IMPATIENCE AND IMMEDIACY: A QUASI-HYPERBOLIC DISCOUNTING APPROACH TO SMOKING BEHAVIOR

TAKANORI IDA

Graduate School of Economics, Kyoto University, Yoshida, Sakyo, Kyoto 606-8501, Japan; Tel. & Fax: +81-75-753-3477; E-mail: ida@econ.kyoto-u.ac.jp

Abstract

This paper investigates smoking status, including nicotine dependence, on the basis of a quasi-hyperbolic discounting approach. This approach reconciles the traditional rational addiction model and the bounded rational addiction model. The paper measures two key parameters: impatience, in line with the former model, and immediacy, in line with the latter model. There are two main conclusions. First, the impatience and immediacy parameters are positively associated with smoking probability. Second, they are positively associated with nicotine dependence.

Keywords: smoking, nicotine dependence, time preference, impatience, immediacy

JEL classifications: D81, D91, I12

1. INTRODUCTION

Addiction has attracted considerable attention in health and behavioral economics, and economists have tried to understand addiction from the viewpoint of decision making over time (Chaloupka and Warner 2000). This viewpoint is relevant because consumers believe that an addictive product such as tobacco increases their current satisfaction, although it actually decreases their future utility by damaging their health. Furthermore, Fehr and Zych (1998) reported that addicts systematically consumed too much compared to the optimal consumption decision and explained this systematic excess consumption in terms of the psychologically salient features of addictive goods. It follows that reinforcement matters for addiction, because a larger stock of past consumption raises the marginal utility of current consumption (Becker and Murphy 1988, Gruber and Koszegi 2001). This paper investigates smoking, including nicotine dependence, the most common form of addiction, on the basis of the quasi-hyperbolic discounting approach proposed by Laibson (1997).

I now briefly describe smoking trends in Japan, where the percentage of smokers in the general population remains higher than the percentages of smokers in other developed nations. In fact, the prevalence rate of smoking among people aged 20 years and over was around 26.3% in Japan in 2006, still higher than the average figure of 24.0% among OECD countries. Although from 1990 to 2006, the smoking prevalence rate for males in Japan dropped from 53.1% to 41.3%, for females, it actually increased from 9.4% to 12.4%. As in other countries, reduction of the smoking rate has been a central issue in Japanese public health policy. *Healthy Japan 21*, a program established by the Ministry of Health, Labour, and Welfare, has promoted risk education, the eradication of smoking among teenagers, the establishment of nonsmoking areas, and effective support for smoking cessation as its four main measures for tobacco control. Nevertheless, the factors that successfully account for smoking behavior still remain undetermined.[1]

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[1]Cutler and Glaeser (2009) analyzed why there was a big difference in smoking rates between the U.S. and Europe. Interestingly, they discussed that the most important factor would be differences in beliefs about the health consequences of smoking between residents of the U.S. and of Europe.

There are two lines of research in the literature on addictive behaviors such as smoking: rational addiction models and bounded rational addiction models (Messinis 1999). A model of the first type was advocated by Becker and Murphy (1988); in this model, utility-maximizing consumers consider the future consequences of their past and current consumptions of addictive substances. The rational addiction model is thus compatible with such traditional economic models as the discounted utility schemes. Considerable research on time preference has reported that smokers are more impatient than non-smokers, and that they more frequently choose earlier-smaller rewards over later-larger rewards.[2] Examples of such studies include Mitchell (1999), Bickel et al. (1999), Odum et al. (2002), Baker et al. (2003), Reynolds et al. (2003), and Ohmura et al. (2005).

The second type of model is the bounded rational addiction model, an example of which is the model developed by Gruber and Koszegi (2001). In their model, the exponentially discounted utility hypotheses were systematically violated: some smokers neither recognized the true difficulty of quitting nor searched for self-control devices to help themselves quit. Gruber and Koszegi (2001) included strikingly different normative implications, because they suggested that government policy should consider not only the externalities imposed by smokers on others but also the internalities imposed by smokers on themselves (see also Winston 1980, Akerlof 1991, Kan 2007).

Are these two addiction models related? If so, are they complements or substitutes? Further, it is necessary to verify whether an addict is both impatient and present-biased. Note that estimating smoking behavior separately based on either a rational or bounded rational addiction model would result in omitted variable bias. These questions will be investigated in this paper. Very few studies, however, have focused on these aspects. One exception is Blondel et al. (2007), who compared the behavior of drug addicts with the behavior of a control group and discovered that the decisions of the drug users were largely consistent with standard decision-making theories. Furthermore, they found no differences in the estimated discount rates between the drug users and the control group.

[2] On the other hand, addiction can be interpreted as decision making under risk because the future health damage is stochastic. Although many studies have investigated the relationship between smoking and attitudes toward risk, the issue remains inconclusive (Mitchell 1999, Reynolds et al. 2003, Ohmura et al. 2005).

These conclusions are interesting, although the size of the sample was only 34. Expanding on Blondel et al. (2007), I draw a large sample to examine the relationship between the rationality and bounded-rationality approaches in the context of smoking.

Next, I discuss two points regarding measurement of the economic-psychological parameters adopted in this paper. First, most previous studies measured the time preference rate and risk preference coefficient separately when they examined smoking from the economic-psychological perspective.[3] Ida and Goto (2009) and Ida (2010), however, simultaneously measured the time preference rate and risk preference coefficient at the individual level using discrete choice experiments (DCE) and mixed logit (ML) model analysis. They found that smokers were more impatient and risk-prone than non-smokers, which was first reported by Viscusi and Hirsh (2001). I will use this simple model to simultaneously measure the parameters.

Second, and more importantly, I elucidate how likely it is that the stationarity axioms, which are required by discounted utility theory, are violated. I then assume that the time-inconsistent smokers have a quasi-hyperbolic discount function (Laibson 1997), so that lifetime utility from period τ onwards is given by

$$U_\tau = u_\tau + \beta \sum_{t=\tau+1}^{T} \delta^{t-\tau} u_t \ ,$$

where u_t is the periodic utility; the parameter β denotes present bias, or immediacy effect; and δ denotes the standard exponential discount factor, which reflects impatience[4]. I investigate whether these $\beta-\delta$ parameters can successfully predict smoking status, including nicotine dependence.

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[3]As Rachlin and Siegel (1994) suggest, the nature of the interaction between these parameters remains controversial because most previous studies measured them separately. This is analytically unsatisfactory. A few studies have integrated the measurements of time and risk preferences—for instance, Rachlin et al. (1991), Keren and Roelofsma (1995), Anderhub et al. (2001), and Yi et al. (2006).

[4]Most recently, however, Van der Pol and Cairns (2011) have sounded an alarm for the easy popularity of quasi-hyperbolic discount model. They have tested whether the quasi-hyperbolic model provides a better description of individual time preference for health outcomes when stationarity is violated, concluding that the quasi-hyperbolic model may not be appropriate as an intertemporal model.

This paper's main conclusions can be summarized as follows. First, I analyze whether the quasi-hyperbolic discounting parameters are associated with smoking. The analysis reveals that a 1% increase in the immediacy parameter (relatedly, β) significantly increases smoking probability by 0.2753%, while a 1% increase in the impatience parameter (relatedly, δ) increases smoking probability by 0.9384%. Second, I investigate how these parameters elucidate nicotine dependence. The analysis shows that a 1% increase in the immediacy parameter decreases the proportion of the low nicotine-dependent smokers by 0.5444% but increases that of the highly nicotine-dependent smoker by 0.4259%. Furthermore, a 1% increase in the impatience parameter decreases the proportion of the low nicotine-dependent smokers by 0.9324% but increases that of the highly nicotine-dependent smokers by 0.9522%. Thus, one can see that the quasi-hyperbolic discounting parameters function as good predictors of smoking status as a whole.

The paper is organized as follows. Section 2 explains the method of sampling data and discusses the characteristics of the sample. Section 3 proposes the strategy for estimating the quasi-hyperbolic discounting parameters and illustrates an ML model analysis. Section 4 explains the estimation models and their results, and Section 5 proposes four hypotheses and discusses the results. Section 6 provides concluding remarks.

2. SURVEY AND DATA

This section explains the survey method and describes the data. In July 2008, I surveyed 494 Japanese adults registered with a consumer-monitoring investigative company.[5] Note that 150 Japanese Yen (JPY) (1.5 US$, given 100 JPY = 1 US$) were paid to respondents who replied to the Fagerström Test for Nicotine Dependence (FTND), and 500 JPY (5 US$) were paid to respondents who replied to the conjoint questionnaire that I describe below. Respondents who answered in an unrealistically short period of

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[5]The samples were adjusted to reflect Japanese demographics for gender, average age, and geographical features of the sampling. Still, the size of sample (494) is limited, and, thus, it will be an important future topic of research to increase the sample and check the robustness.

time were excluded in advance.

Of those sampled, 253 were smokers, in which category the 59 ex-smokers were included, and 241 were non-smokers. In terms of demographics, the proportion of smokers who were female was 36.4%, and the proportion of non-smokers who were female was 51.5%. The average ages of the smokers and non-smokers were 40.5 and 38.1 years, respectively. Similarly, 46.2% of the smokers and 69.7% of the non-smokers were university or junior college graduates, and the annual household incomes were 5.9 million JPY (59 thousand US$) for smokers and 6.3 million JPY (63 thousand US$) for non-smokers.

I defined nicotine dependence as follows. On the basis of the FTND, current smokers were classified as heavy smokers (H), moderate smokers (M), or light smokers (L). FTND comprises the following six questions (Heatherton et al. 1991):

1. How soon after you wake up do you smoke your first cigarette? (1) Within 5 minutes (3 points), (2) 6–30 minutes (2 points), (3) 31–60 minutes (1 point), (4) After 60 minutes (0 points)
2. Do you find it difficult to refrain from smoking in places where it is forbidden, e.g., in church, at the library, at the cinema, etc.? (1) Yes (1 point), (2) No (0 points)
3. Which cigarette would you hate most to give up? (1) The first one in the morning (1 point), (2) All others (0 points)
4. How many cigarettes do you smoke a day? (1) 10 or less (0 points), (2) 11–20 (1 point), (3) 21–30 (2 points), (4) more than 30 (3 points)
5. Do you smoke more frequently during the first hours after waking than during the rest of the day? (1) Yes (1 point), (2) No (0 points)
6. Do you smoke even if you are so ill that you are in bed most of the day? (1) Yes (1 point), (2) No (0 points)

By aggregating the responses, I defined respondents with 0 to 3 points as having low nicotine dependence (L-smokers); with 4 to 6 points, as having moderate nicotine dependence (M-smokers); and with 7 or more points, as having high nicotine dependence (H-smokers). I found that 38.3% of the respondents were L-smokers; 43.8% M-smokers; and 17.8% H-smokers. The proportion female and the proportion university graduates are highest for L-smokers, and the average age is highest for H-smokers. Further, the average income level is highest for M-smokers. The basic statistics are summarized in Table 1.

<Table 1>

3. MEASURING THE IMPATIENCE AND IMMEDIACY PARAMETERS

In this section, I explain the derivation of the impatience and immediacy parameters and show the estimation results. The research strategy was composed of the following two steps. First, I conducted an experimental survey to check whether smokers displayed the discounted utility anomalies. Then, I classified the samples as time consistent or time inconsistent. Second, I used conjoint analysis to measure the immediacy parameter (relatedly, β) for the time-inconsistent samples and the impatience parameter (relatedly, δ) for both the time-consistent and time-inconsistent samples. I depict this strategy in Figure 1.

<Figure 1>

3.1. Discounted utility anomaly

Next, I address the discounted utility anomaly. The standard theory of decision making over time is the exponentially discounted utility model, whose key assumption is a stationarity axiom. This implies that if and only if the utility of 100,000 JPY in the present is indifferent with the utility of 150,000 JPY in one year, then the utility of 100,000 JPY in ten years is indifferent with the utility of 150,000 JPY in eleven years.

Assuming that X and Y denote payoffs ($X < Y$) and t and s denote time delay ($t < s$), the axiom is more formally defined as follows:

$$(X,t) \geq (Y,s) \text{ and } (X,t+\varepsilon) \geq (Y,s+\varepsilon).$$

Note that ε is a positive constant.

At this point, the discounted utility model gives $U(X)/(1 + r)^t \geq U(Y)/(1 + r)^s$ for t and s.[6] However, the discounted utility anomaly of a present-smaller reward being excessively preferred to a delayed-larger reward indicates the following inconsistent preference orders:

$$(X,t) \geq (Y,s) \text{ and } (X,t + \varepsilon) \leq (Y,s + \varepsilon).$$

This anomaly is called *time inconsistency* (Strotz 1956, Prelec 2004). Interestingly, it is observed even in animals, such as pigeons (Ainslie 1975).

I asked the respondents two hypothetical questions in order to investigate the discounted utility anomaly:

Question 1
Alternative 1: Receive 100,000 JPY (1,000 US$) *immediately*.
Alternative 2: Receive 150,000 JPY (1,500 US$) *in X years*.
What X makes the two alternatives equivalent?

Question 2
Alternative 1: Receive 100,000 JPY (1,000 US$) *in one year*.
Alternative 2: Receive 150,000 JPY (1,500 US$) *in Y years*.
What Y makes the two alternatives equivalent?

On the basis of the exponentially discounted utility model, when the utility of 100,000 JPY in the present equals the utility of 150,000 JPY *in X years*, I obtain the

[6]For continuous time, the exponentially discounted utility model is represented by $exp(-rt)U(X) \geq exp(-rs)U(Y)$.

following equation:

$$\text{Utility of 100,000 JPY} = \text{Utility of 150,000 JPY}/(1 + r)^X.$$

Note that r denotes the annual time preference rate.

And when the utility of 100,000 JPY *in one year* equals the utility of 150,000 JPY *in Y years*, I obtain the following equation:

$$\text{Utility of 100,000 JPY}/(1 + s) = \text{Utility of 150,000 JPY}/(1 + s)^Y.$$

If the time preference rate is constant ($r = s$), as the exponentially discounted utility model assumes, then $X/(Y - 1) = 1$ holds. However, the discounted utility anomaly $X/(Y - 1) < 1$ is frequently observed, so the time preference rate decreases for time delay ($r > s$). The main reason for this is the *immediacy effect*, wherein people tend to lay more emphasis on an immediate reward as opposed to a delayed one (Fredrick et al. 2002). For example, in Question 1, because Alternative 1 consists of an immediate reward, Alternative 2 requires that X be a relatively small figure (for example, one year). On the other hand, in Question 2, because Alternative 1 consists of a one-year-delayed reward, Alternative 2 requires that Y be a large figure (for example, three years). The time consistency index is defined as $X/(Y - 1)$. $X/(Y - 1) = 1$ indicates perfect consistency, while $X/(Y - 1) = 0$ indicates perfect inconsistency. It follows that $X/(Y - 1) = 0.5$ for the example above. In this way, I classify the samples as time consistent if $X/(Y - 1) = 1$ and time inconsistent otherwise.

Table 1 (right row) summarizes the proportions of the samples that are time inconsistent. The proportions are 0.299 for non-smokers and 0.352 for smokers, indicating that the behaviors of non-smokers are more consistent with the discounted utility hypothesis than those of smokers. For smokers, the proportions are as follows: 0.330 for L-smokers, 0.324 for M-smokers, and 0.440 for H-smokers, indicating that high nicotine dependence is associated with a less consistent time preference. The proportions are 0.297 for never-smokers and 0.305 for ex-smokers, showing that the tendency is similar for these groups.

3.2. Impatience and immediacy parameters

I now simultaneously measure the impatience and immediacy parameters (along with the risk preference coefficients) at the individual level using the DCE and ML model analysis. An advantage of simultaneously measuring the time preference rate and risk preference coefficient is that the time preference rate can be identified without assuming a utility functional form (risk preference coefficient) ad hoc. Andersen et al. (2008) argued that allowing for risk preference leads to a significant difference in the elicited discount rates.

The stated preference method (conjoint analysis) was used to simultaneously measure time and risk preferences for 494 valid respondents. Conjoint analysis assumes that a service is a profile composed of attributes. If I include too many attributes and levels, respondents find it difficult to answer the questions. On the other hand, if I include too few, the description of the alternatives becomes inadequate. After conducting several pretests, I determined the following alternatives, attributes, and levels.

Alternative 1
Reward, probability, and delay are fixed across profiles.
Reward: 100,000 JPY (1,000 US$)
Winning probability: 100%
Time delay: None

Alternative 2
Reward, probability, and delay vary across profiles.
Reward is either 150,000 JPY (1,500 US$), 200,000 JPY (2,000 US$), 250,000 JPY (2,500 US$), or 300,000 JPY (3,000 US$).
The winning probability is 40, 60, 80, or 90%.
The time delay is 1 month, 6 months, 1 year, or 5 years.

Because the number of profiles would become unmanageable if I considered all possible combinations, I avoid this problem by adopting an orthogonal planning method. Figure 2 depicts a representative questionnaire. I posed eight questions to each respondent.

<Figure 2>

Next, I explain the basic models for estimating the impatience and immediacy parameters for the time-consistent and time-inconsistent samples, respectively.

Time-Consistent Samples

Let the utility of alternative i be V_i (reward_i, probability_i, timedelay_i). The exponentially discounted and expected utility model is assumed for time-consistent samples to derive the functional form of V_i as follows:

Discounted utility: $\exp(-\mathit{IMPATIENCE}*\text{timedelay}_i)*\text{utility}(\text{reward}_i)$,

where *IMPATIENCE* denotes the constant rate of time preference.

Expected utility[7]: $\text{probability}_i*\text{utility}(\text{reward}_i)$.

Accordingly, rewriting V_i, I obtain

$$V_i(\text{reward}_i, \text{probability}_i, \text{timedelay}_i)$$
$$= \exp(-\mathit{IMPATIENCE}*\text{timedelay}_i)*\text{probability}_i*\text{utility}(\text{reward}_i).$$

At this point, I simply specify the functional form of utility as the *RISK*-th power of reward. Such a utility function is called the constant relatively risk-averse form, where the coefficient of the relative risk aversion is denoted by 1-*RISK*. Taking the logarithm of both sides, I obtain

$$\ln V_i(\text{reward}_i, \text{probability}_i, \text{timedelay}_i)$$
$$= -\mathit{IMPATIENCE}*\text{timedelay}_i + \ln \text{probability}_i + \mathit{RISK}*\ln \text{reward}_i.$$

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[7]If we consider index s as the state of nature ($s = 1, \ldots, S$), the expected utility is written as $\Sigma_{s=1,\ldots,S}\ \text{probability}_s*\text{utility}(\text{reward}_s)$. Note that here we simply assume that each alternative has only one state of nature other than the state of zero reward.

Time-Inconsistent Samples

Next, the quasi-hyperbolically discounted and expected utility model is assumed for time-inconsistent samples as follows:

Discounted utility:
$IMMEDIACY*\exp(-IMPATIENCE*\text{timedelay}_i)*\text{utility}(\text{reward}_i)$,
where *IMMEDIACY* indicates the immediacy effect, while *IMPATIENCE* denotes the constant rate of time preference.
Expected utility: $\text{probability}_i*\text{utility}(\text{reward}_i)$.

Accordingly, rewriting V_i, I obtain

$$V_i\,(\text{reward}_i, \text{probability}_i, \text{timedelay}_i)$$
$$= IMMEDIACY*\exp(-IMPATIENCE*\text{timedelay}_i)*\text{probability}_i*\text{utility}(\text{reward}_i).$$

Again, taking the logarithm of both sides, I obtain

$$\ln V_i\,(\text{reward}_i, \text{probability}_i, \text{timedelay}_i)$$
$$= \ln IMMEDIACY - IMPATIENCE*\text{timedelay}_i + \ln \text{probability}_i + RISK*\ln \text{reward}_i.$$

Thus, *IMPATIENCE* is estimated for both the time-consistent and time-inconsistent samples, while *IMMEDIACY* is estimated only for the time-inconsistent samples. (I delete ln before *IMMEDIACY* for simplification for the moment.)

Finally, I explain the estimation models. Conditional logit (CL) models, which assume independent and identical distribution (IID) of random terms, have been widely used in previous studies. However, the property of independence from the irrelevant alternatives (IIA), which is derived from the IID assumption of the CL model, is too strict to allow for flexible substitution patterns. The most appropriate scheme is an ML model that accommodates differences in the variance of random components (or unobserved heterogeneity). Such models are flexible enough to overcome the limitations of CL models by allowing random taste variation, unrestricted substitution patterns, and the correlation of random terms over time. See the Appendix for details on the ML models.

In what follows, I assume that the preference parameters—*IMMEDIACY*, *IMPATIENCE*, and *1-RISK*—follow a normal distribution. One can demonstrate variety in the parameters at the individual level with the maximum simulated likelihood (MSL) method for estimation using 100 Halton draws.[8] Furthermore, as the respondents answered eight questions as part of the conjoint analysis, the resultant data form a panel that offers the option of applying a standard random effect estimation. One can now calculate the estimator of the conditional mean of the random parameters at the individual level.

Table 2 summarizes the measurement results; the values represent the means and standard deviations. They are seemingly too complicated and difficult to interpret. The basic fact that smokers are more impatient than non-smokers is observed. The measured *IMPATIENCE* values, or monthly time preference rates, are 6.2% for smokers and 5.6% for non-smokers. The detailed results for smokers are as follows: 4.8% for L-smokers, 6.3% for M-smokers, and 6.4% for H-smokers, indicating that the heavier smokers are more impatient.

<Table 2>

Note that the measured time preference rates are very high compared with the rates in the economic literature. This is partly because I estimated the preferences using the hypothetical survey; the absent income constraints framework leads to biased responses. Furthermore, the discount factor is a function of the time horizon, which I partly address by the immediacy effect, and this is conspicuous when I consider intertemporal choice within one year. Fredrick et al. (2002) pointed out that there has been tremendous variability in discount rate estimation (from negative to infinity).

It can be seen, on the other hand, that simultaneously measuring the impatience and immediacy parameters leads to some unexpected results. Although smokers (0.98) have higher *IMMEDIACY* than non-smokers (0.85), M-smokers (0.69) have lower

[8]The adoption of the Halton sequence draw is an important issue to be examined (Halton 1960). Bhat (2001) found that 100 Halton sequence draws are more efficient than 1,000 random draws for simulating an ML model.

IMMEDIACY than L-smokers (1.32) and H-smokers (1.28). This may mean that M-smokers suffer the least from present bias.

Another anomaly is observed in that the measured 1-*RISK* values are negative, indicating that the samples are somewhat risk-prone. This is a counter-intuitive result. However, all the coefficients of relative risk aversion are not statistically significant, and therefore, the respondents are totally risk-neutral. It may be because the functional forms that I have assumed are so specific that the unobserved interdependencies among the parameters are not sufficiently addressed.[9]

Although many studies have investigated the relationship between smoking and attitudes toward risk, the issue remains inconclusive (Mitchell 1999, Reynolds et al. 2003, Ohmura et al. 2005)[10]. I reserve final judgment on the results for the moment, because my purpose is to investigate whether the impatience and immediacy parameters are associated with smoking, including nicotine dependence.

4. ESTIMATION MODEL AND RESULTS

In this section, I explain the ordered probit model with a sample selection equation and then discuss the estimation results.

4.1. Estimation model

I begin by explaining the estimation model that I adopted. The decision to smoke can be decomposed into two steps. First, one simply decides whether to smoke. Next, one decides how much to smoke, namely, one's degree of nicotine dependence. This two-step decision is considered an ordered probit model (in which nicotine dependence

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[9]It will be a topic for future research to consider the general approaches that recent research has advocated. For example, Andersen et al. (2008) simultaneously measured time and risk preferences and allowed the discounted utility function to take many alternative functional forms (e.g., exponential, hyperbolic, and so on).

10Gerking and Khaddaria (2011) have interestingly reported that perceived risk deters smoking among young people who have the good belief about the health damage from smoking but do not affect the smoking status of those who hold the opposite belief.

is classified into three groups, depending on FTND scores) with a binomial probit model (in which smoking is denoted by 1 and non-smoking by 0). I now comment on the ordered probit model with the sample selection equation.

The selection equation is a binominal probit model written as follows:

$$d_i^* = \alpha' Z_i + u_i,$$
$$d_i = 1 \ if \ d_i^* > 0 \ and \ 0 \ otherwise. \tag{1}$$

The structural equation is an ordered probit model written as follows:

$$\begin{aligned} y_i^* &= \beta' X_i + \varepsilon_i, \varepsilon_i \sim F(\varepsilon_i \mid \theta), E[\varepsilon_i] = 0, Var[\varepsilon_i] = 1, \\ y_i &= 0 \ if \ y_i^* \leq 0, \\ &= 1 \ if \ 0 \leq y_i^* \leq \mu, \\ &= 2 \ if \ \mu \leq y_i^*. \end{aligned} \tag{2}$$

The system $[y_i, X_i]$ is observable if and only if $d_i = 1$ holds. Selectivity matters if ρ is not equal to zero:

$$[\varepsilon_i, u_i] \sim N[0,0,1,1,\rho]. \tag{3}$$

The full information maximum likelihood (FIML) method is used to estimate the parameters, including ρ. FIML reduces to the limited information maximum likelihood (LIML) method if $\rho = 0$ holds.

The explained variables are given as follows. In the binomial model, the dummy variable is 1 for smoking and 0 for non-smoking; in the ordered probit model, the variable for nicotine dependence ranges from 0 (low) to 2 (high).

The explanatory variables are given as follows. First, the individual characteristic variables are a female dummy variable (*GENDER* = 0 for male, 1 for female), age (*AGE*), age squared (*AGESQ*), school history (*SCHOOL* = 1 for junior high school, 2 for high school, 3 for university, and 4 for graduate school), and annual household income (*INCOME*, million JPN). Next, the following are the economic-psychological parameters that were previously introduced: the immediacy effect (*IMMEDIACY*), the rate of time preference (*IMPATIENCE*), and the rate of risk preference (1-*RISK*).

4.2. Estimation Results

I begin the discussion of the estimation results, which are shown in Table 3, with the results of the binomial probit model.[11] The female dummy and school history are negatively associated with smoking probability, while the age variable is reverse U-shaped (with the peak around 51 years old). Further, annual household income does not influence smoking probability. The risk preference rate does not have a significant influence. Turning to the two key parameters, both *IMPATIENCE* and *IMMEDIACY* are significantly associated with smoking probability. In the following section, I investigate the detailed influence of those parameters on smoking behavior.

Then, I discuss the results of the ordered probit model. The female dummy and school history are negatively associated with nicotine dependence, while age is positively associated with nicotine dependence. Further, annual household income does not influence nicotine dependence. The risk preference rate positively influences nicotine dependence. Similar to the results of the binomial probit model, both *IMPATIENCE* and *IMMEDIACY* are significantly associated with nicotine dependence.

<Table 3>

5. DISCUSSIONS

In this section, I investigate the comprehensive effects of the time preference rate (*IMPATIENCE*) and the immediacy effect (*IMMEDIACY*) on the decision to smoke and on nicotine dependence.

The elasticities of smoking probability for these parameters are displayed in Table 4. Note that the elasticities are measured around the mean values. The first hypothesis is established for the elasticities of smoking probability with respect to the time preference rate.

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[11] At first, I conducted the FIML estimation, but I could not reject the null hypothesis (i.e. $\rho = 0$). Then, I carried out the LIML estimation.

<Table 4>

Hypothesis 1: *IMPATIENCE* and smoking probability
The higher the time preference rate, the higher the smoking probability.

I tested this hypothesis and obtained the following result.

Result 1: Hypothesis 1 is verified.
A 1% increase in the time preference rate significantly increased smoking probability by 0.9384% with 1% significance.

Smoking involves considerations such as current stress relief and future health damage. This explains the positive correlation between the time preference rate and smoking probability. The finding that smokers are more impatient than non-smokers with regard to delay discounting is consistent with previous research (Mitchell 1999, Bickel et al. 1999, Odum et al. 2002, Baker et al. 2003, Reynolds et al. 2004, Ohmura et al. 2005).

At this point, a reservation must be noted. This research only investigated the relationship between smoking and time preferences. I reserve judgment about causality because I cannot determine whether an impatient person tends to smoke or whether a smoker tends to become impatient. A detailed study of causality lies outside the scope of this paper. This is the most crucial area for future research[12].

The second hypothesis is established for the elasticities of smoking probability with respect to the immediacy effect.

Hypothesis 2: *IMMEDIACY* and smoking probability
The higher the immediacy effect, the higher the smoking probability.

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[12]Education is considered to be an important predictor of health. Van der Pol (2011) has investigated the role of time preference in the relationship between education and health, concluding that the effect of education reduces but does not disappear after controlling for time preference rates.

I obtained the following result.

Result 2: Hypothesis 2 is verified.
A 1% increase in the immediacy effect increased the smoking probability by 0.2753% with 5% significance.

Consequently, the immediacy effect also successfully accounts for smoking decisions. This is the most important finding of the paper. If one supposes that smoking results from discounted utility anomalies, higher consistency naturally leads to lower smoking probability. Several studies have regarded addiction as time-inconsistent behavior. For example, Gruber and Koszegi (2001) demonstrated that some smokers failed to recognize the true difficulty of quitting. Kan (2007) empirically studied time-inconsistent preferences in the context of cigarette smoking behavior and concluded that some smokers who wanted to quit had a demand for control devices, e.g., smoking bans in public areas or hikes in cigarette taxes. Result 2 is consistent with these studies.

Next, the elasticities of nicotine dependence with respect to the impatience and immediacy parameters are displayed in Table 5. The third hypothesis is established for the elasticities of nicotine dependence with respect to the time preference rate.

<Table 5>

Hypothesis 3: *IMPATIENCE* and nicotine dependence
The higher the time preference rate, the higher the nicotine dependence.

I tested the above hypothesis and obtained the following result.

Result 3: Hypothesis 3 is verified.
A 1% increase in the time preference rate decreased the proportion of low nicotine-dependent smokers by 0.9324% with 5% significance but increased the proportion of highly nicotine-dependent smokers by 0.9522% with 1% significance. However, a 1% increase in the time preference rate did not influence the proportion of moderately nicotine-dependent smokers.

In light of this result, the time preference rate accounts for the higher and lower degree of nicotine dependence, which is consistent with the findings of previous research. For example, Reynolds et al. (2004) reported a significant positive correlation between the number of cigarettes smoked daily and the time preference rate, and Ohmura et al. (2005) suggested that both the frequency of nicotine self-administration as well as the dosage were positively associated with greater delay discounting.

The fourth hypothesis is established for the elasticities of nicotine dependence with respect to the immediacy effect.

Hypothesis 4: *IMMEDIACY* and nicotine dependence
The higher the immediacy effect, the higher the nicotine dependence.

I obtained the following result.

Result 4: Hypothesis 4 is verified.
A 1% increase in the immediacy effect decreased the proportion of low nicotine-dependent smokers by 0.5444% with 10% significance but increased the proportion of highly nicotine-dependent smokers by 0.4259% with 5% significance. However, a 1% increase in the immediacy effect did not influence the proportion of moderately nicotine-dependent smokers.

The immediacy effect also successfully accounts for nicotine dependence; this finding is consistent with previous research. For example, Gruber and Koszegi (2001) developed a new model of time inconsistency and argued that government policy should consider not only the externalities that smokers impose on others but also the internalities imposed by smokers on themselves. In this context, we can consider the concept of *libertarian paternalism* advocated by Thaler and Sunstein (2008). They insist that with bounded rationality, it is preferable to maintain freedom of choice on the one hand, as well as to design private and public institutions for improving people's welfare on the other hand[13]. In conclusion, both impatience and immediacy can suitably account

[13]It is important to distinguish the welfare effects of happy and unhappy addicts. De

for smoking and nicotine dependence.

6. CONCLUSIONS

This paper investigated smoking status, including nicotine dependence, on the basis of a quasi-hyperbolic discounting approach, which reconciled the rational addiction model and the bounded rational addiction model. First, from the analysis of whether the impatience parameter was associated with smoking, it was found that the time preference rate significantly increased smoking probability. Furthermore, it was found that the higher the immediacy effect, the higher is the smoking probability. Second, from the investigation into how immediacy can elucidate nicotine dependence, it was discovered that immediacy, along with impatience, was positively associated with nicotine dependence. Thus, it became clear that both impatience and immediacy function as good predictors of smoking status.

The above results mark a breakthrough in smoking research. However, some unsolved problems remain. As this research investigated only the relationship between smoking and time preferences, I reserve judgment about causality because I cannot determine whether an impatient person tends to smoke or whether a smoker tends to become impatient. A detailed study of causality lies outside the scope of this paper. This is a crucial area for future research. Furthermore, I assumed that delay and risk were distinguished by the questionnaires. However, the literature, including Rachlin et al. (1991) and Sozou (1998), has demonstrated that both risk and delay of reward elicited the same underlying form of intolerance, because the value of a future reward should be discounted such that there exists a risk that the reward will not be realized. On the other hand, other studies such as Green and Myerson (2004) have shown that time and probability discounting are different and dissociable processes. I consider these issues as potential topics for future research.

Chaisemartin et al. (2011) have recently discussed that workplace smoking ban may improve happy addicts' welfare.

APPENDIX. ML MODEL

Assuming that parameter β_n is distributed with density function $f(\beta_n)$, the ML specification allows for repeated choices by each sampled decision maker in such a way that the coefficients vary over people but are constant over choice situations for each person (Train 2003). The logit probability of decision maker *n* choosing alternative *i* in choice situation *t* is expressed as

$$L_{nit}(\beta_n) = \prod_{t=1}^{T} [\exp(V_{nit}(\beta_n)) / \sum_{j=1}^{J} \exp(V_{njt}(\beta_n))],$$

which is the product of normal logit formulas, given parameter β_n, the observable portion of utility function V_{nit}, and alternatives *j=1, ..., J* in choice situations *t = 1, ..., T*. Therefore, the ML choice probability is a weighted average of logit probability $L_{nit}(\beta_n)$ evaluated at parameter β_n with density function $f(\beta_n)$, which can be written as

$$P_{nit} = \int L_{nit}(\beta_n) f(\beta_n) d\beta_n .$$

In the linear-in-parameter form, the utility function can be written as

$$U_{nit} = \beta_n ' x_{nit} + \varepsilon_{nit} ,$$

where x_{nit} denotes observable variables, β_n denotes a random parameter vector, and ε_{nit} denotes an independently and identically distributed extreme value (IIDEV) term.

Since ML choice probability is not expressed in closed form, simulations need to be performed for the ML model estimation (see Train 2003, p. 148 for details). One can also calculate the estimator of the conditional mean of the random parameters, conditioned on individual specific choice profile y_n, given as

$$h(\beta \mid y_n) = [P(y_n \mid \beta) f(\beta)] / \int P(y_n \mid \beta) f(\beta) d\beta .$$

Here, I assume that the preference parameters—*IMPATIENCE, IMMEDIACY*, and *RISK*—follow a normal distribution.

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TABLE 1: Basic Demographics

	SAMPLE NO.	FEMALE RATIO	AVERAGE AGE	UNIVERSITY GRADUATION RATIO	AVERAGE HOUSEHOLD INCOME (JPY)	TIME INCONSISTENT RATIO
NON-SMOKER	241	0.515	38.14	0.697	6.3 M	0.299
NEVER-SMOKER	182	0.566	35.26	0.714	6.1 M	0.297
EX-SMOKER	59	0.356		0.644	7.2 M	0.305
SMOKER	253	0.364	40.48	0.462	5.9 M	0.352
L-SMOKER	97	0.485	38.30	0.505	5.7 M	0.330
M-SMOKER	111	0.315	40.86	0.450	6.3 M	0.324
H-SMOKER	45	0.222	44.22	0.400	5.5 M	0.467

FIGURE 1: Research Strategy

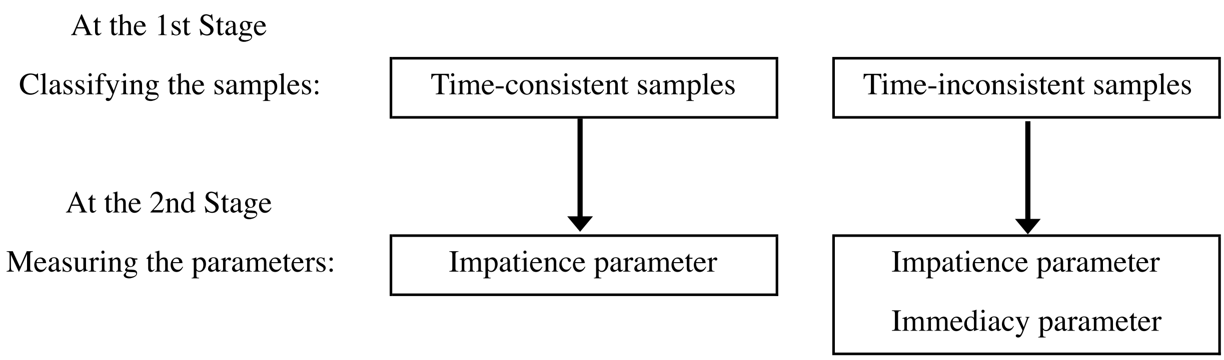

FIGURE 2: Representative Questionnaire

	ALTERNATIVE 1	ALTERNATIVE 2
REWARD	JPY 100,000	JPY 250,000
TIME DELAY	NOW	1 MONTH LATER
WINNING PROBABILITY	100%	80%
	↓	↓
CHOOSE ONE		

TABLE 2: Impatience, Immediacy, and Risk Parameters

		IMPATIENCE	ln IMMEDIACY	1-RISK
NON-SMOKER	MEAN	0.0564 (0.0136) ***	0.8453 (0.4424) *	-0.2356 (0.2686)
	S.D.	0.0336 (0.0146) ***	0.0087 (0.4748)	0.4383 (0.3676)
NEVER-SMOKER	MEAN	0.0497 (0.0101) ***	0.8909 (0.3852) **	-0.1816 (0.2112)
	S.D.	0.0238 (0.0099) **	0.0085 (0.4093)	0.2502 (0.3594)
EX-SMOKER	MEAN	0.0325 (0.0075) ***	0.70475 (0.6188)	-0.0832 (0.4456)
	S.D.	0.00018 (0.01585) **	0.0095 (0.6767)	1.0970 (0.4257) **
SMOKER	MEAN	0.0622 (0.0221) ***	0.9797 (0.5332) *	-0.3244 (0.3634)
	S.D.	0.0358 (0.0230) *	0.1071 (0.6233)	0.7130 (0.4050) *
L-SMOKER	MEAN	0.0484 (0.0147) ***	1.3246 (0.5045) ***	-0.4076 (0.3236)
	S.D.	0.0250 (0.0198)	0.0053 (0.4272)	0.6328 (0.3400) *
M-SMOKER	MEAN	0.0625 (0.0139) ***	0.6938 (0.4735)	-0.1486 (0.3156)
	S.D.	0.0310 (0.0147) **	0.1089 (0.4572)	0.8685 (0.2689) **
H-SMOKER	MEAN	0.0643 (0.0384) *	1.2779 (0.6470) **	-0.5779 (0.5605)
	S.D.	0.0428 (0.0445)	0.0380 (0.6297)	0.7008 (0.7525)

Note1: The values in parentheses denote the standard errors of MEAN and S.D. estimates for the random parameters. *** 1% significant level ($p<0.01$), ** 5% significant level ($p<0.05$), * 10% significant level ($p<0.1$).

Note2: IMPATIENCE and 1-RISK are estimated for both time-consistent and time-inconsistent samples, while ln IMMEDIACY is estimated only for the time-inconsistent samples.

TABLE 3: Estimation Results

SAMPLE NO.	494	
LOG LIKELIHOOD	-535.02089	

	Coefficient	S.E.	
BINOMIAL PROBIT MODEL			
IMPATIENCE	21.8859	2.90418	***
ln IMMEDIACY	0.44596	0.20906	**
GENDER	-0.44718	0.12007	***
AGE	0.04893	0.01851	***
AGE SQUARED	-0.00048	0.00023	**
SCHOOL	-0.58687	0.09891	***
INCOME (M JPY)	-0.0105	0.01771	
1-RISK	0.12317	0.16209	
ORDERED PROBIT MODEL			
IMPATIENCE	19.5937	7.0520	***
ln IMMEDIACY	0.5696	0.2660	**
GENDER	-0.5938	0.2189	***
AGE	0.0390	0.0191	**
AGE SQUARED	-0.0001	0.0002	
SCHOOL	-0.4663	0.2477	*
INCOME (M JPY)	0.0117	0.0188	
1-RISK	0.5069	0.1557	***
THRESHOLD PARAMETER	1.84819	0.12452	***

Note: *** 1% significant level (p<0.01), ** 5% significant level (p<0.05), * 10% significant level (p<0.1).

TABLE 4: Smoking Probabilities Elasticities for Binomial Probit Model

	Elasticity	S.E.	
IMPATIENCE	0.9384	0.1238	***
IMMEDIACY	0.2753	0.1292	**

Note 1: *** 1% significant level (p<0.01), ** 5% significant level (p<0.05).

Note 2: The IMMEDIACY elasticities are calculated only for the time-inconsistent samples.

TABLE 5: Nicotine Dependence Elasticities for Ordered Probit Model

L-SMOKER

	Elasticity	S.E.	
IMPATIENCE	-0.9324	0.4461	**
IMMEDIACY	-0.5444	0.3058	*

M-SMOKER

	Elasticity	S.E.	
IMPATIENCE	0.8341	0.6893	
IMMEDIACY	0.3117	0.2735	

H-SMOKER

	Elasticity	S.E.	
IMPATIENCE	0.9522	0.2638	***
IMMEDIACY	0.4259	0.1812	**

Note 1: *** 1% significant level ($p<0.01$), ** 5% significant level ($p<0.05$).

Note 2: The IMMEDIACY elasticities are calculated only for the time-inconsistent samples.