example,

would be measured by the available inventory of a commodity while demand would be measured by a backlog of unfilled orders.

The distinction between stocks and flows is well known to economists. Yet, economic theories still revolve primarily around flow concepts of supply and demand. An important reason for this emphasis on rates of flow is that both the theory of the firm and the theory of the household have evolved out of a set of equilibrium concepts of profit and utility maximization, respectively. The theory of the firm deals essentially with the determination of an equilibrium rate of production which yields a maximum flow of profits; analogously, the theory of the household is concerned with determining the equilibrium rates of purchase that are consistent with a maximum flow of utility from current purchases. In equilibrium, inventories held by firms and households are at their desired levels. Consequently, there are no inventory discrepancies to generate upward or downward pressure on rates of production and transaction. As a result, inventories and other stock variables do not typically appear in equilibrium models. As Kenneth Boulding has noted,

> In fact the theory of the firm, and of the economic organism in general, has...developed...along the lines of static equilibrium theory of "maximizing behavior." The concept of the balance sheet, unfortunately, has not been employed to any extent in developing the static theory of the firm, so that as generally presented in the textbooks the firm is a strange bloodless creature without a balance sheet, without any visible capital structure, without debts, and engaged apparently in the simultaneous purchase of inputs and sale of outputs at constant rates.[1]

The concept of equilibrium predominates economic analysis. Its influence is seen clearly in the large numbers of models in the literature which derive equilibrium prices and quantities based upon an assumed equality of supply and

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[1] Boulding (1950), p. 34.

demand, both usually considered as rates of flow. More subtly, however, due to the basis of economic analysis in equilibrium theory, dynamic models in economics have also tended to concentrate on the relationship between rates of flow to the exclusion of stock concepts. For example, Paul Samuelson's classic multiplier-accelerator model interrelates rates of production, consupmtion, investment, and income flow;[2] the model does not explicitly include inventories, capital stock, money levels, or other stock variables that intervene between rates of flow. Analogously, Kenneth Arrow and Marc Nerlove present a model in which price changes are governed by excess demand for a commodity.[3] In turn, they assume that excess demand, which may be regarded as the net of consumption less production, is a function of the prices and expected prices of the commodity and (potentially) all substitute and complementary commodities. Therefore, their model allows for the possibility of disequilibrium between production and consumption, but accounts neither for the changes in inventories, backlogs, and other stock variables that would occur in a disequilibrium mode, nor for the way in which these changing stock variables would feed back to influence supply, demand, and prices.

This paper attempts to demonstrate that stock-variable concepts of supply and demand must be incorporated explicitly in economic models in order to capture the rich disequilibrium behavior characteristic of real socio-economic systems. More specifically, the paper raises a number of broad implications for economic theory and modeling practice:

[2]Samuelson (1939).

[3]Arrow and Nerlove (1958).

(1) Stock equilibrium and flow equilibrium in an economic system are not equivalent concepts. (They do not necessarily occur concomitantly.) Stock variables will frequently be out of equilibrium, thereby causing continuing change in rates of flow, even once flow equilibrium has been attained. Consequently, even a description of the equilibrium position of an economic system requires consideration of both stock and flow variables.

(2) The stability characteristics of an economic system can be analyzed properly only in a model which interrelates stocks and flows in a comprehensive manner.

(3) Economic systems are characterized by complex adjustment paths to equilibrium, and such systems cnanot a priori be considered stable in the sense that an initial disequilibrium will be countered within a very short lapse of time.

(4) The efficacy of policies designed to influence such disequilibrium economic behavior as economic growth or instability can be assessed properly only in a model that interrelates stocks and flows.

Several of these points have already been recognized by economists. For example, Duncan Foley and Miguel Sidrauski (1971) discuss the need to incorporate both stock and flow equilibria in a macroeconomic growth model. Nonetheless, this paper contributes to economic theory in three major respects: first, by synthesizing in a single discussion the diverse functions of stock variables and the motivations for including them in economic models; second, by highlighting the inherent theoretical deficiencies of equilibrium models and the large number of dynamic economic models which do not incorporate explicitly all stock variables connecting rates of flow; and third, by suggesting a concrete direction for refinement and extension of economic theory and model-building practice.

II. CONTRIBUTION OF STOCK-VARIABLE CONCEPTS OF SUPPLY AND DEMAND TO DYNAMIC BEHAVIOR

Stock variables play a major role in the dynamics of supply and demand. This section of the paper presents seven points, each of which describes a particular function or mechanism through which stock variables give rise to dynamic disequilibrium behavior. The list of functions is not fully inclusive, but seems to encompass the most relevant points from the standpoint of economic theory.

A. Stock Variables Provide a Mechanism for Equilibrating Supply and Demand

As noted earlier, economic models of the firm center around production, consumption, and prices. In a real firm, stocks of in-process goods and final output intervene between the processes of production and consumption. If production exceeds consumption, inventory will accumulate. Conversely, if production is less than consumption, inventory will be drawn down. Typically, a firm will try to maintain inventory levels that are proportional to its internal level of activity, measured by the firm's average rate of production or sales. Discrepancies between actual and desired inventory generate pressures to expand or contract production by acquiring or disposing of factor inputs. Therefore, inventories provide a mechanism for linking and equilibrating production and consumption rates. Boulding (1950) discusses, in an analogous manner, how the firm acts to preserve a "homeostasis" of its asset structure (its stocks of physical and financial assets). Production and consumption need

not be equal at each point in time. However, for example, if production exceeds consumption, inventories will rise above desired levels, thereby signalling a need to contract output. Consequently, imbalances between production and consumption can be corrected through the physical mechanism of production changes motivated by inventory shortages or excesses, as well as by price changes. Such quantity adjustments to a market imbalance can exert important effects on disequilibrium behavior. For example, Axel Leijonhufvud notes that the "revolutionary element in Keynes' General Theory was the reversal of the Marshallian assumption of infinitely-fast price adjustments relative to quantity adjustments."[4]

Stock variables can link production and consumption through several other mechanisms. For example, suppose that the order rate for a firm's output exceeds the production capacity of the firm. Order backlogs will tend to rise, thereby lengthening the firm's delivery delay (the average period of time required to fill an order). High delivery delay, in turn, can depress incoming orders through lack of availability of the product. Consequently, whereas price is regarded in economic theory as the fundamental market-clearing mechanism, both availability and price can in fact serve jointly as market-equilibrating channels.

Finally, it should be noted that price changes in a firm arising from supply-demand pressures tend to be based on the relative magnitude of stock, rather than flow, variables. For example, upward price pressure may reflect low inventories (indicating inadequate supply) or high order backlogs (indicating excess demand). In either instance, excess demand would cause expansion

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[4] Leijonhufvud (1970), Ch. 2; also see Clower (1965).

of production, leading to a build-up of inventories and reduction or order backlogs. In contrast to the relative size of inventories and backlogs, the balance of production and consumption in a firm does not provide a reliable indication of excess demand or supply. Suppose that production exceeds consumption. Does this discrepancy necessarily indicate excess supply in the market? It might if, for example, inventories equal or exceed desired levels as a consequence of the high production rate. But, alternatively, the high production rate could be a consequence of high desired production due to low inventories or high order backlogs. In this instance, production in excess of consumption would be a consequence of excess product demand.

More attention should be given in economic theory to the way in which price changes and market adjustments are influenced by stock variables such as inventories and backlogs. Robert Clower and Axel Leijonhufvud remark that:

> A theory capable of describing system behavior as a temporal process, in or out of equilibrium, requires a prior account of how trade is organized in the system. Equilibrium, steady-state theory has managed pretty well without such an account. Macroeconomic theory cannot do so. Microeconomic theories of how business and household units behave--of how production and consumption decisions are made--when the system is not in equilibrium will have to be predicated on some such account.[5]

By expanding their theories to encompass the stock variables linking rates of flow, economists will necessarily move in the direction, advocated by Clower and Leijonhufvud, of filling in the details of "how trade is organized" in a complex production-consumption-distribution system.

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[5] Clower and Leijonhufvud (1975), p. 183.

B. Stock Variables Can Induce Opposing Short-Term and Long-Term Effects

Classical economics asserts that an increase in the marginal costs of producing a commodity should lower supply, by shifting the supply curve so that a lower supply is elicited by a given price; lower supply, in turn, should drive up prices due to excess demand. Real economic systems, however, display a much more complicated pattern of interaction among price, supply, and demand. In particular, one frequently observed pattern of behavior exhibits opposing short-term and long-term price responses.

To take a concrete example of such opposing short-term and long-term price and cost responses, consider the behavior of hog prices in commodity markets during 1971. In 1971, corn prices rose dramatically due to a severe corn blight in the Midwestern states. This price increase raised the marginal costs of hog production, since corn is the primary feed for hogs. Many economists expected this increase in costs to lead to higher prices and a lower supply of hogs. But in fact, hog prices declined in 1971 and returned to their 1971 level only about a year later, subsequently continuing to rise. From the standpoint of static equilibrium analysis, such a pattern of price behaviour appears anomalous; but it becomes readily explicable when we expand our notions of supply and demand to encompass the level variables (stocks) in a typical commodity system.

Figure 1 shows the essential stocks and flows that characterize a commodity system such as hog farming. Live hogs are held in two forms: in a mature stock where they are fed for approximately two months before slaughter; and in a breeding stock where hogs are withheld from market for breeding purposes. The breeding stock determines the breeding rate of hogs; after a

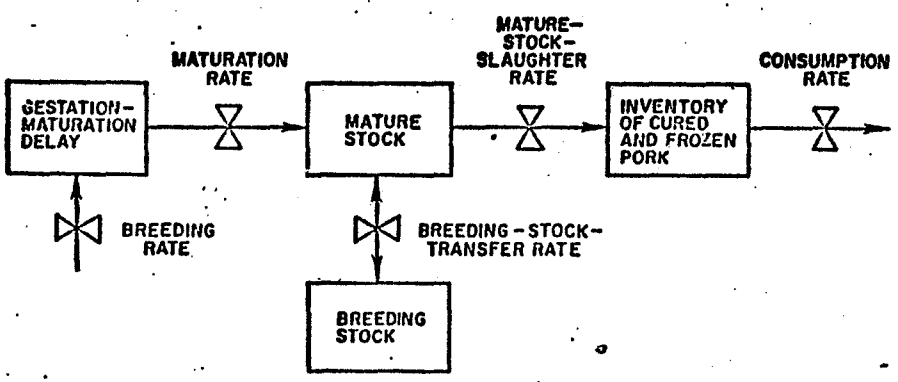

Figure 1. Stocks and flows in a typical commodity system.

ten-month gestation-maturation delay, young hogs flow into the mature stock category.

Of significance in Figure 1, no single variable can alone be termed the "supply of hogs"; instead, at least four distinct concepts are related to the supply of hogs. First, the size of the breeding stock determines the breeding rate, which is equal to the maturation rate in equilibrium. Second, the size of the mature stock measures the number of hogs soon to be coming on the market. Third, the mature-stock-slaughter rate measures the annual rate of addition to final output inventories of cured and frozen pork (analogous to final production rate). Fourth, the inventory of pork measures the amount of the product available for sale and subsequent consumption. As will be shown later, the different variables that measure the supply of hogs can be moving in

opposite directions at the same point in time, thereby generating opposing short-run and long-run pressures on price.

What will be the response of the system shown in Figure 1, and especially the various measures of supply, to an increase in the marginal costs of production? Rising marginal costs lower the profitability of raising hogs and consequently induce producers to lower their desired breeding stock. Producers therefore tend to transfer hogs from breeding stock to mature stock to reduce breeding stock to its desired level. As a result, the short-term response to an increase in marginal cost is to reduce breeding stock, expand mature stock, and increase the flow of hogs onto the market (Figure 2). Thus, an expanded short-term supply and downward price pressure result from increased marginal costs. This response on the part of producers is not irrational, but is largely a necessary physical consequence of the structure of the commodity system. Over the long term, as the breeding stock is reduced, the breeding and maturation rates will decline, and the final output inventory will decline, thereby generating upward pressures on price.[6] This effect is the outcome anticipated in the classical economic analysis of supply and demand, where an increase in marginal costs lowers the production rate. However, the classical result encompasses only the long-term response to supply, while the short-term response runs in the opposite direction.

Two points are illustrated by the hog-production example. First, in an economic system, supply and demand may have multiple manifestations, some being expressed through stock variables. Second, supply and demand can

[6] Figure 2 shows that increased price will eventually reverse the decline in breeding stock, thereby leading to an increase in breeding and maturation rates and an increase in the inventory of cured and frozen pork.

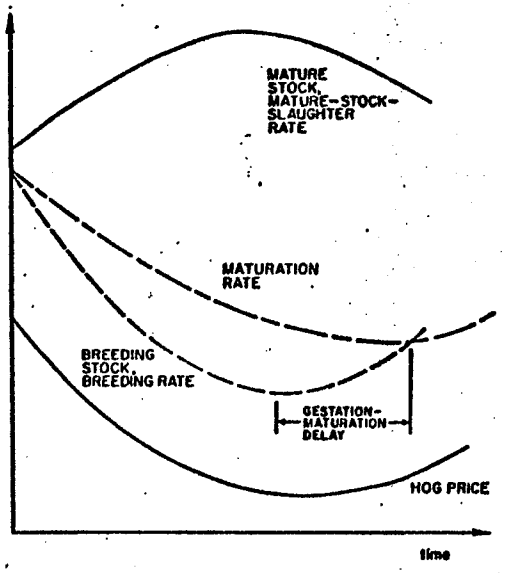

Figure 2. Behavior of commodity system over time.

each change in opposing short-term and long-term directions. Analysis of these divergent short-run and long-run impacts requires an explicit portrayal of the stock variables that influence supply and demand.

C. Stock Variables Induce Amplification of Rates of Flow Through Accumulation Effects

Stock variables can induce amplification of rates of flow, such as production and consumption. The term "amplification" refers to the tendency for a response in an economic system to exceed the amount of change that would at first seem to be entailed by the causes of that response. An example of amplification would be a ten percent increase in production rate induced by a five percent increase in incoming order rate.

To demonstrate one source of such amplification, consider the response of production to a step increase in consumption, shown in Figure 3 as a step increase in incoming orders. The higher consumption would deplete inventories

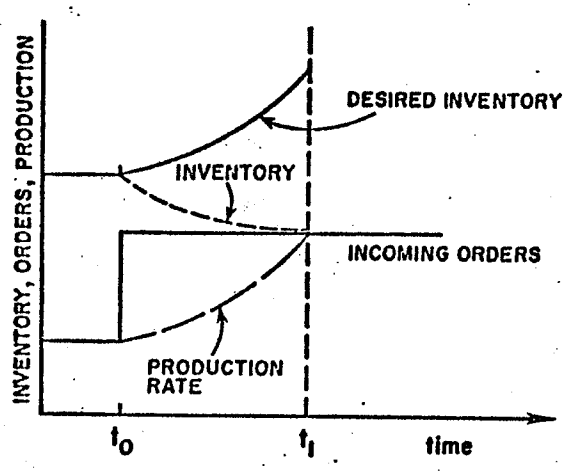

Figure 3. Production overshoot caused by inventory-management policies.

and induce an expansion of production. However, at the point t_1, where production and consumption are equal, inventory would be approximately at its minimum value while desired inventory would have risen in response to the increased level of economic activity. The resulting inventory imbalance would impel continued expansion of production above consumption. Production would have to expand above consumption in order to rebuild the inventories depleted while production was still below consumption, and to build inventories up to a higher absolute level set by the increased desired inventory. Therefore, even when supply and demand are equal in the rate-of-flow sense, supply-demand pressures embodied in stock variables can move the system out of its flow equilibrium. In this simple production-consumption example, rebuilding the diminished inventory necessitated an increase in production above consumption. Such amplification of production, which readily causes successive over- and underexpansion of production relative to consumption, cannot be captured in economic models that are confined to interrelating rates of flow.

By viewing supply and demand as stocks or level variables, we can begin to see how economic processes frequently considered to be stabilizing mechanisms in fact may be destabilizing or at least can prolong disequilibrium behavior. Looking back to Figure 3, suppose that prices tend to rise as long as inventories are inadequate, indicating an insufficient product supply. In this situation, prices would be high and rising most rapidly at the point where production equals consumption, thereby encouraging a production overshoot. Consequently, in a real economy containing inventories, backlogs, and other stock variables, prices may well have a net <u>destabilizing</u>, rather than <u>stabilizing</u>, effect on economic activity. In other words, production behavior can be less stable when production policy responds to price than when

production is governed solely by the physical mechanisms of inventory and backlog correction. Such issues merit careful further investigation. Economic models must realistically treat the full range of mechanisms governing disequilibrium behavior if we are to be able to infer proper conclusions about the stability of economic systems and the desirability of alternative economic stabilization policies.

D. Stock Variables Underline Multiple Modes of Economic Behavior

In an economic system, different time constants or speeds of adjustment may be associated respectively with different stock variables. In turn, differences in adjustment times may give rise to multiple modes of economic behavior. Analysis of such multiple modes is important from a theoretical and policy standpoint because, to the extent that separate processes underlie different modes of behavior, different points of intervention and different policy levers may be called for to influence each mode.

To illustrate these remarks, consider an economy containing two factors of production--labor and fixed capital stock. Labor is augmented through hiring and decreased through separation. Fixed capital stock is increased through investment and decreased through depreciation. Labor and fixed capital differ in two important respects. First, in an economy such as the United States, labor can be acquired fairly readily over a period of weeks or, at most, months. In contrast, construction and delivery of fixed capital require a longer period, perhaps one to three years. The acquisition of new capital equipment must also frequently be preceded by a long planning period. During that time, technical specifications are drawn up, plans are debated and modified,

appropriations are approved, and credit is negotiated if the project is to be financed through debt or equity issues as distinguished from internal finance. To summarize the first difference, then, labor has a short time constant or delay in its planning and acquisition, compared with fixed capital.

Labor and fixed capital also differ in their turnover times. In the United States, labor can be discharged on very short notice or reduced fairly quickly through attrition. In fact, the average duration of employment is approximately two years.[7] In contrast to labor, fixed capital is a relatively durable asset with an average lifetime of ten to twenty years. The second difference between labor and fixed capital, then, is that labor has a much shorter time constant for turnover than fixed capital.

To see the behavioral significance of the two basic differences between labor and fixed capital, consider the inventory-production relationships described in Section II.C of this paper, but let both labor and fixed capital contribute to production. We can isolate the behavioral impacts of adjustments in labor and fixed capital by first holding one factor input constant, subjecting the system to a change in incoming orders, and examining the resultant behavior; then, holding the other factor input constant and repeating the same analysis; and finally, allowing both factors to vary and studying the resulting behavior.

To apply this framework, start by assuming that fixed capital stock is constant, so that production rate can be altered only through changing the level of labor or through short-term changes in capacity utilization. If the incoming orders to a firm in which labor is the only variable factor of

[7] Statistical Abstract of the United States, 1970, p. 218.

production increase, production overshoot will occur in accordance with the mechanisms described in Section II.C. That is, production must expand above consumption, and employment must increase in the short term over its eventual equilibrium value, to replenish depleted inventory stocks and build inventory up to a higher level necessitated by an increased level of business activity. As described in detail by Nathaniel Mass (1975), such interactions between employment and inventories can produce fluctuations in employment, inventory, and production characteristic of the short-term business cycle in the economy.

Now reverse the factor-input assumptions made above, and suppose that labor is held constant while fixed capital stock is allowed to vary. If incoming orders now increase, overshoot and fluctuation in fixed capital stock and production will tend to occur as a consequence of the same structural mechanisms described above. Production must overshoot consumption to build up inventories, whether the underlying factor of production is labor or fixed capital. In other words, the mechanisms producing overshoot and fluctuation are structurally parallel for the two cases of variable labor input and variable capital input.

The difference in behavior in the two instances described above, will primarily be in the periodicities of fluctuation. That is, the cycle associated with adjustments in fixed capital will be relatively long compared with the labor-adjustment cycle, due to the long planning and acquisition delays associated with expanding production by increased fixed capital stock, and the long depreciation delay associated with contracting production through reduced fixed capital stock. As described by Mass (1975), the time constants of adjustment associated with labor and fixed capital may differ sufficiently so that, when labor and fixed capital are both allowed to vary, the economy exhibits a short-term cycle due to labor adjustments superimposed on a longer-term cycle caused by fixed capital investment policies. These

results imply, contrary to the prevalent capital-investment theories of business cycles, that labor hiring and firing policies primarily govern the short-term business cycle, while fixed capital investment is chiefly involved in generating economic cycles of much longer duration.[8] In turn, the results suggest the need for a reassessment of current economic stabilization policies, particularly monetary policies and other policies designed to influence short-term business-cycle behavior by varying incentives for capital investment. Such an evaluation of alternative policies must be performed using models that treat explicitly the various stock variables that influence short-term and long-term cyclic behavior, and which are therefore capable of exhibiting the multiple modes of fluctuating economic behavior characteristic of the real economy.

E. Stock Variables Can Propagate Long-Term Economic Changes

Looking at processes of supply and demand in terms of stock variables provides insight into the mechanisms through which long-term changes can be propagated through the economy. As just demonstrated, the process of fixed capital investment may underlie medium- or long-term economic cycles. For example, Mass (1975) shows how capital accumulation processes can underlie the fifteen- to twenty-year Kuznets cycle of growth in capital plant and potential output. Going further, Jay Forrester (1975) suggests that interactions between fixed-capital-producing and capital-consuming sectors may be involved

[8] See Samuelson (1939), Duesenberry (1958), Hicks (1950), and Kaldor (1940) for a description of major capital-investment theories of the business cycle.

in generating a fifty-year long wave in the economy resembling the Kondratieff cycle. Such long-run behavioral phenomena arise from the way in which disequilibrium values of stock variables within a system promulgate disequilibrium rates of flow; such flows, in turn, cause long-term changes in stock variables characterized by relatively long time constants of adjustment. The particular significance of the capital-investment example cited above lies in the fact that fixed capital investment has traditionally been considered an essential factor in generating the short-term business cycle. However, consideration of the accumulation processes governing fixed capital leads to the conclusion that processes of investment are too slow to interact appreciably in a cycle of only a few years' duration. The position that capital investment is principally involved in generating economic cycles of much longer duration than the short-term business cycle has previously been argued by Moses Abramovitz and others, but remains a minority viewpoint among economists.[9]

Stock variables may also capture attitudinal factors that influence long-term economic development. For example, a recent article dealing with the reasons for overbuilding of office space in New York City describes how long-term attitudes toward risk affect successive building cycles.[10] Office space in New York was significantly overexpanded in the 1920's. The resulting severe financial losses on the part of developers and financial institutions led to the introduction of stringent lending standards. In particular, developers planning to construct a new office building had to have the office

[9] See Abramovitz (1961).

[10] Eleanore Carruth, "The Skyscraping Losses in Manhattan Office Buildings," Fortune (February 1975).

space seventy-five percent leased out before they could obtain long-term credit. Such policies guaranteed at least seventy-five percent occupancy in office buildings, thereby alleviating the threat of overexpansion. However, as time passed, lending standards were gradually relaxed as recollections and fears of the situation in the 1920's subsided and as individuals responsible for introducing the original standards either retired or passed away. The culmination of these declining standards was another massive wave of office construction, leading to high office building vacancy rates in the 1970's.

Such attitudes toward financial risk represent a part of the state or condition of the socio-economic situation and change slowly in response to economic and social forces. As such, they can be described as stock variables or integrations of past attitudes and circumstances. Increased recognition is needed in economics of how socio-economic forces embodied in stock variables, including social values and attitudes, and the underlying process of integration can generate long-term disequilibrium behavior.

F. Stock Variables Measure the Determinants of Economic Welfare

The classical theory of the household assumes that households maximize utility subject to the budget constraint that the value of purchases not exceed present income. Household utility, or welfare, is in turn assumed to be a function of current rates of consumption of the various purchased goods and services. There are several flaws in this static framework. First, the budget constraint specifying that income must equal the total value of household purchases is an equilibrium condition where money balances held by households remain constant. In disequilibrium, however, income may exceed purchases,

leading to net accumulation of money balances; or, alternatively, income may fall short of purchases if consumers draw down their existing money balances. In either instance, changes in money levels lead to changes in the ability or willingness of consumers to spend money in the future. For example, consumer spending in excess of present income will deplete money balances, thereby lowering future spending power.

A second defect of the classical theory of the household is described by Boulding:

> The error in question is the identification of income, either in the form of production or consumption, with economic welfare, or perhaps it would be more accurate to say the use of income as a measure of economic welfare. So ingrained is this identification in our thinking that the assumption passes almost unquestioned, not only in the economics of the neo-classical school as represented by Pigou, but also in the more fashionable Keynesian economics. . . .
>
> The illusion that consumption--and its correlative, income--is desirable probably stems from too great preoccupation with what Knight calls "one-use goods," such as food and fuel, where the utilisation and consumption of the good are tightly bound together in a single act or event. We shall return to the problem of one-use goods later. In the meantime let us direct our attention toward many-use goods, such as houses, automobiles, furniture, crockery, clothing, machinery and tools, buildings, roads, bridges, etc. It is quite clear that the consumption of these goods (which necessitates their production) is something quite incidental to their use and frequently not even closely connected with the degree of use. We want houses, not because they depreciate, get dirty, sag, crack, disintegrate, and need repairs; we want houses because we can live in them, and the living in them is in no way bound up with their consumption. If we had houses that would not depreciate, walls that would not get dirty, or require painting, roofs that would never leak, foundations that would never sag, furniture that would not wear out, crockery that would not break, footwear that never needed repair, clothing that never got ragged or unpressed, we would clearly be much better off: we would be enjoying the services of these things without the necessity of consuming or producing them. Coming now nearer to the one-use goods, consider fuel--that the consumption for fuel for domestic heating merely arises because of the depreciation of warmth by poor insulation; any economy in the consumption of fuel that enables us to maintain warmth or to generate power with lessened consumption again leaves us better off. . . .

> There are important implications of the above analysis, both for economic theory itself and for the policy conclusions which stem therefrom. In the first place it is necessary to separate more clearly than hitherto the concept of income, output, or gross national product from the concept of economic welfare. There may be, and usually is, a correlation between the level of income and of welfare. But this connection is by no means invariable, and it would be most rash to suppose that an increase in income always means in increase in welfare. Irving Fisher saw this forty years ago, when he coined the phrase "psychic income": psychic income is that which is derived from the possession or use of capital, and is the significant welfare concept. "Real" income or "output", on the other hand, is significant only because of the power which it gives us to increase our capital stock, and hence our psychic income.[11]

According to Boulding, then, consumer welfare depends on available stocks of goods and services, rather than on the rates of addition to, or subtraction from, these stocks. Considering the accumulation processes inherent in the act of consumption provides insight into the impact of consumption on the economy. First, changes in price or income which affect consumers' desired stocks can exert accelerator-type changes on production, employment, and income. If, for example, the price of a particular commodity rises, consumers' desired stocks of that commodity will decline. The purchase rate of the commodity must then fall steeply in the short run below the usage rate in order to allow consumer-held inventories of the commodity to deplete. As the level of the commodity declines, however, even if price remains constant, the purchase rate will begin to increase toward the commodity usage rate. Second, purchases of durable goods are deferable since the utility provided by the good depends on the available stock rather than on the rate of purchase. Deferability of purchases depending on the ratio of desired to actual stocks of goods can induce consumption cycles where

[11] Boulding (1949-1950), pp. 77, 80, 83.

purchases alternately exceed and fall below the equilibrium rate of purchase and usage.

Modern consumption theory has tended to depart from the assumption of utility maximization subject to the budget constraint that the value of present consumption not exceed present income. For example, Franco Modigliani's "life-cycle model" of consumption assumes that a household plans its consumption over its entire lifetime "to redistribute the income it gets (and expects to get) over its life cycle in order to secure the most desirable pattern of consumption over life."[12] However, consumption theory still does not adequately incorporate the diverse stock-variable influences on consumption. For example, utility is still assumed to be derived from the purchase rate of goods and services, rather than from the available stocks. Moreover, consumption functions in economic models are seldom accompanied by explicit internal accounting for household money pools and stocks of consumption goods, and infrequently consider the feedback which these stock variables exert on purchase rates. Consequently, such phenomena as deferability of durable purchases are frequently overlooked even in modern consumption functions. To summarize, while consumption theory appears to be moving away from short-term equilibrium analysis, much further refinement is needed to capture all the relevant stock-variable effects that influence consumer welfare and consumption behavior.

[12] Modigliani (1957), p. 105. Also see Ando and Modigliani (1963).

C. Stock Variables Produce Variable Delays that Induce Overshoot and Oscillation

Changes in stock variables can produce variable delays and stock/flow ratios that contribute to disequilibrium behavior.[13] For example, if demand for a particular commodity rises, rising order backlogs and declining output inventories of the commodity can lengthen the delivery delay for the commodity. In turn, as delivery delay rises, consumers of the product must order further ahead in order to be able to maintain their desired usage rate.

The mechanisms through which varying delivery delays can produce fluctuations in consumption were described in an early article by Thomas W. Mitchell. He hypothesized an initial situation in which retailers, caught short of inventories, increase their orders for goods. As goods are shipped, manufacturers' inventories are depleted, thereby creating shortages and raising the delivery delay for goods. At this point, according to Mitchell,

> [r]etailers find that there is a shortage of merchandise at their sources of supply. Manufacturers inform them that it is with regret that they are able to fill their orders only to the extent of 80 per cent; there has been an unaccountable shortage of materials that has prevented them from producing to their full capacity. They hope to be able to give full service next season, by which time, no doubt, these unexplainable conditions will have been remedied. However, retailers, having been disappointed in deliveries and lost 20 per cent or more of their possible profits thereby, are not going to be caught that way again. During the season they have tried with little success to obtain supplies from other sources. But next season, if they want 90 units of an article, they order 100, so as to be sure, each, of getting the 90 in the pro rata share delivered. Probably they are disappointed a second time. Hence they increase the margins of their orders over what they desire, in order that

[13] In contrast, for example, dynamic input-output analysis assumes that stock/flow ratios are always constant over time (Leontief et al., Chap. 2). By virtue of this assumption, such analysis misses a whole range of disequilibrium phenomena.

> their pro rata shares shall be for each the full 100 per cent that he really wants. Furthermore, to make doubly sure, each merchant spreads his orders over more sources of supply.
>
> Herein originates a large false demand upon manufacturers, and herein lies a great defect of our system of competitive private initiative in industry. . . . [T]he false demand is passed back, stage by stage, along the channels of production. . . . What, in turn, is the natural result of this situation? Eventually the streams of production are not only enlarged but overenlarged. There comes a time when the ultimate sources of supply fill nearly all the orders of their customers. The latter are surprised to find their orders filled promptly and fully, and that they are receiving more than a plentiful supply of materials. There is no longer a shortage. Instead, owing to their previous overordering, there is a surplus. Their rate of ordering slows up a little, and the ultimate sources of supply find business not quite so brisk. The producers in the second stages also fill their orders promptly and fully, thus surprising their customers in turn. Result, orders upon the second stages in the production process slow up a little. And so on down to the retailers. The rivers of production have swollen so that the volume of flow is no longer insufficient to fill the apparent capacity of the market as evidenced in orders. Indeed, production has come to exceed the real demand, and the capacity of production organizations. . . .[14]

More attention should be given in economics to analyzing how variable delays produced by changes in system levels influence short-term and long-term disequilibrium dynamics. Such analysis requires explicit representation of both stocks and flows, and consideration of the dynamic changes that can occur in the ratios of system levels to rates of flow through them.

III. CONCLUSIONS

This paper has attempted to show how stock-variable concepts of supply and demand affect short-term and long-term economic behavior. Because of

[14] Mitchell (1924), pp. 645-647.

its historical foundation in equilibrium analysis, economic theory has tended to revolve around relationships between rates of flow, such as production and consumption. Wassily Leontief has noted that "exclusion of stocks from the original input-output scheme limits its applicability as a general equilibrium theory to short-run analysis."[15] But stock variables can cause significant disequilibrium changes through accumulation effects and varying stock-flow ratios, as discussed in Section II, even over periods as short as several months. Analysis of stability characteristics and dynamic properties of an economic system therefore requires explicit treatment of the stock variables that intervene between rates of flow.[16] Expanding economic analysis in this direction should enhance our capabilities to understand economic dynamics, and make headway against the considerable policy problems confronting society such as growth-management and economic stabilization.

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[15] Leontief et al. (1953), p. 12.

[16] Econometric models sometimes try to capture processes of accumulation (integration) implicitly, through distributed-lag formulations directly connecting rates of flow. Such practice appears generally undesirable or unfeasible, however. First, the use of distributed-lag formulations tends to obscure the nature of the underlying accumulation processes, thereby detracting from the clarity of the model and its potential utility in explaining behavior and analyzing alternative policies. Second, and more important from a theoretical standpoint, time constants and delay times across stock variables will seldom be constant. For example, delivery delays for goods will depend on suppliers' available stocks of these goods, and the turnover time of labor in the economy will depend on the multiple time-varying factors that influence termination rates and voluntary quit rates (see Runge [1976] for a comprehensive model of labor flows in a multi-sector economy). Incorporating such variable time constants requires nonlinear formulations that can pose formidable statistical problems in estimating distributed lags. For these reasons, therefore, the most sound practice, both theoretically and empirically, is to formulate models to explicitly include the relevant stock variables.

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