WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

Destabilizing Impacts of Price and Quantity Adjustments to Relative Supply and Demand

by

Nathaniel J. Mass

WP 1017-78

Sept. 1978

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June 2, 1978

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I. INTRODUCTION

Underlying much of economic analysis is the strong presumption that a one-time perturbation in supply or demand will be counteracted rapidly by price and quantity adjustments that restore equilibrium. For example, Baumol (1970) points out that utility of comparative static analysis as well as validity of the static theory of the firm and household, rests on the assumption that economic processes are stable.

The assumption that economic systems are stable has traditionally provided justification for equilibrium analysis of economic systems. And in turn, equilibrium analysis has tended to dominate economic thinking, by providing a filter through which all economic reality is distilled. To see the pervasive impact of equilibrium analysis, one need only observe that "Keynesian economics" is taught in many universities through study of intersecting IS-LM curves (investment = savings; liquidity demand = money). But the IS-LM analysis is a static formulation that derives not from Keynes but from Hicks' 1937 review article on the General Theory and subsequent interpretations. In a similar vein, Joan Robinson (1972) notes:

> consider what was the point of the Keynesian revolution on the plane of theory and on the plane of policy. On the plane of theory, the main point of the General Theory was to break out of the cocoon of equilibrium and consider the nature of life lived in time--the difference between yesterday and tomorrow. Here and now, the past is irrevocable and the future is unknown.
>
> This was too great a shock. Orthodoxy managed to wind it up in a cocoon again.

In a time when national and world economy are being shaken by disequilibrating events, equilibrium analysis is being strongly called into question. Recent major criticisms of equilibrium analysis include Kaldor (1972), Phelps Brown (1972), Worswick (1972), and Kornai (1971). However, these critiques are largely descriptive and point up the arbitrariness of equilibrium assumptions. This paper attempts to carry the argument one step further by developing a model of stock-management by producers. In a real production system, stocks are held as buffers due to uncertainty and imperfect coupling of flow rates (such as production and sales). Model analysis shows that typical stock-management policies of producers violate the conditions required for prompt restoration of equilibrium. The broad implications are:

1. Both price and quantity adjustments to relative supply and demand tend to induce persistent disequilibrium behavior;

2. Equilibrium analysis is therefore a weak and potentially misleading technique, particularly for short-run study; and

3. Proper dynamic analysis requires realistic portrayal of decision processes of economic agents, including comprehensive interrelating of stocks and flows.

More specific results are presented in the text.

II. THE CLASSICAL VIEW OF SUPPLY AND DEMAND

The classical view that imbalances in supply and demand are soon rectified leading to equilibrium is based on a simple model of supply and demand that has been refined in many ways. In the basic model, supply and demand for a particular commodity are assumed to depend on the price of that commodity. In one refinement, demand may also be considered a function of tastes and consumer income. Alternatively, demand for a particular commodity may depend partly on prices of all complementary and substitute goods. A still further extension suggested by Arrow and Nerlove (1958) bases demand and supply on both current and expected future prices. Nonetheless the simplest model of supply and demand bases both only on the price of that commodity (and on other factors such as tastes which are approximately constant over the time frame of the analysis). This model will be the basis of the discussion here for two reasons: first, it is the pervasive focus in the literature of most treatments of stability of equilibrium (see, for example, Samuelson (1947), Chapter IV, and Negishi (1962); and second, it permits a clear focus on the dynamics of supply and demand adjustment.

To complete the model of supply and demand adjustments, we now need a theory for how supply and demand adjust to an initial imbalance. Representing the adjustment process for supply and demand is necessary because any justification for the stability of economic processes must derive from a dynamic analysis of time paths of supply and demand adjustment. Samuelson's (1947) correspondence principle states the relationship between equilibrium analysis and preceding dynamic analysis as follows:

> ...the problem of stability of equilibrium cannot be discussed excapt with reference to dynamical considerations, however implicit and rudimentary. We find ourselves confronted with this paradox: in order for the comparative-statics analysis to yield fruitful results, we most first develop a theory of dynamics. This is completely aside from the other uses of dynamic analysis as in the studies of fluctuations, trends, etc.

The classical view of supply and demand embodies two possible models of supply and demand adjustment. The Marshallian model focuses on quantity adjustment. It assumes that excess demand elicits expansion of supply while insufficient demand evokes a reduced supply. The Walrasian model emphasizes price adjustment. Price is assumed to be bid upward in the face of excess demand and to fall in the fact of excess supply. As an illustration of the Walrasian assumptions, Lipsey (1960) assumes that excess demand for labor will raise wages while excess supply of labor will lower wages; moreover, he assumes that the speed of wage change depends on the excess demand as a proportion of the labor force. Similar pricing models are presented in Samuelson (1947), Hansen (1951), Phillips (1958), Arrow and Nerlove (1958), Negishi (1962), and Fisher (1972).

Both the Marshallian and Walrasian models lead to similar implications that equilibrium will be stable. Under the Walrasian assumptions, there will be excess supply, leading to price reductions, whenever the current market price is above the equilibrium price, and conversely. In turn, lower price reduces output and augments demand to eliminate excess supply. Similarly in the Marshallian model initial excess supply will lower production. As output falls, the supply price declines (in accordance with the assumption of diminishing returns implicit in the upward-sloping supply curve), thereby encouraging demand. Supply and price will fall and demand will increase until the excess supply is alleviated and equilibrium is restored. Therefore, both the Marshallian and Walrasian models imply that price and quantities supplied and demanded adjust to imbalances with no overshoot. Further, if price changes rapidly in the face of imbalances, excess demands or supplies will be readily eliminated.

The classical model therefore leads to the implications that:

1. Price adjustments are a stabilizing force in the economy; and
2. Equilibrium analysis is a useful technique since the real world is characterized by smooth and rapid equilibration of supply and demand.

The following section identifies limitations in assumptions of the classical model that tend to negate both conclusions above for the actual economy.

III. CRITIQUE OF THE CLASSICAL VIEW

The classical model has been criticized on several counts. For example, Kaldor (1972) emphasizes neglect of increasing returns to scale. Phelps Brown (1972) and Worswick (1972) criticize assumptions of perfect competition and profit maximization that underlie the supply curve. This paper does not attempt a comprehensive critique, but focuses on a single major omission of the classical model: namely, failure to interrelate stocks and flows.

In the classical model, supply and demand essentially represent rates of flow. For example, supply is a rate of production that rises with increasing price. Analogously, demand represents a stream of purchases whose volume declines with increased price. However, in a real firm, the supply of product is only partially represented by the rate of production, but also by the output inventory, representing the available final goods for consumption. Inventory is a stock variable that is increased by the flow of production and decreased by the flow of shipments or sales. In a similar way, demand for a firm's product is represented not only by the flow of purchases, but also by the size of the firm's backlog of unfilled orders. Order backlog, like inventory, is a stock variable. It is augmented through incoming orders and decreased through shipments or sales.

Stock variables such as inventories and backlogs have been largely neglected in the development of the theory of the firm and household because of the equilibrium focus of such theories. In the equilibrium of the firm, production and consumption must be equal. Inventories are at their desired levels and consequently exert no impact on production decisions. However, in real life, stock variables such as inventories and order backlogs exist and they influence production and consumption decisions. As described by Clower and Leijonhufvud (1975), "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." From this perspective, stock variables such as inventories and backlogs comprise a part of the organization of trade and production.

In recent years, many econometric studies beginning with Stanback (1961), Zarnowitz (1961), and Mack (1967) have examined impact of stock variables on production. However, such studies generally involve single-equation models that do not address impacts of stock variables on stability, evaluation of which would require more encompassing systems models. In fact, the most important rationale for including both stock and flow variables in economic models stems from the impact that stock variables exert on dynamic behavior.

To preview results of the next section regarding impact of stock variables on stability, consider the response of production within a typical firm to a step increase in consumption, shown in Figure 1 as a step increase in incoming orders. The higher consumption would deplete inventories and induce expansion of production. Production tends to lag consumption both because management takes time to perceive that the increased order rate is not an aberration and due to delays in acquiring factors of production to expand output. However, at point t_1, where production and incoming orders are equal, inventory would be approximately at its minimum value while desired inventory would have risen due to the increased level of production and sales. The resulting inventory imbalance would necessitate continued expansion of production above consumption rate. Production must expand above consumption in order to replenish the inventory that was depleted while production was still below consumption, and to build inventory up to a higher absolute level. Such amplification of production can cause successive over- and underexpansion of production relative to consumption and cannot be captured in economic models that are confined to interrelating rates of flow. [Metzler (1941) first discusses inventory dynamics that produce fluctuating production behavior.]

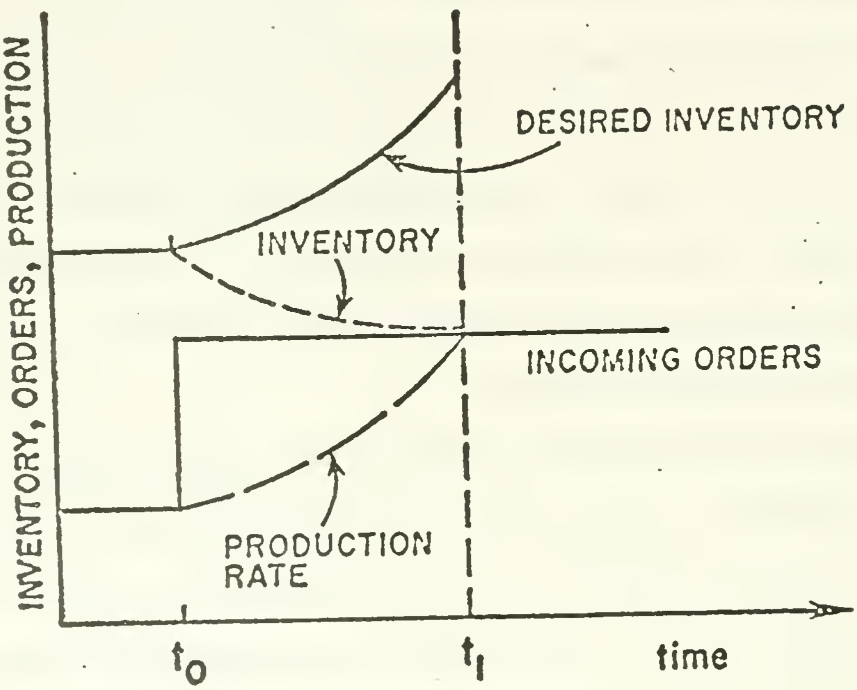

Figure 1. Production overshoot caused by inventory-management policies

The behavior in Figure 1 shows, in simplified form, how adjustments to relative supply and demand conditions will in fact generally tend to be cyclical, rather than smooth, in nature. These conclusions differ from the stable adjustment pattern implied by the classical model of supply and demand. The difference in conclusions arises from considering the effects of stock-variable measures of supply and demand on economic behavior. In an economic system, stock variables will frequently be out of equilibrium, thereby causing continuing change in rates of flow, even once flow equilibrium of production and consumption has been attained. This was seen in Figure 1 where inventory was inadequate, leading to upward pressure on production, even once production and consumption rates were equal.

Section IV extends the analysis just presented of physical stock variables by also incorporating price adjustments to supply and demand imbalances, and price impacts on production and consumption. Section IV thus integrates both the Marshallian and Walrasian assumptions in a model based on management of stock variables.

IV. INFLUENCE OF STOCK VARAIBLES ON STABILITY OF PRICE AND QUANTITY ADJUSTMENTS

IV.A Description of the Production-Sector Model

This section describes a basic production-sector model used to analyze stability of price and quantity adjustments. Although simple, the model aims to extend the classical model of supply and demand by including both the stock and flow measures of supply and demand that influence decision-making in an actual firm. The model therefore attempts to explain real production activity by portraying actual management decision making in the face of uncertainty and limited information. (Eichner and Kregel (1975) contrast such empirical observation with normative optimizing theories.) The model consists, then, of a description of how inventory, backlog, production, price, and sales change over time. A brief description of the model structure is given below. Mass (1975) describes an elaboration of the model.

Inventory I in the sector is the accumulation of production rate PR less shipment rate SR. Thus, we have

$$I(t) = I(t_0) + \int_{t_0}^{t} (PR(t) - SR(t))dt \qquad (1)$$

where $I(t_0)$ is the initial value of inventory at time t_0.

Production rate PR is assumed to be an increasing function f_1 of employment E, where labor is assumed for simplicity to be the only variable factor of production.

$$PR(t) = f_1(E(t)); \quad f_1' \geq 0 \qquad (2)$$

Shipment rate SR is assumed to depend on the desired shipment rate of the sector and on a measure of the availability of final output invenotry, the latter termed the multiplier from inventory for shipments MIS. The desired shipment rate DSR simply equals the order backlog B of the sector divided by normal backlog coverage NBC which represents the normal or desired delivery delay of the sector. NBC is here assumed to be a constant. The multiplier from inventory for shipments MIS is an increasing function of the ratio of final output inventory I to desired inventory for shipments DIS. Desired inventory for shipments is proportional to desired shipment rate and represents how much inventory the sector would have to hold to permit shipments at the desired rate. (The constant of proportionality is called normal inventory coverage NIC.) As inventory rises, the multiplier from inventory for shipments increases, indicating that higher availability of produce can raise shipment rate for a given order backlog B. Conversely, as inventory falls, lesser availability of product lengthens delivery delay and lowers shipment rate for a given order backlog. Note that this representation of shipment rate as a continuous monotonic function of inventory aptly describes a firm with an aggregate product line in which decreased inventory indicates a lesser probability of filling a given order in a given period of time. Recognition of impacts of inventory availability on shipments dates back to Thomas W. Mitchell (1923) and Wesley C. Mitchell (1927).

$$\begin{aligned} SR(t) &= DSR(t) \cdot MIS(t) \\ DSR(t) &= B(t)/NBC \qquad (3) \\ MIS(t) &= f_2(I(t)/DIS(t)); \quad f_2' \geq 0,\ f_2(1) = 1 \\ DIS(t) &= DSR(t) \cdot NIC \end{aligned}$$

Backlog B is simply the integration over time of incoming orders

IO less shipment rate SR. Order backlog is a measure of demand for output that arises due to delays in filling orders, especially in industries where some part of the product must be manufactured to order. Backlog thus decouples incoming orders and shipments.

$$B(t) = B(t_0) + \int_{t_0}^{t} (IO(t) - SR(t))dt \qquad (4)$$

Employment E is the integration of net hiring rate NHR. For simplicity, the model does not distinguish hiring rate, termination rate, and quit rate but combines these all into a single rate of flow.

$$E(t) = E(t_0) + \int_{t_0}^{t} NHR(t)dt \qquad (5)$$

Net hiring rate NHR(t) represents a correction term that attempts to bring employment E in line with desired employment DE. NHR equals the employment discrepancy, DE-E, divided by a time to adjust employment TAE.

$$NHR(t) = (DE(t) - E(t))/TAE \qquad (6)$$

Desired employment DE is computed on the basis of the production function of the sector (Equation (2) above) and the sector's desired production rate DPR (as distinguished from its present production rate). DE measures the number of men that would be required for the sector to produce at its desired rate.

$$DE(t) = f_1^{-1}(DPR(t)) \qquad (7)$$

Desired production rate DPR is a multiplicative combination of two terms. The first term equals the average shipment rate ASR plus a correction for inventory and backlog. When inventory and backlog equal their desired values, desired production equals average shipments, thereby indicating that the sector's current shipment rate is adequate to cover demand. If inventory is above the desired level, or if the backlog becomes excessive, desired production will exceed the average production rate, thereby inducing expansion of output. The second term in Equation (8) for DPR represents the effect of price on desired production rate. The formulation assumes that desired production is raised (through the multiplier on desired production from price MDPP) when price is high, indicating profitable opportunities to be exploited in the market; desired production is lowered as price falls. At the extreme, when price is zero, the formulation assumes that there are no incentives for production, and desired production consequently falls to zero (see Equation (9) below). Overall, the formulation shows how both price and physical manifestations of supply and demand (in the form of average sales and actual and desired inventory and backlog) interact to influence production. Thus, for example, a high price will encourage production through MDPP, but production rate will be lowered if the sector is unable to sell its output at that price, as indicated by a low average sales rate, high inventory, or low backlog. As mentioned earlier, the model thus integrates both Marshallian and Walrasian views of production behavior by incorporating both price pressures on production as well as pressures from physical excess demand or supply.

$$DPR(t) = \left(ASR(t) + \frac{DI(t) - I(t)}{TCI} + \frac{B(t) - DB(t)}{TCB}\right)(MDPP(t)) \qquad (8)$$

The multiplier on desired production from price MDPP is an increasing function of the ratio of price P to a constant normal price NP.

The normal price NP then can be thought of as the constant, long-run marginal cost of producing one additional unit of output. According to the formulation, desired production is increased, for given demand conditions, when price is high and reduced when price is low. This formulation for MDPP would have to be extended in a more detailed model containing variable wage rates and additional factors of production. The purpose here, however, is to focus on the most basic set of impacts of product price on supply and demand.

$$MDPP(t) = f_3(P(t)/NP); \quad f_3' \geq 0,\ f_3(1) = 1,\ f_3(0) = 0 \tag{9}$$

Average shipment rate ASR is imply an exponential average (Koyck transformation) of actual shipment rate SR. The averaging represents the time required for a firm to perceive and form expectations about the level of demand for its product.

$$ASR(t) = ASR(t_0) + \int_{t_0}^{t} \frac{SR(t) - ASR(t)}{TAS} dt \tag{10}$$

Desired inventory DI is assumed to equal a fixed number of months coverage (represented by normal inventory coverage NIC) of average shipment rate ASR. This reflects the need in a typical firm to hold a level of output inventory that is in some relation to the firm's level of business.

$$DI(t) = ASR(t) \cdot NIC \tag{11}$$

Desired backlog DB is represented as the product of the average shipment rate ASR and a constant normal backlog coverage NBC. NBC represents the sector's desired delivery delay for its product; an order backlog equal to DB would result in a delivery delay of NBC months if shipments equaled the average shipment rate.

$$DB(t) = ASR(t) \cdot NBC \quad (12)$$

Price P is the integration over time of price multiplied by the fractional change in price FCP. Price is therefore represented as a stock variable that changes in response to supply/demand pressures captured in FCP. Price is bid upward in the face of excess demand and downward due to excess supply. Price is similarly treated as a stock variable in Samuelson (1947), Lipsey (1960), Arrow and Nerlove (1958), and Negishi (1962).

$$P(t) = P(t_0) + \int_{t_0}^{t} (P(t) \cdot FCP(t))dt \quad (13)$$

The fractional change in price FCP is an increasing function of the delivery delay ratio DDR. DDR is defined as the ratio of delivery delay DD to normal backlog coverage NBC (the latter representing the sector's target delivery delay for output). Delivery delay is chosen as a measure of supply relative to demand because:

1. It is a common managerial index of supply-demand conditions; and
2. It captures the impact of inventory and backlog on supply-demand conditions: either low inventory or high backlog increases delivery delay, raising price.

Delivery delay DD represents the amount of time required to fill an order and is defined therefore as the ratio of backlog B to average shipment rate ASR.

$$FCP(t) = f_4(DDR(t)); \quad f_4' \leq 0, \; f_4(1) = 0 \quad (14)$$

$$DDR(t) = DD(t)/NBC \quad (15)$$

$$DD(t) = B(t)/ASR(t) \quad (16)$$

Finally, incoming orders (consumption demand) are specified as a normal (constant) rate of incoming orders NIO modified by a decreasing function of price. Mass (1975) extends this model to include income effects on consumption.

$$IO(t) = NIO \cdot f_5(P(t)/NP); \quad f_5' \geq 0, \ f_5(1) = 1 \tag{17}$$

IV.B Behavioral Results

This section presents a variety of computer simulations of the model developed in Section IV.A. Computer simulation is used as a vehicle of analysis because the model is too complex to be solved readily analytically; under these circumstances, simulation provides a convenient and clear mechanism for analyzing different supply and demand adjustment mechanisms.

The model is initialized in equilibrium with parameter values that might represent a typical consumer-goods sector of the economy. The parameters are chosen to conform to statistically-estimated values for a production-sector model more complex than described here. Senge (1978) discusses estimation results. However, it should be emphasized that the focus of the analysis below is on general behavioral properties of the system rather than on precise forecasts, and such modes are largely independent of the precise parameter values assigned.

Figure 2 shows behavior of the model in response to a step increase in incoming orders when desired production and order rate are assumed to be independent of price ($f_3 = f_5 = 1$ for all values of the independent variables). The purpose of this simulation is to study the impact of quantity adjustments--changes in production due to changing shipment rate, inventory, and backlog. Later simulations will incorporate influences of price, first on desired production alone, and then on both desired production and incoming order rate. The step increase in orders is used as a simple test input to see the inherent dynamic characteristics of the system. Other test inputs, such as random variation in order rate, could also be used, with results similar to those described below.

Figure 2 shows a damped oscillation in production rate, inventory, backlog, and other system variables with a periodicity of approximately 54 months. This periodicity is in the range of short-term business cycles that generally span three to six years.

Causes of the fluctuation in Figure 2 are essentially those described earlier in conjunction with Figure 1. Production rate must initially expand above incoming orders to replenish inventory, which declines as long as shipments exceed production; to build inventory up to a new higher desired level; and to reduce order backlog which rises to an undesirably large value during the period when incoming orders exceed shipment rate. Thus, in Figure 2 production rate rises by 20% in response to a 12% increase in incoming orders, and eventually overshoots below incoming orders as too large an inventory accumulates. The results suggest that the basic physics of inventory and backlogs and typical stock-management policies will generally induce oscillatory adjustments in production and employment. Thus, consideration of stock variables such as inventories and backlogs immediately begins to show how the stable adjustment pattern of supply and demand implied by the classical model cannot realistically describe real-world production processes.

The system described above will exhibit a continuing fluctuation average of 54-month periodicity in response to a random fluctuation in orders around a constant average value. This illustrates the

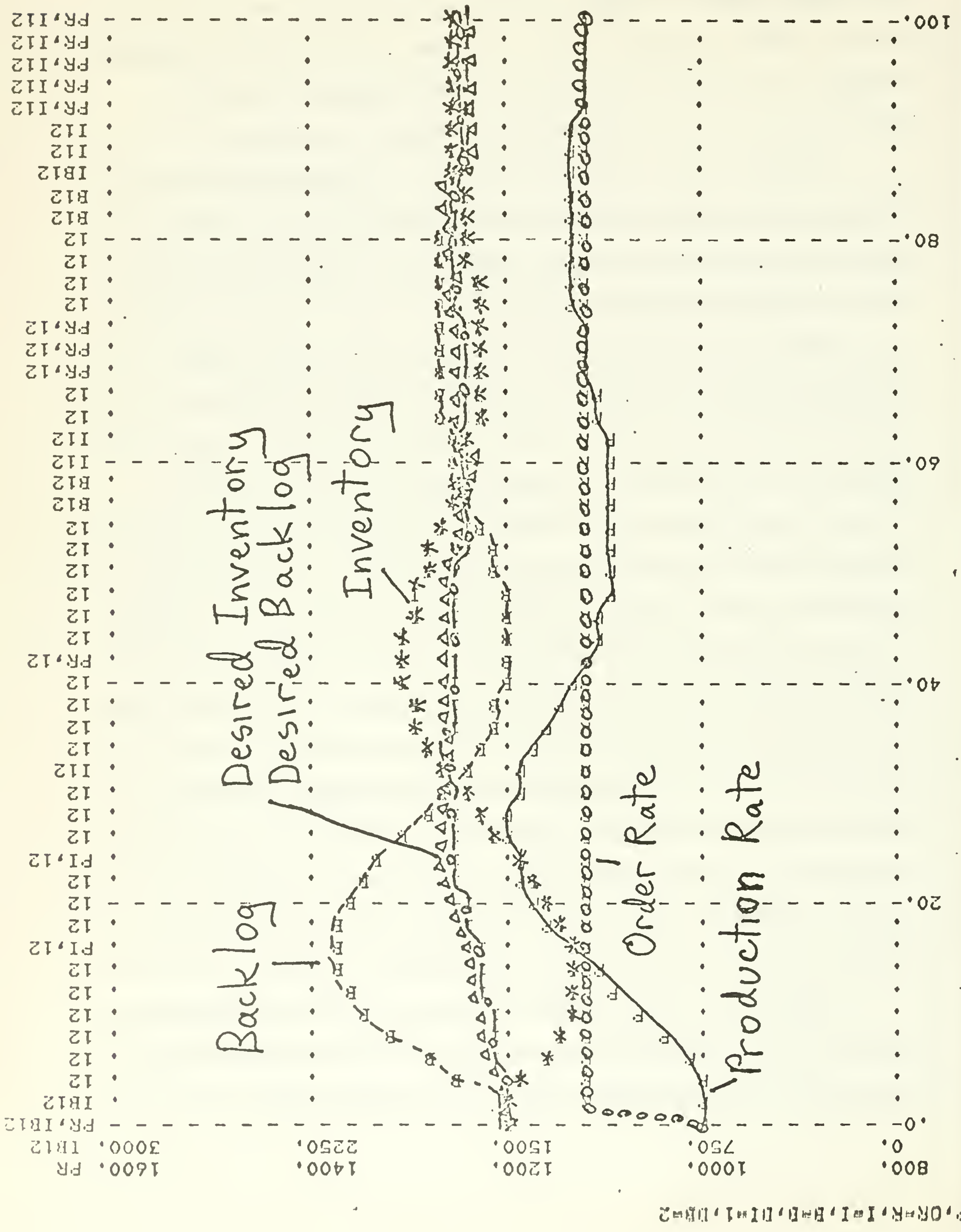

Figure 2. Step response of production-sector model with no price feedbacks

characteristic property of random noise, as discussed in Frisch (1933), to trigger a fluctuation at the natural frequency of a potentially oscillatory system. As Frisch states,

> The most important feature of the free oscillations is that the length of the cycles and the tendency towards dampening are determined by the intrinsic structure of the swinging system, while the intensity (the amplitude of the fluctuations is determined primarily by the exterior impulse. An important consequence of this is that a more or less regular fluctuation may be produced by a cause which operates irregularly...
>
> Knut Wicksell seems to be first who has been definitely aware of the two types of problems in economic cycle analysis--the propagation problem and the impulse problem--and also the first who has formulated explicitly the theory that the source of energy which maintains the economic cycles are erratic shocks. He conceived more or less definitely of the economic system as being pushed along irregularly, jerkingly. New innovations and exploitations do not come regularly he says. But, on the other hand, these irregular jerks may cause more or less regular cyclical movements. He illustrates it by one of those perfectly simple and yet profound illustrations: "If you hit a wooden rocking horse with a club, the movement of the horse will be very different to that of the club."

Figure 3 builds on the preceding analysis by showing response of the production-sector model to a step increase in orders when desired production is assumed to be an increasing function of output price. Thus, a high price now stimulates production, while low price deters production. Figure 3 exhibits fluctuating behavior with a periodicity of fifty months. Oscillations in production rate and other system variables are expanding slightly over the ten-year duration of the simulation. In fact, these oscillations are bounded by system nonlinearities and converge to a steady-state oscillation if the simulation is extended further out. Compared with Figure 2, production fluctuations are heightened. Thus, when production responds positively to price, behavior is <u>less</u> stable than without any feedback from price. Sources of this lessened stability are explained below

In Figure 3(a), as order rate increases at month 2, order backlog begins to rise and inventory falls somewhat. (Note that the vertical plot scales in Figure 3 are identical to those used in Figure 2.) Rising backlog and depleting inventory, along with increasing average sales, raise desired production. However, price also now influences desired production. The destabilizing effects of this additional price influence can be seen in Figure 3. In Figure 3(a), as backlog increases and inventory declines initially, delivery delay (not plotted) rises, thereby generating upward price pressure. Delivery delay reaches a peak at about month 12, as can be seen by observing the peak at month 12 in the fractional change in price in Figure 3(b). The positive fractional change in price raises price (Figure 3(b) and augments desired production through the multiplier on desired production from price that increases above 1 (Figure 3(b)). Delivery delay peaks at approximately the point when production rate intersects, order rate and begins to rise above it. Thus when production crosses order rate, price is higher than normal <u>and rising at approximately its maximum annual rate</u>.

Delivery delay peaks out when production and shipments rise above order rate. However, delivery delay is then still above normal, as seen in the positive fractional change in price in Figure 3(b) from months 12 to 22. Price thus continues to rise until about month 22, exerting sustained upward pressure on production rate. At month 22, for example, price is approximately $1.40/unit compared with a normal price of $1.00/unit. The

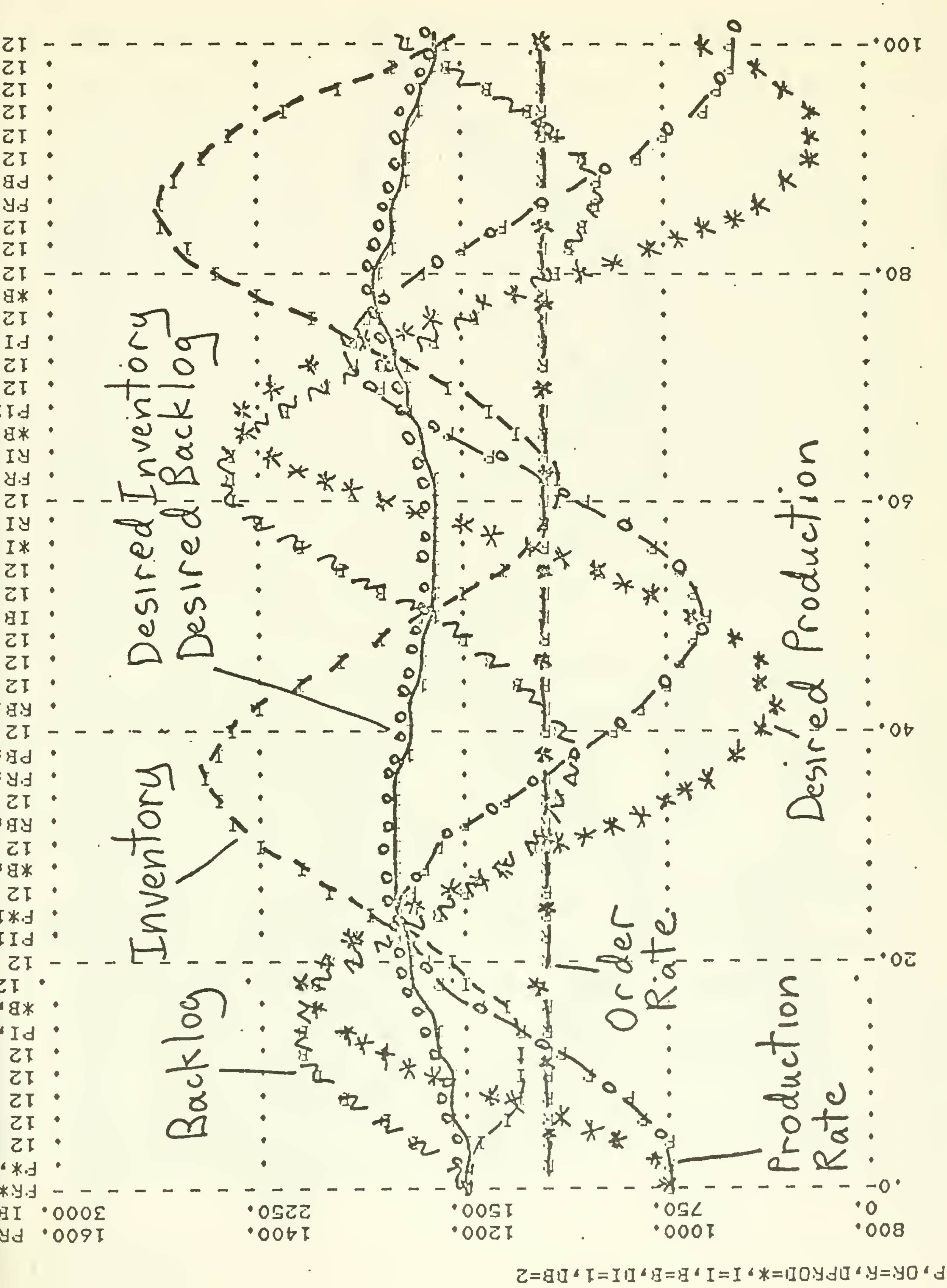

Figure 3. Response of production sector with desired production dependent on price to step increase in order rate

Figure 3(a)

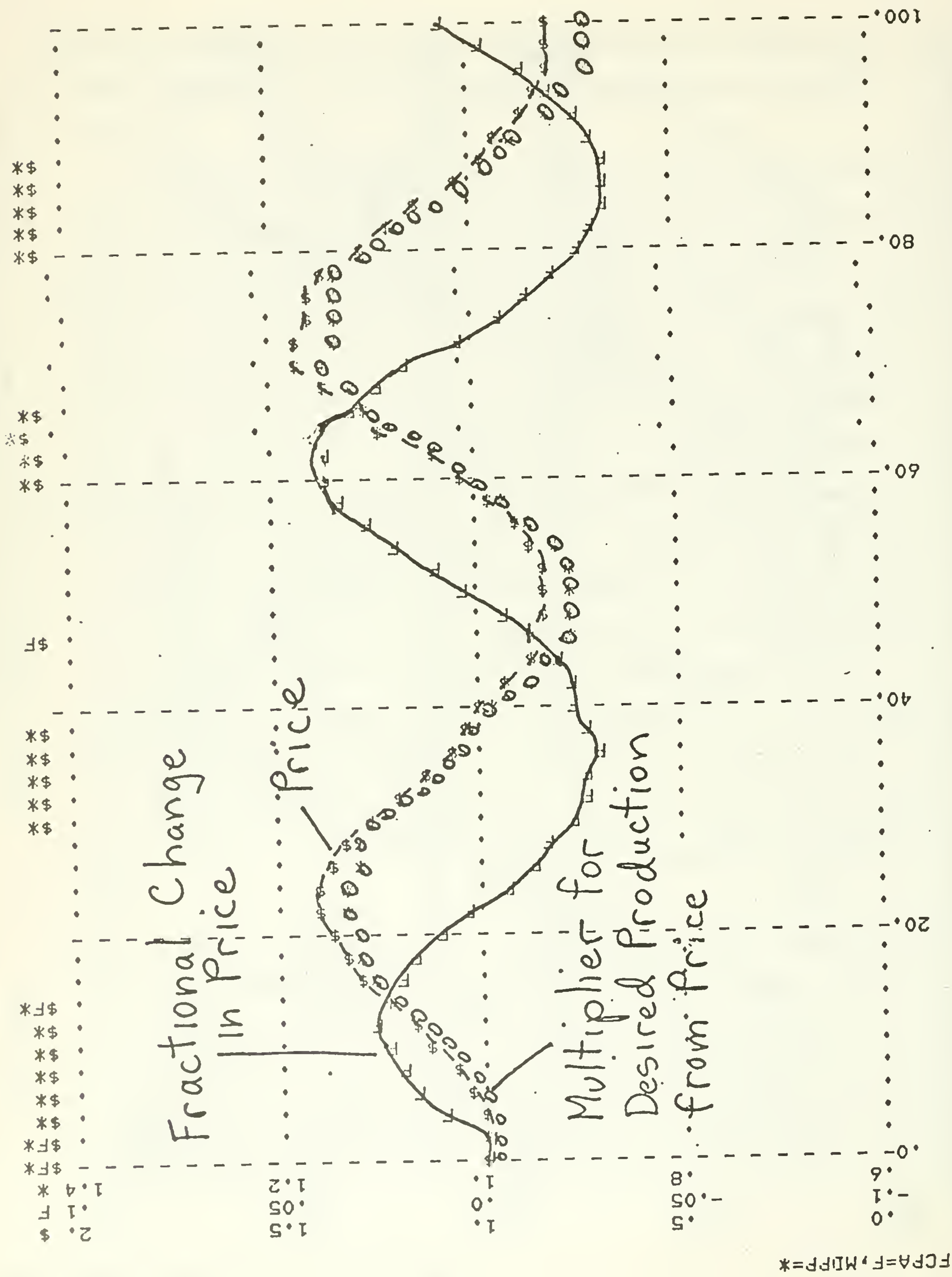

Figure 3. Response of production sector with desired production dependent on price to step increase in order rate

Figure 3(b)

resulting increase in profit per unit stimulates desired production from price (Figure 3(b)). Desired production (Figure 3(a)) reaches a peak value of about 1300 units/month around month 20, compared with an initial value of 1000 units/month and an order rate of 1120 units/month. The multiplier for desired production from price remains above 1 until about month 38 in Figure 3(b). Thus production is maintained well above the rate dictated by average shipments and inventory and backlog conditions. Production rate peaks at approximately 1270 units/month around month 24, and only declines to equal order rate at month 35. In particular, note that from month 22 to month 38, inventory is above desired inventory and backlog is below desired backlog (Figure 3(a)) but production rate is held up by the multiplier on desired production from price above one (Figure 3(b)). Thus high price and profitability uphold production until it becomes evident that the product cannot be sold effectively at the high price.

Eventually, in Figure 3(a), high inventory and low backlog lower delivery delay substantially below normal, thereby leading to falling price. Inventory reaches a peak value and backlog a minimum value around month 36 and price falls below normal soon after. Thus, high inventory, low backlog, and low price all come to generate downward pressure on production. Price eventually falls to a minimum value of about $.80/unit at month 50. In roughly the same month, inventory falls below desired inventory and high backlog begins to generate upward pressure on production, but low price holds down production. Production rate does not rise to cover order rate until a large backlog surplus and inventory shortage develop. These conditions eventually necessitate a large increase of production above incoming order rate.

The above discussion gives, in specific terms, the explanation for the instability and continuing fluctuation in production rate and employment seen in Figure 3. Production behavior is much less stable than that observed in the production-sector model without price influencing desired production (see Figure 2). The lessened stability arises from the way in which price changes magnify changes in desired production caused by inventory and backlog. The argument can be summarized as follows. In the face of increased orders, inventory depletes and backlog rises, thereby expanding production. Delivery delay rises as well, and peaks at about the time when production equals to order rate. At this point inventory and backlog discrepancies are about maximum, because, for example, inventory falls as long as production is below shipments. The discrepancies are reflected in a peak delivery delay. Therefore, fractional change in price is highest when production equals orders. Rising price therfore encourages expanded production even when production begins to exceed orders. Price continues to rise as long as delivery delay remains above normal. Delivery delay is restored to normal around the peak of production where inventory shortages and high backlog are alleviated. However, price is at a maximum at this point, and persisting high price encourages overproduction until excess inventory develops. Thus production behavior can be less stable when price influences supply than when supply is governed only by the quantity-adjustment mechanisms of inventory and backlog correction. Note that the same result would arise in any model that recognizes that inventory shortage or high backlog represents a condition of excess demand that can continue to raise price even when production and order rates are equal.

Behavior of the model in Figure 3 resembles actual business-cycle behavior cited in Gordon (1965). For example, backlog peaks about three-quarters of a year ahead of production, which in turn peaks almost a year ahead of inventory. Also, peaks in price and production nearly coincide. Comparison with real-life data thus supports the model result that high prices near peaks of production can accentuate overexpansion.

It should be readily apparent now how the production-sector model discussed above differs from the classical model of supply and demand presented in Section II. The classical model does not contain any of the stock variables that would continue to generate upward or downward pressure on price, supply, and demand even when production and consumption rates come into balance. Consequently, the classical model cannot exhibit the potentially destabilizing effects of price changes as seen previously.

Figure 4 builds further on the previous analysis by allowing both desired production and incoming orders to respond to price. Previously, supply alone responded to price. The elasticity of order rate with respect to price is approximately 0.5. The figure shows the production-sector response to an initial exogenous step increase in order rate. Figure 4 shows lightly-damped fluctuations with a period of 37 months. Behavior is thus somewhat more stable than in Figure 4 where price affected desired output but not order rate. But the behavior is considerably less stable than in Figure 2 where feedbacks from price on supply and demand were not incorporated.

Detailed explanation of behavior in Figure 4 is not provided here since the causes of fluctuation are essentially the same as in Figure 3. Note, however, in Figure 4(a), that production rate and order rate are

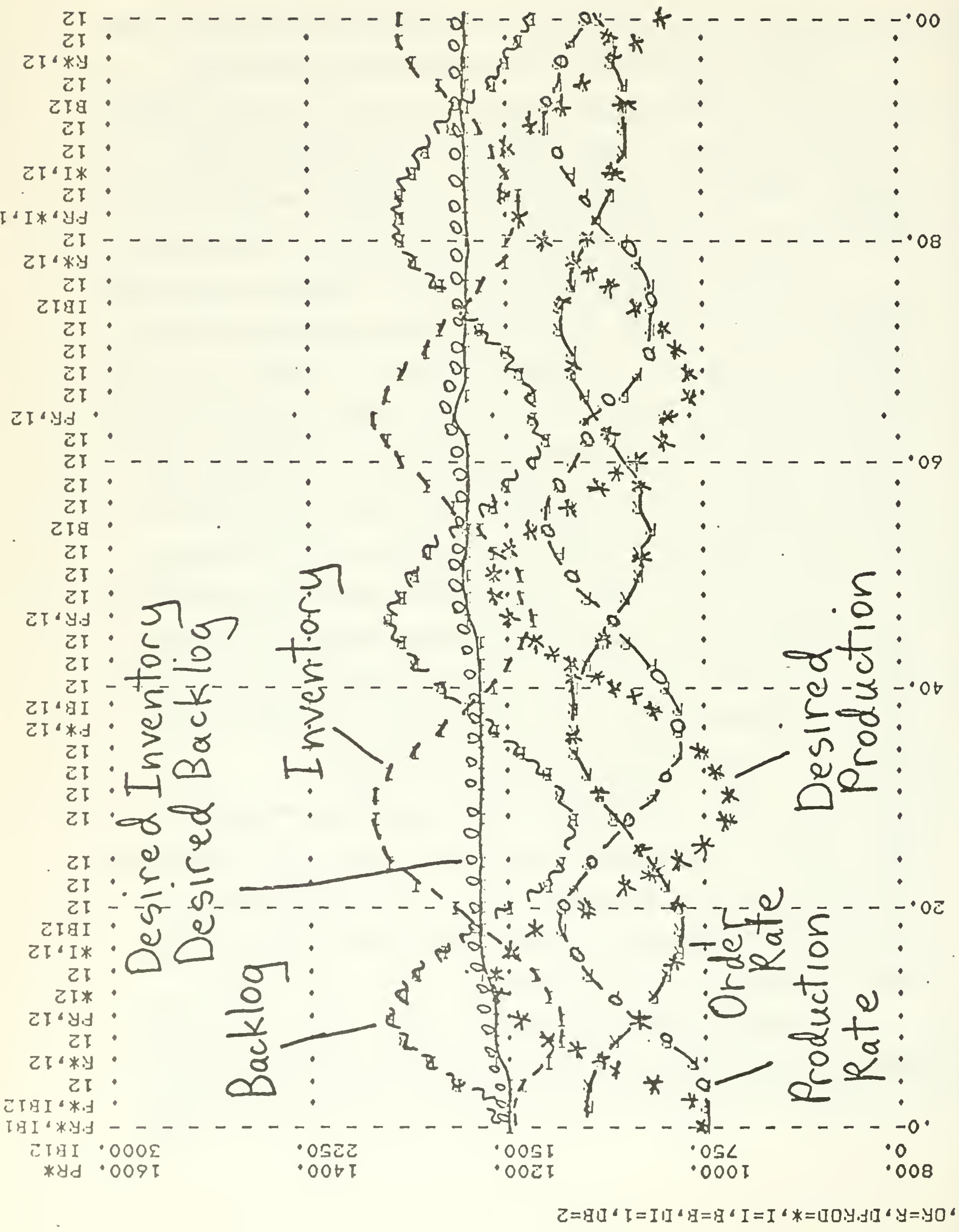

Figure 4(a)

Figure 4. Step response of production-sector model with price

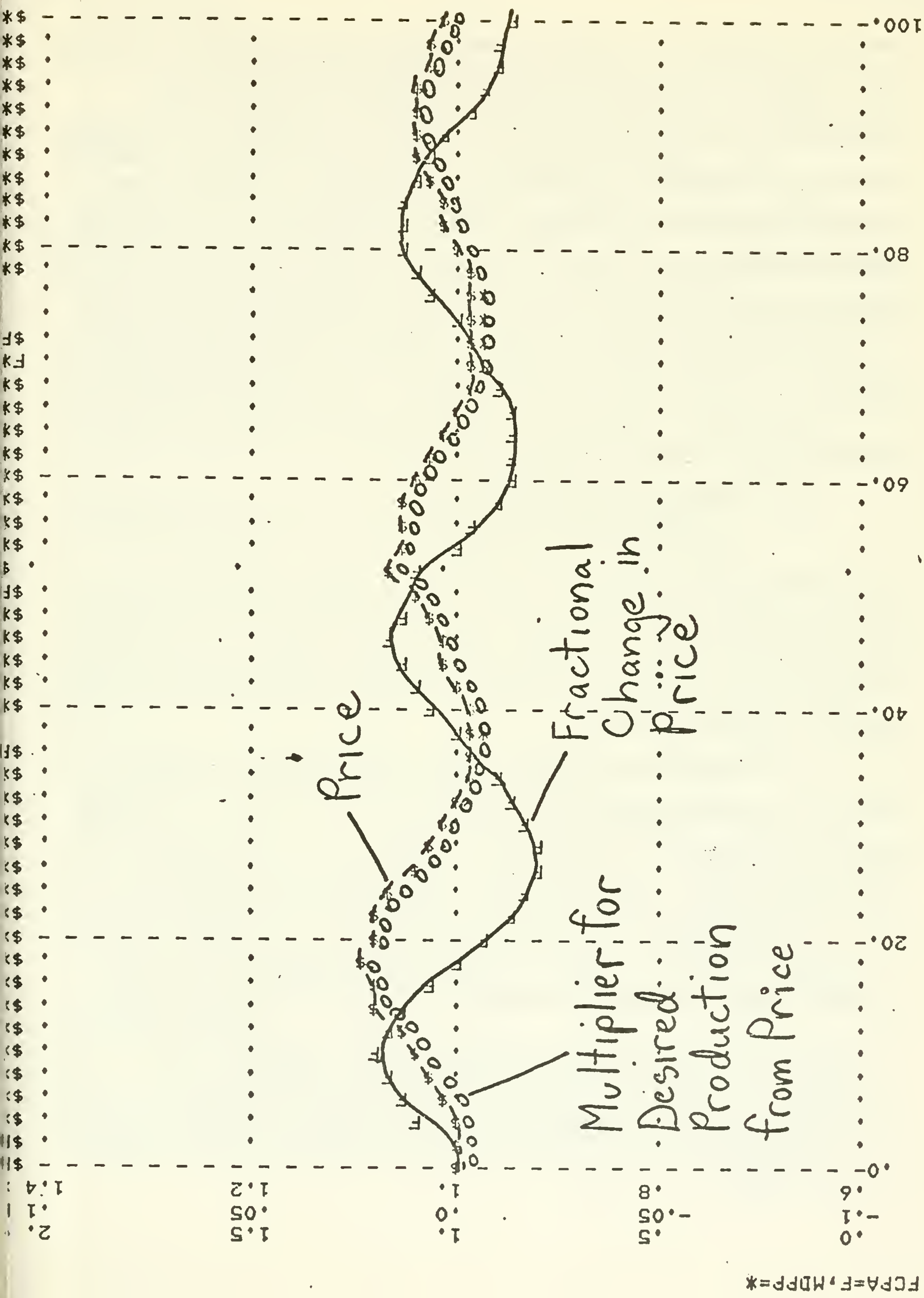

Figure 4(b)

Figure 4. Step response of production-sector model with price feedbacks to desired production and order rate

nearly 180 degrees out of phase. Moreover, production tends to be rising most rapidly when orders are falling most rapidly, and conversely. Production and order rates are out of phase due to influence of inventory and backlog conditions on production, delivery delay, and price. For example, around month 45, backlog is high and inventory low. Production is therefore stimulated, but high delivery delay raises price (Figure 4(b) and thereby depresses orders. Since order rate is a function only of price, order rate tends to fall most rapidly around the point of maximum delivery delay. In contrast, production rate is rising most rapidly around the point of maximum delivery delay because of:

1. rapidly rising prices and
2. a roughly maximum discrepancy between actual and desired inventories and backlogs.

Thus production and order rate tend to cross sharply around the point of maximum delivery delay. Moreover, order rate is minimum at the point of maximum price, which occurs at about the peak of production when delivery delay is returned to normal.

The tendency for production and orders to be out of phase in Figure 4 somewhat mitigates the stabilizing effect of price in lowering orders during times of excess demand. Because peaks in price and production nearly coincide, demand is reduced most at the point of overexpanded production. Behavior could be even less stable in a more complete model that reflected tendency for rising prices to encourage advance buying by consumers. In such a system, demand tends to be upheld when prices are rising and then cut back sharply when prices peak because of reduced speculative incentive to buy and a more-than-adequate consumer stock of goods.

V. CONCLUSIONS

This paper has attempted to show that price and quantity adjustments can sustain prolonged disequilibrium behavior of production; and second,that price feedbacks to production and orders can be destabilizing compared with behavior when prices are fixed (compare Figures 3 and 4 where price are active with Figure 2). These conclusion derive from model analysis that shows how management of stock variables in a typical firm, such as inventories and order backlogs, can generate overshoot and fluctuation. The results imply that equilibrium analysis of consumer and producer behavior may be a weak tool for understanding real-world behavior and may be a misleading guide to the effects of government policies.

Fluctuating behavior in Figures 2 to 4 arises from delays in acquiring and disposing of factors of production and from typical corporate policies that respond to imperfect information. These assumptions are important to emphasize, because in a production system in which producers have perfect information about demands and with no lags in hiring labor or acquiring other factors, fluctuations from stock-management policies need not occur. But such an economy bears no relation to present-day economies, and is of theoretical rather than practical concern. [Kornai (1971) and Eichner and Kregel (1975) discuss the theoretical preoccupation of classical and neoclassical economics with optimal rather than existing economic states.]

The preliminary results summarized above suggest a number of important areas for further study. For example, it was shown that price responses to relative supply and demand can destabilize production behavior. Further examination of this outcome requires realistic models of corporate price-setting policies. Existing pricing models in the econometric literature tend to be deficient in this regard. For example, many pricing models assume that prices are based on either a fixed markup of direct labor and material costs or a markup that depends on some measure of excess demand (for example, see Modigliani (1973)). However, markup models typically ignore the conflicting pressures on price in actual corporations. For example, consider behavior of prices during periods of weak demand. Under such conditions, low demand creates a pressure to lower prices. However, in the wake of the 1973-74 recession, the steel industry, and other industries operating at near one-half capacity, have been raising prices to build liquidity and to protect faltering return on investment. Such price increases during periods of over-capacity can be highly destabilizing. Therefore, pricing dynamics need further examination to gauge behavioral impact of influences on corporate price-setting decisions such as liquidity, return on investment, and traditional profit margins. Such analyses can be conducted using expanded versions of the production-sector model developed in Section III.

More broadly, economic models need to be oriented toward more comprehensive treatment of stock variables. Existence of stock variables decouples rates of flow such as production and consumption and thereby underlies disequilibrium economic behavior. At first blush, this recommendation will be taken as describing the existing state of affairs in recent economic model building, where inventories, capital stock, and other stock variables are treated. But looking beneath the surface at _how_ such variables are treated immediately points up deficiencies. For example, investment functions in the literature base capital investment on incentives for adding capital plant. But those investment rates do not depend on availability of final output inventories of capital goods so delivery delays for capital goods are implicitly constant (Jorgensen, Hunter, and Nadiri (1970) surveys major investment functions). A comprehensive treatment of stock variables would imply that every rate of flow is connected to both the stocks from which it emantes and to which it is directed. Moreover, constraints on the rate of flow due to sizes of both source and destination would be represented. Fuller treatment of disequilibrium behavior resulting from interaction among stock variables appears to be a critical link toward attaining deeper understanding of growth, fluctuation, and instability.

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