Inventory, Labor and Price Movements in Business Cycles

-Based on Multi Agent Simulation

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Abstract

The purpose of this paper is to show a new understanding of business cycles by practicing multi-agent simulation in autonomous decentralized markets. In this paper we construct the model of dispersive markets with autonomous agents that is different from Neo-classical economic models. We adopt multi-layered adjustment firms as agents. The multi-layered adjustment firm takes a sequence of routinized behaviors in a nested time structure. In the first layer, the firm does quantity adjustment. In the second layer, it does price adjustment.

This paper examines the following two points. We compare the labor market with higher rate of regular labor called Japanese type (J-type) and the other one with lower rate of regular labor called American type (A-type) in view of volatility on business cycles. It is found that the latter is more volatile than the former. We also showed countercyclical movements of the production and the price at the macro dimension.

1 Introduction

The purpose of this paper is to show a new understanding of the business cycle by practicing multi-agent simulation in autonomous decentralized markets. In this paper we try to construct the model of dispersive markets with autonomous agents that are in many ways different from well-organized and centralized ones in orthodox economic models. General Equilibrium theory depicts the 'one-price to one-good' type market with a price-adjusting auctioneer. Because all selling and buying transactions are cleared off simultaneously in the market, money plays no role but means of circulation enabling indirect exchange of goods and services.

But we observe that in reality all economic agents come in market processes with not only goods and services but also money, and buying or selling is fulfilled as a separate transaction one by one in a sequence. In each transaction money must be paid from one to another agent in the opposite direction of flow of goods and services. Market is not a gigantic exchange place where all the selling and buying transactions of all kinds of goods and services are done all at once, but an integrated and decentralized network of individual selling and buying sequential processes. In the latter case, the interrelations among agents are not so tight but rather loose because buffer stocks of money or inventory create slackness both in price and quantity. Agents do not maximize unique function of utility or profit in response to the single information with regard to change of prices, but they satisfice adopting routinized patterns of decisions and actions in response to such local information with regard to change of stocks. For example, ups and downs of buffer inventory show the gap between the expected sales and the realized ones of agents. Satisficers have a bigger degree of freedom in their decision-making and behavior than rational maximizers. Such agents are autonomous in the sense that they can select any possible patterns of routinized behaviors and change them adaptively in the course of time. That is why we call such a market 'autonomous decentralized.' We believe that the great significance of inventory and money as decoupling and informational function will be shown in our model. It is now clear that we cannot but use a method of computer simulation in order to examine working and movement of a complex system of autonomous decentralized market.

Here we adopt multi-layered adjustment firms as agents. The multi-layered adjustment firm takes a sequence of routinized behaviors in a nested time structure. The nested time structure has three layers. In the first layer, the firm does quantity adjustment. In the second layer, it does price adjustment. In the third layer, it invests to plants and equipment. But as space is limited, we shall concentrate on the first two layers.

The multi-layered adjustment firm regards inventories as the most important local information. Each firm has two thresholds of inventory, which are upper one and lower one. For example, when actual inventories exceed the upper threshold, the firm recognizes overproduction. When actual inventories, on the other hand, come short of lower threshold, the firm recognizes underproduction. The firm exclusively relies on its recognition to decide its production level.

Metzler [9] firstly opened the way to explain business cycle phenomena based on the inventory mechanism. He thought of inventories as a destabilizing factor and demonstrated that an inventory-accelerator could produce cycles in simple Keynesian models. According to Blinder and Maccini [4], many macro economic theorists similarly think of the inventories as a destabilizing factor, whereas the prevailing micro economic theory viewed the inventories as a stabilizing one. Thus the paradoxical problem on inventories remains unanswered.

Many models that explain business cycle from inventories adjustment have mostly ignored price adjustment. However, we believe that both quantity adjustment and price adjustment are indispensable to construct the theory of business cycle. We therefore employ as the unit of analysis multi-layered adjustment firm: the firm equipped with both the quantity adjustment and the price adjustment mechanisms.

Such preceding papers as Reagan [10] and Blinder [3] took both quantity adjustment and price adjustment simultaneously. They thought that inventories played an important role to cause rigidity and asymmetry in price adjustment based on the rigorous micro foundation. In their models, when demand rapidly increases, the firm disposes of the inventories at first. If the firm is not able to meet increasing demand, the firm raises the price so that it can clear the market. On the other hand, when demand rapidly decreases, the firm piles inventories up and make the price stay. They tried to explain price rigidity in the downward due to asymmetry of price adjustment by these models. However, these papers neglect the interaction of the goods market and the labor market and assume that the markets are always cleared off. Accordingly, they could not investigate the business cycles from the viewpoint of the interplay of aggregate demand and supply as well as the possibility of excess demand or excess supply in markets. In short, they do not present a new view of market and business cycles. In contrast, our model explores business cycles based on the modeling of autonomous decentralized markets.

In order to understand the characteristics of our article, the development of the micro theory cannot be neglected. The mainstream micro theory is called the Production-Smoothing or Buffer-Stock Model. These models are summarized to two points.

First, the firm possesses buffer stocks to prepare for the unanticipated demand change. Second, the firm makes production smoothing to cope with the change of marginal costs depending on the utilization level. It is possible to extend this basic model (Blanchard [1]) in many ways.

For example, Holt, Modigiliani, Muth, and Simon [6] has presented an extended model characterized by the loss caused by the stock out cost. In this model two costs are clearly classified. The first one is the cost of carrying inventories, which rises monotonically with inventories. The second one is the expected cost of stocking out which, for any given level of expected sales, falls with inventories. This model can thus create a positive covariance between inventory investments and expected sales. Furthermore it explains that the variance of production is bigger than that of the sale. Most of modified models are criticized because these models are only treating inventory of finished goods and there is no theoretical ground that, as assumed in the model, the marginal cost increases with utilization level. Blinder and Maccini [4], instead of extending the Production-Smoothing or Buffer-Stock model, switch over to the (S, s) Model which can reflect more stylized facts.

In the (S, s) Model each firm has the upper limit (S) and the lower limit (s) of the inventory and try to maintain the normal level by increasing/decreasing orders when inventory go under/over the s/S. This model is not dealing with the inventory of finished goods in manufacturing sectors but with that of raw materials and supplies in manufacturing or wholesale/retail sectors, which accounts for most of the inventories. They mainly consider the circulation of the goods, not the production of goods. Since the inventory cost is to be constant in our model, there is no need to take the increasing marginal cost into account.

Blinder [2] and Caplin [5] has introduced the model assuming that all firms have the same upper limits and lower limits of inventory possession but that each firm has a different initial inventory and different sales. They have made a conclusion, however, that empirical studies on the models are too premature to explain the contradictory relationships of the micro side and macro side in the inventory theory.

The model of our article is more or less similar to the (S, s) Model. But it was invented independently of it, taking the idea from Marshall's concept [8] of multi-layered time structure. The big difference between the (S, s) Model and our model is that the latter sets as the unit of analysis a multi-layered firm that undertakes the price adjustment in addition to the quantity adjustment. As explained in Section 2, we introduce both the normal cost principle and the full cost principle from the Post-Keynesian price theory[1]. The multi-layered adjustment firm may be regarded as integrating manufacturing and wholesale/retails supplier vertically. Similarly, the inventories are assumed to be a sort of compound goods that includes the finished goods as well as raw materials and supplies. This enables us to focus on the production of goods rather than the circulation process of goods. Furthermore, the demand is determined endogenously in our model by introducing the labor market so that it can analyze the relation between wages and unemployment rates.

This paper examines the following two points by multi-agents computer simulation.

① We set two different types of labor market: the labor market with higher rate of regular labor called Japanese type (J-type) and the other one with lower rate of regular labor called American type (A-type). We compare J-type with A-type from the standpoint of macro stability. Is there any difference on the Phillips curves between J-type and A-type?

② As our model takes the assumption of increasing returns to scale[2], the process of adjustment is different from that of the conventional decreasing returns to scale. Can we see the counter-cyclical relation between production and price at the macro level?

The plan of the paper is as follows. We give an outline of the model in section 2. In section 3, we show simulation results and indicate their

[1] Paul Downward [7]

[2] The assumption of decreasing returns to scale does not match stylized facts reported in many empirical studies on manufacture sector. Therefore, the assumption of increasing returns to scale, we consider, is not arbitrary but realistic.

implications . Lastly, we make a brief conclusion on this simulation and refer to the future study.

2 The framework of the model

2.1 Time structure (Triple nested time structure)

Time structure has triple hierarchical loops of short-term, middle-term and long-term. The unit of short term loop is week(w), the unit of middle-term loop is month(m), the unit of long-term loop is year(y) [3]. For example, 30 years can be expressed as 30y=360m=1440w[4]. The multi-layered adjustment firm adjusts utilization rate in the short-term loop, and revises the price in the middle-term loop.

2.2 Market (Dispersive market with autonomous agents)

We assume that there is only one kind of homogeneous good in this model. Firms[5] face consumers and sell their products at a certain price. Consumers are assumed to be in a line and come in the market by turn to buy products from firms at the current lowest price. When all products are sold out, consumers waiting in a line simply give up purchase. At the macro level, the short side of demand and supply is realized as sales.

$$X(t) = min(S(t), D(t)) \tag{1}$$

[3] The relations of variables in time structure are shown in fig.15. How the firm adjusts quantity and price is shown in fig.16.

[4] w is expressed as t in the following formulas.

[5] We regard these firms as vertically integrated firms, each of which is composed of manufacturing, wholesale and retail sections.

where $X(t)$: aggregate sales at period t, $S(t)$: aggregate supply at period t, $D(t)$: aggregate demand at period t.

2.3 Supply side

2.3.1 Production function

The production function is supposed to be a linear form.

$$Q(i,t) = u(i,t-1) * Q_{\max}(i) \tag{2}$$

where i: i-th agent, u: utilization rate, $Q_{max}(i)$[6]: the capacity of production of i-th firm.

Each firm increases or decreases the utilization rate when stock level is beyond its upper threshold of inventory or under its lower threshold of inventory. We discuss the way of adjusting utilization rate at 2.5.1.

2.3.2 Price setting

Price is not determined by an auctioneer as in centralized market. In decentralized market with autonomous agents, each firm sets its own price. In this article, price setting is described by two types.
First, in case of the normal cost principle

$$p(i,t) = nc(i) * (1 + Vmp(i,t)) \tag{3}$$

where nc: the normal cost[7], which is constant, Vmp: variable markup[8]. The price setting is done through changing Vmp.
Second, in case of the full cost principle

$$p(i,t) = k(i,t) * (1 + Fmp(i)) \tag{4}$$

[6] $Q_{max}(i)$ is set 200.
[7] The value of nc is set 2.
[8] The initial value of Vmp is set 0.3.

where $p(i,t)$: the price set by i-th firm[9], $k(i,t)$ is the actual cost per unit, Fmp is the fixed markup. The price setting is done through changing k. We discuss the price adjustment in detail at 2.5.2.

2.3.3 Supply function

Supply is determined as the sum of production in this period and inventory in previous period.

$$S(i,t) = Q(i,t) + Z(i,t-1) \tag{5}$$

where $S(i,t)$: the supply of i-th firm at period t, $Q(i,t)$: the production of i-th firm at period t, $Z(i,t-1)$: the inventories held by i-th firm at period $t-1$. In our simulation, we assume that there is no negative inventory, that is, $Z \geq 0$.

2.3.4 Cost function per unit

This model takes the assumption of increasing returns to scale as it is a better approximation of reality. As utilization rates rise, unit cost becomes lower. The cost function in the case of endogenous demand is

$$\begin{aligned} k(i,t) = C_{min} + (1-u(i,t-1)) * k0 + w(i,t-1) * Ld(i,t-1) \\ + sc * Z(i,t-1)/S(i,t) \end{aligned} \tag{6}$$

where k: the cost per unit, $k0$: the cost parameter (=1), $Ld(i,t-1)$: the demand for labor per product by i-th firm, sc: inventory cost per product. Since we assume that one unit of labor is needed for per product, (6) can be rewritten as:

$$\begin{aligned} k(i,t) = C_{min} + (1-u(i,t-1)) * k0 + w(i,t-1) \\ + sc * Z(i,t-1)/S(i,t) \end{aligned} \tag{7}$$

[9] The initial value of p is set 2.6.

$$C_{min} = 1 - Q_{max} * set \tag{8}$$

C_{min} means the parameter of increasing returns to capacity of production. C_{min} also depends on the capacity of production. As the capacity of production becomes larger, C_{min} becomes smaller. *set* is increasing return to scale parameter. In this simulation *set* is 0.004.

2.4 Demand side

2.4.1 Demand function

We introduce endogenous demand in this model. In this case, our simulation is based on the following demand function.

$$D(t) = \alpha * I(t)/P(t)^a \tag{9}$$

$$I(t) = w(i, t - 1) * L_d(i, t - 1) \tag{10}$$

where α: a parameter for strength of demand, a: demand elasticity, $P(t)$: the highest price among sold goods, not the market clearing price, $I(t)$: aggregate wage income.

2.4.2 Labor market

Labor demand function is necessary to be introduced to build endogenous demand model. Since the labor demand per product is assumed to be one, labor demand function is written as:

$$L_d(i, t) = Q_{max} * u(i, t) \tag{11}$$

Whenever labor demand exceeds a maximum regular labor ($maxRL$), the firm displays a flag. The number of flag is recorded to the Upwageflag (UW). If labor demand is below a minimum regular labor ($minRL$), the firm displays a flag. The number of flag is recorded to the Downwageflag (DW). The $maxRL$ is not equal to the $minRL$. They generally satisfy the relation as:

$$maxRL(i) \gg minRL(i) \tag{12}$$

$$\begin{aligned} if(L_d(i,t) &\geq maxRL(i)) \\ UW(i,t) &= UW(i,t-1)+1 \end{aligned} \tag{13}$$

$$\begin{aligned} if(L_d(i,t) &\leq minRL(i)) \\ DW(i,t) &= DW(i,t-1)+1 \end{aligned} \tag{14}$$

If either UW or DW exceeds the threshold for revise of wage, wage is revised as:

$$\begin{aligned} if(UW(i,t) &\geq TW(i)) \\ w(i,t) &= w(i,t-1)*(1+wc) \end{aligned} \tag{15}$$

$$\begin{aligned} if(DW(i,t) &\geq TW(i)) \\ w(i,t) &= w(i,t-1)*(1-wc) \end{aligned} \tag{16}$$

where TW: the threshold for revise of wage, $w(i,t)$[10]: nominal wage, wc: the width of wage revise.

If the nominal wages of all firms are not the same, the labor demand function becomes a step function. Due to unlimited labor supply in this model, the production is constrained not by labor supply(Ls) but by effective demand.

$$L_s = L_d \tag{17}$$

[10] The initial value of w is set 1.

2.5 The way of multi-layered adjustment

2.5.1 Quantity adjustment

A multi-layered adjustment firm thinks of inventories as the most important local information. Inventories have three distinctive functions; information, buffer and speculation. Inventories as information let a firm notice the gap between the expected demand and the actual demand. Inventories as buffer absorb the gap between them to make production constant. Inventories as speculation make a profit from price movement. In this article, we think that inventories as information are most important. A firm adjusts its utilization level in short-term loops. Each firm has the upper limit and the lower limit of the inventories as in the (S, s) model. S is called 'upper limit inventory threshold value', and s is called 'lower limit inventory threshold value' in our model. If the actual inventories go over an upper limit inventory threshold value, the firm pulls down the utilization rate. Similarly, if the actual inventories go down to a lower inventory threshold value, the firm pushes up the utilization rate. The upper limit and the lower limit of inventory threshold value become cognitive filters for the firm and can let the firm recognize the unanticipated change in demand for its products. The firm adjusts its utilization rate as follows.

$$
\begin{aligned}
if(Z &\geq Zuth) \\
u(i,t) &= (E(D(i,t-1)) - (Z(i,t-1) - Zuth))/Q_{max} && (18) \\
DP(i,t) &= DP(i,t-1) + 1 && (19)
\end{aligned}
$$

$$
\begin{aligned}
if(Z &\leq Zlth) \\
u(i,t) &= (E(D(i,t-1)) - (Z(i,t-1) - Zuth))/Q_{max} && (20) \\
UP(i,t) &= UP(i,t-1) + 1 && (21)
\end{aligned}
$$

where $Zuth$: the inventory upper limit threshold value, $Zlth$: the inventory lower limit threshold value[11], $E(D)$: the expected demand, DP : Downprice flag, UP : Upprice flag.

Each firm estimates the expected demand based on static expectations (It estimates demand in the present period as the same as the realized demand in the previous period).

$$E(D(i,t)) = D(i,t-1) \tag{22}$$

In this article, the size of upper limit threshold value becomes a buffer stock to the unanticipated demand change. Moreover, when the demand increases rapidly with the price change, it also becomes a speculative inventory although it is not necessarily intended for speculation. Therefore, three features of the inventory are embodied in this model.

2.5.2 Price adjustment

Price is adjusted in middle loops. The firm revises a price when UP exceeds a price revision threshold value UP_{th} and DP exceeds a price revision threshold value DP_{th}. In case of normal cost principle,

$$\begin{aligned} if(UP &\geq UP_{th}) \\ Vmp(i,t) &= Vmp(i,t-1) * (1+pc) \end{aligned} \tag{23}$$

$$\begin{aligned} if(DP &\geq DP_{th}) \\ Vmp(i,t) &= Vmp(i,t-1) * (1-pc) \end{aligned} \tag{24}$$

where pc : the width of price revise.

[11] In our simulation, $Zlth$ is set 0. Then Z=0 holds as $Z \geq 0$

2.6 Bankruptcy

If total profit (total negative profit, i.e., total loss) falls below the credit limit to the firm, bankruptcy occurs. The credit limit is assumed to be proportional to the capacity of production. But in our model, even if bankruptcy occurs, new firms never enter. Thus the number of the firms tends to decrease.

3 Simulation Results

3.1 Basic Parameters

$Zuth$, Pth and TW are basic parameters in our model. Thus we need examine the relation of them. Fig.1 shows that the relation between upper threshold of inventory and price revision threshold. Fig.1 draws three dimensional diagram on the result of ending 100 times out of 1440 turns with regard to the aggregate production, which is computed by the combination of the parameters of price revision threshold and upper threshold of inventory. The combination of lower upper threshold of inventory and null price revision threshold shows poor performance in output level. The highest output levels cluster around relatively lower price revision threshold. Fig.2 shows the relation between TW and Pth. The combination of higher TW and lower Pth gives the highest output level. If TW is lower than Pth, rise of wage squeezes firm's profit. As a result, the firm is prone to get into the red and may go bankrupt. If TW is higher than Pth, the firm is able to pass the rise of wage on the price so that it may escape from bankruptcy. We set parameters as follows considering the relationship of these parameters.

3.2 Parameter Setting

The significant results of simulations are clarified in this chapter. The number of the firm is 5. The following parameters are used.

$Zuth$={30,31,32,33,34}, UP_{th} =DP_{th}= 12, pc=0.1, TW=36, wc=0.1, $maxRL$=0.8, a=1, α=1.3, sc=0. The number of turns is 1440w (1440w=360m=30y).

We focus on relationships among labor practices, wage, price, and output. We consider that each firm regards regular labor as buffer inventory of labor to unexpected change of demand and tries to preserve regular labor enough to absorb such external shocks. Accordingly, the parameters $minRL$ represent the characteristics of labor practice of A-type or J-Type of firm. We simulate two kinds of labor practice in Case 1 and Case 2 as follows.

Case 1: A-type labor practice, $minRL = 0.3$

Case 2: J-type labor practice, $minRL$= 0.6

3.3 Dynamics of the System

3.3.1 Aggregate Production

We set the different parameters of the $minRL$ in Case 1 and Case 2. It is implied that $minRL$ could also be regarded as equivalent to the fixed capital for each firm if it is difficult or, at least, it takes considerable time for the firm to employ or fire regular workers. At first, we analyze aggregate production level.

$minRL$ is the parameter closely related to the wage revision in the downward. *Ceteris paribus*, as $minRL$ becomes larger, DW is likely to increase because the actual labor demand will more often falls below the lower limit of regular labor $minRL$. On the other hand, UW is closely related with $maxRL$, not $minRL$. Thus it is more likely to revise the wage in the downward in Case 2 (J-type) than in Case 1 (A-type) although J-type tends to preserve more regular labor than A-type. As basic demand is $minRL$ multiplied by nominal wage, and nominal wage is set 1 in our model, the size of $minRL$ expresses that of basic demand.

We can see from fig.3 and fig.4 that aggregate production in Case 1 (A-type) fluctuates more sharply than that in Case 2 (J-type). This is due to the advantage of the larger initial basic demand for J-type.

3.3.2 Phillips curve

We plotted the points of rate of unemployment and rate of inflation on the monthly basis in fig.5 for A-type and fig.6 for J-type. The existence domain of the points for J-type is more compact than that of A-type. This indicates the lower volatility for J-type than A-type. It is often observed that there coexist the positive rate of inflation and the positive rate of unemployment. Stagflation is not rare in our simulation. As far as we observe, it is unclear whether the slope of Phillips curves is positive or negative in both cases.

3.3.3 Aggregate production and Price

The nominal wage tends to monotonically and geometrically increase for type-A and type-J as seen in fig.7 and fig.8 . The average speed of increase is higher for type-J than that of type-A. On the other hand, the price tend to increase with cycles for type-A and type-J as seen in fig.13 and fig.14. Type-J has steeper and deeper cycles than type-A.

The real wage moves on compound waves of short cycles and mid-term cycles for type-A in fig.9 and for type-J in fig.10 . It stays within 0.8 to 1.8 for type-A and within 0.95 to 1.55 for type-J. The real wage for type-J is more stable. The profit rate also moves on the similar waves but completely countercyclical for type-A in fig.11 and for type-J in fig.12. This shows that the real wage run counter the profit rate. This can be explained as follows. As nominal wage increases almost geometrically, the movement of real wage is the same as the countercyclical element in the movement of the price, while the movement of price is isomorphic to that of variable markup as the normal cost nc remains constant. The cyclical element in the movement of markup is the same as the movement of profit rate. It follows that the real wage moves contrary to the profit rate.

We also observe that the output of production and the price are countercyclical in fig.13 and fig.14. The production falls down abruptly on the top of price increase. This seems to show the phenomena of crises, the sudden collapses of boom.

Our simulation does not explicitly introduce money but we actually assume that there is money stock on the side of firms or laborers. If wage are paid in advance, firms should hold money stock necessary for payment to laborers. Otherwise, the products cannot be bought in the goods markets. If wages are paid late, laborers should hold money stock at initial period. This simulation creates continuing inflation without increase of money supply. This is contrary to the opinion of Neo-classical school that increase of the quantity of money causes inflation that is the only monetary phenomenon.

4 Conclusion

①The basic demand for products depends on the demand for labor by firms. More correctly, it is determined by the demand for regular workers multiplied by their nominal wage. Accordingly, the higher rate of regular workers does not necessarily lead to the stability of basic demand for products. Truly, if we presuppose the downward stickiness of wage, the higher rate of regular workers means the bigger basic demand. But the reduction of nominal wage may result in the decrease in the basic demand. Type-J with the higher rate of regular workers in most cases stays more stable with respect to the rate of inflation and the rate of unemployment. In contrast, as to type-A with the higher rate of regular workers, the unemployment rate and the inflation rate are rather higher and stagflation is frequently observed.

②On the assumptions at the micro level that each firm has a production function with increasing returns to scale, and that it has upper and lower thresholds of buffer inventory for goods and labor, we find countercyclical movement of the output and the price level at the macro level. This agrees with the results obtained in many empirical studies.

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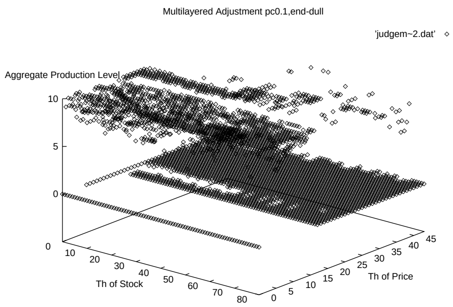

Figure 1: The relation between $Zuth$ and Pth

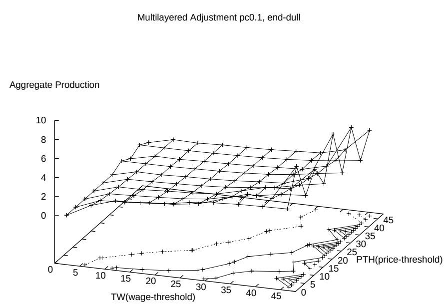

Figure 2: The relation between TW and Pth

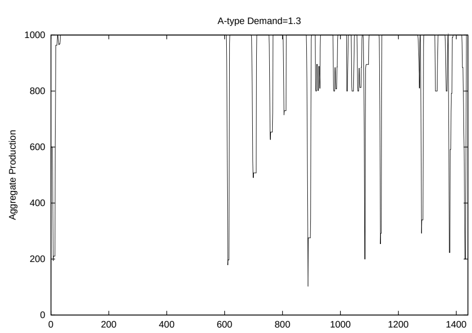

Figure 3: Case 1

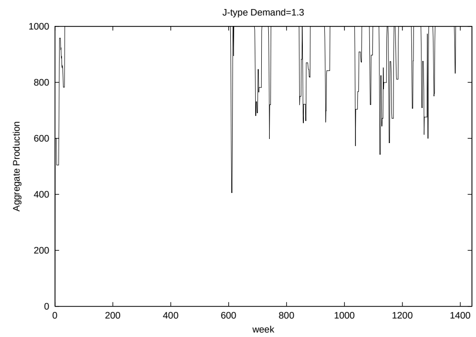

Figure 4: Case 2

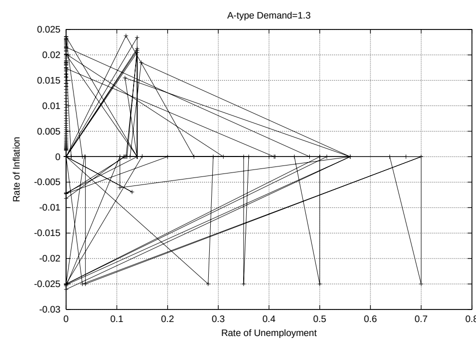

Figure 5: Case 1

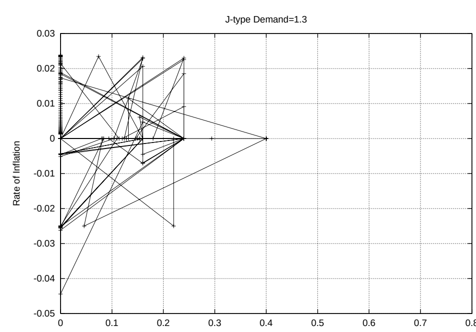

Figure 6: Case 2

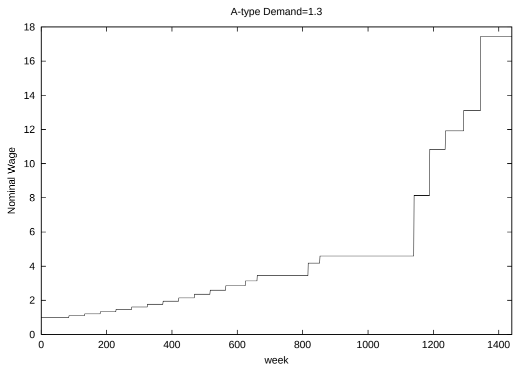

Figure 7: Case 1

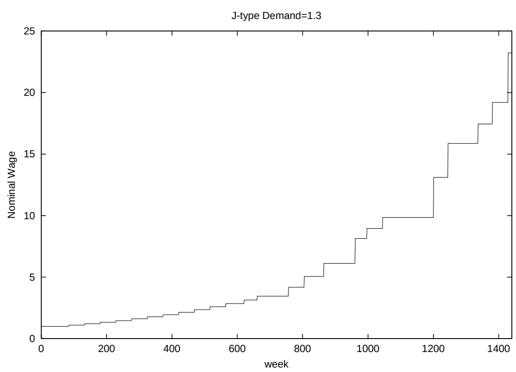

Figure 8: Case 2

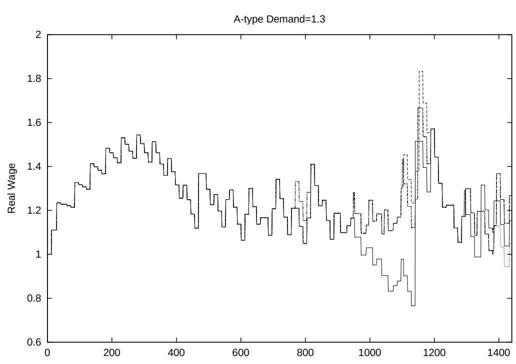

Figure 9: Case 1

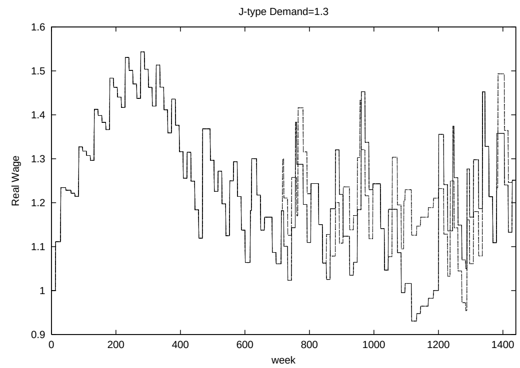

Figure 10: Case 2

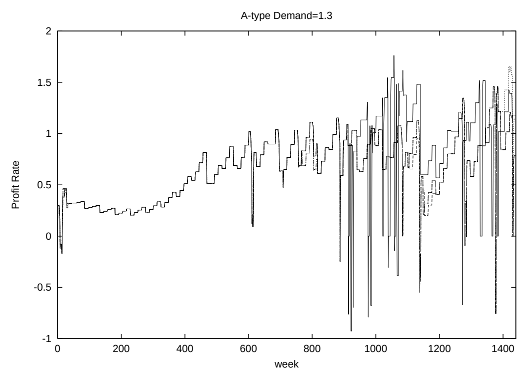

Figure 11: Case 1

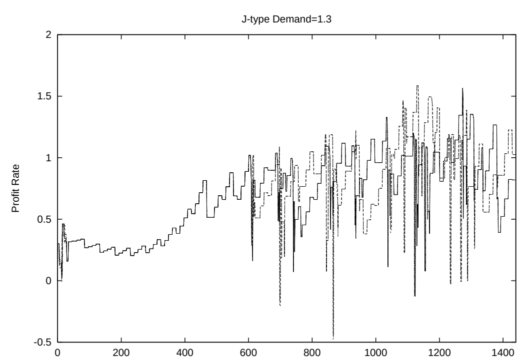

Figure 12: Case 2

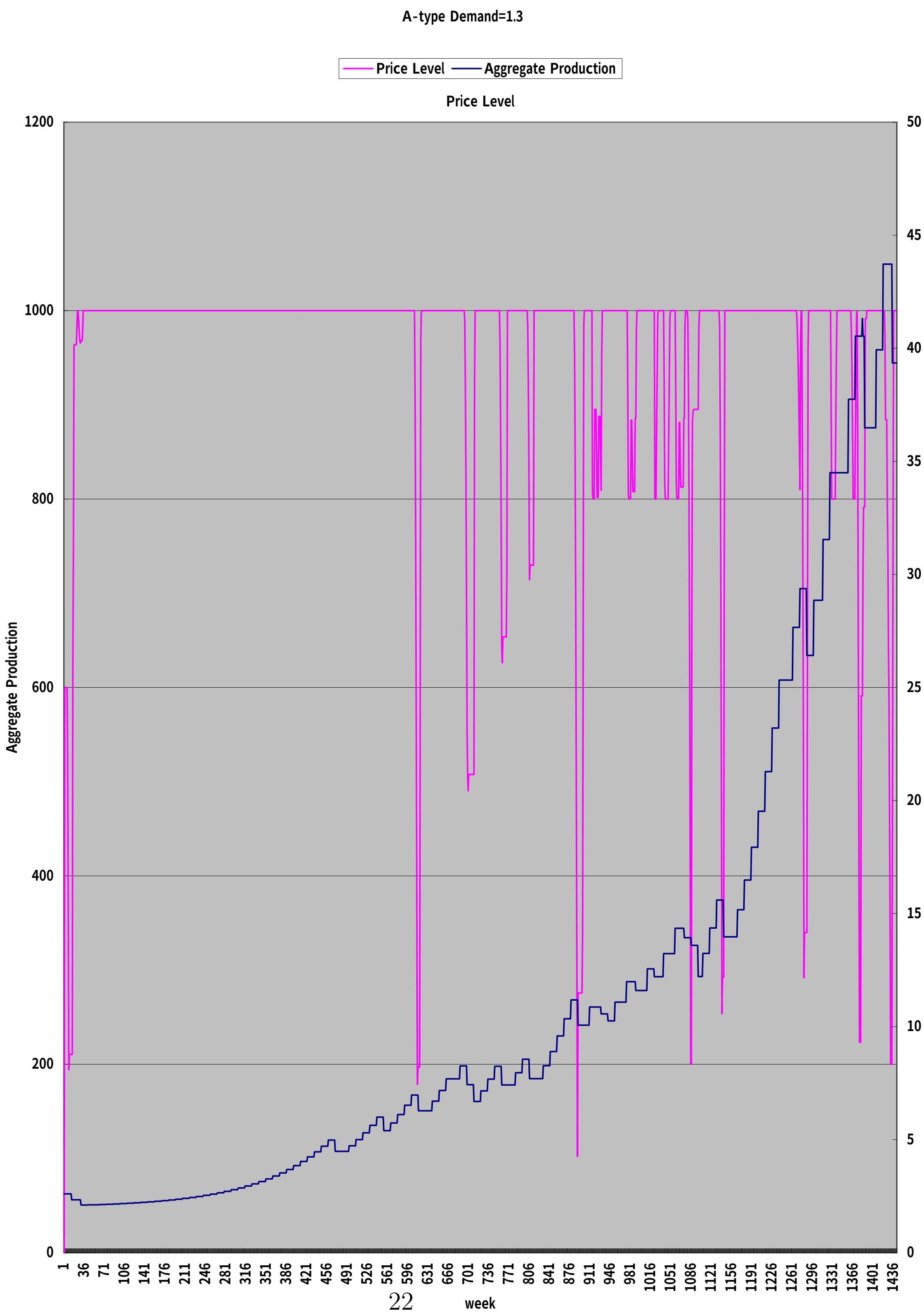

Figure 13: Case 1

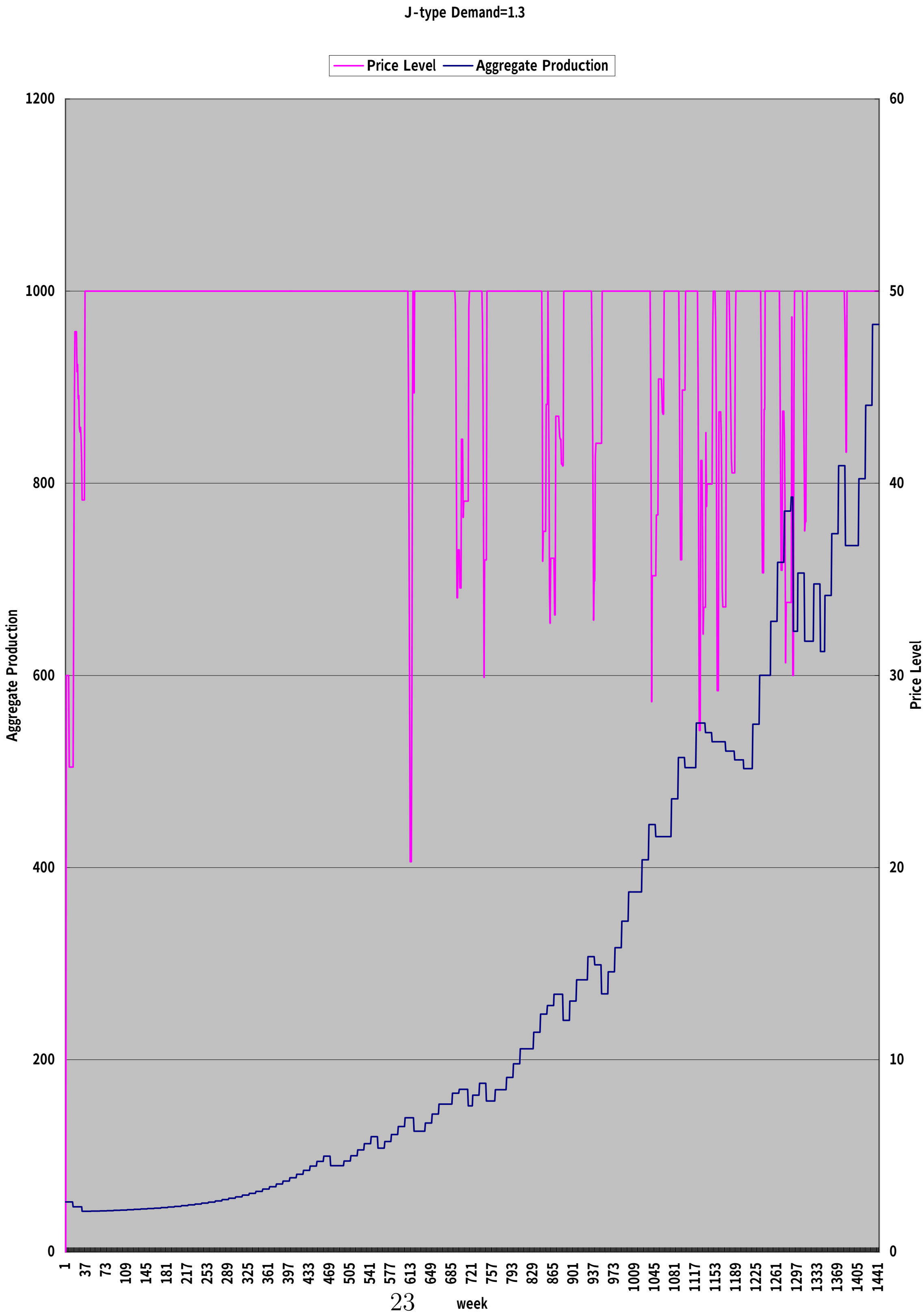

Figure 14: Case 2

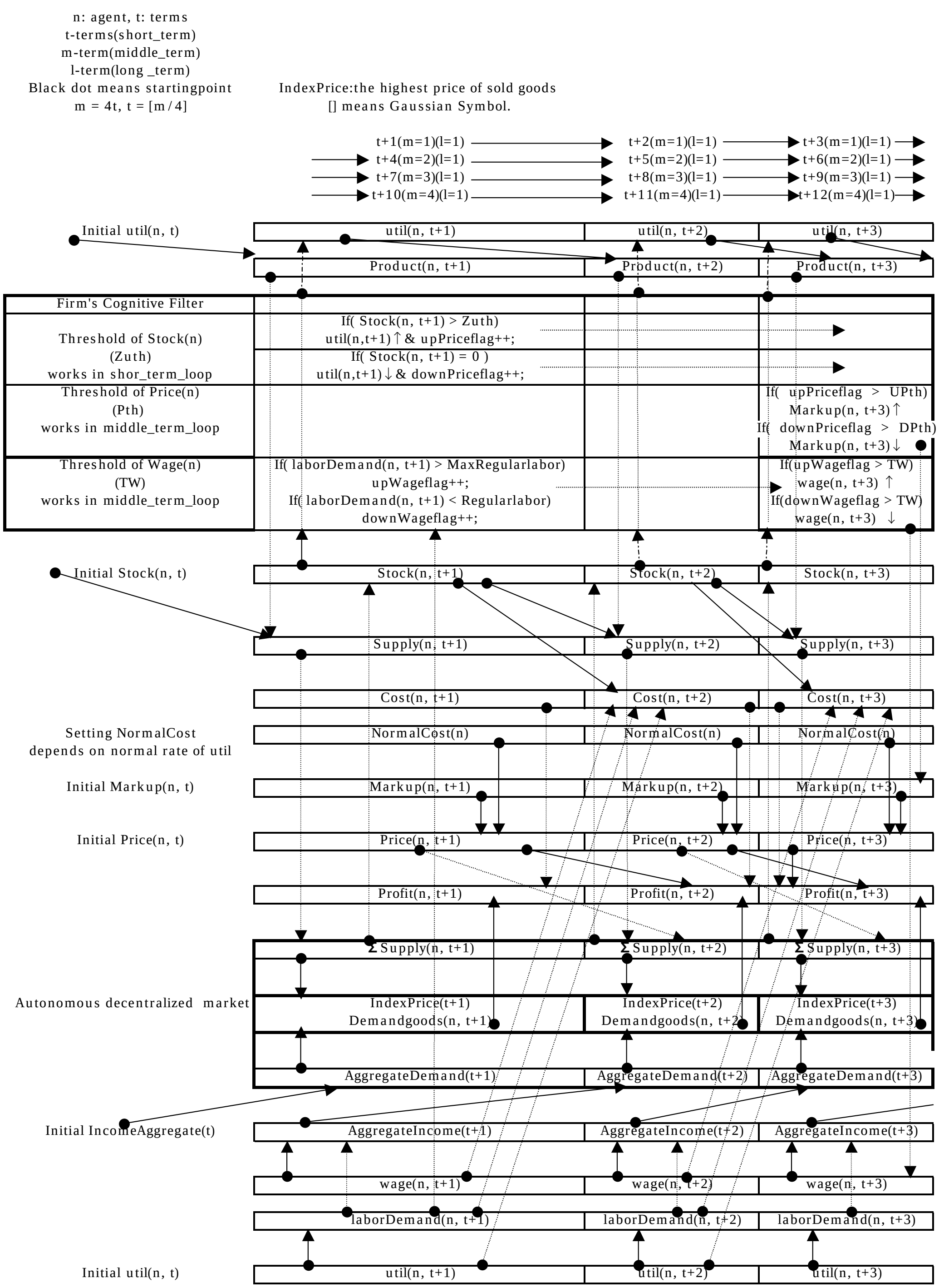

Figure 15: Relations of Variables

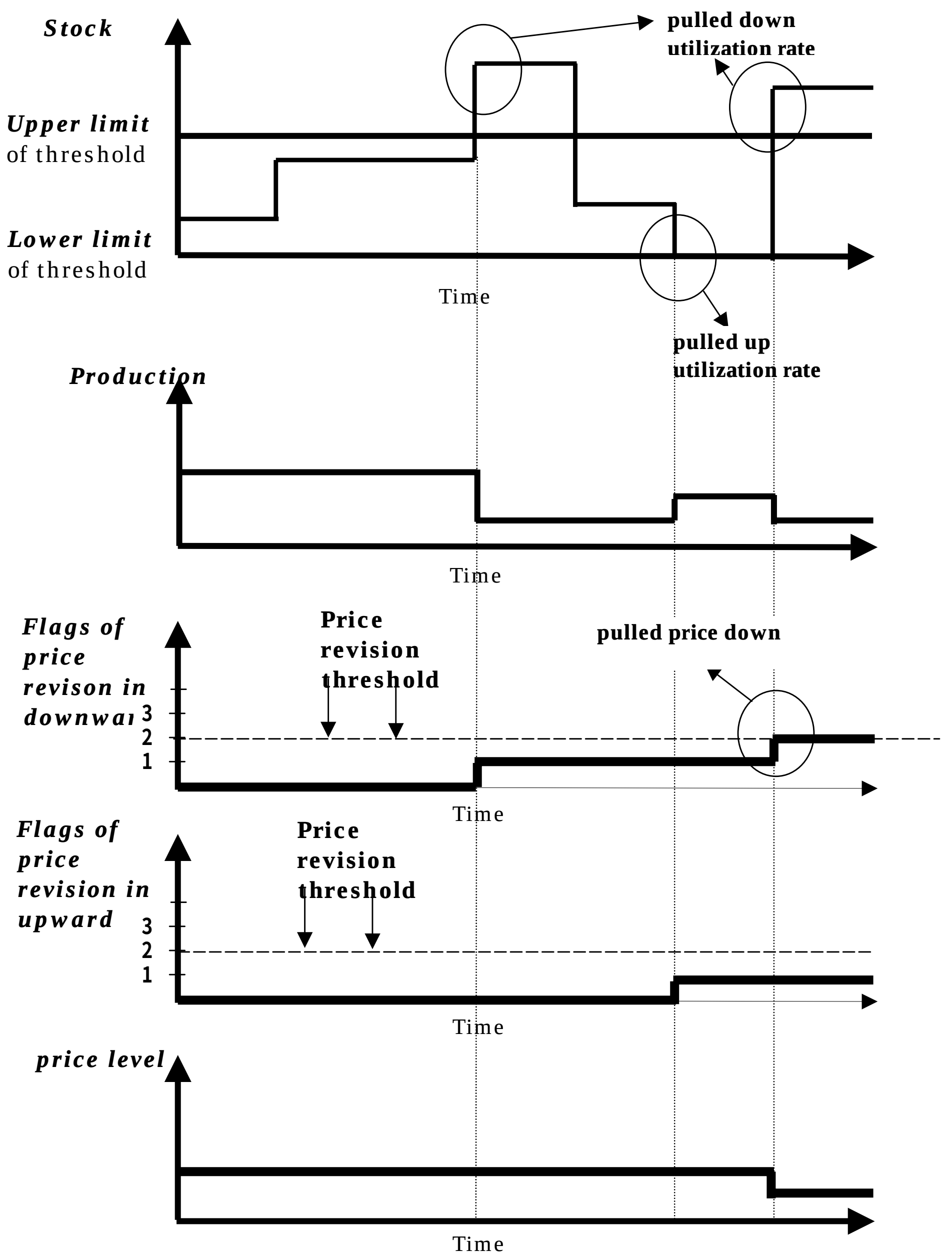

Figure 16: Adjustment of Quantity and Price