Do People Actually Use Backward Induction?
: An Experimental Test of Real Choices

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Abstract

This paper studies whether decision makers really use backward induction in their real life. Our approach is to test the model including present bias suggested by O'Donoghue and Rabin in 'Doing it Now or Later' is applicable or not. We studied it as real choices of subjects in several ways. We make our subjects select the order that they will present in their class. We made it different in two ways. (1) We made a difference in the degree of difficulty of preparing the presentation. (2) difference in the evaluation of presentation by the order: The earlier student presents their task, his evaluation is higher. In both cases, we found a strong aversion to be the 1st presenter. This result suggests the present bias because almost all subjects selected the first half weeks of alternatives.

We also gave subjects a reward option with self control: One class cancelation with 5 days short extensions added to usual class. Most selected day to cancel was surprisingly the last day of alternatives for subjects. This result means they use their choice as a commitment device not to avoid their class. This fact means students use backward induction when they are planning the future. Therefore we can conclude that people actually use backward induction in their planning.

1 Introduction

1.1 Motivation

This paper studies whether decision makers really use backward induction in their real life.

Backward induction is one of the most important theoretical assumptions of decision makers behavior in dynamic settings. However, little attention has been given to the reality of this assumption. Economists have treated this assumption as an obvious fact.

We noticed several facts that make us suspect that our students do not use backward induction. We found most students do not understand the theory of backward induction in our examination of the theory of economics. We also found some students take almost half or over half the necessary number of units in order to graduate in the final (the 4th) year. Furthermore, we noticed that the main reason for students to give up graduation is cased by the self control problem.:some students cannot wake up early in the morning and some cannot endure the ninety minutes class. Our interest is to know the reason why they cannot solve their inter-temporal problem.

It is well known that recognition of behavior and understandings of rationality of people has changed dramatically in the last years. Bounded rationality is forgiven in modeling economics, so the definition of a rational person has also changed.

In classic dynamic theory settings, a perfect rational person is time consistent, and all of the rest is thought to be a naive person. However, recent studies show that some irrationality or preference reversal in multi temporal settings are forgiven.

One prominent idea to accommodate both preference reversal and solving self control problem is introduced by Ted O' Donoghue and Matthew Rabin [5]. This idea differentiates the rational agent from irrational agent by recognition of own present bias that is distinct from

the future and the present. Now we know almost all of us are not inherently time inconsistent, and have some present bias to some extent.

They call the person who knows their existence and the size of present bias to be a sophisticated person. Sophisticated people apply backward induction at each node and succeed in keeping their plans by expecting their inter temporal problem in their future node. In contrast, the person who dose not recognize the size of their own present bias and believes himself to be a time consistent person to be naive.

By their definition, naive people use backward induction in their planning. They do not distinguish naive people from sophisticated people whether people use backward induction form future node or not. The failure of their behavior is caused by the lack of ability to keep their plans.

Our purpose is to study people using backward induction as a field experiment. We can observe people's planning ability by giving them simple settings. We use the model of Ted O'Donoghue and Matthew Rabin [5] to judge it for two reason. At first, their model assumes all types of persons including naive persons use backward induction. So if their model is not applicable, we have to say that backward induction is not useful at all in solving decision making problems. Next, their idea makes our analysis easy because we can easily evaluate the size of the present bias in the subjects planning by using the model of Ted O' Donoghue and Matthew Rabin.

Our other intention of this study is to test whether using backward induction is useful not only in planning it but keeping it.

1.2 Background

Dynamic decision making without backward induction leads theoretically the agent to some dynamic inconsistency. It has been recognized that dynamic inconsistency on economic decision making contains many aspects. The points to solve inter-temporal decision

making depend on two things.

The first point is whether an agent can plan to solve inter-temporal problems that require some trade off between the now and the future. To make appropriate plans, backward induction is absolutely necessary. We are interested in whether students can use backward induction in their planning of real life or not rather than they just understanding the theory.

The other important factor to solve inter-temporal problem is a self control problem: whether agents keep their plan or not. In early literatures, Strotz [8] already suggested people may sometimes fail to maximize their life-time utility because of the lack of willpower to carry out life-time plans. Economics focuses on how to make optimal plans rather than how to keep them because the latter problem is thought to be a psychological matter.

These two points on the inter-temporal decision making can be divided in some experimental settings because the ability to make some appropriate plans and keeping it is another matters in the minds of agents. The reason why these two things have not been discussed separately is we only observe the results of people's decisions in real life that planning and keeping it is entangled. For example, when we observe a retired person who has little savings, we suspect they may be naive. In fact, it may be impossible for him to make an appropriate lifetime plan because of his lack of ability to think how to live his life: he may not use backward induction to make his lifetime plan.

We focus on the former point rather than the latter point because the self control problem is already investigated.

When we consider whether an agent can keep his plan depends on many things, the most important thing seems to be will power. In addition, precommitment is needed to keep their choice in the past:precommitment. And weather one succed to keep their plans or not depends on of the alternatives in the future nodes.

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If the willpower is not so strong and the commitment device is limited, an agent may fail to keep his plan. However, if alternatives are limited, time inconsistency will scarcely occur. Therefore, the options in the future decision node have crucial roles.

1.2.1 The definition and insight from Strotz

Recently, time inconsistency problems are explained from many aspects. One is hyperbolic preferences, the bias of time preference rate.

Ainsile [1] and Lowenstein and Prelec [4] describe this problem as a hyperbolic discounting. Hyperbolic discounting means people discount the near future to a greater extent than distant future more largely than exponential discounting. When people use hyperbolic discount in the multi-period problem, they will be time inconsistent. The essence of hyperbolic time preference as pointed out by Aruel Rubinstain [7] is to distinguish today from tomorrow. This is called present bias. The stationarity of tomorrow and the day after tomorrow is stable and this is not the reason for time consistency. The reason for time inconsistency is present bias, and in fact, a lot of evidence of such present biases has been found in economic, psychological and neuron-economic experiments. The theory of self control problem using present bias is made by many economists using the axiomatic method.

Strotz [8] already stress the importance of the self control problem in economic problems. He explains it by taking the example of savings: sometimes people consume too much compared to their plans and they must revise their plans. Furthermore, Strotz [8] points out that some people need a pre-commitment. The idea of pre-commitment is also important when we trace the development of theories which include self control problem as models by Faruk Gul and Wolfgang Pesendorfer [3] and Ted O'Donoghue and Matthew Rabin [5]. These models describe the modern problem that we have too attractive alternatives in choice sets.

1.2.2 self control problem

The model of Frauk Gul and Wolfgang Pesendorfer [3] focuses on the self control problem and shows it in the multi-temporal settings. People who intend to complete their diet may maximize their utility by reducing their options of consumption. This model captures the most important point of pre-commitment: The people with self control problem may lose their happiness by having alternatives. And their model accommodates the multi-selves assumption: In the morning, someone decides not to eat too much at dinner in vain because the evening self wants to eat a big meal. The essence of pre-commitment is the intention of morning self to limit the evening self by depriving the alternatives for the evening self.

1.2.3 Backward induction and sophisticated choice mechanism

Ludwig von Auer [2] makes clear the relationships inter-temporal decision making and alternatives from the starting node of decision making to the next to last node in the future of the decision making. He describes the strategy against self control problem as a specific dynamic choice mechanism. He describes the failure of self control problem as a preference reversal, in other words, a dynamic change of preference.

von Aure define sophisticated people those who can use backward induction rather than willpower to keep their plans.

Naive choice defined by Strotz[8] is further defined by von Auer[2] as a kind of multi- temporal choice set dependence. The idea leads to Strotz [8] who pointed out the essence of naive choice as a myopic choice: a naive agent always selects what currently seems to be the best option.

We take one choice mechanism to understand the importance of backward induction introduced by von Auer[2] to re-consider the importance of backward induction.

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He defines the notion of *resolute choice* as a naive choice originally introduced by Mc-Clennen. The person who sticks to the preference of the first decision every node by conscious decision not by habit. The resolute choice mechanism necessarily results in keeping their plans because the future choice is made by the past resolution. von Aure characterizes this mechanism not to be a sophisticated one because resolute choice dose not use backward induction from the terminal of the decision node. von Aure does not describe the further, however, we can guess the reason why the resolute choice is not sophisticated. One reason is this choice possibly fails to maximize the agent's intertemporal utility when the more attractive option is added after planning. Even clearly with the new option the agent's utility is enhanced, the person who made the resolute choice sticks to his first preference regardless of new options. Next, the preference in the first node may decrease agent's lifetime utility. If you imagine the life plan to be a soccer player. In the first node, sacrificing his time to practice soccer may be useful, but in the next node, this may not useful and the smart decision is to give up becoming a soccer player. We cannot be happy by choosing simple resolutions.

Therefore, von Auer defines the agent who has resolute choice mechanism as a short sighted person even though that agent can keep to his plan at the beginning of the term. In the dynamic choice with self control such as saving, keeping his plan seems to be important. In resolute choice mechanism, people always keeps his plans because of the narrow time window. von Auer judges the choice mechanism without backward induction from the future node as a lack of deep thought and he cannot call it a sophisticated choice mechanism.

von Auer describes some pre-commitment by the earlier self as a feature of the overcoming self control problem. The sophisticated choice is defined in many ways by von Auer. The many variations come form the difficulty in forgiving indifferent alternatives. If some alternative is

always strongly preferred, sophisticated choice is easy to describe. Any sophisticated choice is made from the last terminal when the choice set is finite, and the choice is done to avoid decreasing utility in future node. The option becomes the source of the self control problem in the future node, so sophisticated agent mentally eliminated it now.

von Auer also emphasizes the pre-commitment to be an inner device and not a compulsive force from the outside. This is the crucial point for our experiment.

The forward looking choice mechanism leads to the neglecting some options in the first choice set. This occurs when the earlier self wants to conquer his own self control problem. To exclude the worst case in the future, *cautious choice* mechanisms makes the agent abandon almost all alternatives.

von Auer's idea is to define choice mechanism by feature of choice set rather than adhere to the preference of decision maker because the available option in the choice set itself maybe too attractive in the future, the agent may apply such choice with strong self commitment.

1.2.4 Naive people can use backward induction or not?

We especially focus on the model by Ted O'Donoghue and Matthew Rabin [5]. They made clear by their model introducing self control problem with simple settings. They distinguished the time-consistent people and sophisticated people from naive people by the presence and cognition of present bias. Their prominent contribution is introducing present bias in the multi-temporal problem and the 'sophisticated people' by their definition:people who are aware of the existence of present bias in their behavior are sophisticated. Their model shows the behaviors concretely of such people in many cases. We describe the details of their model later.

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2 Experiments

We are interested in whether subjects can make appropriate plans in multi-temporal settings rather than whether they keep their plan or not.

We observe the behaviors of the subjects who are confronting some self control problem by forcing them to do some task or give a reward with conditions. We made some situations for subjects to take action and then observe their choice in many experimental settings. Subjects must choose different timings when they must carry out some action. We also investigated the case without self control for the purpose of comparison.

We used both experimental method and questionnaire without reward design. In hidden experiment 1 and 2, we do not pay any reward because it is unnatural procedure from an educational viewpoint. The reason we call these experiments hidden is because there is ho assignment with the experimenter and subjects, therefore subjects are not aware their decision making is part of an experiment.

In experiments 3 to 6, subjects are aware they participate in an experiment, so we paid a reward. Experiment 7 is a questionnaire, and part of a hidden experiment, so there is no reward.

2.1 Basic Procedure of Experiments

We make our subjects decide the timings of something in real choices. The purpose is to observe the timing. We have variations as below. (See basic data of experiments.)

In all experiments, the interval of one unit of time is one week because the class is held once a week. Our subjects are always students in these experiments. We give various events that can only be done one time. Subjects always have to decide the timing to do something.

2.2 The purposes and design of experiments

We have several purposes.

1 : to observe whether subjects use backward induction or not.

In hidden experiment 1 and 2, we can use the models by Ted O'Dono-ghue and Matthew Rabin [5] directly. In this experiment, we are trying to succeed in making subjects act at once.

Especially, in hidden experiment 1, we made the same situation with their salient cost model perfectly. The problem subjects try to solve is to decide the timing to prepare their presentation with increasing cost schedule over time.

In hidden experiment 2, we made a similar situation with the salient cost. However, we could not make totally the same situation. In salient cost model, for example, naive people facing the increasing reward schedule over time cannot wait for the enjoyable event and they miss the more fun event. It was difficult to make such a situation in a real life of university, therefore we made situation with decreasing rewards over time. To enjoy greater reward, subjects must decide he may take the cost earlier. The reward is the evaluation of the presentation and the cost is preparing their presentation.

When planning, naive subjects will not take account the cost seriously, so they may choose the earlier timing to get greater evaluation. In contrast, sophisticated students will choose an appropriate term considering their present bias.

2 : to observe whether subjects have present bias or not: to distinguish time-consistent subjects and sophisticated subjects from naive subjects.

This is easy to observe. If students have no present bias, they must choose to be the first presenter in both hidden experiment 1 and 2

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because the first presenter in experiment 1 has the least cost to prepare and the first presenter in experiment 2 has the greatest evaluation. For the time consistent person, the present bias is small so there is no incentives to be the second and 3ed presenter. However, we expect most students do not select to be the first presenter because of their present bias.

3: to observe and judge whether subjects conquer their self control problem or not.

We can observe each subject's behavior after planning. In almost all experiments except experiment 3, we can observe and judge whether subjects conquer their self control problem actually or not from the contents of their presentation. Furthermore, if the subjects do not appear before the class when they must present, we conclude he is apparently naive.

4: to observe whether sophisticated subjects use some commitment devices to conquer self control problem.

In experiment 4 and 5, we made an option of cancelation of class with short extensions to be added to 5 classes. If a subject is naive, he will select the cancelation at the earlier time and make the time of extensions later. And the naive student may not attend his class after given cancelation because he cannot endure to have the extension class because of his present bias which he does not recognize.

Sophisticated students recognize that such behavior results in a bad evaluation. If a subject is sophisticated, he will select the time of cancelation later and make the extension days earlier because they have strong incentives to skip their class after given cancelation. Only cancelation is given to subjects in experiment 5 to compare with experiment 4.

5: to distinguish whether sophisticated subjects use some commitment devices or they have some anomaly in the time discount rate.

In experiment 4 to give one cancelation contingent with the 5 times extensions, even if we observe the sophisticated answers to make one cancelation to be later, we cannot distinguish if they have some anomaly in the time discount rate: negative time preference rate and they love to wait.

In order to distinguish time anomaly and precommitment device, we prepare the easy experiment to measure their time discount rate in experiment 3. In experiment 3, we prepare the alternatives for subjects without self control to have some fun event. If time discount rate is under one, subjects are expected to choose the early alternative to have fun event.

2.3 Basic Data of Experiments

No	action	self-control	action of today	execution day	subjects
1	presentation with	with	with	9 May 2007	3rd year 10 groups
2	presentation with	with	with	7 May 2007	1st year 10 students
3	have fun without	without	without	4 July 2007	3rd year 16 students
4	cancel class with	with	without	6 June 2007	3rd year 18 students
5	cancel class with	with	with	6 June 2007	3rd year 18 students
6	cancel class without	without	without	2 July	1st year 10 students
7	do homework with	with	without	2 July 2007	1st year 10 students

2.4 Overview of results

No	action	alternatives	most selected	rate of most selected	second most selected
1	presentation	11 weeks	2nd	4/10(groups)=0.4	4th (3groups)
2	presentation	8 weeks	3rd	4/10=0.4	2nd,4th (each 2)
3	have fun	10 weeks	1st	6/16=0.4	6th (4)
4	cancel class	today + 5 weeks	5th	6/18=0.333	2nd (4)
5	cancel class	11 weeks	11st	6/18 =0.444	6th (3)
6	cancel class	10 weeks	1st	5/10=0.5	5th,6th,7th (each 1)
7	do homework	8 weeks	1st,2nd and last	each 3/10=0.33	—

2.5 The model to test in each experiment

2.5.1 General Utility Model with present bias

To study the subjects use of backward induction, we test the (β, δ)-preference approach by Ted O'Donoghue and Matthew Rabin[5]. This approach is expressed as below.

By their definition, for all t, the utility with (β, δ)-preference can be represented by

$$U^t(u_t, u_{t+1}, \cdots, u_T) \equiv \delta^t u_t + \beta \sum_{\tau=t+1}^{T} \delta^\tau u_\tau \qquad (1)$$

where $0 < \beta \leq 1$, $\delta \leq 1$

Beta shoes the size of present bias and when $\beta = 1$, this model reduces to an ordinal utility model, which discount the future exponencially.

We observe subjects's planning ability and check their plans are reasonably explained by equation (1). If people actually use backward induction and this model can express their self control problem, we can anticipate their behavior. We will come to the details later.

2.5.2 Basic Model to test in all experiments

Basic Model (β, δ) paradigm to test is as below.

$$U^t = (v_0 - c_0) + \beta\{\delta(v_1 - c_1) + \delta^2(v_2 - c_2) + \delta^3(v_3 - c_3) + \cdots + \delta^n(v_n - c_n)\} \qquad (2)$$

where v_t shows reward at time t and c_t shows cost at time t. Application of model to each experiment is showed later subsection.

> **Hidden Experiment 1: Salient Cost:** We give some task with a varying degree of difficulty: the later a subject presents the more difficulty he confronts. The salient cost becomes greater the later time the student selects. For example, if we postulate the cost of

the first presenter to be 10 which is the lowest, we can assume the cost schedule is such that c_1, c_2, c_3, $\cdots$, c_{11}=10, 15, 20, ...60 because the cost becomes greater gradually in dependence of the turn of presentation by 5. The subjects are not aware of the cost schedule to prepare a presentation, however, it is not difficult to imagine such a schedule as this, because the cost to be first presenter is lowest and gradually they have to understand all preceding chapters that have been presented.

If we ignore the effect time discount rate, for simplicity we assume the value of it to be the one, the model reduces the generated model introduced by O'Donoghue and Rabin[5].

Model of experiment 1: a variation of the salient cost model

The model of (β, δ) becomes to be

$$U_t = -c_0 + \beta\{\delta(-c_1) + \delta^2(-c_2) + \delta^3(-c_3) + \cdots + \delta^{10}(-c_{10}) + \delta^{40}v_{40}\} \quad (3)$$

$$\{c_1, c_2, c_3 \cdots c_{10}\} = \{10, 15, 20 \cdots 55\} \quad (4)$$

$$v_{40} = \bar{v} \quad (5)$$

In this case if the value of time discount rate is close to 1, and present bias of a student is not close to 1, he never select to be 1st presenter. In this case, to be the second or third presenter is the statistics of the sophisticated people.

If we ignore the effect of time discount rate, for simplicity we assume the value of it to be the one, the model reduces the generated model of salient reward model introduced by O'Donoghue and Rabin[5].

Salient Cost Model

If a person does activity in period τ, then instantaneous utilities are $u_\tau = -c_\tau$, $u_{T+1} = v_\tau$, $u_t = 0$ for all $t \in \{\tau, T+1\}$,

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$$U^t \equiv \begin{cases} \beta v_\tau - c_\tau & \text{if } \tau = t \\ \beta v_\tau - \beta c_\tau & \text{if } \tau > t \end{cases} \tag{6}$$

In each term, the subjects compare to take the cost now or to take the cost next time. If the utility becomes larger by preparing at time τ,

If we give subjects clear cost schedule, from answers of subjects we can easily calculate the size of β, we can calculate the size of discount rate of each subject. If a subject answer he would like to present in the τth week, he compare two equations.

$$U^t = \beta v_\tau - c_\tau \tag{7}$$

$$U^{t+1} = \beta v_{\tau+1} - \beta c_{\tau+1} \tag{8}$$

In this case, from

$$\beta v_\tau = \beta v_{\tau+1}, \tag{9}$$

we get

$$\beta < \frac{c_\tau}{c_{\tau+1}} \tag{10}$$

sophisticated people know even if they plan the future by equation, the time has come, their intertemporal utility is described by equation, so the present bias is relevant even if the present is not contained in the alternatives to choose.

In this experiment, cost schedule is not given clear except the condition that cost increases over time, and the fact we can judge from observation is limited to whether each subject is sophisticated or naive.

Hidden Experiment 2: An Example of Salient Reward Model

We give some task with variation of additional points: the farmer a subject present the more points he get, with self-control, without present bias. The model of (β, δ) becomes

$$U_t = v_x - c_0 + \beta\{\delta(-c_1) + \delta^2(-c_2) + \delta^3(-c_3) + \cdots + \delta^8(-c_8) \tag{11}$$

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Subjects select τ, for all t $\in \neq \{\tau, T+1\}$, $c_t = 0$

$$\{c_1, c_2, c_3 \cdots, c_8\} = \bar{c} \tag{12}$$

$$\{v_x\} = \tau \times 5 \tag{13}$$

We cannot estimate the value of β and δ both immediately, so we focus on only β. The planning subjects confronting in the experiment 2 can expressed by the equation as below. When we ignore the time discount rate δ, the model reduces to the model as below. This is not totally the same as the *salient reward* model introduced by O'Donoghue and Rabin [5].

Salient Reward Model

If a person does activity in period τ, then instantaneous utilities are $u_{tau} = v_\tau, u_{T+1} = -c_\tau$, $u_t = 0$ for all t $\in \neq \{\tau, T+1\}$,

$$U^t \equiv \begin{cases} v_\tau - c_\tau & \text{if } \tau = 1 \\ v_\tau - \beta c_\tau & \text{if } \tau > 1 \end{cases} \tag{14}$$

We cannot calculate easily the size of β of each subject except a subject select the first turn to present. This case is expressed by comparison of two equations.

$$40 - \bar{c} > 35 - \beta\bar{c} \tag{15}$$

we get

$$\beta > \frac{35}{40} \tag{16}$$

If subjects select the 2nd turn, we can get the size of maximum β itself. We can also get the size of time discount rate by introducing it in model. For example, if a subject wanted to be the 2nd presenter, $\quad 35\text{-}\beta\bar{c} > 30\text{-}\beta\delta\bar{c}$

so that $$\delta > \frac{30}{35}$$

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Experiment 3: We give subjects an immediate fun event without self control, today is not included in alternatives.

The first alternative subjects are given is the 2nd week of autumn semester. The first day of alternatives is 14 weeks after from the execution day. The equation subjects confront is expressed as below.

$$U^t = \beta\{\delta^{14}v_{14} + \delta^{15}v_{15} + \cdots + \delta^{25}v_{25}\} \tag{17}$$

select τ

$$v_\tau = \bar{v} \tag{18}$$

$$v_{-\tau} = 0 \tag{19}$$

Notice that self control do not affect on decision making of subjects. Theoretically, if time discount rate is under 1, the first alternatives will be selected by any students.If time discount rate is zero, it is irrelevant when a fun event is held.

Experiment 4: We give subjects an opportunity to cancel one class. Subjects are required to make a decision with self control because they must accept 5 days short time extensions of their classes. 3 days 20 minute extensions and 2 days 10 minute extensions. Subjects can NOT decide the day when they take extensions. This procedure is to avoid complexity for subjects. Subjects consider the days are determined in a probabilistic way because the class is sometimes extended without preliminary announcement when the teacher judged the understanding of text by students is not sufficient. Subjects know that extensions would be random from the start of the experiment. So this condition will affect their decision making.

The problem subjects confront is to change from their usual plans.
The equation of usual plans for students is

$$U^t = -c_0 + \beta\{\delta(-c_1) + \delta^2(-c_2) + \delta^3(-c_3) + \cdots + \delta^5(-c_5)\} \tag{20}$$

Students face the problem to select the time to cancel one class. Cancelation is made under condition with 3 days 20 min extensions and 2 days 10 min extensions. The utility reflecting changed plans is

$$U^t = -\acute{c_0} + \beta\{\delta(-\acute{c_1}) + \delta^2(-\acute{c_2}) + \delta^3(-\acute{c_3}) \cdots + \delta^5(\acute{c_5})\} \qquad (21)$$

1 Each student decides the time to cancel one class between today and 5 weeks later.

$$c_\tau = 0 \qquad (22)$$

2 Each subject need not decide when extensions are done because all weeks except cancelation day, extensions are need to cancel one week. The extension days are selected from the other day of the classes, so we express the day as t=-τ,

This means

$$\acute{c}_{-\tau} = \bar{c} \times \frac{110}{90} \qquad (23)$$

or

$$\acute{c}_{-\tau} = \bar{c} \times \frac{100}{90} \qquad (24)$$

Experiment 5: We made subjects decide the day of cancelation of one class. Decision making is done with self control because the extensions of classes is required. The purpose of this experiment is to compare with experiment 4 which include today as an option to cancel. In this experiment, today is not included in alternatives.

Usual plans for students is

$$U_t = \beta\{\delta^{17}(-c_{17}) + \delta^{18}(-c_{18}) + \delta^{19}(-c_{19}) + \cdots + \delta^{27}(-c_{27})\} \qquad (25)$$

Students decide when they enjoy an opportunity to cancel one class with an exchange of conditions to extensions. The plans after accepting a cancelation with extensions are expressed by

$$U^t = \beta\{\delta^{17}(-c'_{17}) + \delta^{18}(-c'_{18}) + \delta^{19}(-c'_{19}) \cdots + \delta^{27}(-c'_{27})\} \quad (26)$$

The utility of the day of cancelation is

$$\acute{c}_\tau = 0 \quad (27)$$

Conditions of extensions are expressed by

$$\acute{c}_{-\tau} = \bar{c} \times \frac{110}{90} \quad (28)$$

or

$$c'_{-\tau} = \bar{c} \times \frac{100}{90}$$

$$(29)$$

The description of the problem the students faces are

Experiment 6: We made subject to select when they hope cancel one class without extension of class or without obligation. This is experiment to compare with experiment 4 and 5 because the decision making of subjects is done without self control. Options are not include today.

$$U_t = +\beta\{\delta(-c_{21}) + \delta^{23}(-c_{23}) + \delta^{24}(-c_{24}) + \cdots + \delta^{31}(-c_{31})\} \quad (30)$$

$$\acute{c}_\tau = 0 \quad (31)$$

22 weeks after experiment starts is 8 October, however, it is excepted, because the day is public holiday in Japan.

Questionnaire with hidden experiment 7: Planning doing homework, decision is made with self control, without present bias

$$U_t = \beta\{\delta(-c_4) + \delta^5(-c_2) + \delta^6(-c_3) + \cdots + \delta^8(-c_8) + \delta_{32}v_{32}\} \quad (32)$$

$$\{c_4, c_5, c_6 \cdots, c_8\} = \bar{c} \quad (33)$$

$$\{v_{32}\} = \bar{v} \quad (34)$$

As students who take additional class how to finish homework, the day of additional class is 4 weeks and a day after the questionnaire day, therefore, with under condition

$$\{c_4\} < \bar{c}, \quad c_\tau < \bar{c} \tag{35}$$

$$\{v_{32}\} = \bar{v} \tag{36}$$

3 Result and Analysis

Hidden Experiment 1: Give some task with various degrees of difficulty, the later a subject presents the more difficulty he confront. Decision is made with self control, with present bias

Our intention: We try to observe whether they use backward induction under conditions easy to understand. It is obvious for them to do their task early, so their choices show their present bias and time discount rate.

Detail of Procedure: We explain subjects to choose the one chapter of the book titled 'MBA finance'. The contents of this book is pretty difficult for them. Because they are 3rd year undergraduate students, and most of them are not good at mathematics and logical thinking. So they have limited understanding of the contents of book when they glance at it, however, they understand the difficulty becomes worse for them if they select the latter part of this book. This is done as a hidden experiment and all subjects did not notice this is a experiment. Two or three students form one group to make the presentation, so we cannot observe individual attitude in this experiment. It is a limitation of this experiment.

We make each group to write their hopes from 1st to the 3rd.

After collect them, we decide a winner of each chapter by rock-paper-sassors. In this hidden experiment, we completely observe their real hope. However, there is one limit that we cannot observe individual decision making. In our class, all students have to present at least once and the contents and the way to express it is evaluated with a rank of unit in the end of the fiscal year. Therefore, the reward of this problem is given in the distant future. Rank of unit is *impossible (to give unit), possible, good, very good, excellent.* Students know by escaping the time to present or giving up their presentation will result in the *impossible.* Students also understand if they select the latter chapter, they will be confronted with more difficult contents to present. We show the difficulty as size of cost by 5 points. Rank of unit is *impossible (under 60 points), possiblefrom 60 to 69 points, goodfrom 70 to 79 points, very goodfrom 80 to 89, excellentfrom 90 to 100.*

Final Procedure to decide the real timing: After decisions of all subjects are made, the answers are enveloped and collected in one box. After collect all hopes, we decide a winner of each chapter by rock-paper-sassors. In this hidden experiment, we completely observe their real hope.

Our expectation of results is that many subjects will avoid being the first presenter because it means they have to begin to write the abstract immediately. All of the students are thought to have present bias. Sophisticated students is considered to select earlier turn to presentation. Some may be the first presenter because of the self control and pre-commitment.

The Result was really straightforward. Theoretical expectation was strikingly right. Most subjects wanted to be the second presenter.
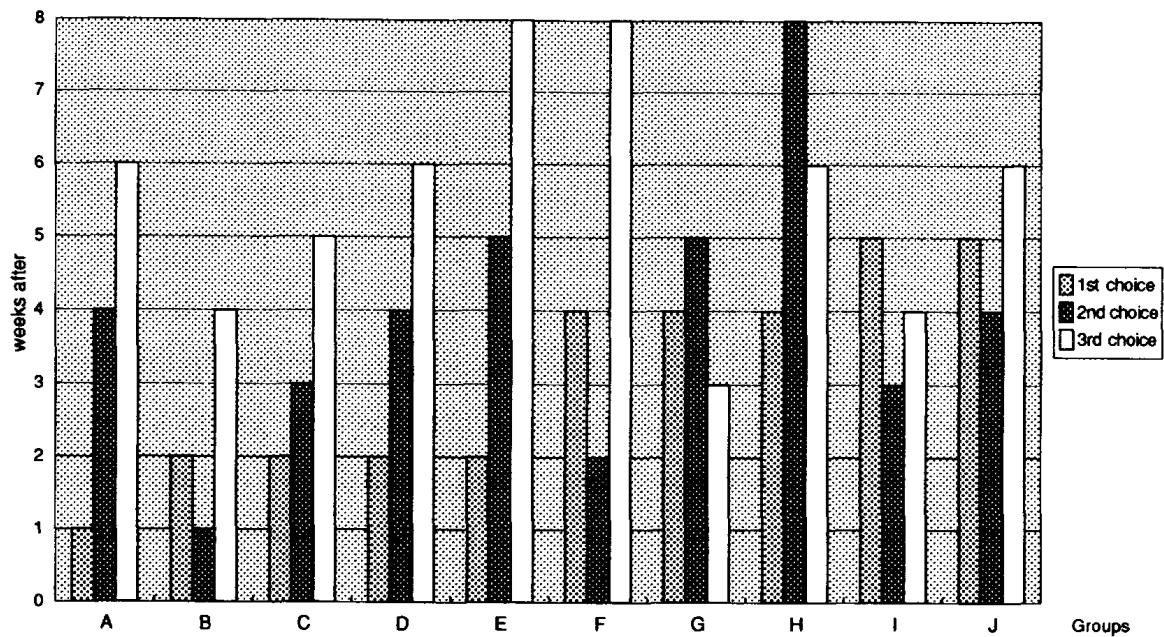
Figure 1: The responses to select the week to present in hidden experiment 1

(see Figure 1) Their idea is easy to interpret. They avoid being the first presenter for two reasons. One is the main stream of explanation of hyperbolic preference. If a subject selects to be the 1st presenter, he must prepare from today. Another reason to avoid the 1st presenter is to avoid uncertainty. The first presenter takes the big risk because most subjects have little experience to present some logical contents on economics in front of members of one class. In our hidden experiment, there is enough reasons to be 2nd presenter because the difficulty is second lowest and the uncertainty is low in comparison to the 1st presenter. and the evaluation day is in distant future. The discount rate of one week is thought to be close to 1, so that if each subject wants to maximize their utility, the intertemporal cost is minimized by selecting the 2nd presenter. The second most selected replies were to be the 4th presenter. The subjects skipped the 3rd chapter because of the volume they have to present. The 3rd chapter has almost twice the volume as any other chapter. This result is easy to interpret. The

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uncertainty is too big to choose to be the 1st presenter. The present bias may come from the uncertainty.

One group selected to be the 1st presenter. The answer can be interpreted in two ways. One possibility is the present bias of them is not large. The second possibility is they need strong commitment. We would like to call this is a *cautious choice* by sophisticated person even the enforcement power from outside to keep their plan is great in this experiment. In this experiment, the subject could select other alternative to leave the more attractive option in the future.

Hidden Experiment 2: We give subjects some task with variation of additional points: the sooner a subject presents the more points he gets. The problem the subjects confront is with self control and present bias.

Method is below. We explain subjects to choose the one essay from a book of essays, the difficulty is almost the same as all essays. I told that students if they choose the earlier presentation, they will be evaluated high at 5 points. Choice must be made between 8 weeks because the students were 8, so that the most high evaluation 40 is given for the brave first presenter. All students have to present at least once and the contents.

Subjects are students in the 1st year, therefore they do not really understand that escaping the presentation or giving up their presentation will result in the *impossible* or *possible* at best.

They can understand the fact the difficulty to write summary of one essay is almost the same because the volume of each one essay is two pages. We make the difference in the evaluation of presentation by the order: The earlier student presents his task, his

evaluation is higher by 5 points to evaluate.

Final Procedure of decide the real timing: After decisions of all subjects are made, the answers are enveloped and collected in one box. After collect all hopes, we decide a winner of each chapter by paper-stone-?. In this hidden experiment, we completely observe their real hope.

Our expectation of results is that all subjects avoid being the 1st presenter because of the present bias from uncertainty.

The Result was easy to interpret. Most replies were to be the 3rd presenter. The subjects have 8 weeks of alternatives. The structure we gave subjects was different from the experiment 1, however, the reason for the selection of subjects seemed to be the same: uncertainty and present bias. In this experiment, present bias which is crucial to decide the term. The reason to be the 3rd presenter is explained by the size of present bias is smaller than 0.833=25/30.

None of subjects wanted to be the last or the second last presenter. Most students wanted to be from the 2nd or the 4th presenter. So our incentive system worked well. The reason that most wanted to be the 3rd and not the 2nd is the size of uncertainty for the 1st degree students. The size of uncertainty is great because it will be the first presentation of the new academic year for all students.

Some of the answers we got have no contradictions in their behavior. I am their fixed teacher for the duration of the 1st year of university life, therefore, I could observe their behavior and their evaluations of all units of all subjects.

Actually, we observed only one student to be the 1st presenter, and
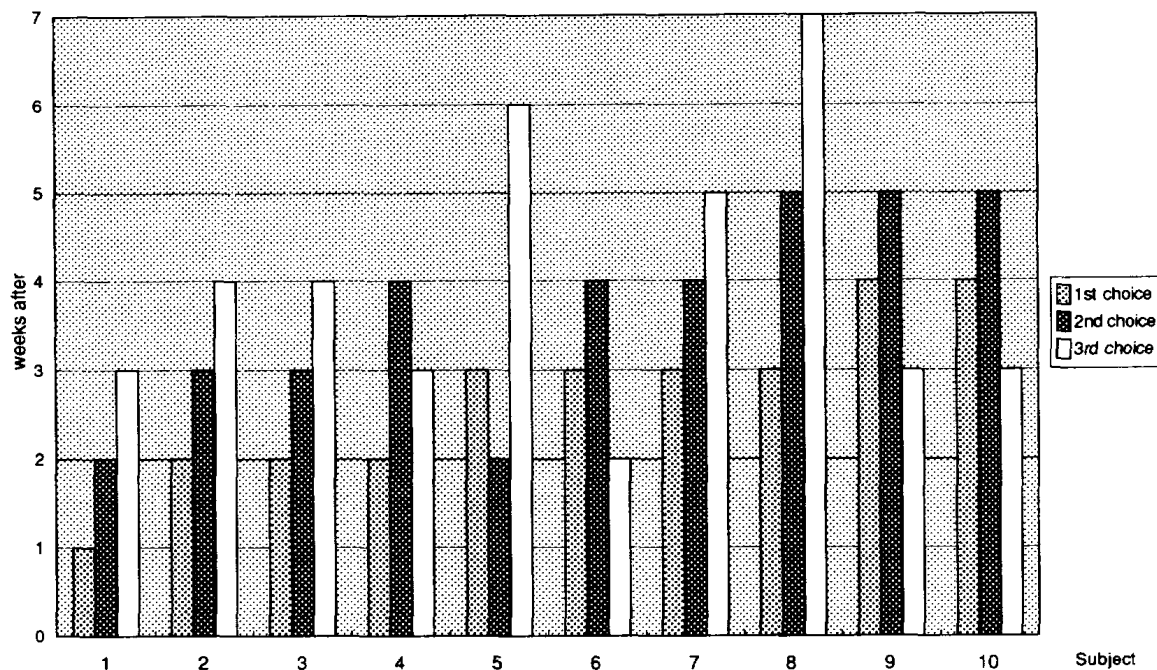
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Figure 2: The responses to select the week to present in hidden experiment 2

he actually presented as a first presenter and presented on every days as required. He is thought to conquer his present bias by knowing the existence of it.

In many cases we can judge subjects actually solved their problem to maximize utility conscious to their self control problem because 4 students to be the 2nd to 4th presenter actually have done their task until the last lesson of the spring semester. However, in experiment 1 and 2, I basically force them to keep their plans, so that their self control problem is half solved. In experiment 4 and 5, we found the some pre-commitment device by the subject themselves.

There are two students who answered to be the 3rd presenter but they escaped their presentation and consequently they escaped the class itself. This is common way for naive students to avoid their duty. Finally as a result these two students cannot come to the

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class because they are too uncomfortableness.

Experiment 3: We give an immediate fun event without self control *purpose of this experiment* is to observe discount rate alone. If we give subjects some task with deadline like experiments 1 and 2, all subjects have something self control problem. First our purpose is to study whether people use backward induction. In this only fun case, there is no self control and no difficulty.

Method is to select when she comes to our class again between 2nd and the next last week of autumn season. We omitted the first week because we need one week to prepare to welcome her, and omitted the last week because this week is near to the text examination and all of them would like to avoid the last week. To avoid self control problem, we would like to prepare just fun for the subjects. It is be difficult for us to realize fun class for our subjects because they are students of my seminar class. From educational view, We are not permitted to give just fun in my seminar class. So we made specific situation. So we have to plan according to the contents of our seminar class to teach intertemporal economics and finance. So we took special procedure to reconcile the pleasure and educational aspects in our class as below.

We happened to become acquainted with a very beautiful, pretty, young girl with a warm personality She is 22 yeas old and she is one of advocators of Social Responsibility Investment. She can explain excellently the activity and purpose of SRI. We invited her to my class on 11 July. Our students were very excited because we have no girl in our class and few girls in the Faculty of Economics, Keiai University. After her lecture, we ran questionnaires. From the result of questionnaires, almost all students but one strongly wanted her to come again to their class even though they cannot understand completely the contents of what she tells them.
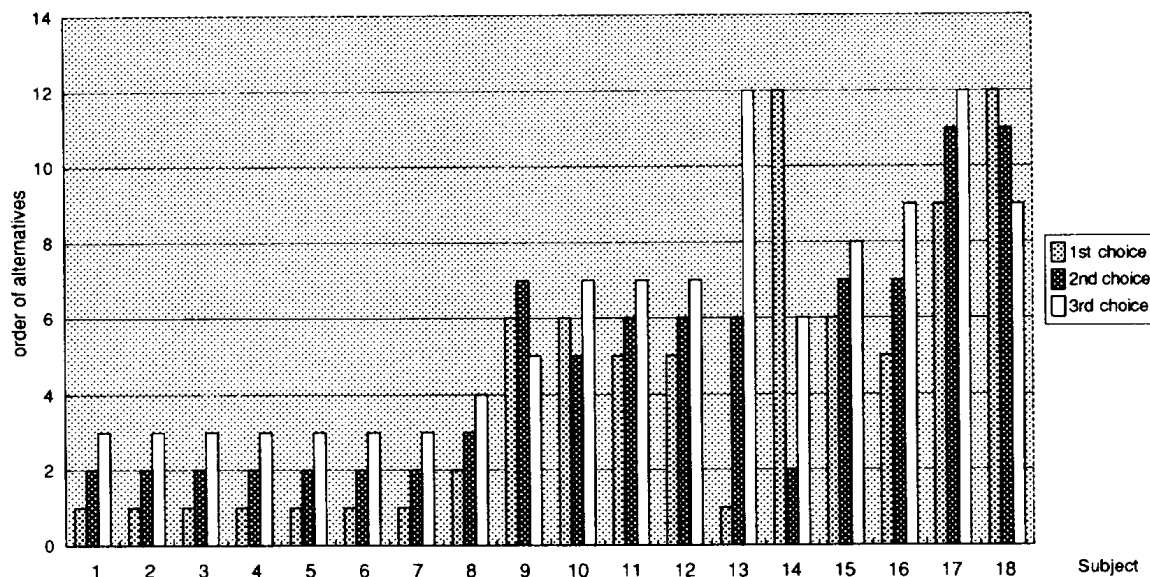
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Figure 3: The responses to select the week to have special guest in the class in experiment

Final Procedure of Experiment: After the decisions of all subjects are made, the answers are enveloped and collected in one box. The assistant of experimenter selects one envelop. The answer selected decides the execution day of the presentation.

Our expectation of results are that almost all subjects are thought to select the 1st or the 2nd week of the 12 weeks of autumn semester except in the case where subjects have anomaly in time discount rate.

Result: Almost all students selected the 1st week.

And the reason written is also interesting. Some reason was given directly for example 'I want to see' flower ' in the first of the semester'. Besides such reason, some students answered it was the good season for her to come. Two students selected the last week of alternatives because of the negative discount rate. This anomaly is thought to come from 'enjoy waiting'.

Some subjects selected middle weeks as an alternatives. This was secondly most often observed. We can interpret this result in two ways. 1) there are little interest to see her again, so the subjects are indifferent. 2) they enjoy waiting to an extent, but the last week is too far. they thought there must be a fun event in the middle of the weeks of the autumn semester, because 12 weeks is too long for them.

Analysis of Result is easy. If there are no selfcontrol problems, agents select to have fun in the earlier days. It is interesting when we compare the result with self control problem. We observe the honesty of my students.

Experiment 4: We give subjects an option to cancel of a class with condition. The alternatives are including present. *our intention* is to see whether the students use backward induction or not when subjects need some self control. This case has common feature with experiment 3 in giving some fun by cancelation of a class. To create a self control situation, we made the subjects endure three 20 min extensions and two 10 minuets extensions on other days.

Method is below. The subjects they can select the week the cancelation of class including now. If 'this week' is selected in the last procedure of this experiment, then all the members will be dismissed immediately. Our intention is to see the strength of present bias.

Procedure of Experiment: The subjects must select one cancelation week only in 6 weeks including today. The condition is more realistic than experiment 2 because they have to endure 3 times 20 min extension. The reason of short extension is as below. If we conditioned 3 times 30 min, extension of the class in only 5 weeks which means all of the left class is extended 4/3 of the normal

length of the class. We consider this condition is too tight for all the subjects. We were afraid that almost all subject would select 'no cancelation with no extension', so we dared to shorten the minutes from 30 to 20.

The result expected theoretically: Many students select 'now' if present bias is strong. The last week is selected by the student who strongly feel self control problem.

Our expectation of result may be the next week of the execution day of experiment will be selected by many students because almost all students have no plan that day because they have been informed of nothing in advance.

Result was surprising and it shows evidence of subjects using backward induction. It is clear that their choice decreases their whole intertemporal utility, so this is strong evidence to show they are sophisticated. Most subjects answered they want to cancel the class in the last week. They are sophisticated because they know it might be hard if they had chosen the earlier cancelation of a class, so now they must endure the extension (cost) after they have enjoy the reward. If the discount rate is too large, such a decision does not economically maximize intretemporal utility. We interpret the result as follows. Decision is made by comparison of two equations. One equation is based on the case of no cancelation and no extensions, the other is based on the case of one cancelation and five class extensions. We notice that the only answer to weaken present bias is the answer 'to cancel today and dismiss immediately'. Compare with experiments 1 and 2, where the present bias comes from the uncertainty rather than the impatience, four students actually answered they hope no cancelation because they have part-time job after this class. They
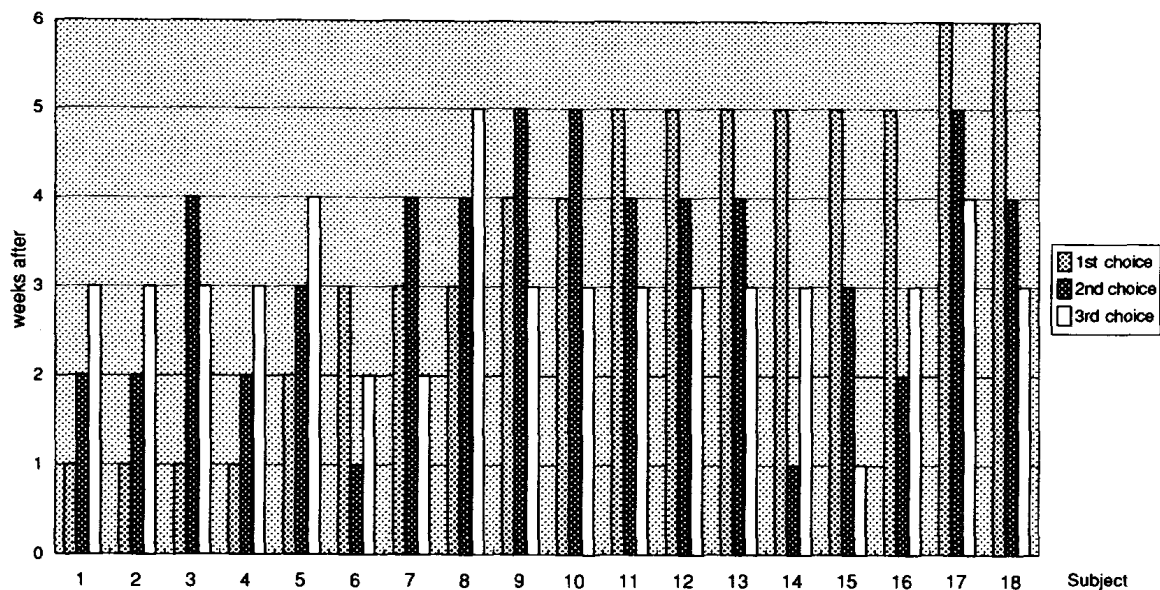
Figure 4: The responses to select the week to cancel one class with 5 days short extensions in 4 : alternatives are 6 weeks and including that day of experiment

are too honest from my point of view and they are patient enough to endure every weeks classes. Actually, the escape from our class in the spring semester scarcely occurred between the subjects who answered the last week or no cancelation.

Experiment 5: We give subjects an option to cancel a class between 11weeks with contingent. Alternative is not including today, Decision making of subjects is not include present. They are ask for select one week of distant future. The day of execution was June and their choice of the day for cancelation of class was from the 1st week of November to the third week of December.

Method is as below. We engage subjects to make a holiday of one class between the 12 weeks classes in autumn semester contingent with the extension of lesson for 20 minutes 3 times and 10 minutes 2 times. The reason we do not 4 days 20 minutes 4 times extension is for the students who have every week part time job after each

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class. For such students, 20 minutes extension is limit of extention to arrive at their job place on time. So 10 minutes extension is far easy to accept. We expect this condition makes the interpretation of results to be complex and difficult, however, it is necessary to escape their hope to be 'no cancelation'.

One class is 90 min in Keiai University and is held from PM 2:40 to PM 4:10. The cancelation of our class means they substantially finish all of their class of that day 90 min earlier. We consider this option must be attractive.

Decision making problems of subjects are (1) select cancelation of a 90 min class or three times 30 min extensions. (2) select one week to cancel a class.

Our expectation of result is the answers have some variation. The reason is as below. If some subjects hold self control problem to some extent, consume something fun time in near future and after the fun time, they are destined to endure hard time to study long. Our class is really hard[1] If extension is too severe for them, they may select no extension and no cancelation.

Result was almost the same as experiment 5. In this experiment, we observe the last alternative is the most selected even though the self control problem is weaker than experiment 4. In this setting, they are given 12 alternatives: the from 17th week after to 27 weeks after the experiment day. The interesting thing was that the 2nd most selected replies were the just around the middle between the 17th week and the 27th week. We interpret this result as follows. We did not make the subjects decide the 5 days of extensions, so that subjects don't need to consider concretely when the class would be extended. Usually extensions are done in probabilistic way in our class. However, if he selects early day to cancel, the reward necessarily would become before the cost to take
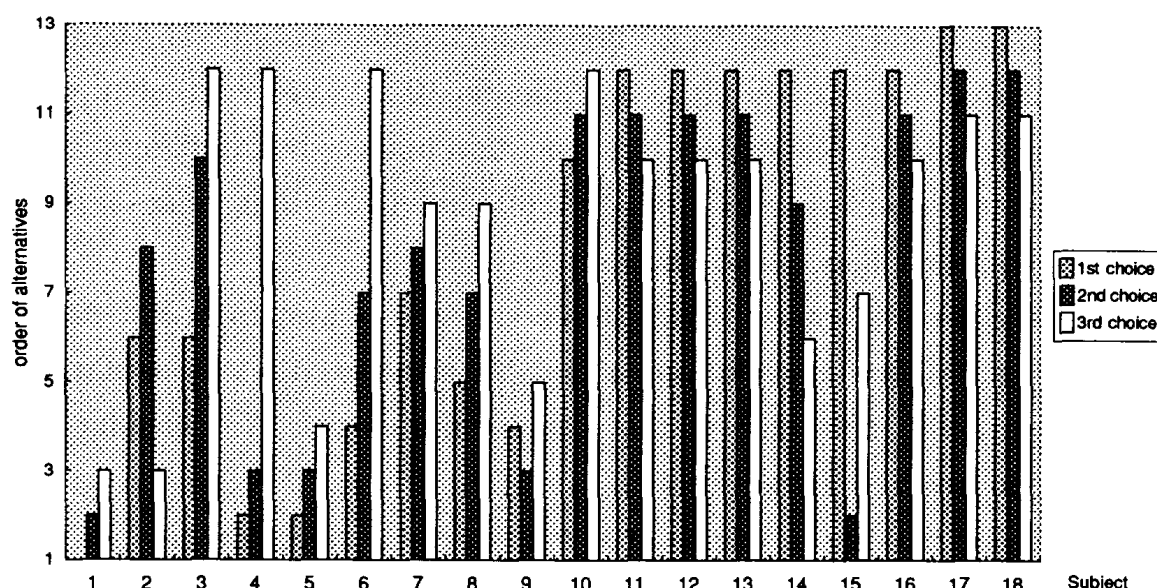
Figure 5: The responses to select the week to cancel one class have great fun in the class in experiment 5 : alternatives are 12 weeks and 1st alternatives are 17 weeks later from the day of experiment

reward. Therefore, it is possible that subjects select to avoid such situation. We conclude from experiment 4 and 5 that most subjects are sophisticated because if they select cancelation earlier, they might escape their class. They are afraid that they may escape some classes with extensions. This type of decision is by second thought because it is one of the cautious choice defined by von Aure [2]. In this choice mechanism, agents *mentally erase* the alternative which may cause some self control problem in the future choice node from his choice set in the beginning.

This planning experiment was useful to see how to conquer the self control problem of sophisticated. subjects.

Experiment 6: We give an cancelation of a class without self control. Alternatives do not include present. *Our intention and Method* is to compare the result with experiment 5 . Subjects select the week to cancel one class in autumn semester. The execution day of

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experiment was during spring summer, the present bias should be taken into account only by the sophisticated students. And I give an option of one cancelation *without* extension of any classes. This is not educational, however, it is impossible to extend my class because this is the 3rd class of the day and the 4th class is my lecture of economics.

The subjects must select one cancelation week within 11 weeks except the fist day and last day of autumn semester. The reason of exception of the first day is from educational one. The reason of the last day exception is to escape invalid answers for experimenter: If we left the last day as one alternative, almost all students may select that day to prepare for exams at the end of the semester.

The result expected theoretically is many students select 'now' if present bias of each student is strong. The last week will be selected by the student who strongly feels self control problem.
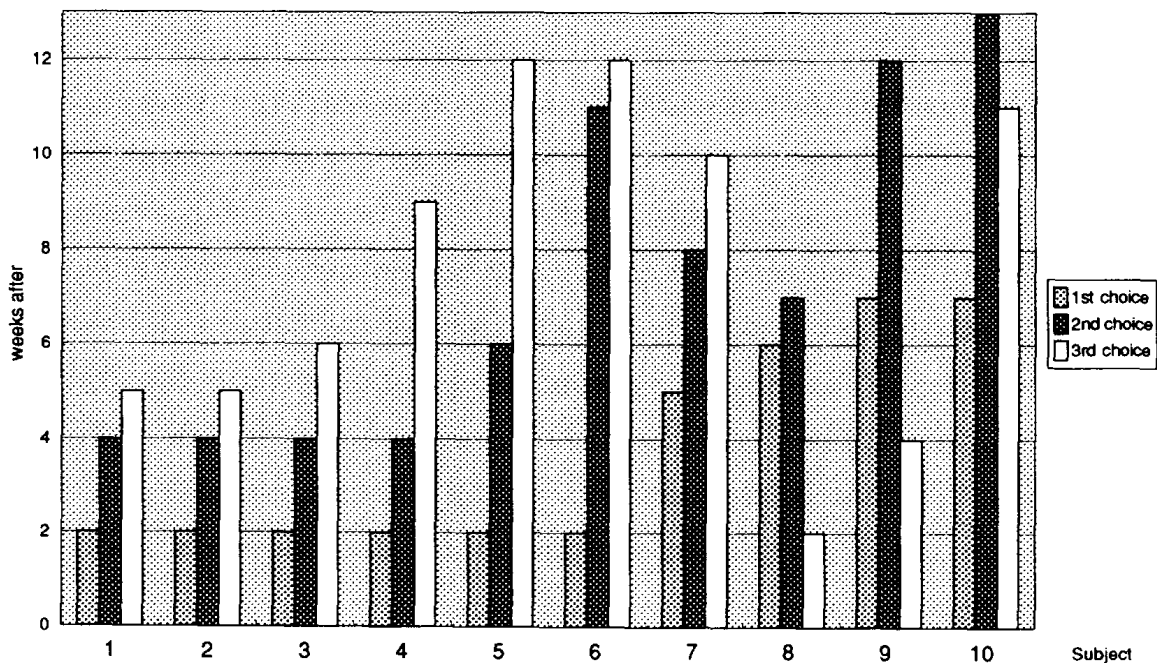

Figure 6: The responses to select the week to cancel one week without self control

Our expectation of result is the next week of the execution day of experiment is selected by many students because almost all students will have no plan on that day because they have been informed of nothing in advance.

Result were really interesting when we compare the result of experiment 5. Most replies were to select 1st weeks of the alternatives. The difference of result is thought to come from the absence of the self control of the subjects. The distance from the execution day was different, however, all alternatives are included in the autumn semester.

Questionnaire with hidden experiment 7: We made subjects declare the day of doing homework. Decision making is done without self control directly, however the planning is done with self control. Alternatives do not include today.

Our intention is to observe subjects attitude toward immediate cost of doing task. Alternatives do not include present but if subjects are sophisticated, they should take into account their present bias rather than discount rate. I stressed the subjects to answer frankly because this questionnaire had no relevance to their evaluation. believe their answers are completely honest because students need not pretend to be good students in front of me because I am really gentle from educational reason not to quit or hate the days of university[2] They also aware the system by which they are evaluated: that is, the contents of the presentation and the turn they presented by hidden experiment and the frequency to present the classes.

We make subject expect when they complete homework. Homework is to summarize one essay. The subjects are 1st degree students

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and they had learned how summarize essay logically for the last 3 months in their classes. They are told to complete homework until the first week of the autumn semester, 27 September.

Hidden experiment was done in 31 June. It was hidden experiment for subjects. They did not notice this choice was some experiment at all.I asked their request to have some additional lecture to complete homework. The additional lecture is not counted as a presentation for one class. Usually every presentation is counted and the frequency is important for their degree of this class unit. However, additional class for 60 minuets is not counted for that unit, so the meanings of additional class for subjects is only to some advice for completing homework. The day of additional class was held just after seasonal examination, the most favorable day for all students.

Our expectation of answers for this experiment for this option is easy. If a student is sophisticated, he will take this option. Such a student will select the earlier days of summer holidays. If a student is naive, he will never take this option because he believes he can do it himself. Such a student must select the latter days of summer holidays.

Results shows strong evidence of backward induction. We already observed the positive discount rate and present bias from experiments 3 and 5, we got surprisingly a sophisticated result. Almost all students selected of the 2nd week after the examination that meas they plan to do homework soon. However, some students refused to have 1 hour additional class to finish homework held just before the summer vacation. The students who answered to skip this class may be naive. The judgement is done when they submit their homework to me in September. Only 4 students came to the

additional class. The 3 students who came to this class were the all presenters. The last one is the who didn't declare to come. This was also interesting results when we evaluated the reality of their answers of questionnaires.

I gave no incentives to come to the additional class except helping homework. This is to complete the purpose to investigation as to whether the subject is sophisticated or not: whether they keep to their declared plan or not.

Most those who declare 'not to come' answered the last week to submit homework. They are also sophisticated in the meanings of O'Donohue and Rabin [5] in that they are aware of their present bias. This shows some limitation of their definition of the sophisticated decision.

Two months later, the autumn semester began, and the first class was held on 1st day of October. We require subjects to submit the homework. In the first plan, four students responded they wanted to finish their homework within 2 weeks, however, in the second plan, the students changed their plan to finish their homework on or just before the deadline. So they seem to be afraid of failing to doing their duty.

And we found one student is naive in the meaning of O'Donohue and Rabin. He believed himself to be time consistent, so even if he procrastinates doing his homework for his present bias and positive time discount rate, he had confidence to finish homework just before the deadline. In fact, he did not submit his homework on time.

He is also naive in the meaning of von Aure because he does not use backward induction at all. He knows he has a strong present bias, and he does not pretend to be a good student, so he answered
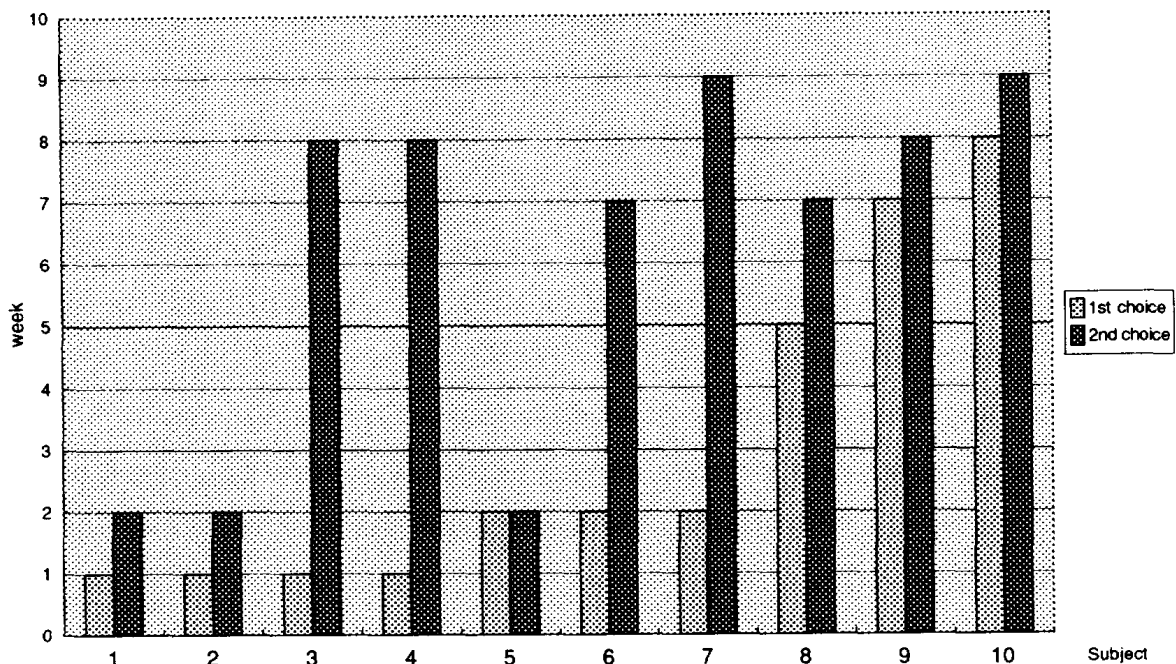
Figure 7: The responses to plan doing homework during summer vacation

very honestly. So the recognition of the present bias was useless to him.

Only half the students who chose the 2nd week to complete their homework did so. The others turned out to be naive people even though they use backward induction in their planning.

We can conclude that the ability to plan doing some task and keeping of it is another matter.

4 Conclusion

The results of all experiments were consistently interpreted.

First of all, we got the evidence subjects use backward induction when they plan to do something with self control. In contrast, when subjects are not confronted with the self control problem, we observed they do not use backward induction because it is not important. The results without self control problem were straightforward and really

easy to interpret. In this case, present bias was not so important.

As O'Donohue and Rabin [5] suggest, the present bias plays an important role when people need to solve self control problems. Especially, we found most subjects use backward induction because they are aware of their present bias when they faced some self control problem in experiment 1 and 2 which enforce subjects to solve intertemporal trade off problems. They took into account their own present bias when they must choose the day to take some cost.

The use of cautious choice, one of the sophisticated choices redefined by von Aure was repeatedly observed under specific conditions. In our experiments 4 and 5, half of our subjects have chosen the last day for one class cancelation. That means they planned the days of extensions of class to come earlier than the day of cancelation. This is the only way for subjects to conquer their self control problem by using enforcement power not to escape the class. In this case, those who selected the last day of cancelation completely erased their attractive alternatives to escape the short extended class. This is strong evidence of backward induction and we can judge such students are very sophisticated.

We can conclude the present bias of subjects comes from uncertainty of events rather than impatience when we compare the results of the experiments: to decide the timing of presentation to the results to decide the timing of cancelation of the class. Regardless of the advantage to be the earlier presenter, few subjects want to be the 1st presenter in hidden experiment 1 and 2. In contrast, to enjoy cancelation is not an uncertain event. In contrast half the subjects planed their cancelation for the final day which shows the subjects patience and therefore they are sophisticated.

From observation of present bias, We can conclude the (β, δ)-paradigm is useful when we interpret the planning and behaviors of sophisticated subjects.

However, we doubt naive people think themselves as time consistent

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and using backward induction when they plan their intertemporal problem. From the results of hidden experiment 1, three students replied they want to present in the 3rd week, however, they did not do anything or escaped from the class totally. They planned like a sophisticated person, but they proved to be naive. This result may come from the fact they cannot use backward induction itself, therefore, the definition of von Auer is more applicable to understand the choice mechanism of naive people.

Our sample is now too small to conform our interpretation by empirical method, however, if we can take samples several years in the same way, we will establish the fact that students use backward induction.

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Note

1) I am called devil mother because I never forgive anyone not to answer or 'I don't know'. Almost all students are ordered to redo of their presentation again and again. I sometimes hit their head when they are not thinking or chatting.