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Cognitive Biases in Perceiving Feedback Loop Dominance

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Abstract: *Feedback loop dominance is a key concept to understand structural driving forces of system behavior. In this paper, we propose two kinds of shifts in dominant feedback loops: continuous shifts (CS) and discrete shifts (DS). With the help of questionnaires, we verified three hypotheses regarding cognitive biases in perceiving the shifts in dominant feedback loops: 1) failure in perceiving continuous shifts, 2) tendency of decision making based on discrete shifts, and 3) different perception on the dominant feedback loops between level variables and rate variables. We discussed the implication of these cognitive biases on time delay and timing strategy in decision-making processes.*

I. Feedback Loop Dominance in Decision Making Situation

Feedback loop dominance is a key concept that provides a linking pin between system structure and its behavior. Recent studies showed crucial developments in understanding the feedback loop dominance and its shift. As Richardson pointed out, the concept of feedback loop dominance is important in the study of system dynamics as a whole (Richardson 1991). Feedback loop dominance means, "there is a loop that is primarily responsible for model behavior over some time interval" (Richardson & Pugh 1981, p.285). Ford defines it more specifically as "a feedback loop dominating the behavior of a variable during a time interval in a given structure and set of system conditions when the loop determines the atomic pattern of that variable's behavior (Ford, 1999, p.8)." Previous studies proposed various methods to find the feedback loop dominance (Richardson 1995, Kampmann 1996, Kim 1995, Mojtahedzadeh, 1996, Ford 1999). Among them, behavioral approach proposed by Ford provides simple and insightful method to trace and understand its impacts on the system behavior.

Feedback loop dominance points out what structure is a driving force of system behavior. Even though the importance of feedback loop dominance in understanding system behavior is widely recognized among system dynamicists, its implications on the decision-making behavior are rarely studied. As long as the concept of feedback loop dominance is an essential tool in understanding dynamic behavior of systems, its importance to the decision-makers who deal with complicated dynamics of social systems cannot be ignored.

Decision-makers are supposed to observe dynamic streams in their organizations and environments to detect when their strategic intervention is required. They must be alert and agile to the continuous dynamics occurring in and out of their situation. As representative decision-makers in dynamic business environments, Andrew Groves and George Soros emphasized the importance of strategic inflection points. Andrew Groves, president of Intel, pointed out that one of the most important roles for decision-makers is to catch the strategic inflection point when strategic measures will change the whole landscape of the market and industry. In this regard, it seems that the strategic inflection points lie not far from the concept

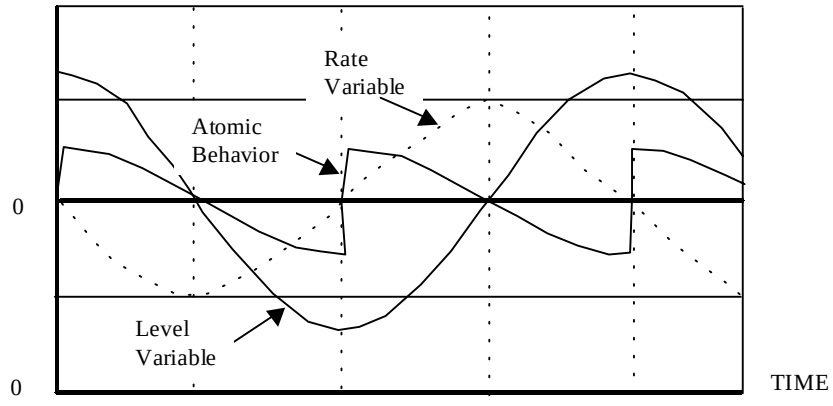
of the feedback loop dominance and its shift. However, the fundamental problem of this concept is that there are no practical tools for finding out the inflection points in the real world. Furthermore, studies on decision-makers showed that they tend to fail in understanding rather simple dynamics of feedback systems (Sterman 1987, 1989). In this sense, more analytic study on how decision-makers perceive the inflection points or shifts in the feedback loop dominance is necessary.

II. Cognitive Biases on Dominance Shifts: Continuous vs. Discrete Shifts

Behavioral studies of system dynamics found that decision-makers tend to misperceive the role of feedback loops and thus fail to forecast future behavior of complex systems (Sterman 1987, 1989, Paich & Sterman 1993). These studies focus on the point that decision-makers have difficulties in deducing system behaviors from its structure. While decision-makers conjecture system behavior from its structure, they have to uncover what kind of structural forces lie behind the system behavior. In fundamental sense, decision-makers usually have little information on the system structure, while they have information overload on the system behavior.

The decision-makers in dynamic social systems perceive changes in their environments and make judgement on what are the driving forces and when they should use their measures to exploit the changes to their advantage. However, their perception and judgement of the system changes are usually performed by their insights rather than by scientific theory and models. Their judgements on the system changes are prone to error.

Figure 1 shows a typical fluctuating behavior that contains many shifts in feedback loop dominance indicated by atomic behavior defined by Ford (1999). In figure 1, we classified shifts in feedback loop dominance into continuous shifts (CS) and discrete shifts (DS). While continuous shifts show slow changes of atomic behavior, discrete shifts come with the abrupt change of atomic behavior. Also, one can find that the sequences of CS and DS are opposite between level variable and rate variable. In the bottom of figure 1, we also presented different sequences of CS and DS in a level variable and a rate variable.



Level Variable	Discrete Shift	Continuous Shift	Discrete Shift	Continuous Shift	Discrete Shift
Rate Variable	Continuous Shift	Discrete Shift	Continuous Shift	Discrete Shift	Continuous Shift

Figure 1. Continuous Shift (CS) and Discrete Shift (DS) in Feedback Loop Dominance

One of the earliest findings in the study of human perception is a threshold theory. It says that people can perceive only the stimuli stronger than the threshold level. In figure 1, one can find that DS will be easier to be detected than CS. Firstly, because the abrupt changes of atomic behavior at DS are usually above the threshold of one's perception. Secondly, behavior of variable itself changes from growing mode to decaying mode at the point of DS. Changes in the behavior of the variable at DS are perceived as the qualitative changes that are hard to miss. Thus we can make our first hypothesis as follows.

Hypothesis I: ***A discrete shifts in the feedback loop dominance (DS) will be perceived more frequently than a continuous shifts in the feedback loop dominance (CS) at a point of time when crucial change occurs.***

As systems move away from the previous state in the undesirable directions, decision-makers perceive problems and plan to make some measures to correct them. If the above hypothesis is valid, decision-makers will tend to perceive problems more frequently at DS rather than at CS. And thus they will make policy measures against system behavior more frequently around DS. This forms our second hypothesis. However, even though one perceives problems at DS, one can decide and implement policy measure before or after the DS depending upon the characteristics of that measure. The important thing here is that decision makers will perceive problems at DS and thus his policies will be based on the problems at DS rather than at CS. Our second hypothesis can be stated as follows.

Hypothesis II: ***Decision making against the shift in the feedback loop dominance will be based on the perception of DS rather than CS.***

It is a well-known fact that the behavior of level variable is nothing but an accumulation of the rate variable. Naturally it comes that the CS of the level variable will correspond to the DS of the rate variable (a dotted line in figure 1). When the point of CS of the level variables corresponds to the point of DS of its rate variable. From this difference of dominant feedback loop shifts between the level variable and the rate variable, we can predict that decision-makers will perceive the shift of feedback loop dominance differently between the level variable and its rate variables.

Hypothesis III: ***Decision-makers will perceive the shift of feedback loop differently between the level variable and its rate variable.***

If decision-makers see the behavior over time graph of a level variable, they will perceive shifts of dominant feedback loops more frequently at the point of DS of the level variable. On the contrary, if they see the behavior of the rate variable that changes the level variable, they will perceive the dominant feedback loop shifts at the point of DS of the rate variable that corresponds to the point of CS of the original level variable. This difference in cognition is similar with the frame theory of Tversky and Kahneman (1979). Decision makers' response to their choice situation differs when their utility is expressed in terms of gains from when it is represented in terms of losses. Decision makers' choice is determined by what frame the choice situation is described in. In the same vein, decision-makers' perception on the shifts in the feedback loop dominance will be determined by what type of variable (level or rate) is provided to them. In this sense, our third hypothesis tells that there will be framing effect in perceiving feedback loop dominance.

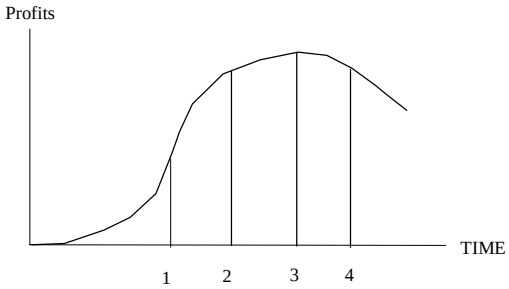
III. Experiments On the Perception of Feedback Loop Dominance

In order to verify our hypotheses, we made simple questionnaires. We distributed the questionnaires randomly among a class of undergraduate students and received responses from them. It took usually 2 or 3 minutes per question for students to make an answer. The first question is to indicate the time when the feedback loop dominance shifted after reading a simple story of the company. Figure 2 shows two versions of this questionnaire given to the students. One is for the level variable of profits, and the other is for the rate variable of change ratio of profits.

Question 1-a. Please read carefully following story and answer the question based on it.

> There was a growing company. One day a new person took over as the president of this company. He made a new policy as soon as he took over. His new policy immediately decreased the competitiveness of that company. Following figure shows the historical change in the profit of the company.

When do you think was the time the new person took over as president and implemented his new policy? Select the number given below and place it in the bracket. ( )



Question 1-b. Please read carefully following story and answer the question based on it.

> There was a growing company. One day a new person took over as president of the company. He made a new policy as soon as he took over. His new policy immediately decreased the competitiveness of that company. Following figure shows the historical change ratio of the profit of the company.

When do you think was the time the new person took over the position of president and implemented his new policy? Select the number given below and place it in the bracket. ( )

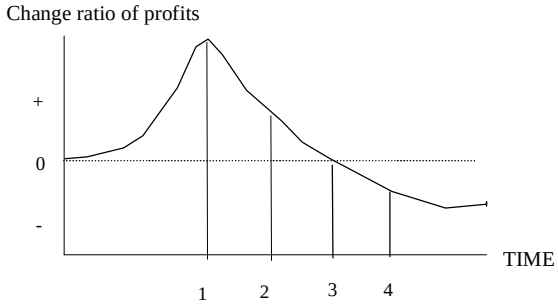
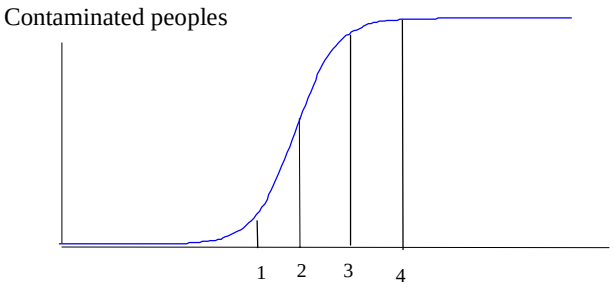


Figure 2. Qeustions for the task of indicating feedback loop dominance shift

Question 2-a. Please read carefully following story and answer the question based on it.

> One of your officers reported that an epidemic was about to spread in your country. In order to protect your people from the epidemic, you can inject a vaccine to them. However, since this vaccine has some side effect, you must be careful in using it. Following figure shows the number of people contaminated by the epidemic.

Assume that you are a policy maker. When would you recommend administering the injection of the vaccine to the people? Select the number given below and place it in the bracket ( )



Question 2-b. Please read carefully following story and answer the question.

> One of your officers reported that an epidemic was about to spread in your country. In order to protect your people from the epidemic, you can inject a vaccine to them. However, since this vaccine has some side effect, you must be careful in using it. Following figure shows the contaminating ratio of the epidemic.

Assume that you are a policy maker. When would you recommend administering the injection of the vaccine to the people? Select the number given below and place it in the bracket ( )

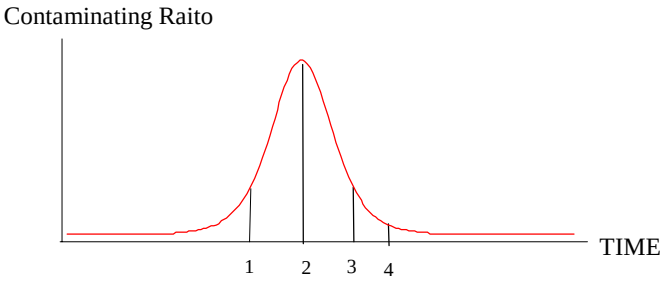
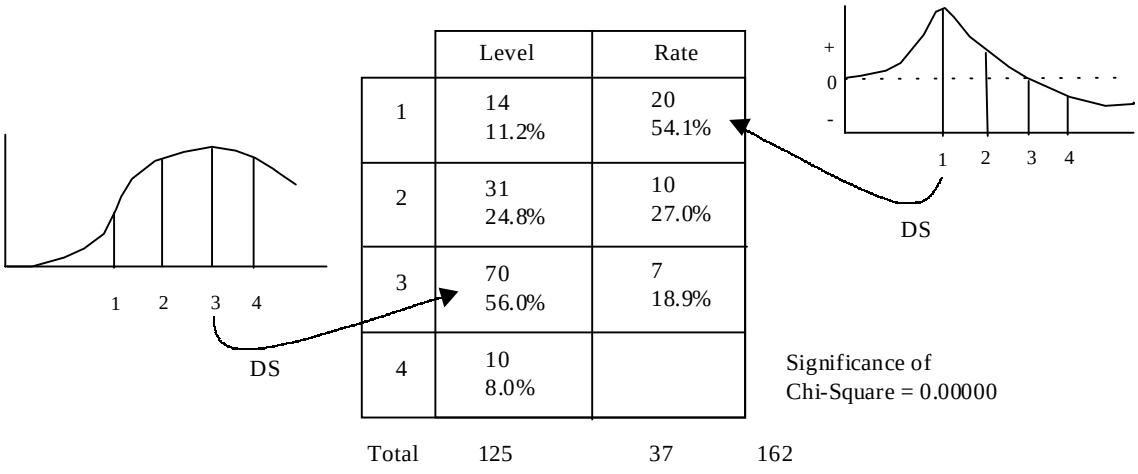


Figure 3. Questions for the task of deciding when to command the injection of vaccine

Our second question is to decide an appropriate time to take action to protect people from the epidemic. Figure 3 shows two versions of this question with a level variable of the number of contaminated people and with a rate variable of contaminating ratio respectively. In this question, policy makers can use the injection of vaccine to retard the contamination. But he cannot use the vaccine without risk, because the vaccine is known to have some side effects. This information is provided to the students in order to eliminate their tendency to use vaccine at the earliest time possible that was found in the pretest period. With the information of the side effects, students are expected to choose the time for injecting vaccine before there are crucial change in the contamination process, that is, before shifts in the dominant feedback loops.

Figure 4 shows the results of our experiments on the first question. Firstly, let us examine the results of question 1-a that is shown in figure 4. In this question, those who replied 1 perceived that introduction of wrong policy was made at the point of CS. This answer is correct because the story makes it explicit that the decrease in the competitiveness occurred immediately with the introduction of the new policy. Those who replied 3 thought that the policy was introduced at the point of DS. This answer is wrong because decrease in the competitiveness does not mean direct decrease in the profits. Decrease in competitiveness does not mean negative competitiveness. It will take time to move to negative competitiveness and loose profits. However, more than half students answered 3 as a point of time when policy was introduced. This results shows that our first hypothesis will be valid for many decision-makers.

Also we can find this cognitive bias of perceiving DS as a time of crucial change in the result of question 1-b in figure 4. In question 1-b, all things are same as in the previous question 1-a, except that we presented rate variable of changing ratio of profits instead of the level variable of profits. Since other things are same between question 1-a and question 1-b, if students are logical in their answering, the distribution of their answers on the time of policy introduction must be similar for both questions. Because most students answered 3 in question 1-a, if there is no cognitive bias, students must answer also 3 in question 1-b. However, in question 1-a, more than half students replied 1 as a point of policy introduction. That is because answer 1 means DS for the rate variable. This is an additional evidence of the first hypothesis of cognitive bias toward DS.



	Level	Rate
1	14 11.2%	20 54.1%
2	31 24.8%	10 27.0%
3	70 56.0%	7 18.9%
4	10 8.0%	
Total	125	37

Significance of
Chi-Square = 0.00000

Figure 4. Experimental results of indicating feedback loop dominance shift

Comparing results of question 1-a of level variable and question 1-b of rate variable, the third hypothesis can be tested. In figure 4, one can find that there is a great difference in the perception of feedback loop dominance between the level variable and the rate variable. When presented with level variable, most students pointed 3, while more than half students who are presented with rate variables indicated 1. This difference comes from the fact that the DS of level and rate variable occurs at different time, and decision makers stick to the DS rather than CS without regard to the type or content of the variable.

The question of epidemic contamination was introduced to test cognitive bias toward DS in

decision-making situation. Question in the epidemic case is different from the previous question. While the previous question is related to judging the time of crucial change retrospectively, this question deals with decision making with expectation of the future. Furthermore, this question requires policy intervention of injecting vaccine not on the time of crucial change but before. The timing of policy is important, because too early intervention will produce unnecessary investment and side effects while too late intervention will be unable to take effect. In this question, students are expected to take action before there is a shift in feedback loop dominance. In figure 3 of questionnaire, the feedback loop dominance shifts from positive to negative at answer 2. Thus policy makers are expected to take remedy to protect people from the epidemic around answer 1 before the shift in feedback loop dominance.

In question 2-a, more than half students replied 2 as their intervention points for injecting vaccine to stop contamination. This answer is based on the perception that crucial change in the epidemic system will take place around the time of DS, that is, answer 3. Also we can find that nearly 60% of students who are presented with rate variable replied 1 as their intervention point. This answer is also affected by the DS of rate variable. This tendency of considering DS as a crucial change indicates that the first hypothesis is valid.

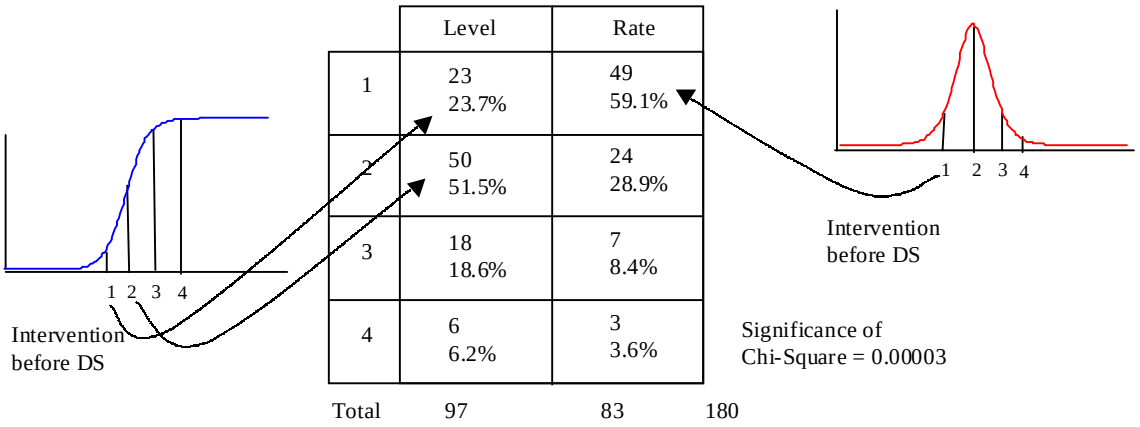


Figure 5. Experimental results of deciding when to command the injection of vaccine

As in the first question, students answered their intervention time differently for questions with level variable and with rate variable. This result also validates our third hypothesis of framing effect between level and rate variables. Also, one can find that most of students' decision on their intervention time is based on DS. In the question with level variable, 75.2% answered 1 and 2, and they can be interpreted to be based on DS. In the question with rate variable, 59.1% answered 1, because there is only one option that can be chosen before DS. Thus we can conclude that most decision-makers base their timing of policy intervention on DS rather than CS. From this experiment, we can find that cognitive bias toward DS will affect timing of policy intervention by way of assuming the point of DS as their reference point for taking action. This result validates our second hypothesis.

IV. Discussions: Time Delay and Timing Strategy of Policy Intervention

In our experiments, we did not include any time delay. Even though there is no time delay in decision-making situation we have taken, our experimental results say that there will be some delay in the process of decision making because of the cognitive biases in the feedback loop dominance. When a change in the structural force occurs around the point of CS, perception of this change will be made near the point of DS that will come much later. Decision-makers perceive and react to the changes only after changes in the system structure is completed. They react only to the system behavior. The source of the changes occurred in the system structure when the dominant feedback loops shifted far before their perception.

The time gap between CS and DS may be the fundamental source of time delay in the part of decision-makers. We can show this psychological time delay in decision making process as archetypal causal map in figure 6. Figure 6 can be compared to the archetype of "Balancing Process with Delay". The difference between them is the location of source of delay. In the archetype of "Balancing Process with Delay", time delay occurs in the causal arrow from 'corrective action' to 'actual conditions'. This means the time delay occurs in the system rather than in the decision-makers. In figure 6, time delay occurs in decision making process.

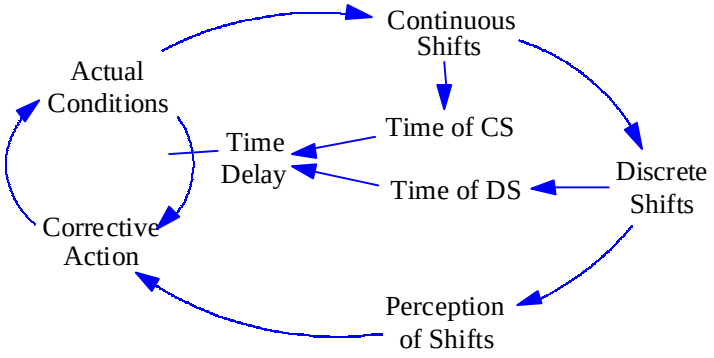


Figure 6. Typical causal map for time delay on the part of decision making process

In the left part of figure 6, one can see typical balancing process with delay, which occurs in the decision-makers' perception. In the right part of figure 6, one can see why the time delay comes in the mind of decision-makers. Changes in the actual conditions start around time of CS, and some times later, these changes produce discrete shifts. Decision-makers tend to perceive DS at a time when systemic changes begin. With this cognitive bias toward DS, the time gap between CS and DS will determine the 'Time Delay' between 'Actual Conditions' and 'Corrective Action'. In this sense, some of time delays in the decision-making processes can be interpreted and explained as a behavior resulting from hidden cognitive biases. More extensive studies in the source of time delay and hidden cognitive biases in dynamic decision making processes are required.

In this study, we did not discussed on the relative importance of CS and DS. The strategic inflection points by Andrew Groves seem to be closer to CS rather than DS. He stressed in his book that one couldn’t detect the strategic inflection points without extreme alertness. Difficulty in finding CS implies its relative importance, because those who know the time of CS will have strategic advantage to others who do not know it. CS is more difficult to be detected but more important than DS.

The importance of CS might come from the nature of CS. Since the gain of feedback loops changes incrementally or slowly around CS, one can conjecture that it will be easier to keep the system from the dominance of undesirable feedback loops around CS. Also it may be more efficient to change system around CS than DS. In this regard, CS can imply policy leverage points in time dimension. But people tend to fail in perceiving CS and thus have difficulties in using CS for their decision-making. If CS can provide the policy leverage points, cognitive bias on feedback loop dominance discussed above will lead decision makers to fatal failures in exploiting leverage points as well as in perceiving system changes.

However, to our knowledge, there is no systematic discussion on comparing the efficiency of policy intervention at CS and at DS. More generally speaking, even though desirable point of time for policy intervention has great importance in decision-making situation, system dynamicists have paid little attention to this subject. By comparing the efficiency or behavioral pattern of policy intervention between CS and DS, our understanding in the timing of policy intervention will be enhanced.

V. Concluding Remarks

Tackle things before they have appeared.
Cultivate peace and order before confusion and disorders have set in.
In handling affairs, people often spoil them just at the point of success.
With heedfulness in the beginning and patience at the end, nothing will be spoiled.
(Chapter 64, Tao Teh Ching by Lao Tzu)

The timing of policy intervention has been one of the fundamental puzzles in human societies since the very beginning. It is difficult to abide by the admonition given by Lao Tzu. On the contrary to Lao Tzu, decision makers tend to show heedfulness at the end (DS) and great patience in the beginning (CS). By behaving opposite to the lesson of Lao Tzu, decision makers spoil their systems. Systems thinking can provide a modern version of old admonition for timing of heedfulness and patience, that is, the timing of policy interventions.

In this paper, we proposed two classes of feedback loop dominance shifts; continuous shift and discrete shift. From several experiments we could find that people tend to perceive DS more frequently than CS and their decision making showed tendency of being based on DS rather than CS. We discussed that the different perception of CS and DS can provide a simple and fundamental explanation on why there is a time delay in policy-making processes. We also found that there is a framing effect between level variable and its rate variable. By using this framing effect, cognitive bias on the feedback loop dominance can be exploited to enhance the quality of decision making. We hope that the concept of CS, DS, and cognitive bias on them can provide a new insight for future study of the pattern and efficiency in the timing of the policy intervention.

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