Effect of Time Delay on Model Behavior and its Implication for Electronic Transactions in Cyber Space

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Abstract

Newly emerging digital economy provides us a new economic opportunity that replace traditional form of material transaction in physical space with a electronic transaction in cyber space. One notable characteristic of electronic transaction is that thanks to the information technology, electronic transaction can occur with minimal information and delivery delay. One of the key questions with regard to this changing transaction type is the effect of reduced time delay on the level of production, consumption and price of goods in electronic transaction. This paper examines the effect of time delay on electronic transaction by comparing changes in model behaviors in response to changes in time delay such as information recognition delay, delivery delay, production and marketing capacity acquisition delay etc. Three models were used to compare behavior changes; beer game model, commodity production cycle model, and market growth model. Results indicated that effect of reduced time delay on model behavior depends on several factors; competitiveness of market, price elasticity of supply and demand, availability of human resources. Also, the result suggest that availability of human resource is the key factor for a sustained growth of electronic transaction.

1. Introduction

Rapidly increasing volume of electronic transaction indicates that future market would look quite differently from today's market in several important ways. Comparing traditional transaction in physical space with electronic transaction in cyber space, the most notable characteristic of electronic transaction is that it can occur with minimal information and delivery delay. Then, the key question with regard to this changing characteristic of transaction is the effect of reduced time delay in obtaining and processing market information on the level of production, consumption and on the price of goods and service. This paper examines the effect of time delay on electronic transaction by comparing changes in model behaviors in response to changes in time delay such as information recognition delay, delivery delay, production and marketing capacity acquisition delay etc. Three models were used to compare behavior changes; beer game model, commodity production cycle

model, and market growth model.

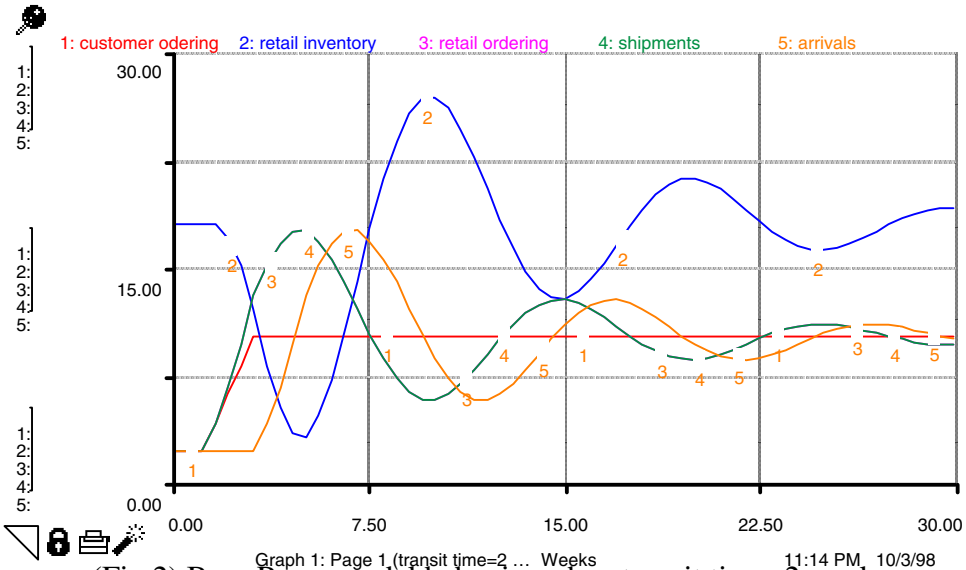
2. Structure and Behavior of Beer Game Model

Beer game model consists of three sectors; customer, retailer, and wholesaler. Retailer tries to keep 12 box of beer as an inventory and he orders beer when retail inventory fall short of target inventory. Model assumes retailer orders beers based on the following function.

retail_ordering = weekly_sales+(target_inventory-retail_inventory)/2

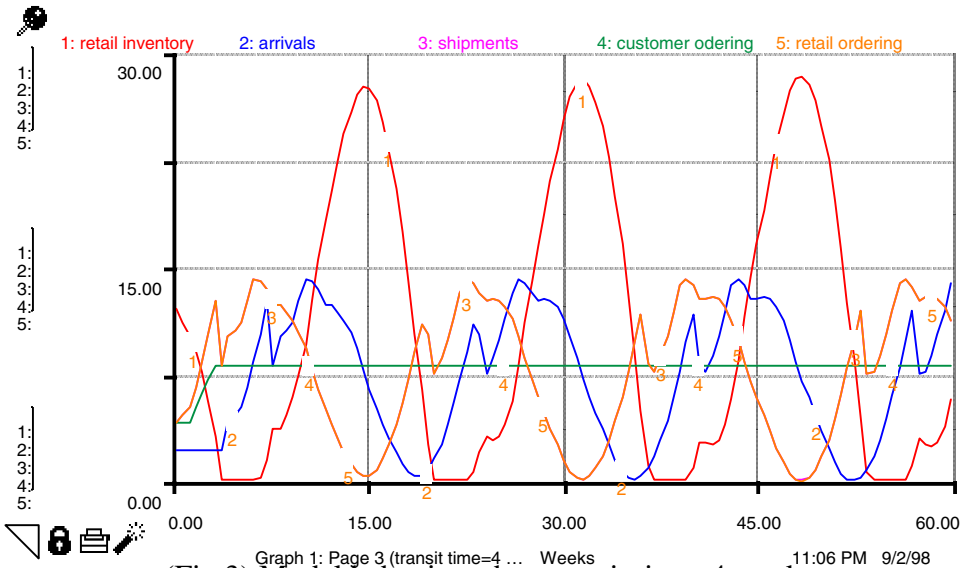
(Fig 1) Structure of Beer Game

In this model, transit time is time needed to deliver beers to retailer. Transit time was set to 2 weeks in the base run meaning that it took 2 weeks before beers arrived to retailer after beers were shipped out. (Fig 2) shows fluctuating model behavior when beer sale jumped up suddenly from 4 to 8 unit.

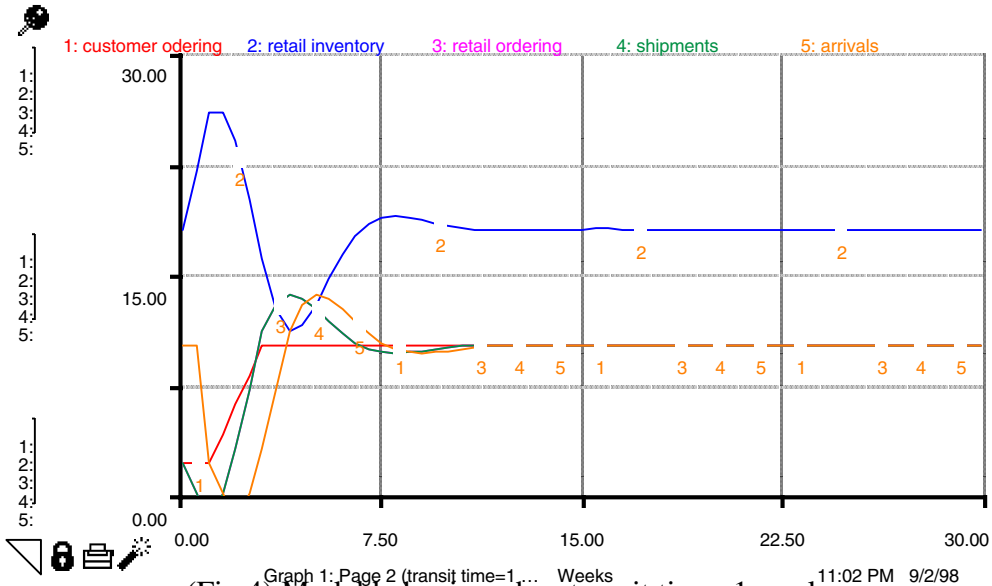


(Fig 2) Base Run - model behavior when transit time=2 weeks

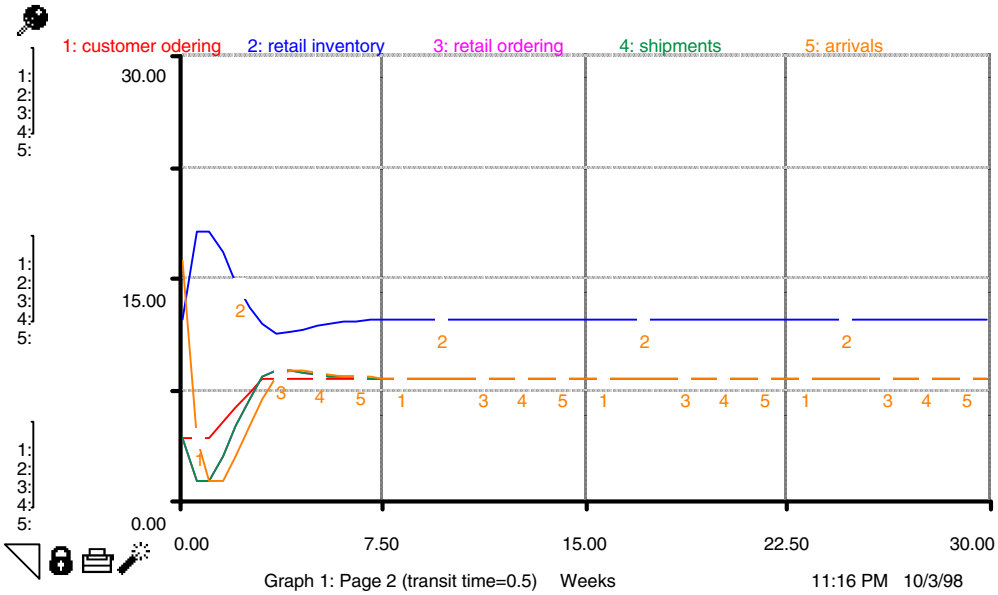
(Fig-3), (Fig-4) and (Fig-5) shows model behavior when transit time is 4, 1 and 0.5 weeks respectively. As shown in these figures, it takes longer time to reach equilibrium point as transit time become longer.



(Fig 3) Model behavior when transit time=4 weeks



(Fig 4) Model behavior when transit time=1 week



(Fig-5) transit time=0.5 week

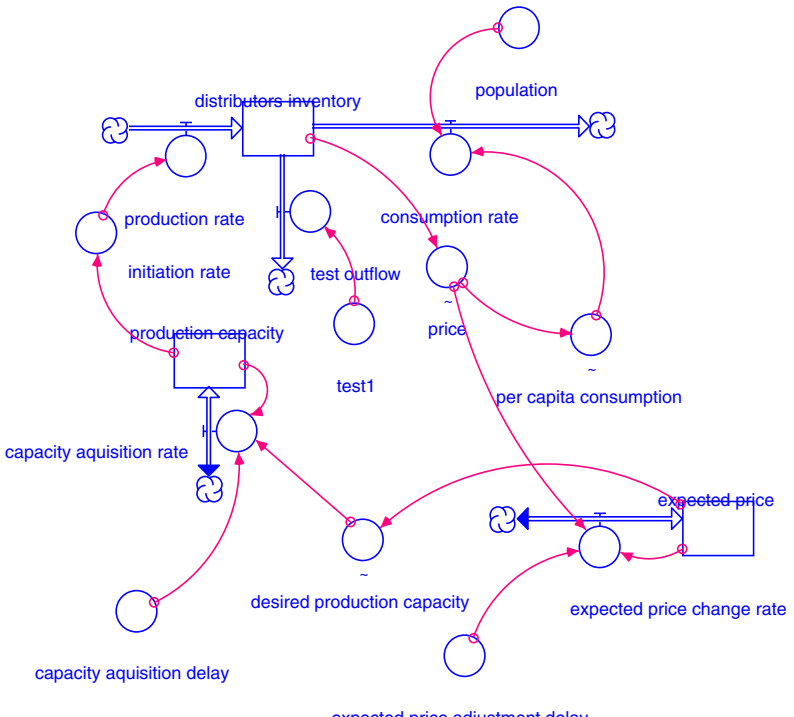
In the beer game model, delivery delay is one important factor that makes the amount of retail inventory fluctuating up and down. The shorter delivery delay, the sooner retail inventory reaches to equilibrium value and amplitude of oscillation become smaller.

4. Commodity Production Cycle Model

Any material with following characteristics is defined as a commodity in the commodity production cycle model. First, it is undifferentiable. Thus, no producer can obtain higher price or better trading terms through advertising or product modification. He must accept the open market price which prevails at the time of sale. Second, variable production costs, labor and materials, are small compared to fixed costs. Thus, in the short term, output of the commodity will be relatively insensitive to price changes. Third, for commodity users, the commodity price is only a small fraction of the final product cost. Consumption is relatively price inelastic.

1) Structure of model

(Fig-6) shows the flow diagram of commodity production cycle model. The model consists of three sub sectors; production, distribution and consumption sector. Price links these three sectors.



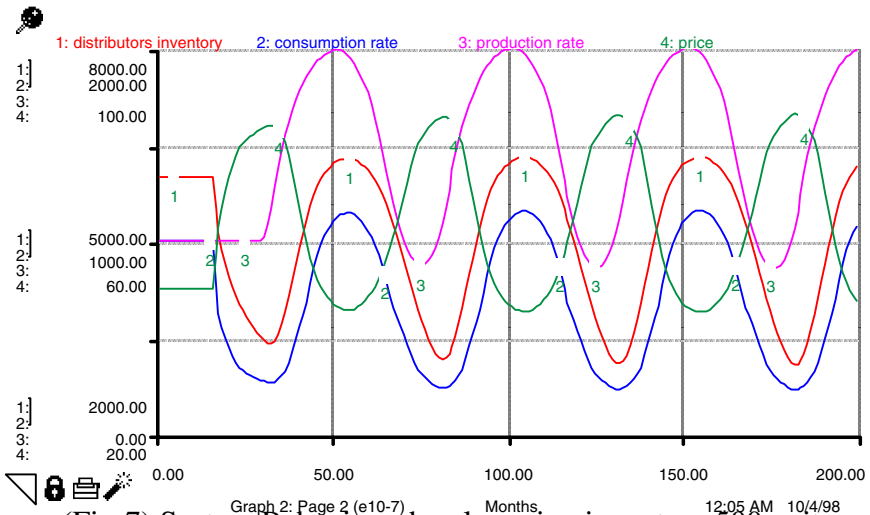
(Fig-6) Commodity Production Cycle Model

In the model, distributors tries to keep optimal inventory level by adjusting commodity price. When the inventory fluctuates, distributors adjust actual market price to bring their inventory within an acceptable range. Market price of commodity determine expected price of commodity and this expected price in turn determine

desirable production capacity. In this model, three types of time delay occurs. First, it takes time for every product before it becomes inventory. Second, it also takes time to form an expected price of commodity. This time delay to form expected price in turn delays decision on the level of production capacity. Third, it takes time to expand production capacity. Even if manager decides to expand production capacity, it does not expand immediately. Following section examines system response to the changing delay time.

2) Model behavior

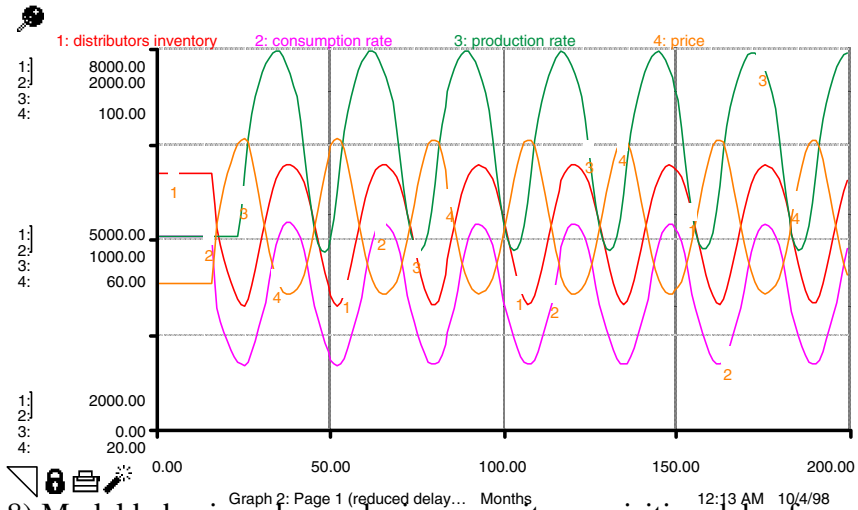
When lowering inventory 500 unit every month from the equilibrium value at month 15, the system response to an initial disequilibrium is shown in the (Fig 7).



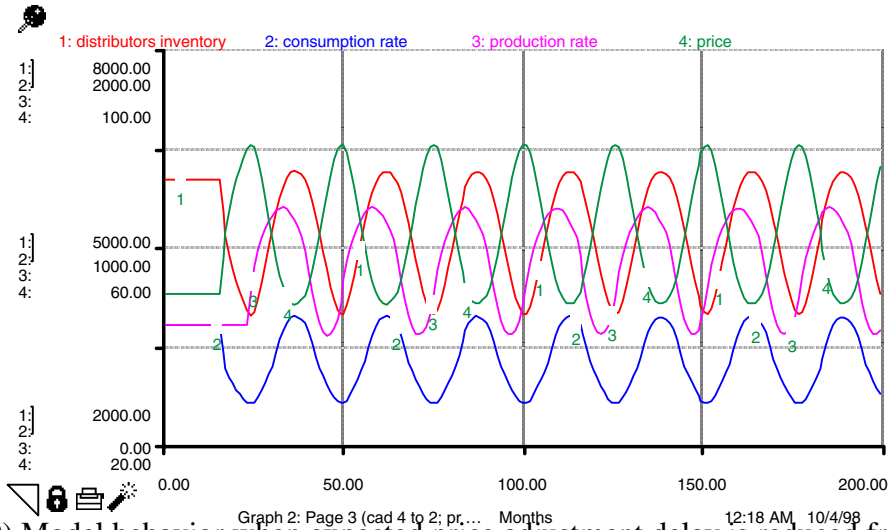
(Fig-7) System Behavior when lowering inventory 500 unit

(Fig-7) shows rapid decrease in inventory lead to increase in commodity price. This price increase in turn decrease consumption level and increase commodity's expected price. When expected price become higher, it signals to expand production capacity. But production capacity does not expand immediately and it takes at least 4 months in this model. This time delay in production capacity expansion is reflected in the (Fig 7). Production increase lagged about 4 months behind the price increase. Increasing production increases inventory and increased inventory in turn decrease commodity price and it signals to decrease production capacity. Decreased inventory pushes price up and down consumption level. Increased price again lead to production capacity expansion and so on and so on. Result is the continuous fluctuation of model behavior.

(Fig-8) shows model behavior when capacity acquisition delay is reduced from 4 to 2 months, delay in production rate (this is actually an inventory rate) is reduced from 12 to 6 months and delay time of an expected price adjustment is reduced from 5 to 2 months. As shown in the (Fig-8), reducing time delay does not damp amplitude of oscillation but shorten period of oscillation.

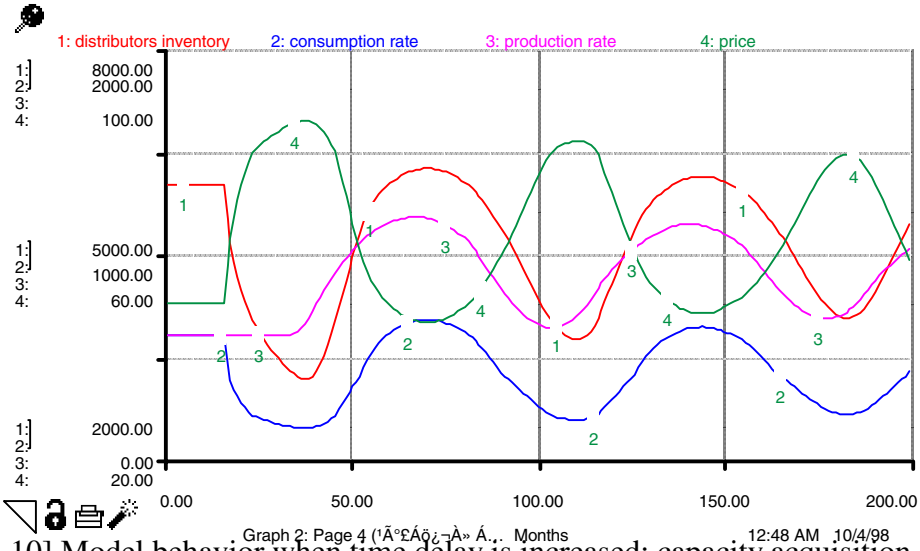


(Fig-8) Model behavior when reducing capacity acquisition delay from 4 to 2 month, delay in production rate from 12 to 6 months, and expected price adjustment delay from 5 to 2 months



(Fig-9) Model behavior when expected price adjustment delay is reduced from 2 to one month

(Fig10) shows model behavior when capacity acquisition delay is increased from 4 to 8 months, delay in production rate from 12 to 16 months, and expected price adjustment delay is increased from 5 to 10 months. We can see again that reducing time delay shorten period of oscillation. Also we can see that when delay time of expected price adjustment is reduced as shown in (Fig-9), amplitude of price oscillation and that of consumption level oscillation become smaller.



[Fig-10] Model behavior when time delay is increased; capacity acquisition delay from 4 to 8 months, delay in production rate from 12 to 16 months, and expected price adjustment delay from 5 to 10 months

5. Market Growth Model

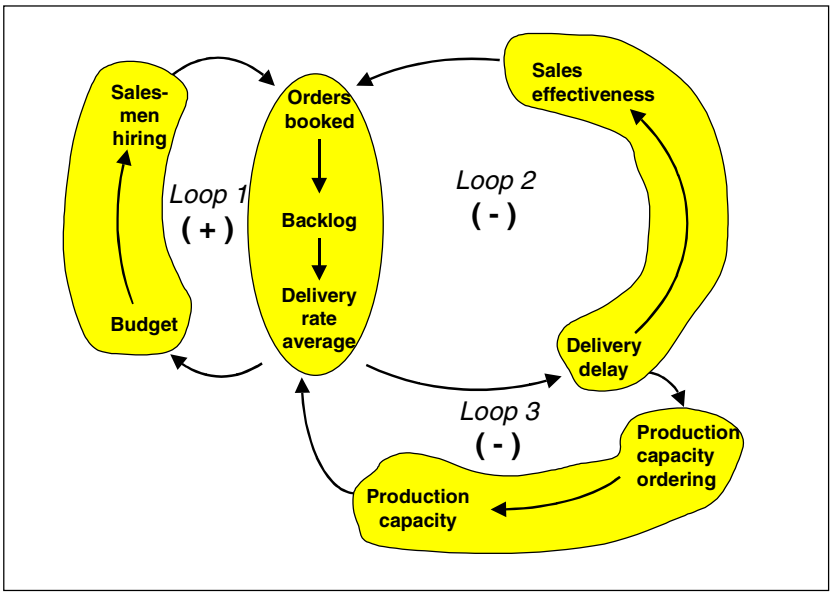
Market growth model by J. Forrester identify and explain system which can cause stagnation of sales growth even in the presence of an unlimited market. The model explain that sales stagnation, or even sales decline is due to overly cautious capital investment policy. In other words, the model explain how the lagging production capacity limits sales growth even in the presence of an unlimited market. .

With regard to the purpose of this paper, special concern must be paid to the model behavior in response to the changes in time delay. In this model, time delay occurs at five points; DDI(delivery delay indicated), SH(delay in salesman hired), DDRC(delivery delay recognized by company), DDRM(delivery delay recognized by market), and PCR(production capacity receiving delay).

Comparing model behavior with and without or reduced time delay will provide an important insight for an electronic transaction in cyber space because electronic transaction in cyber space occur with minimum information and material delay.

1) Structure of market growth model

(Fig-11) shows three major loops of the market growth system being considered in the model. Loop 1 is a positive feedback loop involving the marketing effort in terms of hiring of salesmen. Loop 2, however, is a negative feedback loop and tends to adjust the incoming order rate to equal the production capacity. Loop 3 is a negative loop involving production capacity. In this loop, ordering new production capacity is a function of delivery delay only. Rising order backlog, as indicated by delivery delay, is taken as an indication of inadequate capacity, and orders for more capacity are placed. These orders, after an acquisition delay, add to the production capacity. Loop 3 is a negative feedback loop which is attempting to change production capacity to adjust the order backlog to a value determined by a management goal for proper delivery delay. As the delivery delay rises, production capacity is raised to bring down the delivery delay.



[Fig-11] Structure of market growth model

2) Behavior of Market Growth Model

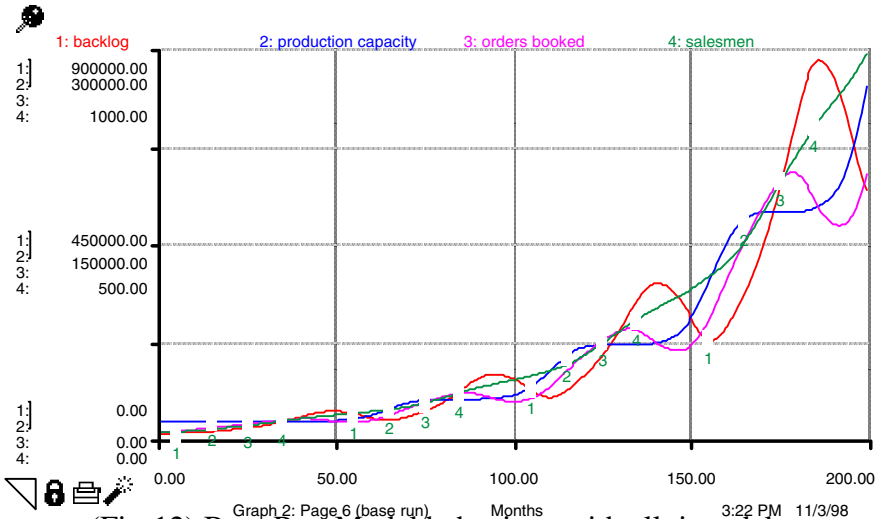
As mentioned earlier, there are five time delay related variables in this model; DDI(delivery delay indicated), SH(delay in salesman hired), DDRC(delivery delay recognized by company), DDRM(delivery delay recognized by market), and PCR(production capacity receiving delay). <Table 1> shows various testing value to see changes in model behavior in response to changing values of time delay related variables. Base run column shows model parameters when time delay occur at every five points while test run A, B, C, D shows model parameters when time delay exist in PCR(production capacity receiving delay) and SH(delay in salesman hiring), no time delay at all, time delay exist only in PCR, time delay exist only in SH respectively.

<Table-1> Testing model behavior by changing switch value and time delay variables

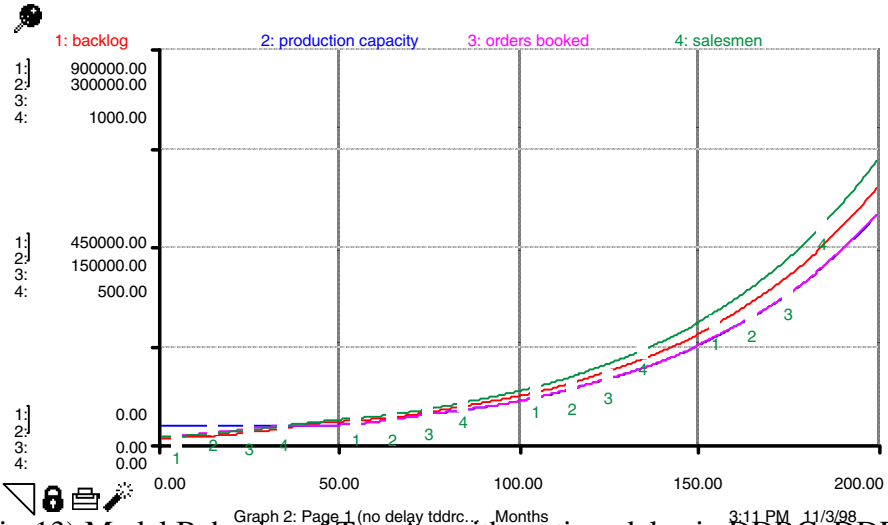
variables		bas erun	testing			
			A	B	C	D
sw1	activating effect of salesmen growth on order booked and backlog if sw=1	1	1	1	1	1
sw2	activating effect of delivery delay on effectiveness of salesmen if sw=1	1	1	1	1	1
sw3	activating effect of delivery delay on production capacity growth if sw3=1	1	1	1	1	1
production capacity receiving delay	time delay in increasing production capacity expansion	12	12	0	12	0
salesman adjustment time	time delay in hiring salesmen	20	20	0	0	20

time for delivery delay recognized by company	time delay in recognizing delivery delay by company	4	0	0	0	0
time for delivery delay recognized by market	time delay in recognizing delivery by consumer	6	0	0	0	0

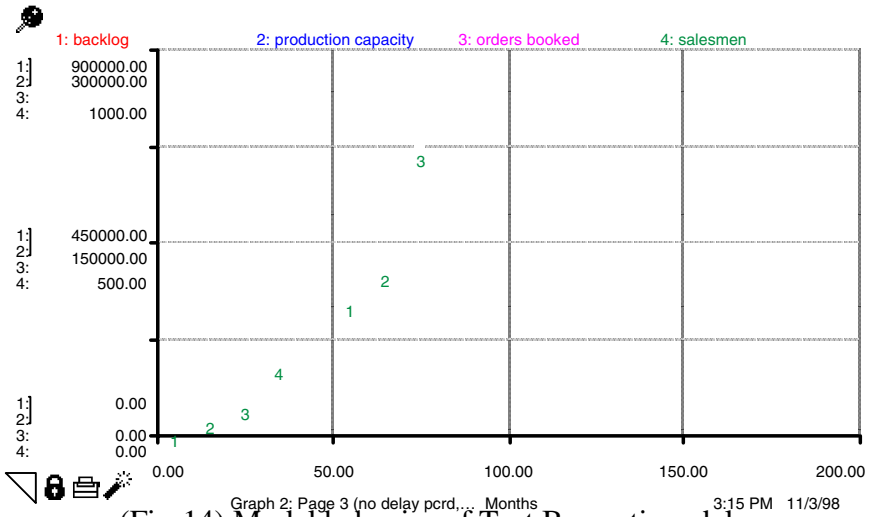
(Fig-12) shows base run model behavior and (Fig-13) shows model behavior of test A, when there are no time delay in DDRC and DDRM (delivery recognized by company and market). Comparing two figures, we can notice that production capacity and backlog increase continuously without fluctuation when there are no time delay in DDRC and DDRM while production capacity and backlog increase with fluctuation when time delay exist. One notable thing is that production capacity increases much higher with time delay than without it.



(Fig-12) Base Run Model behavior - with all time delay

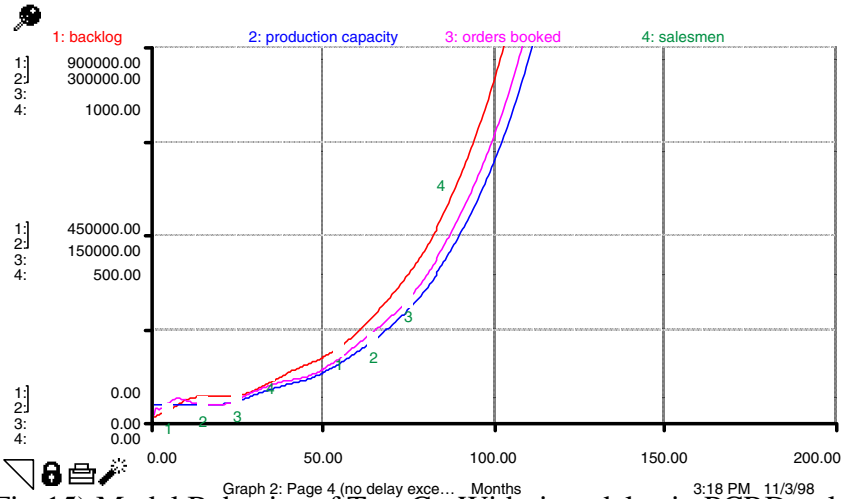


(Fig-13) Model Behavior of Test A - without time delay in DDRC, DDRM



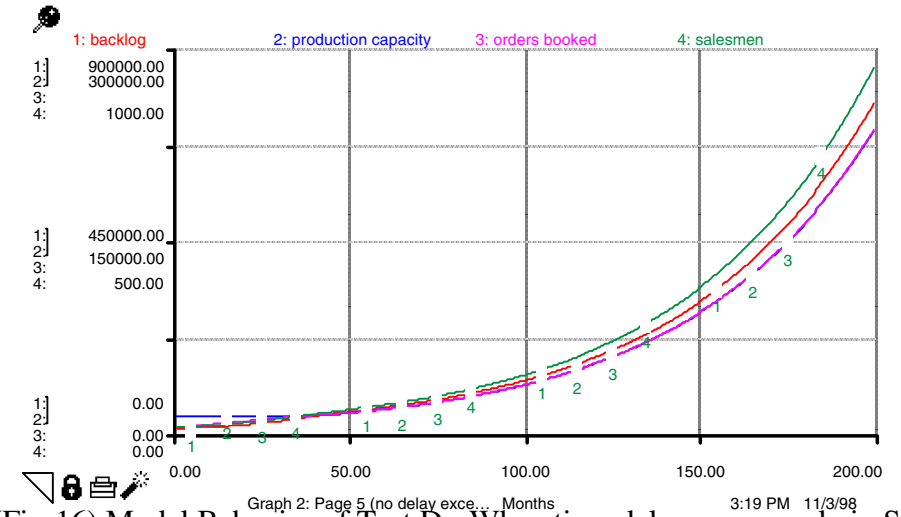
(Fig-14) Model behavior of Test B - no time delay

(Fig-14) shows model behavior when there are no time delay in PCRD(production capacity receiving delay), SH(salesman hiring delay), DDRC(delivery delay recognized by company), DDRM(delivery delay recognized by market). The model behavior indicate that if there are no time loss in obtaining and processing market information with regard to delivery delay, if there are no time delay in salesmen hiring and production capacity acquisition, market growth is unlimited.



(Fig-15) Model Behavior of Test C - With time delay in PCRD only

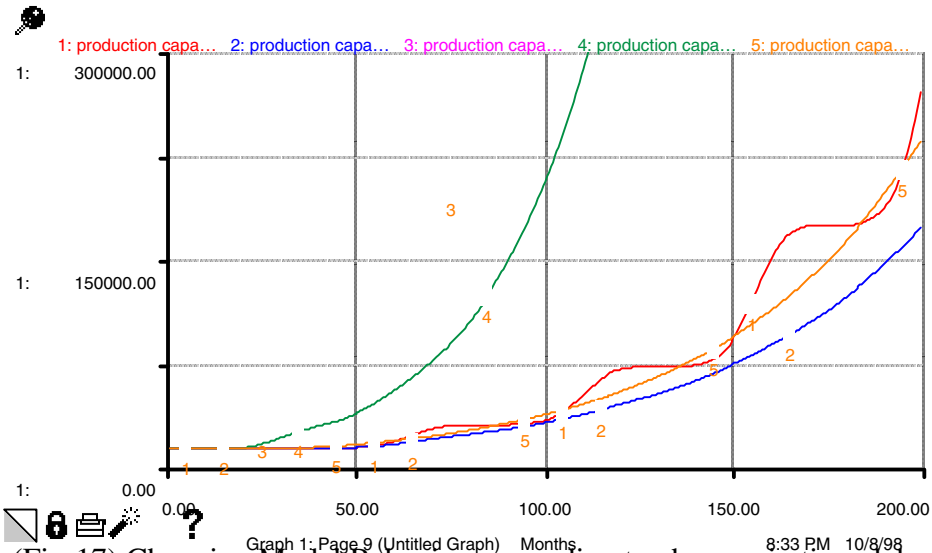
(Fig-15) shows model behavior when time delay occurs only in production capacity acquisition. Model behavior shows that production capacity and orders booked increase rapidly too. Even though increase rate of production capacity and orders booked is lower than Test B model behavior, production capacity and orders booked is increasing exponentially.



(Fig-16) Model Behavior of Test D - When time delay occurs only in SH

(Fig-16) shows model behavior with time delay in salesmen hiring only. This test assumes there are no time delay in capacity expansion and obtaining and processing market information. Production capacity increase continuously in this case too. But comparing size of capacity expansion with Test C model behavior shows a big discrepancy. Production capacity growth is much higher when there are time delay in production capacity only than with time delay in salesmen hiring only. This may implies that when there are unlimited possibility of market growth, the most important variables affecting market growth is securing manpower without time delay rather than production capacity expansion without time delay.

(Fig-17) shows various behavior of production capacity in response to changing time delay. (1=Base Run, 2=DDRC DDRM delay, 3=no delay, 4=PCR delay, 5=SAT salesman adjustment time delay).



(Fig-17) Changing Model Behavior responding to changes in time delay

Following <Table 2> summarize model behaviors tested so far responding to changes in time delay.

<Table-2> Summary of Model Behavior when Time delay is reduced

	Beer Game Model	Commodity Cycle Model	Market Growth Model
Oscillating Period	shorten, dampen	shorten	dampen
Oscillating Amplitude	reduced	reduced	dampen
Time to reach equilibrium	shorten	oscillating	capacity expansion growth size in order: 1.no delay, 2.PCRD, 3.base run, 4.SAT, 5.DDRC, DDRM
delay point	delivery delay (transit time)	-time delay in production rate -time delay for expanding production capacity -time delay to form an expected price	-delivery delay -salesman adjustment delay, -production capacity acquisition delay -DDRC -DDRM

6. Discussion

We have been discussed so far changes in model behavior responding to changes in time delay using beer game model, commodity cycle model, and market growth model.

All these model shares same characteristic that they deal with transaction of material goods in physical space, traditional market. In beer game model, there is a time delay that need to deliver beer from wholesaler to retailer. In commodity cycle model, there are time delays related with production capacity expansion, production rate, and expected price. There are several time delays in market growth model including SAT, PCRD, DDRC, DDRM.

One notable thing with regards to these time delay variables is that these delay time can be reduced or at least minimized in many instances in electronic transaction in cyber space. Thus, testing model behavior in respond to reduced time delay can suggest several important implication for electronic transaction in cyber space. Findings are as follows.

First, when delay time is increased, amplitude of oscillation (inventory, commodity price, production capacity) gets bigger.

Second, when testing model behavior with reduced or minimized time delay, oscillating period become shorten or oscillation damped down. In other words, when time delay is reduced, model experience either a more extensive oscillation or a stable growth.

Third, when there is no time delay, size of production capacity expansion of each model tends to be reduced. In other words, when production capacity can be adjusted without time delay, and when market information with regard to delivery delay can be obtained and processed without time delay by the business manager and consumer, market can be stabilized more rapidly but with a cost of reduced market size.

Fourth, in case of market growth model, time delay needed to hire and train salesmen limits market growth more seriously than time delay in production capacity expansion. This implies that electronic transaction in cyber space can be limited not by production capacity but by human resources.

Finally, commodity cycle model and market growth model shows quite different model behavior when time delay is reduced. When delay time is reduced, production and price oscillation period become shorter and amplitude become greater in commodity cycle model, while production and price oscillation damped down rapidly and shows a stable growth in market growth model. The reason for this different model behavior can be explained by model's different assumption. First of all, commodity cycle model assumes price elasticity of demand and supply is relatively inelastic. In other words, consumption and production of commodity is relatively stable to price changes in commodity cycle model. However, there are no such assumption in market growth model and the model assumes production capacity expansion depends on effectiveness of sales efforts. Since we assume market information -information necessary to make a production capacity expansion decision- can be obtained without time delay and assume production capacity can be expanded with a minimum time delay in cyber space, production and consumption can be adjusted each other rapidly and thus, shows a model behavior of stable growth.

This implies two things. First, commodity price, supply and consumption level oscillate more when commodity in cyber space has a characteristic of inelastic demand and supply, monopolistic power. Same is true when it takes a substantial time to produce the commodity and when consumers are accustomed to use the commodity. Second, when production and consumption are elastic to price change and when it does not take long time to produce the commodity, production and consumption shows a sustained stable growth.

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