Modifying the Beer Game to make its dynamic structure more salient

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Abstract

This paper suggests that the misperception of feedback individuals show may depend on the frame presented to them. A brief summary of Kahneman's work about heuristics is used to argue that the Beer Game may not be neutral: its very presentation may influence the cognitive processes and the observed performance. Some modifications to the Beer Game material and rules are proposed in order to make the feedback and delay structure more easy to grasp. While this is currently only an argumentation, empirical work will be done in the coming month and be presented at the conference.

Keywords: system thinking skills, tacit knowledge, learning, expertise

Introduction

It has been proposed that an "anchoring and adjustment heuristic" operates in stock management situations and that subjects fail to take into account the effects yet-to-come of control actions already taken (Sterman, 1989). This has lead to speak of "misperception of feedback" (p. 322).

In the following years, the difficulties to perceive and think about the dynamics of systems have been the object of several strings of work. The "misperception of feedback" continues to be studied in increasingly simple settings (Moxnes, 2000, 2004; Jensen and Brehmer, 2003); the stock management situation used by Sterman in 1989 is being studied to assess the effects of information sharing (Croson and Donohue, 2006). Maani and Maharaj (2004) studied system thinking in general, and there emerged a string of studies about stock-and-flow thinking (Booth-Sweeney and Sterman, 2000; Ossimitz, 2002; Kainz and Ossimitz, 2002; Jensen, 2005, Schaffernicht, 2005).

All of these studies coincide in that humans systematically go wrong when facing dynamics complexity. However, beside Sterman (1989), this line of studies did not make use of the contributions from the field of "Judgment under uncertainty" (Kahneman et al., 1982) about cognitive heuristics and biases. In 2002, Daniel Kahneman was rewarded with the Nobel Prize for Economics.

His prize lecture gave an overview of this field (Kahneman, 2002; 2003), in which he relates to the "general proposition that changes and differences are more accessible than absolute values" (p. 450). There is a tension between this general proposition and the idea that only the levels (of stocks) can be measured at a given moment in order to inform a decision (Forrester, 1961). Could it be that our assessment instruments – for instance the Beer Game – is presented in such a way that it makes the task more difficult?

The remainder of these pages is an incipient attempt to analyze instruments like the Beer Game as for their compatibility with findings from cognitive psychology. In the following section, a brief review of the main concepts and ideas from this field is offered. Then, several uses of the Beer Game are examined as for the kind of cognitive system and process they appeal to. Based on this, a modification to the Beer Game presentation is proposed and a protocol for experimentation specified.

For the time being (2/28/2006), the empiric part has not been carried out yet; however, first findings will be presented at the conference.

Judgment under uncertainty

Perception, intuition and reasoning in two cognitive systems

Scholars who study judgment under uncertainty distinguish two modes of thought: intuitive and controlled. According to this view, the most basic form of thought is perception, which is bound by current stimulation. However, the same mental system of perception also operates in the intuitive thinking mode. This "system 1" processes are fast, automatic, parallel, effortless, associative and difficult to control or modify. Their content is – beyond percepts – conceptual representations that can be evoked by language and refer to past, present or future. "System 2" operates with the same contents, but in a slow, serial, effortful, rule-governed, controlled and flexible manner.

Another difference is made between impression and judgments. The former are generated by system 1 in response to attributes of objects of perception or thought (that is, our thoughts can be treated just like external objects by system 1); they are not necessarily voluntary or explicit. The latter always involve system 2; a judgment may be intuitive – based upon impressions – but it is always monitored by system 2.

As a consequence, an error in judgment is always an error or system 2, too.

Accessibility and its determinants

Accessibility is defined as "the ease with which particular mental contents come to mind" (Kahneman, 2002: 452). Accessibility is a continuous dimension: on one end, there are features for which system 1 directly generates a perceptual impression. In the visual realm, this is the case with the height of a tower or the average or prototype characteristics of a set of objects. This is to say that in Figure 1, the height of the tower does not have to be constructed by system 2, it is automatically generated by system 1.

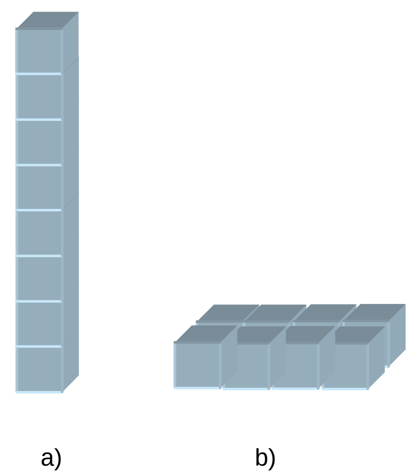


Figure 1: the height of the tower as impression and as judgment (adapted from Kahnemann, 2002: 452)

Also. there are system 1 processes that automatically construct typical representations like the mean or prototypes. This is why the average behavior of a variable like the one represented in Figure 2.

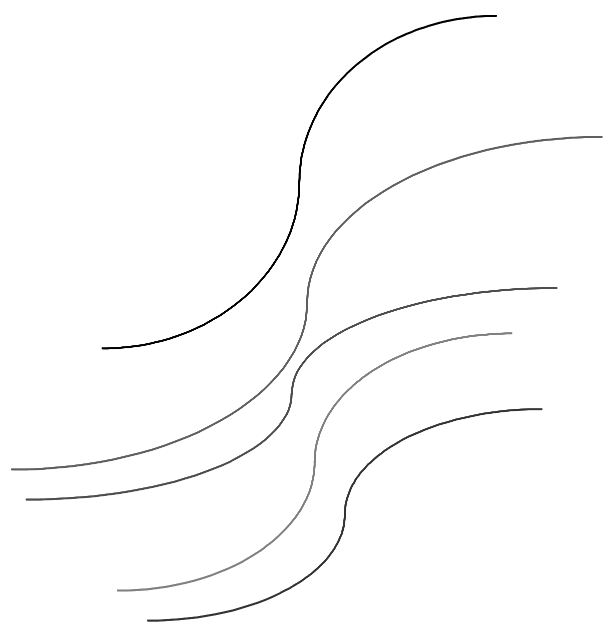


Figure 2: the prototypical shape of curves is a perceptual impression

At the other end of the continuum, there are "slow, serial and effortful operations that people need a special reason to undertake" (Kahneman, 2002:453). For instance, the way we represent tasks like the "stock-and-flow" thinking tests or the Beer Game, may thus change the particular point on the continuum; it has to be noted that experience and skill help to increase the accessibility.

Accessibility depends on *stimulus salience*, *selective attention* and *response activation*. Stimulus salience is, first of all, determined by the actual physical properties of a scene or an object. System 1 routinely generates impressions of physical properties like size, distance and loudness, but also abstract properties like similarity, causal propensity, surprisingness and affective valence (Kahnemann, 2002: 454).

Attention can overcome salience; if a given stimulus is particularly arousing, all its features become accessible (not only the exposed ones). For example, mentioning the term “public debt” in a decision task temporarily arouses mental content related to this concept, where using “people in a store” (for the same task structure) would not. By this way, different response modes may become activated inadvertedly.

The context of the general situation that surrounds a task or stimulus influences accessibility. This may have undesired consequences; think of the recent case of caricatures in the religious realm, published by a Danish newspaper: the same caricature in a different religion has a different meaning for members of the other religious community. Also think of the word “complexity” and what it means according to if it appears in a cybernetic or a system dynamics text.

It seems that system 1 tries to resolve ambiguity, and often the subject only becomes aware of the most likely alternative. This is being observed in the case of “experienced decision makers working under pressure, […] rarely need to choose between options because in most cases only a single option comes to their mind.” (Kahneman, 2002: 455).

Framing

The influence of the context inside which a task is presented contradicts the idea that preferences are not affected by variations of irrelevant features. The presentation frames the thinking of the decision maker, like in the following “asean desease” example (taken from Kahnemann, 2002: 457):

> *Imagine that the United States is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:*
>
> - *If Program A is adopted, 200 people will be saved*
> - *If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved*
>
> *Which of the two programs would you favor?*

When presented this way, the majority of subjects prefer Program A. Now consider a different version of the problem:

- *If Program A’ is adopted, 400 people will die*
- *If Program B’ is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die.*

The fact that now the majority chooses Program B reveals a framing effect.

Again, some frames seem to appeal to systems 1 and 2 in different ways. In a study using isomorph problems to the well-known “towers of Hanoi” problem, it was found that the problem was easier to solve when the transitions were represented by motion (Kahnemann, 2002: 458).

Also, it appears that subjects do not tend to substitute different representatins of the same situatin: “passive adoptin of the formulatin seems to be a general principle […]” (Kahnemann, 2002:458).

Changes or states

“A general property of perceptual systems is that they are designed to enhance the accessibility of changes and differences” (Palmer, 1999, cited in Kahnemann, 2002:459). These changes and differences are dependent on references; for instance, a grey box inside a black one generates a difference that is “lighter”, but inside a white box it would be “darker”, like illustrated in Figure 3:

Figure 3

According to Kahnemann (2002), this means that the evaluation of decision outcomes should be reference-dependent, too. This is to say, when a subject is offered a choice between two gambles, the decision would be taken on ground of the expected gain or loss, not the expected state of wealth by the end of the gamble.

Attribute substitution

Originally, three heuristics o judgment were proposed: representativeness, availability and anchoring (Kahnemann et al., 1982; Kahnemann, 2002), but today there is supposed to be a common process of attribute substitution that explains judgment heuristics. “A judgment is said to be mediated by a heuristic when the individual assesses a specified *target attribute* of a judgment object by substituting a related *heuristic attribute* that comes more easily to mind” (Kahnemann, 2002: 466; emphasis in original). The former heuristics can be seen as particular cases of heuristics. A new case is the affect heuristic (Slovic et al., 2002, cited in Kahnemann, 2002): the affective valence of a stimulus thus may intervene in responses that express attitudes. In all, “the essence of attribute substitution is that respondents offer a reasonable answer to a question that they have not been asked” (Kahnemann, 2002:469).

“Prototype heuristics can be roughly described as the substitution of an average for a sum [It is] the process of substituting an attribute of a prototype for an extensional attribute.” (Kahneman, 2002:474).

This is a very short introduction of some important aspects of the work by Kahneman and others. It is mentioned here to stress three points:

1. the way a situation or task is presented to individuals has an influence on the thought processes;
2. in different frames, different attributes may fall victim to substitution;
3. motion, changes and differences come to mind more easily than states.

Arguably, these contributions can be used to critically look at the situations that the system dynamics researcher confronts his subjects with. This will now to be done for the exemplary case of the Beer Game.

Looking at the Beer Game

The Beer Game is based upon a structure made up of four companies in a simplified beer market: factory, distributor, wholesaler and retailer. Each of these companies consists of several stocks, in general the beer being brewed or received from a purveyor, the beer in stock and the beer being sent downstream to a customer. Additionally, each has to keep track of the backlog of unsatisfied orders, receive incoming orders, process them and sent new orders upstream. Finally there is the stock of cash, since the goal of the game is to collectively minimize the cost for stocking and for being out-of-stock. There are flows of expenditure or cost each period that accumulate in this stock.

Usually each of the company roles is assigned to one individual, and their reward depends on achieving fewer costs than their companion teams.

Sterman (1989) focuses on the “supply line” and “stock” stocks, and the proposed heuristic takes into account both of these stocks and the loss rate (that is: the rate at which each company “loses” beer to its customers). The “anchor” of the heuristic is the expected loss rate, which is thought to be highly salient and gradually adjusts to experience. The order rate then depends on this expected loss rate and desired adjustments to the supply line and the actual stock.

The typical game board, the record-keeping material and the instructions to players focus on the stocks (momentary quantities) of beer and orders:

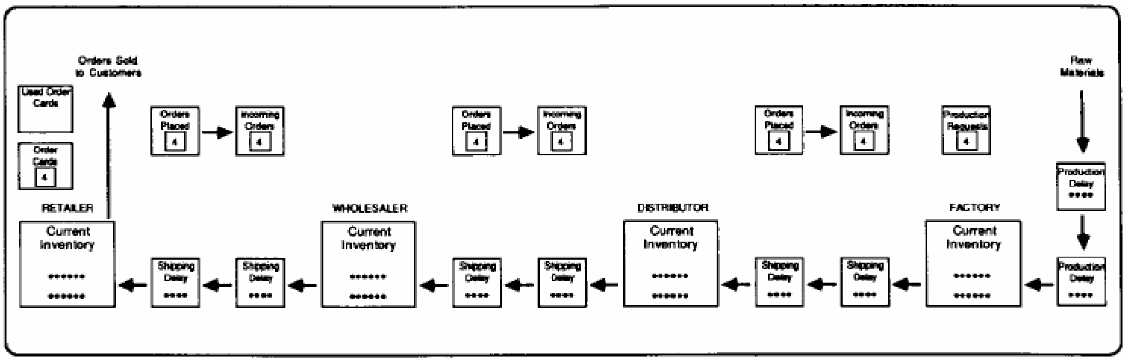


FIGURE 2. "Beer Distribution Game" Board.

Initial conditions are shown: each inventory contains 12 pennies; each shipping/production delay contains 4. Orders are 4 throughout the distribution chain. During actual play the order cards are face down at all times. Each simulated week requires all subjects to carry out five steps:

1. *Receive inventory and advance shipping delays*. The contents of the shipping delay immediately to the right of the inventory are added to the inventory; the contents of the shipping delay on the far right are moved into the delay on the near right. The factory advances the production delays.

2. *Fill orders*. Retailers take the top card in the customer order deck, others examine the contents of "Incoming Orders". Orders are always filled to the extent inventory permits. Unfilled orders add to the backlog, if any. The number of orders to fill is the incoming order plus any backlog from the prior week.

3. *Record inventory or backlog on the record sheet*.

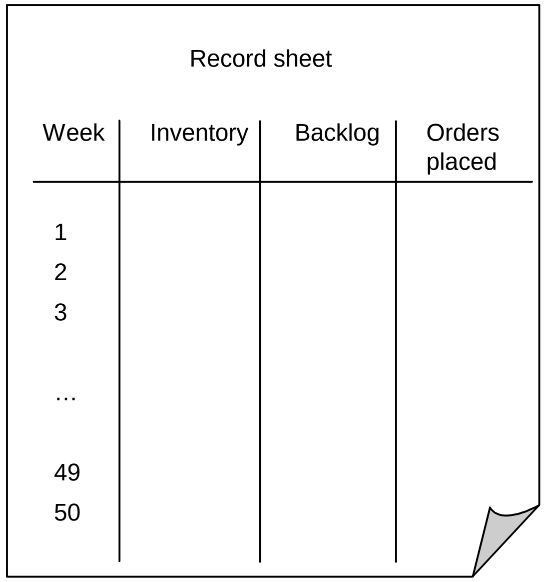
4. *Advance the order slips*. Order slips in the "Orders Placed" box are moved to the "Incoming Orders" box on the immediate right. Factories introduce the contents of "Production Requests" into the top production delay.

5. *Place orders*. Each player decides what to order, records the order on the record sheet and on an order slip which is placed face down in the "Orders Placed" box. Factories place their orders in "Production Requests."

Note that only step 5, Place Orders, involves a decision on the part of the subject. Steps 1–4 handle bookkeeping and other routine tasks.

Figure 4: the Beer Game (Sterman, 1989: 327)

The record sheet mentioned in step 3 has one record for each week's inventory, backlog and orders placed:


Record sheet

Week	Inventory	Backlog	Orders placed
1			
2			
3			
…			
49			
50			

Figure 5: the Beer Game record sheet

The calculation of costs and the drawing of graphs that show the behavior of the two stocks (beer and orders) over time are delayed to the end of the game, that is: excluded from what forms part of the thinking going on during the game.

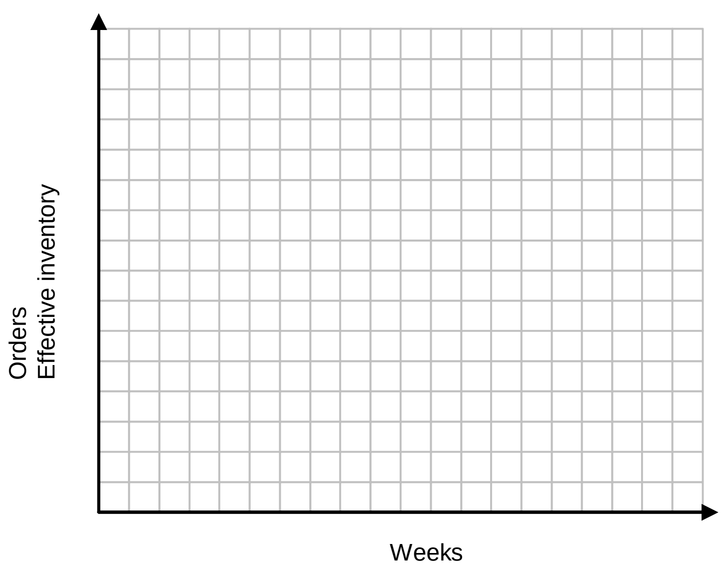


Figure 6: the Beer Game graphing pad

It is interesting to note that more recent studies that use the Beer Game (Croson and Donohue, 2006) give their players information about stocks, too.

Interpreted in terms of the previous section, this means that players are confronted with certain stimuli that direct their attention towards beer and orders (not money) and to do so with information about states (the stocks) rather than changes or differences.

Sterman reported that individuals fail to acknowledge the future effects of control actions (1989:334): the typically did not take into account the supply line, that is, the orders they had already sent upstream. Later studies have suggested that players' performance may improve under different circumstances. For instance, information sharing – especially downstream – has been shown to reduce the bullwhip effect (Croson and Donohue, 2006).

If we interpret the game board and additional material as the physically salient attributes, would performance improve when attributes representing change (rather that state) are presented?

Modified record-keeping material for the Beer Game: towards an experiment

The following modifications are proposed in order to obtain a frame that allows to capture changes and differences. The underlying idea is making the delayed action feedback easier to grasp.

The record keeping sheet shall have the following content:

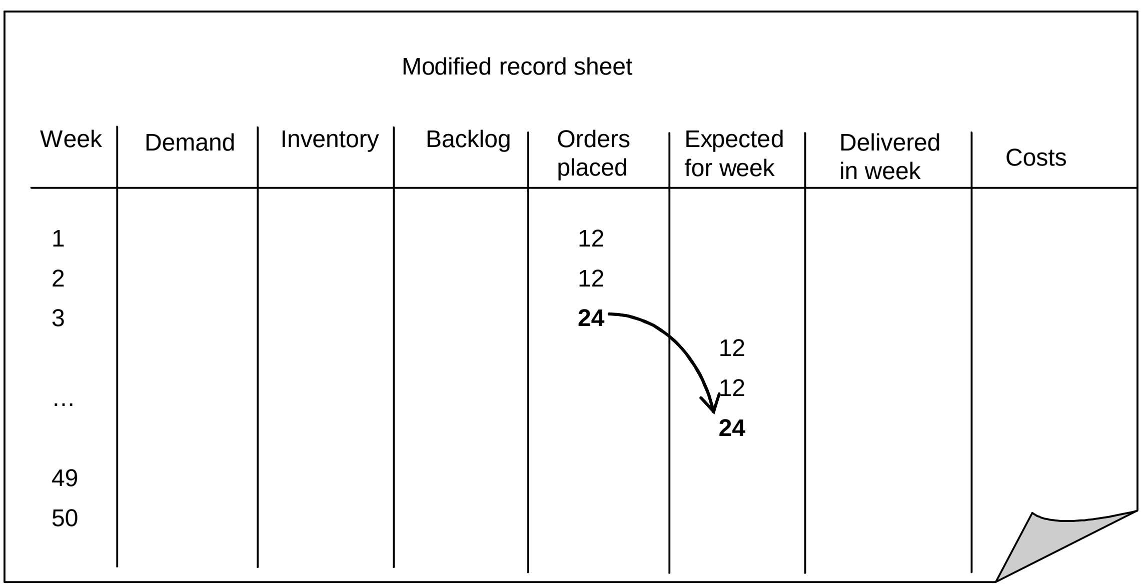


Figure 7: the modified record keeping sheet

Now in addition to the standard sheet, the player records the demand he faces, the expected and the actual week of delivery for each order (to be written into the respective week's line!) and the costs. At the same time, the graphing pad shall be used each week:

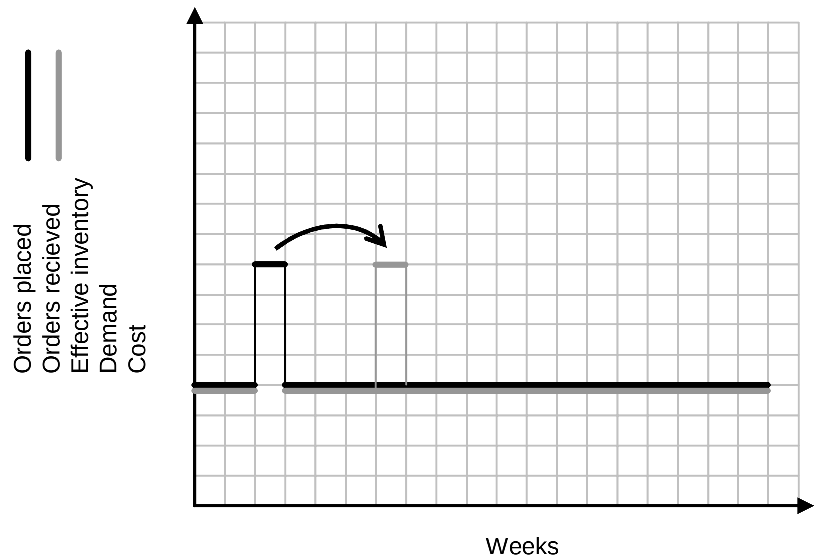


Figure 8: the modified graphing pad

Transferring each week's state of affairs allows connecting the weeks and see what is changing. These modifications may – other things staying the same – make the attributes of the delay and feedback structure more salient; players will be able to see the delays and the cost side of the game.

Should this be the case, then the performance of players in the Modified Beer Game would be better. This means that improved performance in this version of the game might allow to reflect upon how the "dynamic complexity" of this game is distributed between the game "interface" and the thinking individuals.

A first experience

A first practical experience was carried out with tree groups of undergraduate business students in their fourth or fifth year, 5 female and 7 male. (Group 1: 3 male, 1 female; Group 2: 4 female; Group 3: 4 male).

The material (see Appendix 1) proved hard to use. The graphing panel was meant to draw the behavior-over-time graph of 4 variables (it would not be practical to plot on 4 different sheets); since the players did not have 4 different colors, they represented each point by the initial of the variable's name. Since there is space for 50 weeks, each cell is too small in order to represent the 4 variables without difficulties. Due to these problems, only 23 weeks were played (in three hours); however, this was sufficient to generate interesting data.

Also, there were many problems with record-keeping, as half of the players committed recurrent mistakes. The general impression was that this is too much record keeping in order to play smoothly.

This makes it advisable that future experiences with this modified game version be done over networked computers.

There are three questions to be answered:

1. did the players find out about the delay structure?
2. if so: did they keep it in mind when taking decisions??
3. if so: did this make them perform better?

Did players find out about the delay structure?

Of the 12 players, only 7 kept record of their expected delivery week. For those 7, one can compare their expectations to what the game's structure determines. We will here only present one illustrative case; a detailed analysis of each player is to be found in appendix 2.

The following figure displays the orders, expected delivery and theoretically correct delivery of one of the players:

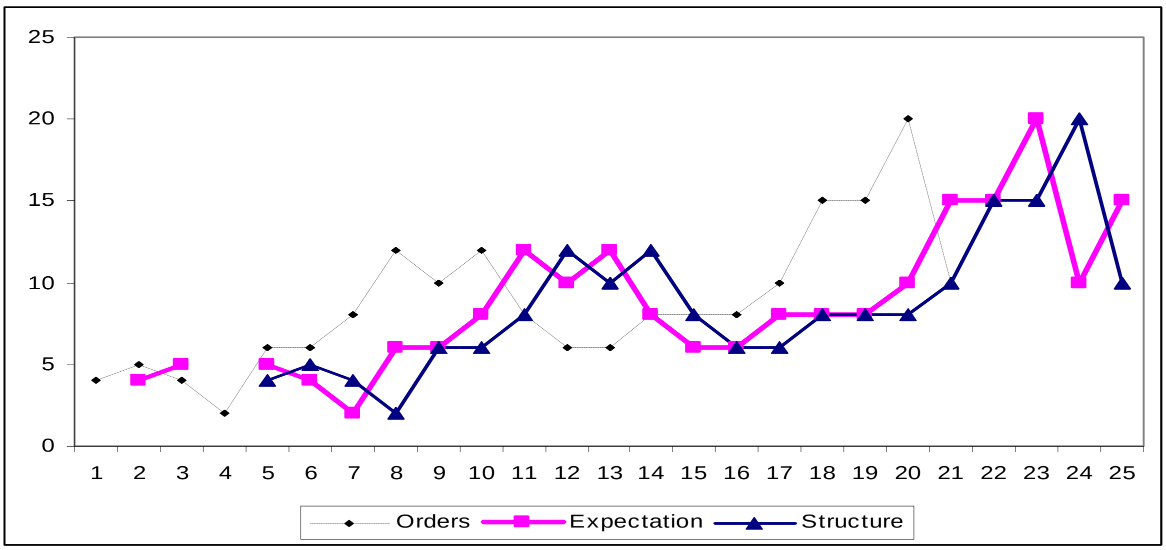


Figure 9: expected versus correct delivery

Clearly, the player recognized there some time has to pass between passing an order and having the corresponding beer in his stock. However, he estimated three weeks, not four: his mental delay was consistently one week shorter than the real one.

The very fact that these expectations had to be recorded on the sheet aroused attention for the delays in the game. Still the sheer visual information of the game board did not seem to suffice to compute the correct delay: out of the 7 players who recorded their expectations, 3 thought it was 3 weeks over the entire period. The others changed their opinion during the game: from 4 to 3, 3 to 2, 2 to 3 and 2 to 1 week(s) respectively. None of them found out the true situation.

Is there something that could make them recognize that their belief is wrong?

The one event that might serve to this end is the real delivery: if it is different from expectations, it would only be logical to correct the expectation. At least this is what might happen if the real deliveries happen to correspond to the orders emitted four weeks earlier.

In order to be useful to detect one's mistake, the real delivery must be different from the expected one and equal to the theoretically correct one. However, this is not the case many times, due to the stock-out problems of purveyors.

The following figure shows the seven players' opportunities (when they received a possible correction signal). The white bars represent the differences between expected and theoretically correct deliveries; a positive bar means "no difference", a negative one means "different". Note that "no difference" does not mean "correct belief", since the equality of numbers between the two deliveries may stem from coincidence. The red (gray) bars represent a "signal": the actual delivery in this week shows an error between the expected and the theoretically correct delivery quantity.

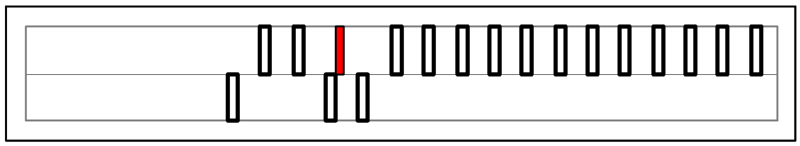
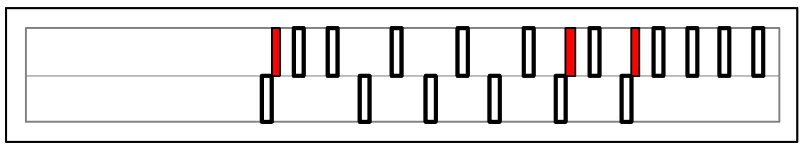
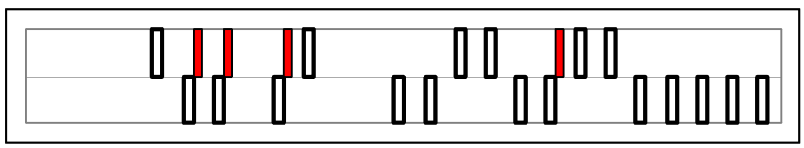
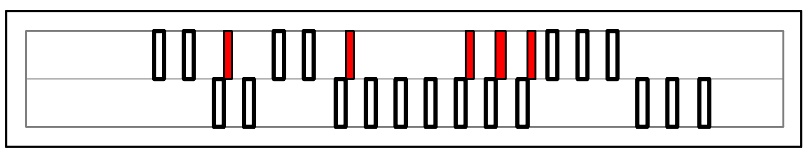
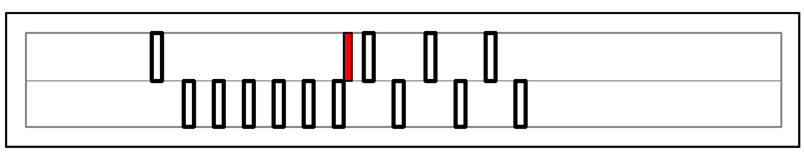
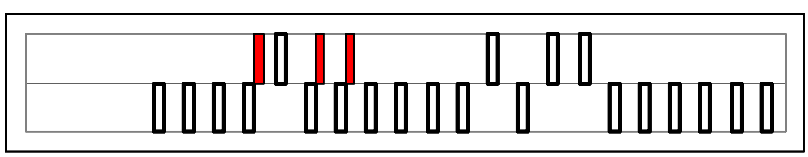
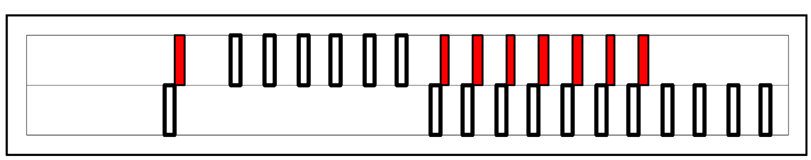
Player	*Belief (weeks)*	*Believed delivery delay (weeks)*
1	*3*	
2	*3->2*	
3	*2->3*	
4	*2->1*	
5	*3*	
6	*3*	
7	*4->3*	

Figure 10: false expectations and error signals

Each of the error signals appears together with an incorrect expectation. However, many such erroneous expectations do not fall together with an error signal. Only in the case of player 7 there is a continued sequence of error signals. None of the players ceased to display false expectations after an error signal had appeared.

It may be almost impossible to recognize these signals amidst many apparently wrong signals. If many times the provider sends a quantity that is simply different from the one ordered *and* the theoretically correct one, did the players actually have a chance?

Did players keep in mind the delays when taking decisions?

When deciding the next order, each player is free to set up his own decision policy. System dynamics recommends to take into account the delay structure. What did these 7 players think of when taking their decision: their expressed expectation or the actual deliveries? What role did the demand and the back-log play?

The players state that even though in principle, they knew there was a delay, this did not bear a sizeable influence on their ordering decisions once the provider failed to deliver the ordered quantities, and back-logs started to mount up. They expressed that without the impossibility of communicating beyond the order and bee interchange, it might have been possible to perceive which part of the incoming information corresponds to the client's distorting the original information; however, these declarations have been made after the fact, and thus are only declarations.

Did these players perform better?

The fact of having the delays in mind while playing would be worth while if it allows to obtain improved behavior (of which the eventual cost performance depends). Two of the three groups obtained overall costs of over $100.000, which discards any claim to good performance. One of the groups finished with $31.850, which is rather good. However, their record sheets had many mistakes and so their decisions were based on faulty information: it is now not possible to know what they would have done without these erroneous records.

One of the groups showed the typical ordering oscillations:

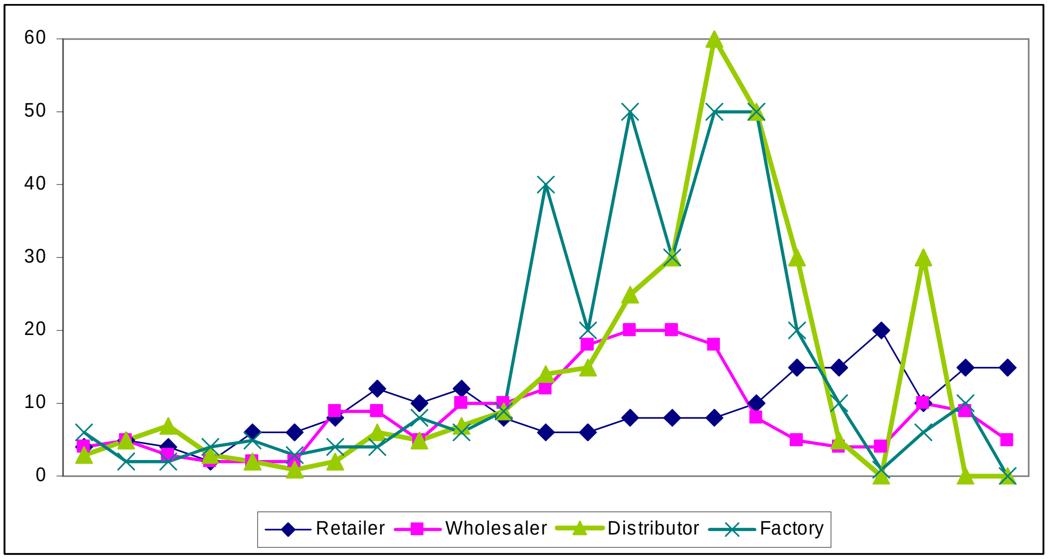


Figure 11: oscillating orders

We also see the usual amplification. Accordingly, their stocks display the well-known cyclical behavior:

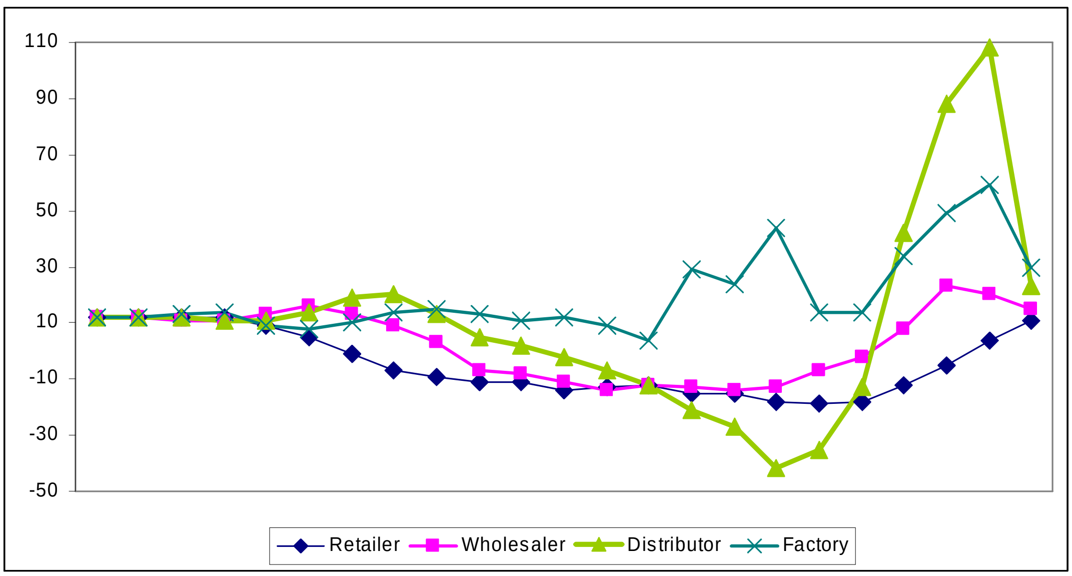


Figure 12: oscillating stocks (interpreting back-logs as negative stock)

Another group seemed to have taken less varying decisions, as their stocks appeared to indicate; however, after subtracting the back-log from the stocks, they appeared to have refused to correct an ever-growing deficit. The details are presented in appendix 3.

Discussion

As the game unfolded, it became clear that keeping record of more variables generates an overload. Also, even if the player's attention is drawn towards the delays, many of the signals the game provides make it difficult to recognize the mistake in the believed delay, and the players may even come to think that the delay structure is not so important after all: seen from their standpoint, how could one tell if the wrong amount of delay or the very idea of taking into account the delays is at fault?

One way to reduce the disturbing impact of the actual delivery quantities would be to keep track of the orders by grouped items. If you buy from an Internet vendor like amazon and chose to have your goods delivered as soon as possible each, they may become delivered separately, based on availability: much like the Beer Game. So if we can make players see where the beer they ordered as at each moment, this might help to underline the delays' importance instead of diffusing it.

As stated above, the players already found they had to record too much; order tracking would further add to this. Thus it seems that this modified version of the game should be played over networked computers; a properly designed program would do the record keeping and the graph plotting, too.

Consequently, such a computer program will be designed, offering the traditional interface and the experimental one. A new round of sessions will be held and its results reported.

Conclusions

This paper proposed an argument for the field of misperception of feedback: the way a task like the Beer game is presented to the individuals is part of the frame that may influence their processes and their performance. A very brief overview over judgment heuristics allowed to state that

1. the way a situation or task is presented to individuals has an influence on the thought processes;
2. in different frames, different attributes may fall victim to substitution;
3. motion, changes and differences come to mind more easily than states.

In the case of the Beer Game, it was argued that the standard presentation of this game is a possibly hazardous frame, since it directs attention towards states rather than changes and away from a dynamic perspective. Some simple modifications have been proposed, in order to make the delay and feedback structure more salient to players.

A first empirical experience has been undertaken, allowing to find that when being prompted to think about possible delays, players tend to identify them, though mis-estimating the delays' true extension and failing to correct this error during the Game. It has been conjectured that the only possible signal for correction – the actual delivery quantity – is distorted by the stock-out and back-log recovery; so it is recommended to introduce order-item tracking into the modified Game interface.

Beyond this rather narrow application of judgment heuristics to the Beer Game, it is suggested here that the field of judgment heuristics may be used in other experimental "systems thinking" work, too.

References

Booth-Sweeney, L. and Sterman, JD., 2000. Bathtub dynamics: initial results of a systems thinking inventory, System Dynamics Review **16**(4): 249–286

Croson, R. and Donohue, K. 2006. Upstream versus downstream information and its impact on the bullwhip effect, System Dynamics Review **21**(3): 249-260

Forrester, J. 1961. Industrial Dynamics, Cambridge MA: Productivity Press.

Gilovich, D. Griffin & D. Kahneman (Eds.), Heuristics and biases (pp.397–420).

Cambridge: Cambridge University Press.

Jensen, E. and Brehmer, B., 2003. Understanding and control of a simple dynamics system, System Dynamics Review **19**(2): 119-138

Jensen, E. 2005. Balancing Bathtubs in Math Class, Proceedings of the 23rd International System Dynamics Conference, Boston, MA., 2005 (CD)

Kainz, D. and Ossimitz, G., 2002. Can Students learn Stock-Flow-Thinking? An emprical Investigation. Submitted for the 2002 Conference of the System Dynamics Society, Palermo, Italy.

Kahneman, D., Slovic, P. and Tversky, A. (eds.) 1982 Judgment under uncertainty: heuristics and biases, Cambridge University Press

Kahneman, D. 2002. Maps of bounded rationality: a perspective on intuitive judgment and choice, Nobel prize lecture, December 2002 (http://nobelprize.org/economics/laureates/2002/kahneman-lecture.html; accessed on 2/28/2006); American Economic Review **93**(5):1449

Maani, K. and Maharaj, V., 2004. Links between systems thinking and complex decision making, System Dynamics Review **20**(1): 21-48

Moxnes, E., 2000. Not only the tragedy of the commons: misperceptions of feedback and policies for sustainable development, System Dynamics Review **16**(4):325–348

Moxnes, E., 2004. Misperceptions of basic dynamics: the case of renewable resource management, System Dynamics Review **20**(2): 139-162

Ossimitz, G., 2002. Stock-Flow-Thinking and Reading stock-flow-related Graphs: An Empirical Investigation in Dynamic Thinking Abilities, 2002 System Dynamics Conference, Palermo, Italy

Palmer, S. E. 1999. Vision science: Photons to phenomenology. Cambridge, MA: The MIT Press.

Schaffernicht, M., 2005. Are you experienced? A model of learning systems thinking skills, Proceedings of the 23rd International Conference on System Dynamics, Boston, July 2005

Slovic, P., Finucane, M., Peters, E., & MacGregor, D. G. 2002. The affect heuristic. In T.Gilovich, D. Griffin & D. Kahneman (Eds.), Heuristics and biases (pp.397–420).

Cambridge: Cambridge University Press.

Sterman, JD. 1989. Modeling managerial behavior: misperceptions of feedback in a dynamic decision making experiment. Management Science **35**(35): 321-339

Appendix 1: the record-keeping sheets

The players are asked to record the different items on this sheet:

Team ________

Role: ________ (**R**etailer / **W**holesaler / **D**istributor / **F**actory)

Week	Demand	Stock	Backlog	Orders	Delivery		Costs		
			atrasada	placed	expected	actual	Stock	Out of stock	Total
	(bottels)	(bottels)	(bottels)	(orders)	(bottels)	(bottels)	($)	($)	($)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									

Figure 13: the record keeping sheet

Additionally, they have to add each week's new information on the graph pad: orders placed, actual delivery, demand, stock total cost:

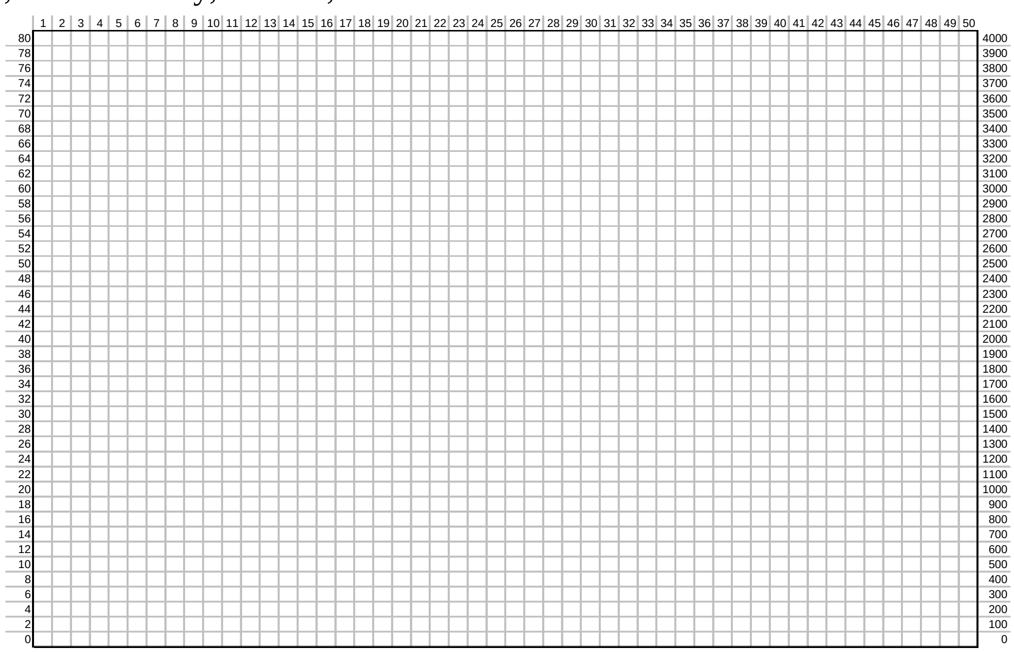


Figure 14: the graphing sheet

Appendix 2: the players' delivery expectations

Player 1

Orders	Expectation	Structure	Delivered	Difference	Signal
4			4		
4	4		4		
4	4		4		
8	4		4		
8		*4*	*4*		
8		*4*	*4*		
12	**8**	4	8	-1	0
8	**8**	***8***	*8*	*1*	0
8	**8**	***8***	*8*	*1*	0
8	0	***8***	*8*	*-1*	1
8	20	12	8	-1	0
8	8	8	8	1	0
8	8	8	12	1	0
8	8	*8*	*8*	*1*	0
8	8	8	4	1	0
8	8	*8*	*8*	*1*	0
8	8	*8*	*8*	*1*	0
8	8	*8*	*8*	*1*	0
8	8	*8*	*8*	*1*	0
8	8	*8*	*8*	*1*	0
8	8	8	12	1	0
8	8	*8*	*8*	*1*	0
8	8	*8*	*8*	*1*	0

Table 1: player 1's expectations

As indicated by the sequence of thee "8" (the fat-typed numbers), player 1 believed the delivery delay was 3 weeks: Some of the expected numbers is surprising since it is not related to the orders.

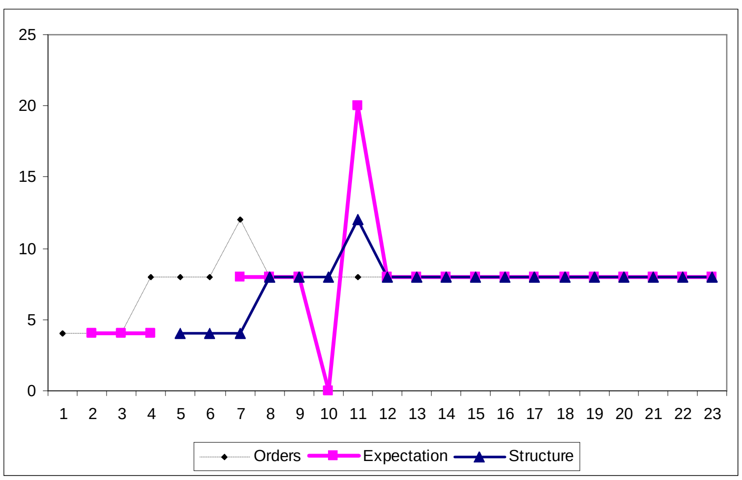


Figure 15: player 1's expectations

Player 2

Orders	Expectation	Structure	Delivered	Difference	Signal
4			4		
4	4		4		
4	4		4		
4	4		4		
8		4	4		
8		4	4		
8		4	4		
12	8	4	4	-1	1
12	8	8	8	1	0
8	**8**	8	8	1	0
0	**12**	**8**	12	-1	0
8	**12**	**12**	8	1	0
8	**8**	**12**	4	-1	0
8	8	**8**	8	1	0
12	8	0	8	-1	0
8	**8**	8	8	1	0
8	**12**	8	8	-1	1
8	**8**	**8**	8	1	0
8	8	**12**	12	-1	1
8	8	**8**	8	1	0
8	8	8	8	1	0
8	8	8	8	1	0
8	8	8	8	1	0

Table 2

Placer 2 started out thinking the delay is 3 weeks (the 8-8-8-12 sequence above), but later on started to relieve it was 2 weeks (the 8-12-8 sequence).

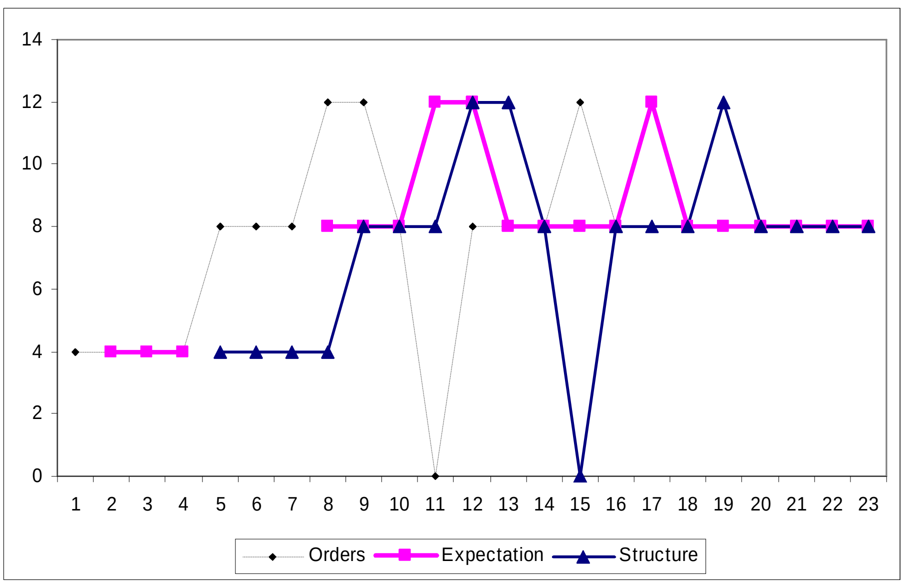


Figure 16

Player 3

Orders	Expectation	Structure	Delivered	Difference	Signal
6			4		
4			4		
6	**6**		4		
6	**4**		4		
4	**6**	***6***	*6*	*1*	0
8	**6**	***4***	*4*	*-1*	1
8	4	***6***	*6*	*-1*	1
12		***6***	*6*		
8	8	*4*	*4*	*-1*	1
10	8	*8*	*4*	*1*	0
12		*8*	*8*		
12		*12*	*12*		
12	**10**	8	7	-1	0
10	**12**	**10**	8	-1	0
12	12	**12**	6	1	0
12	**12**	12	9	1	0
12	**10**	**12**	10	-1	0
15	**12**	***10***	*10*	*-1*	1
16	12	**12**	13	1	0
15	**12**	12	9	1	0
10	**15**	**12**	3	-1	0
15	**16**	**15**	12	-1	0
10	**15**	**16**	8	-1	0
	10	**15**		-1	
	15	**10**		-1	

Table 3

Player 3 expected the orders 6-4-6-6-4 to be delivered 2 weeks later. Then he reconsidered and thought the sequence 8-8-2-8 (and continuation) would have to arrive 3 delayed.

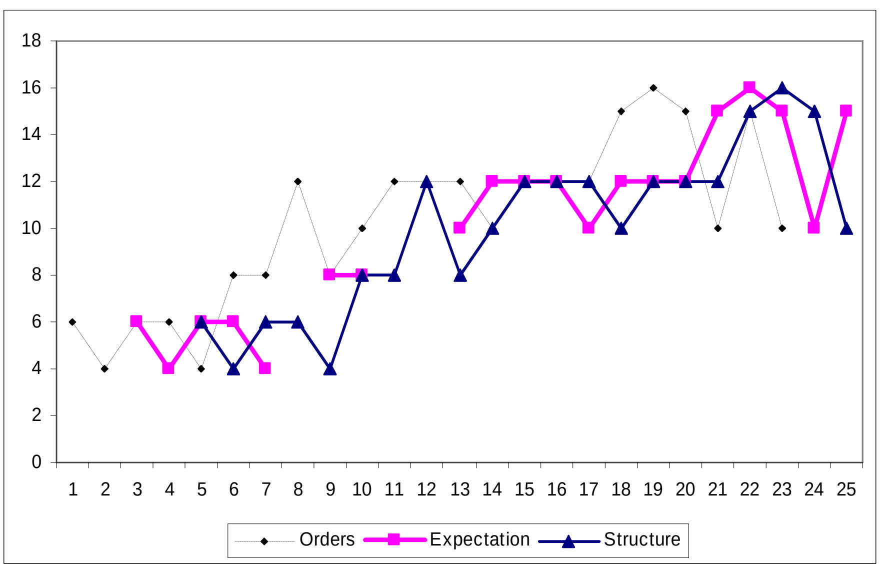


Figure 17

Player 4

Orders					
4			4		
4			4		
5			4		
5	4		4		
4	4	4	6	1	0
4	6	4	6	1	0
4	6	*5*	*5*	*-1*	1
4	4	5	4	-1	0
5	4	*4*	*4*	*1*	0
5	4	*4*	*4*	*1*	0
10	6	*4*	*4*	*-1*	1
10	6	4	8	-1	0
12	10	5	6	-1	0
20	**10**	5	9	-1	0
20	**12**	*10*	*10*	*-1*	1
20	**20**	***10***	*10*	*-1*	1
20	20	***12***	*12*	*-1*	1
20	20	**20**	10	1	0
20	20	20	3	1	0
30	**20**	20	10	1	0
30	**30**	20	8	-1	0
30	30	20	10	-1	0
30	30	**20**	15	-1	0
		30			

Table 4

Player 4 started with rather strange expectations (why should he receive 6 if he did not order them ever?), but then (10-10-21-20) believed the delay to be 2 weeks; the final sequence (20-20-30-30) reveals that in his mind the delay had shortened to 1 week.

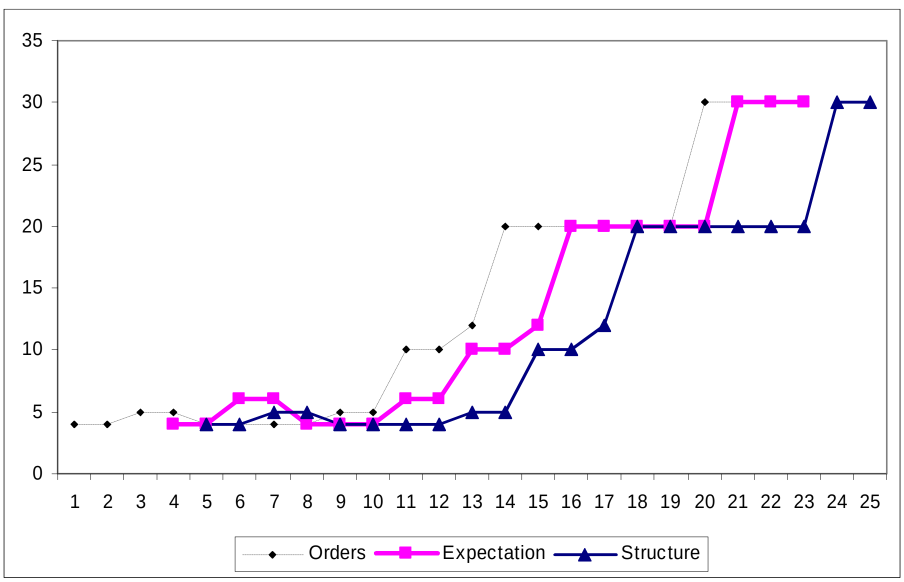


Figure 18

Player 5

Orders	Expectation	Structure	Delivered	Difference	Signal
4			4		
4			4		
7			4		
8	4		7		
7	**4**	4	7	1	0
10	**7**	**4**	5	-1	0
9	**8**	**7**	5	-1	0
7	**7**	**8**	11	-1	0
7	**10**	**7**	13	-1	0
3	**9**	**10**	15	-1	0
3	**7**	***9***	*9*	*-1*	1
2	**7**	**7**	7	1	0
2	**3**	**7**	3	-1	0
3	**3**	**3**	7	1	0
8	**2**	**3**	2	-1	0
18	**2**	***2***	*2*	*1*	0
10	**3**	**2**	3	-1	0
38		**3**	10		
25		*8*	*8*		
0		18	10		
10		*10*	*10*		
10		38	20		
10		25	10		
		0			
		10			

Table 5

Player 5 thought the delay is 3 weeks all over the game (for example: 4-7-8-7-10).

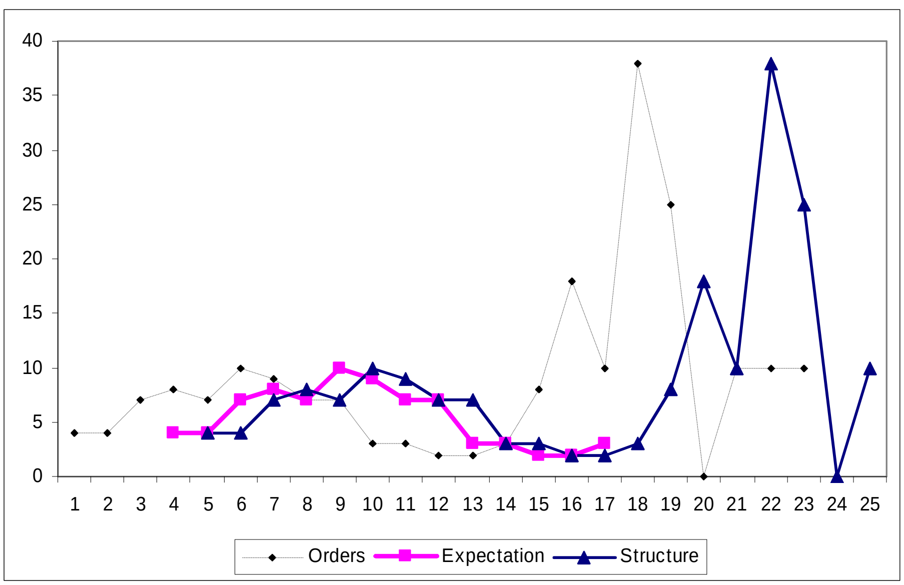


Figure 19

Player 6

Orders	Expectation	Structure	Delivered	Difference	Signal
4			4		
5	4		4		
4	5		4		
2			11		
6	**5**	4	5	-1	0
6	**4**	**5**	4	-1	0
8	**2**	**4**	7	-1	0
12	**6**	**2**	2	-1	1
10	6	**6**	6	1	0
12	**8**	6	6	-1	1
8	**12**	**8**	8	-1	1
6	**10**	**12**	5	-1	0
6	**12**	**10**	9	-1	0
8	**8**	**12**	9	-1	0
8	**6**	**8**	5	-1	0
8	6	**6**	8	1	0
10	8	6	5	-1	0
15	8	8	7	1	0
15	**8**	8	9	1	0
20	**10**	**8**	14	-1	0
10	**15**	**10**	15	-1	0
15	**15**	**15**	13	-1	0
15	**20**	**15**	8	-1	0
	10	**20**		-1	
	15	**10**		-1	

Table 6

Player 3 expected the 5-4-2-6-6- sequence to be delivered 3 weeks after passing the order. This believed delay is still visible by the end of the table, as indicated by the 8-15-15-20-10 sequence.

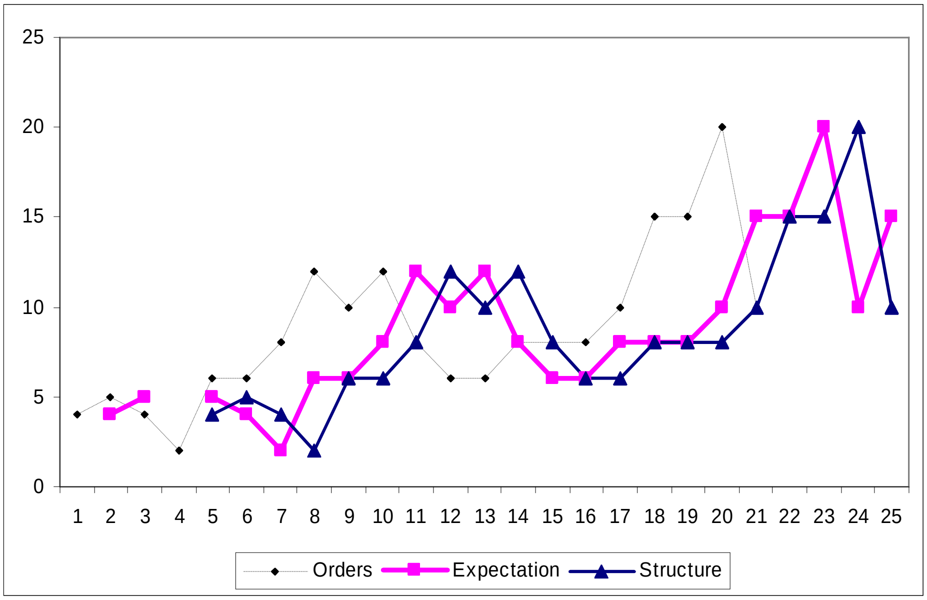


Figure 20

Player 7

Orders	Expectation	Structure	Delivered	Difference	Signal
3			4		
5	3		4		
7			4		
3			5		
2	5	3	3	-1	1
1		5	2		
2	**7**	**7**	2	1	0
6	**3**	**3**	2	1	0
5	**2**	**2**	9	1	0
7	**1**	**1**	9	1	0
9	2	2	5	1	0
14	6	6	8	1	0
15	7	*5*	*5*	*-1*	1
25	**9**	*7*	*7*	*-1*	1
30	**14**	***9***	*9*	*-1*	1
60	**15**	***14***	*14*	*-1*	1
50	**25**	***15***	*15*	*-1*	1
30	**30**	***25***	*25*	*-1*	1
5	**60**	***30***	*30*	*-1*	1
0	**50**	**60**	18	-1	0
30	**30**	**50**	4	-1	0
0	**5**	**30**	10	-1	0
0	0	**5**	60	-1	0

Table 7

Player 7 started with a 7-3-2-1 sequence revealing an expected delay of 4 weeks; however, the 9-14-15-25 sequence that appears in the lower part of the table shows 3 a change of mind to 3 weeks.

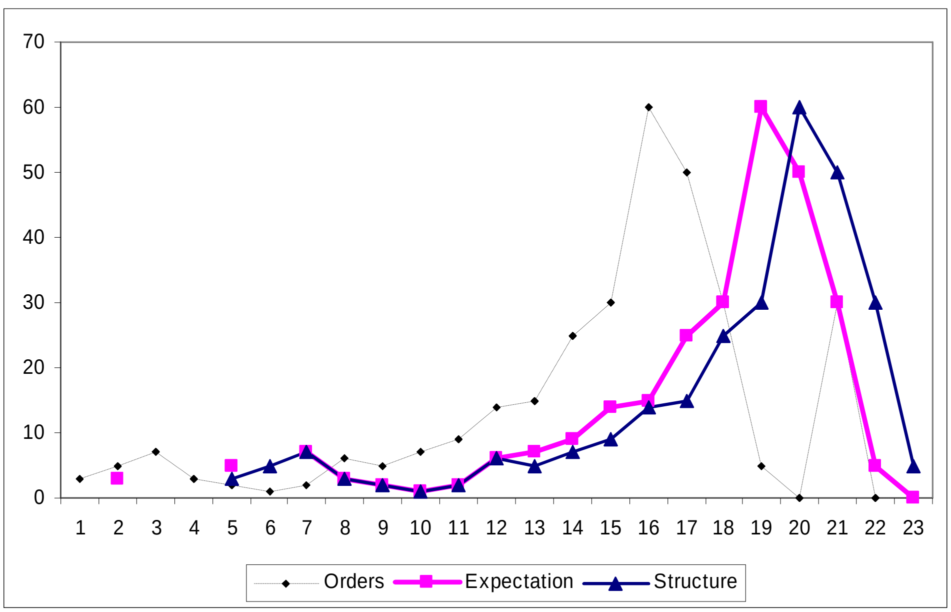


Figure 21

Appendix 3: orders and stock behavior of the three groups.

Group 1

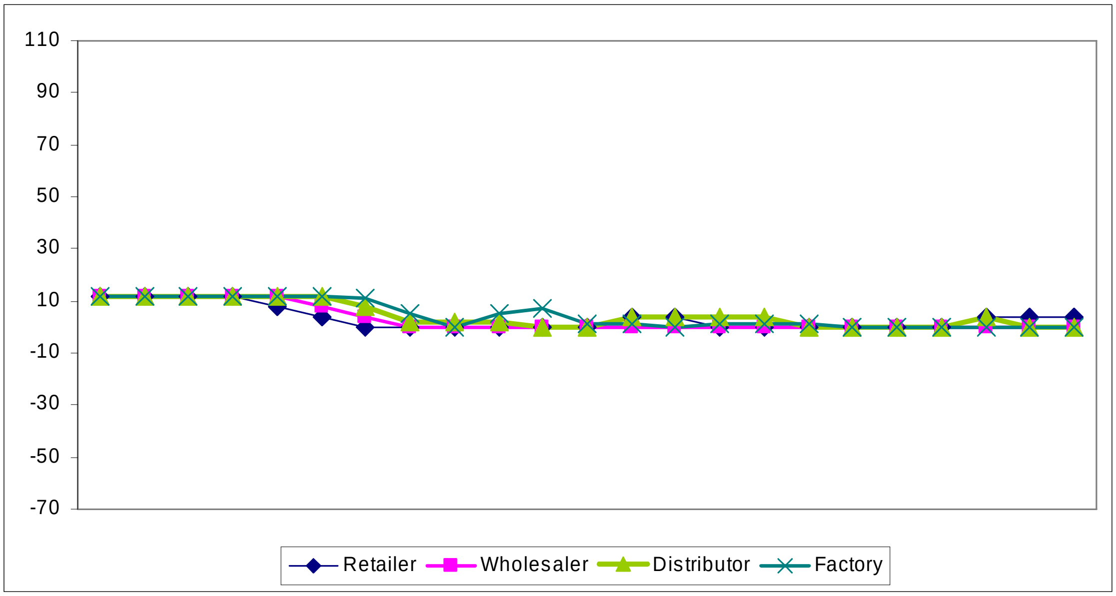


Figure 22

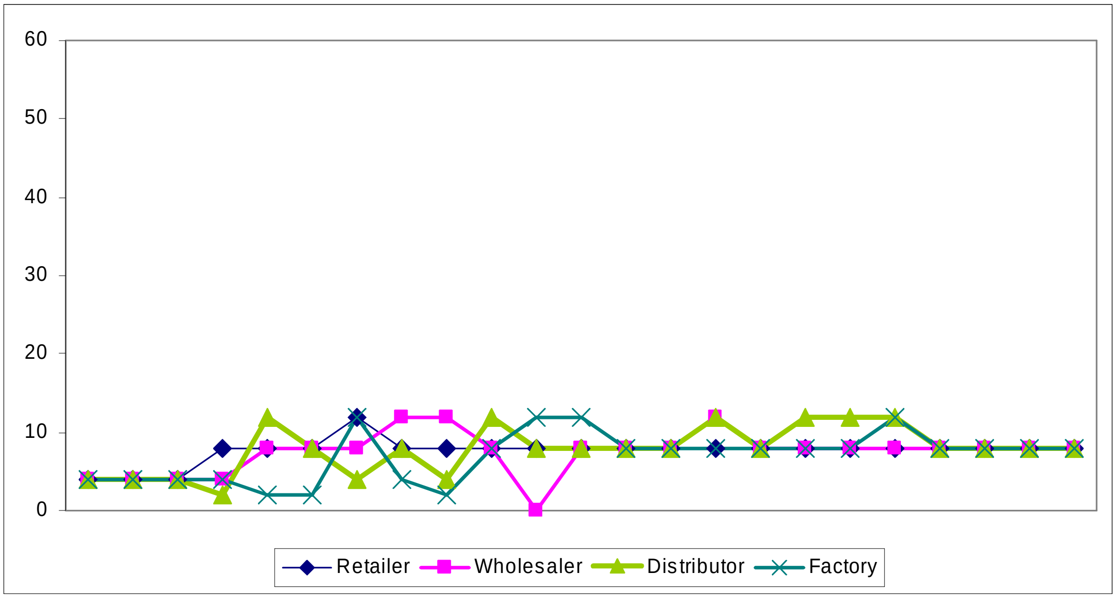


Figure 23

Group 1 performed relatively well, due to a lucky constellation: due to an error on the factory's record sheet, the factory decided to brew rather few beer, and for the distributor and the wholesaler, it turned out that they kept 0 stock, receiving each week just the 8 units they needed to deliver to their client.

Group 2

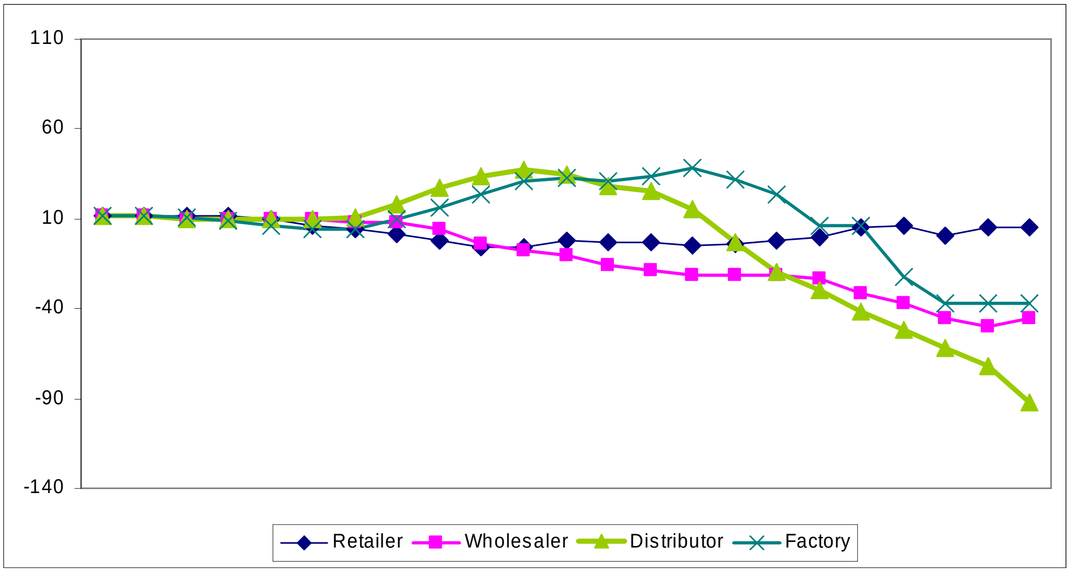


Figure 24

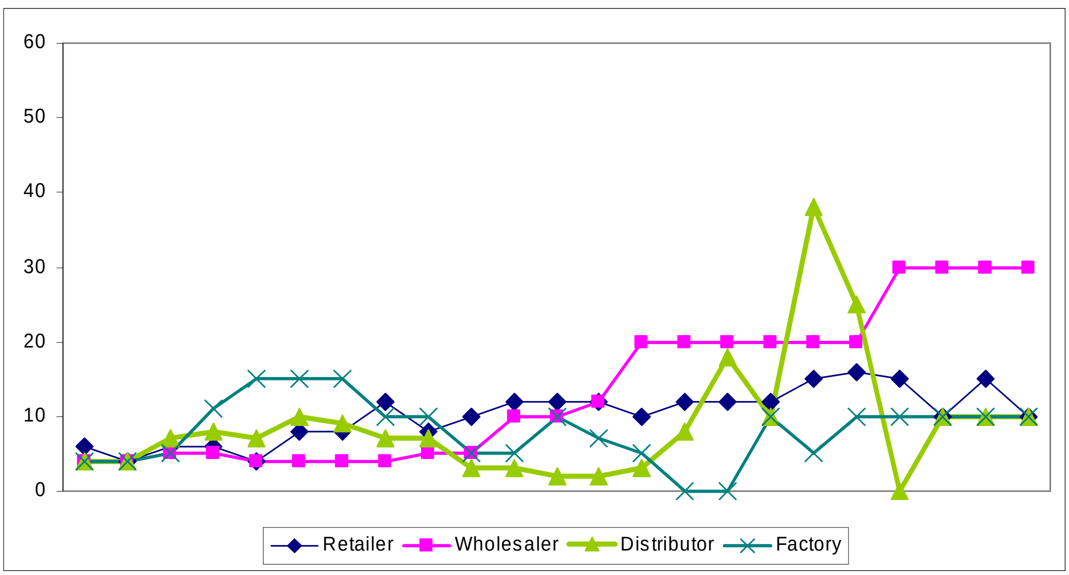


Figure 25

Group 2 played with a very conservative factory owner, who preferred a large back-log to overstocking (the distributor, too, to some extent). This explains their low and declining stock (and high costs, of cause).

Group 3

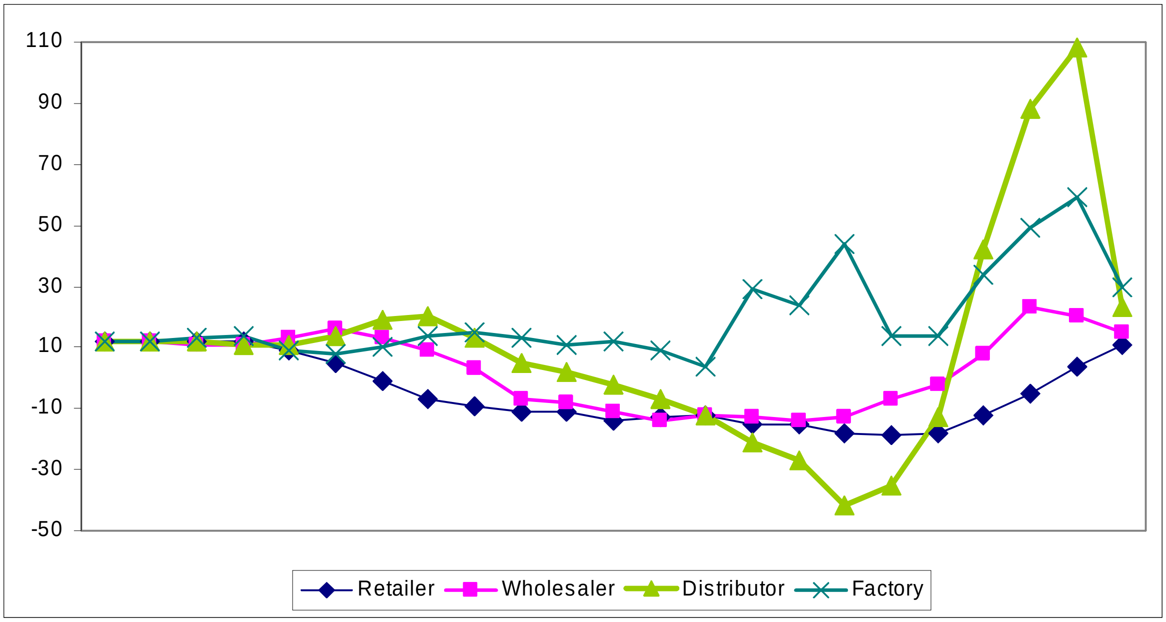


Figure 26

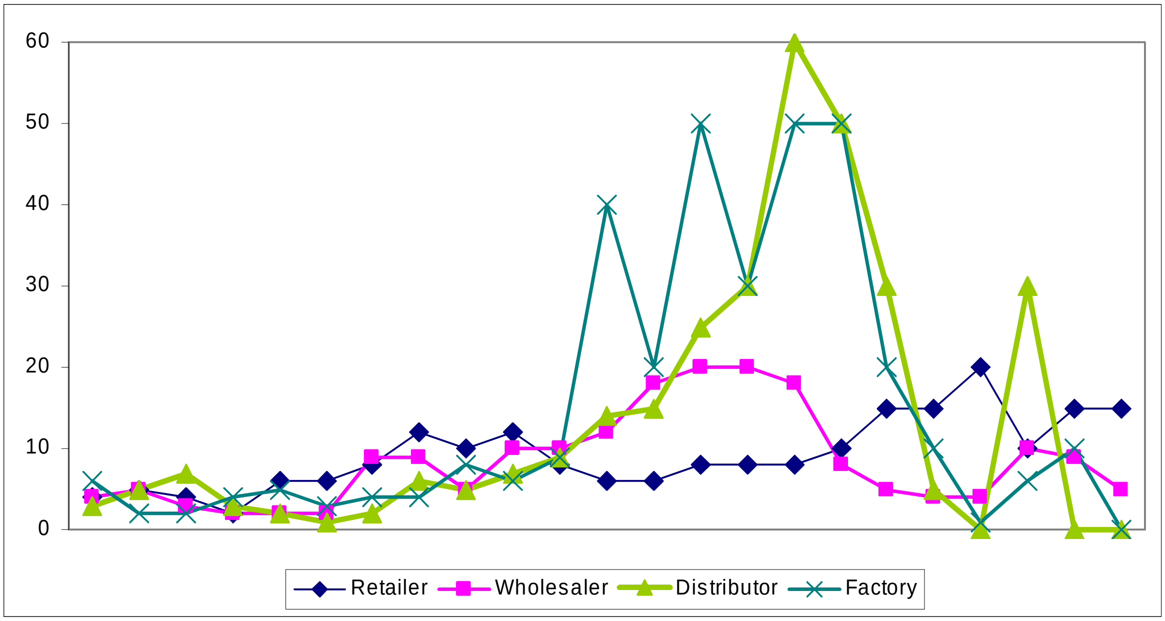


Figure 27

Group 3 performed rather "traditionally", displaying oscillation and amplification.