

**Can Economic-Psychological Parameters
Account for Smoking Status?
Time Preference, Risk Aversion, and Anomaly**

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Abstract This paper investigated smoking status, including nicotine dependence, on the basis of four economic-psychological parameters. Two of them are rational addiction parameters—time preference rate and risk aversion coefficient—and the other two are bounded rational addiction parameters—time consistency index and risk consistency index. The time preference rate is positively associated with smoking probability, while the risk aversion coefficient is negatively associated with smoking probability. At the same time, the time and risk consistency indexes are negatively associated with smoking probability. Although economic-psychological parameters can account for smoking status on the whole, certain exceptions are found with regard to risk preference. These exceptions can be attributed to nicotine dependence.

Keywords smoking, anomaly, time preference rate, risk aversion coefficient

JEL classifications D81, D91, I12

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I. Introduction

Addiction has attracted considerable attention in health and behavioral economics, and economists have tried to understand addiction from the viewpoints of decision making over time and under risk (Chaloupka and Warner 2000). On the one hand, addiction can be interpreted as decision making over time, since consumers believe that an addictive product such as tobacco increases their current satisfaction, although it actually decreases future utility by damaging their health. On the other hand, addiction is decision making under risk because the future health damage is stochastic. This paper investigates smoking, the most common form of addiction, including nicotine dependence, on the basis of the time preference rate, risk aversion coefficient, discounted utility anomaly, and expected utility anomaly.

We now briefly describe smoking trends in Japan, where the percentage of smokers in the general population remains higher than those in other developed nations. In fact, the prevalence of smoking among people aged 20 years and over was around 26.3% in 2006, higher than the average figure of 24.0% among OECD countries. Although from 1990 to 2006, the smoking prevalence for males 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 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, 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 remain undetermined.

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 and expected utility schemes. Considerable research on time preference has reported that smokers are more impatient than nonsmokers and more frequently choose earlier-smaller rewards over later-larger rewards. 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). On the other hand, research on risk preference is not adequate enough to determine a link between smoking and risk-prone preferences. Thus, further research on this relationship is required. Another problem is that past studies measured the time preference rate and risk aversion coefficient separately when examining smoking from the economic and psychological perspective². Ida and Goto (2009), however, simultaneously measured the time preference rate and risk aversion 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 nonsmokers.

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 and expected utility hypotheses were systematically violated: individuals neither recognized the true difficulty of quitting nor searched for self-control devices to help them quit. Gruber and Koszegi included strikingly different normative implications, since 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 complementary or substitutes? These questions will be investigated in this paper. Further, we need to verify whether an addict is both impatient and time-inconsistent and whether a risk-seeking smoker is likely to violate the expected utility hypothesis. Note that estimating smoking behavior separately based on either rational or bounded rational addiction model would cause an omitted variables bias. Very few studies, however, have focused on these aspects. One exception is Blondel et al. (2007), who compared the behavior of drug addicts with that of a control group and discovered that the decisions of the drug users, over time and under risk, 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, although the former did appear to be more risk-seeking. These

²A 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).

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

Next, we explain the two approaches for measuring the economic-psychological parameters adopted in this paper. First, we developed a simple method to simultaneously measure the *rate of time preference* and the *coefficient of risk aversion*. As Rachlin and Siegel (1994) suggest, the nature of the interaction between these parameters remains controversial because most previous studies measured them separately, which is analytically unsatisfactory. Accordingly, this paper simultaneously measures the rate of time preference and the coefficient of risk aversion at the individual level by following Ida and Goto (2009). Second, we elucidate how likely the stationarity axioms, which are necessary for the discounted utility theory, and the independence axiom, which is necessary for the expected utility theory, are violated³. We refer to these anomalies the *time consistency index* and the *risk consistency index*, respectively. These indexes indicate the incidence rates of anomalies, where the indexes are normalized such that 0 indicates perfect inconsistency and 1, perfect consistency. We investigate whether the four economic-psychological parameters can successfully predict smoking status, including nicotine dependence.

Finally, this paper's main conclusions can be summarized in two points. First, we analyze whether the economic-psychological parameters are associated with smoking. The analysis reveals that a 1% increase in the time preference rate significantly increases smoking probability by 0.7089%, while a 1% increase in the risk aversion coefficient significantly decreases smoking probability by 0.2031%. Furthermore, as expected, a 1% increase in the time consistency index decreases smoking probability by 0.7497%, while the risk consistency index decreases smoking probability by 1.2606%. Second, we investigate how the economic-psychological parameters elucidate nicotine dependence. Our analysis shows that a 1% increase in the time preference rate

³A most interesting study related to this issue is Tanaka et al. (2009), who conducted experiments in Vietnamese villages to determine the predictors of risk and time preferences. They found that household income was correlated with patience but not with risk; in addition, they expanded measurements of risk and time preferences beyond expected utility and exponential discounting.

expectedly increases the nicotine dependence score by 0.1540%, but a 1% increase in the risk aversion coefficient increases the nicotine dependence score by 0.1013%, contrary to expectation. Furthermore, a 1% increase in the time consistency index expectedly decreases the nicotine dependence score by 0.5901%, and a 1% increase in the risk consistency index less intuitively increases the nicotine dependence score by 0.4597%. Thus, we can see that the economic-psychological parameters function as good predictors of smoking status on the whole, although exceptions were discovered with regard to risk preference. These exceptions can be attributed to nicotine dependence.

The paper is organized as follows. Section II explains the method of sampling data and discusses the characteristics of the sample. Section III proposes the discounted and expected utility models for estimating the economic-psychological parameters and illustrates an ML model analysis. Section IV explains the estimation models and their results, and Section V proposes four hypotheses and discusses the results. Section VI makes concluding remarks.

II. Survey and Data

This section explains the survey method and the data. In July 2008, we surveyed 435 Japanese adults registered with a consumer monitoring investigative company⁴. Of them, 253 were smokers and 182 were nonsmokers⁵. In terms of demographics, the ratio of female smokers was 36.4% and that of female nonsmokers was 56.6%. The average ages of smokers and nonsmokers were 40.5 and 35.3 years respectively. Similarly, 38.7% of the smokers and 57.1% of the nonsmokers were university graduates, and the annual household incomes were JPY 5,950,593 (US\$59,506, given JPY 100 = US\$1) and JPY 6,052,198 (US\$60,522) for smokers and for nonsmokers, respectively.

⁴The samples were adjusted to represent Japanese demographics for gender, average age, and geographical features.

⁵ Around 250 smokers and nonsmokers were collected; the smokers included ex-smokers and never-smokers. The 59 ex-smokers were excluded from the sample in order to simplify the analysis.

We defined nicotine dependence as follows. On the basis of the Fagerström Test for Nicotine Dependence (FTND), current smokers were classified as heavy (H), moderate (M), and light (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, we defined respondents with 0 to 3 points as having low nicotine dependence (L-smokers); 4 to 6 points, as moderate nicotine dependence (M-smokers); and 7 and above, as high nicotine dependence (H-smokers). We found that 38.3% of the respondents were L-smokers; 43.8%, M-smokers; and 17.8%, H-smokers. The female ratio is the highest for L-smokers, and the average age and ratio of university graduates are the lowest in the case of H-smokers. Further, the average income level is the highest for M-smokers. The basic statistics are summarized in Table 1.

<Table 1>

III. Measuring Economic-psychological Parameters

In this section, we explain the derivation of the economic-psychological parameters and show the estimation results. First, we used conjoint analysis to measure the time preference rate and risk aversion coefficient. Second, we conducted an experimental survey to check the discounted and expected utility anomalies.

A. Time Preference and Risk Aversion Parameters

The stated preference method (conjoint analysis) was used to simultaneously measure time and risk preferences for 435 valid respondents⁶. Conjoint analysis assumes that a service is a profile composed of attributes. If we include too many attributes and levels, respondents find it difficult to answer the questions. On the other hand, if we include too few, the description of the alternatives becomes inadequate. After conducting several pretests, we determined the following alternatives, attributes, and levels.

Alternative 1

Reward, probability, and delay are fixed across profiles.

Reward: JPY 100,000 (US\$1,000)

Winning probability: 100%

Time delay: None

Alternative 2

⁶An advantage of simultaneously measuring the time preference rate and risk aversion coefficient is that the time preference rate can be identified without assuming a utility functional form (risk aversion coefficient) ad hoc. Andersen et al. (2008) argued that allowing for risk aversion leads to a significant difference in the elicited discount rates.

Reward, probability, and delay vary across profiles.

Reward is either JPY 150,000 (US\$1,500), 200,000 (US\$2,000), 250,000 (US\$2,500), or 300,000 (US\$3,000).

The winning probability is 40, 60, 80, or 90%.

The time delay is 1 month, 6 months, 1 year, or 5 years.

Since the number of profiles becomes unmanageable if we consider all possible combinations, we avoided this problem by adopting an orthogonal planning method. Figure 1 depicts a representative questionnaire. We posed eight questions to each respondent.

<Figure 1>

Next, we explain the discounted and expected utility models that form the basis for estimating the time preference rates and risk aversion coefficients. Let the utility of alternative i be $V_i(\text{reward}_i, \text{probability}_i, \text{timedelay}_i)$. The exponentially discounted utility model and the (linear in probability) expected utility model are used to derive the functional form of V_i as follows:

Discounted utility: $\exp(-TIME * \text{timedelay}_i) * \text{utility}(\text{reward}_i)$,
where the parameter $TIME$ denotes the rate of time preference.
Expected utility⁷: $\text{probability}_i * \text{utility}(\text{reward}_i)$.

Accordingly, rewriting V_i , we obtain

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

At this point, we simply specify the functional form of utility as the $RISK$ -th power of

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

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 logarithms of both sides, we obtain

$$\begin{aligned} & \ln V_i(\text{reward}_i, \text{probability}_i, \text{timedelay}_i) \\ &= -TIME * \text{timedelay}_i + \ln \text{probability}_i + RISK * \ln \text{reward}_i. \end{aligned}$$

Two points should be noted here: first, a greater level of impatience implies a larger $TIME$; second, since a risk-averse attitude is denoted by $1-RISK \in [0,1]$, a greater level of risk aversion implies a larger value of $1-RISK$.

Finally, we explain the estimation models. Conditional logit (CL) models, which assume independent and identical distribution (IID) of random terms, have been widely used in past studies. However, the property of independence from the irrelevant alternatives (IIA), derived from the IID assumption of the CL model, is too strict to allow flexible substitution patterns. The most appropriate scheme is an ML model that accommodates differences in the variance of random components (or unobserved heterogeneity). These 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 (McFadden and Train 2000). See the APPENDIX for details of the ML models.

In what follows, we assume that the preference parameters regarding time and risk follow normal distribution.

$TIME$ (rate of time preference)

$RISK$ (coefficient of relative risk aversion represented by $1-RISK$).

We can demonstrate variety in the parameters at the individual level using the maximum simulated likelihood (MSL) method for estimation by setting 100 Halton draws⁸. Furthermore, as the respondents answered eight questions as part of the conjoint

⁸The 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.

analysis, the resultant data form a panel that offers the option of applying standard random effect estimation. We can now calculate the estimator of the conditional mean of the random parameters at the individual level.

Table 2 summarizes the measurement results of the time preference rate and risk aversion coefficient, where the values represent the means and standard errors. The measured time preference rates (monthly) are 7.0% for smokers and 5.1% for nonsmokers, which is consistent with Ida and Goto (2009). The t value with respect to the difference in both figures is 140.3 and thus, is highly significant. The detailed results for smokers are as follows: 5.6% for L-smokers, 7.7% for M-smokers, and 8.2% for H-smokers, indicating that higher nicotine dependence is associated with more myopic preference. The t values with respect to the differences in these figures are 67.3 between L- and M-smokers, 27.3 between L- and H-smokers, and 5.1 between M- and H-smokers. All the results are highly significant.

Next, the measured risk aversion coefficients are 3.9% for smokers and 10.7% for nonsmokers, which is also consistent with Ida and Goto (2009). The t value with respect to the difference in both figures is 51.3 and thus, is highly significant. The detailed results for smokers are as follows: 5.6% for L-smokers, 4.2% for M-smokers, and -0.8% for H-smokers, indicating that higher nicotine dependence is associated with less risk-averse preference. Note that the heaviest smokers are classified as risk-prone. The t values for the differences in these figures are 3.3 between L- and M-smokers, 20.4 between L- and H-smokers, and 11.6 between M- and H-smokers. All these results are also highly significant.

<Table 2>

B. Discounted and Expected Utility Anomalies

Next, we address two anomalies. First, we explain the discounted utility anomaly. The standard theory of decision making over time is the exponentially discounted utility model, whose key assumption is a *stationality* axiom. This implies that if and only if the utility of JPY 100,000 at present is independent of the utility of JPY 150,000 in one year, then the utility of JPY 100,000 in ten years is independent of the utility of JPY 150,000

in eleven years.

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

$$(X,t) \geq (Y,s) \Leftrightarrow (X,t+\varepsilon) \geq (Y,s+\varepsilon).$$

Note that ε is a positive constant.

At this point, the discounted utility model demonstrates $U(X)/(1+r)^t \geq U(Y)/(1+r)^s$ for t and s ⁹. However, the discounted utility anomaly of a present-smaller reward being excessively preferred to a delayed-larger reward indicates the following inconsistent preference orders:

$$(X,t) \geq (Y,s) \Leftrightarrow (X,t+\varepsilon) \leq (Y,s+\varepsilon).$$

This anomaly is called *time inconsistency* (Strotz 1956)¹⁰, which is interestingly observed even in the case of animals, including pigeons (Ainslie 1975).

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

Question 1

Alternative 1: Receive JPY 100,000 (US\$1,000) *immediately*.

Alternative 2: Receive JPY 150,000 (US\$1,500) *in X years*.

What X makes the two alternatives independent?

Question 2

Alternative 1: Receive JPY 100,000 (US\$1,000) *in one year*.

Alternative 2: Receive JPY 150,000 (US\$1,500) *in Y years*.

What Y makes the two alternatives independent?

⁹For continuous time, the exponentially discounted utility model is represented by $\exp(-rt)U(X) \geq \exp(-rs)U(Y)$.

¹⁰A model considers a decreasing discount rate as hyperbolically discounting, which is represented by $U(X)/(1+t)^r$.

On the basis of the exponentially discounted utility model, when the utility of JPY 100,000 at present equals the utility of JPY 150,000 *in X years*, we obtain the following equation:

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

Note that r denotes the annual time preference rate.

On the other hand, when the utility of JPY 100,000 *in one year* equals the utility of JPY 150,000 *in Y years*, we obtain the following equation:

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

If the time preference rate is constant ($r = s$), as the exponentially discounted utility model assumes, then $X/(Y - 1) = 1$ holds. However, 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. 2000). In Question 1, since Alternative 1 includes an immediate reward, Alternative 2 requires that X be a relatively small figure (for example, one year). On the other hand, in Question 2, since Alternative 1 includes 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.

Next, we explain the expected utility anomaly, whose key assumption is the *independence* axiom. If lottery X is preferred to lottery Y , mixing lotteries X and Y with irrelevant third lotteries W and Z with common probability $1 - P$ preserves the preference orders:

$$(X, P; Z, 1 - P) > (Y, P; Z, 1 - P) \Leftrightarrow (X, P; W, 1 - P) > (Y, P; W, 1 - P).$$

We asked the respondents two questions in order to investigate the expected utility anomaly:

Question 1

Alternative 1: Receive a *guaranteed* JPY 100,000 (US\$1,000).

Alternative 2: Receive JPY 200,000 (US\$2,000) at $X\%$.

What X makes the two alternatives independent?

Question 2

Alternative 1: Receive JPY 100,000 (US\$1,000) at 50%.

Alternative 2: Receive JPY 200,000 (US\$2,000) at $Y\%$.

What Y makes the two alternatives independent?

On the basis of the expected utility model, when the utility of JPY 100,000 at 100% equals the utility of JPY 200,000 at $X\%$, we obtain the following equation:

$$\text{Utility of JPY 100,000} = X/100 \times \text{Utility of JPY 200,000}.$$

The preference between Alternatives 1 and 2 is preserved when dividing them by a common ratio. For example, when the utility of JPY 100,000 at 50% equals the utility of JPY 200,000 at $Y\%$, we obtain the relationship $2Y/X = 1$. However, the expected utility anomaly $2Y/X < 1$ is frequently observed. This is called the common ratio anomaly or the violation of the independence axiom (Allais 1953). The main reason for this is the *certainty effect*, whereby people markedly prefer an assured reward in comparison to a risky reward (Starmer 2000). In Question 1, since Alternative 1 is a certain reward, Alternative 2 requires that X be of a relatively large value (for example, 0.8). On the other hand, in Question 2, since Alternative 1 includes a risk (with probability 0.5), Alternative 2 requires that Y be of a small value (for example, 0.3). The risk consistency index is defined as $2Y/X$. $2Y/X = 1$ indicates perfect consistency, while $2Y/X = 0$ indicates perfect inconsistency. It follows that $2Y/X = 0.75$ for the example above.

Table 2 also summarizes the measurement results of the time and risk consistency indexes, where the values represent the means and standard errors. The measured time consistency indexes are 0.7971 for smokers and 0.8375 for nonsmokers, which indicates that nonsmokers are more consistent with the discounted utility anomaly hypothesis than smokers. The t value for the difference in both figures is 21.3 and thus, is highly

significant. The detailed results for smokers are as follows: 0.8196 for L-smokers, 0.8070 for M-smokers, and 0.7241 for H-smokers, indicating that heavier nicotine dependence is associated with less consistent time preference. The t values with respect to the differences in these figures are 3.2 between L- and M-smokers, 12.3 between L- and H-smokers, and 10.8 between M- and H-smokers. All these results are highly significant.

Next, the measured risk consistency indexes are 0.8756 for smokers and 0.8905 for nonsmokers, which indicates that nonsmokers are more consistent with the expected utility anomaly hypothesis than smokers. The t value for the difference in both figures is 13.5 and thus, is highly significant. The detailed results for smokers are as follows: 0.8681 for L-smokers, 0.8667 for M-smokers, and 0.9137 for H-smokers. Therefore, we do not observe an intuitively plausible relationship between nicotine dependence and the risk consistency index, since, contrary to our expectation, the heaviest smokers have the most consistent risk preferences. The t values for the differences in these figures are 0.6 between L- and M-smokers, 13.0 between L- and H-smokers, and 13.7 between M- and H-smokers. Not all of these results are significant. Risk anomaly can perhaps be attributed to the certainty effect and be interpreted as loss aversion. It remains unclear why risk preference appears to be more complicated than time preference.

IV. Estimation Model and Results

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

A. Estimation Model

We begin by explaining the estimation model that we 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, the nicotine dependence. This two-step decision is considered an ordered probit model (whose FTND scores range from 0 to 10) with a binomial probit model (where smoking is denoted as 1 and 0 otherwise). Let us now comment on the ordered probit model with the sample selection equation.

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

$$\begin{aligned} d_i^* &= \alpha' Z_i + u_i, \\ d_i &= 1 \text{ if } d_i^* > 0 \text{ and } 0 \text{ otherwise.} \end{aligned} \quad (1)$$

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

$$\begin{aligned} y_i^* &= \beta' X_i + \varepsilon_i, \varepsilon_i : F(\varepsilon_i | \theta), E[\varepsilon_i] = 0, Var[\varepsilon_i] = 1, \\ y_i &= 0 \text{ if } y_i^* \leq \mu_0, \\ &= 1 \text{ if } \mu_0 \leq y_i^* \leq \mu_1, \\ &\quad \vdots \\ &= 10 \text{ if } \mu_9 \leq y_i^*. \end{aligned} \quad (2)$$

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:

$$[\varepsilon_i, u_i] : N[0, 0, 1, 1, \rho]. \quad (3)$$

The full information maximum likelihood (FIML) method is used for estimating the parameters, including ρ .

The explained variables are given as follows: in the binomial model, the dummy variable is 1 for smoking and 0 otherwise; in the ordered probit model, the FTND score ranges from 0 (lowest nicotine dependence) to 10 (highest).

The explanatory variables are given as follows. First, the individual characteristic variables are female dummy variable (GENDER = 0 for male, 1 for female), age (AGE), school history (SCHOOL = 1 for junior high school, 2 for high school, 3 for university, and 4 for graduate school), and annual household income level (INCOME = 1 for very low, 2 for low, 3 for lower middle, 4 for upper middle, 5 for high, and 6 for very high).

Next, the following are the economic-psychological parameters that were previously introduced: rate of time preference (TIME), coefficient of risk aversion (1-RISK), time consistency index (TIME CONSISTENCY), risk consistency index (RISK CONSISTENCY), interaction term of TIME and TIME CONSISTENCY, and interaction term of 1-RISK and RISK CONSISTENCY.

B. Estimation Results

We begin our discussion of the estimation results, which are shown in Table 3, with the results of the binomial probit model. Female dummy and school history are negatively associated with smoking probability, while age is positively associated. Further, annual household income does not influence smoking probability. The time preference rate does not have a significant impact on smoking probability, but the risk aversion coefficient has a positive influence. Similarly, the time consistency index is negatively related with smoking probability, while the risk consistency index is not related. Finally, the interaction term of the time preference rate and the time consistency index positively impacts smoking probability, while the interaction term of the risk aversion coefficient and the risk consistency index has a negative impact. We will analyze the comprehensive effects of the economic-psychological parameters on smoking probability by considering the interaction terms in the next section.

We now turn to the results of the ordered probit model. Female dummy and school history are negatively associated with nicotine dependence, while age is positively associated. Further, annual household income does not influence nicotine dependence. The time preference rate does not significantly impact nicotine dependence, but the risk aversion coefficient negatively influences nicotine dependence. Similarly, the time consistency index is not significantly related to nicotine dependence, while the risk consistency index is negatively related. Finally, the interaction term of the time preference rate and the time consistency index positively impacts nicotine dependence, and that of the risk aversion coefficient and the risk consistency index has the same impact. In the next section, we will analyze the comprehensive effects of the economic-psychological parameters on nicotine dependence by taking the interaction terms into consideration.

In addition, since the correlation between the two error terms is not statistically significant, we cannot conclude that selectivity matters. Thus, we can even choose to separately estimate the models using limited information maximum likelihood (LIML).

<Table 3>

V. Discussion

In this section, we investigate the comprehensive effects of such economic-psychological parameters as the time preference rate, risk aversion coefficient, time consistency index, and risk consistency index on the decision to smoke and 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 with respect to the elasticities of smoking probability with the time preference rate and risk aversion coefficient.

<Table 4>

Hypothesis 1: time preference rate, risk aversion coefficient, and smoking probability
The higher the time preference rate, the higher is the smoking probability. On the other hand, the higher the risk aversion coefficient, the lower is the smoking probability.

We tested the above hypothesis by considering the main effects and the interaction terms, and obtained the following result.

Result 1: Hypothesis 1 is verified.

A 1% increase in the time preference rate significantly increased smoking probability by 0.7089%. Further, a 1% increase in the risk aversion coefficient significantly decreased smoking probability by 0.2031%.

Attitudes toward smoking are ambiguous as they involve considerations such as current stress relief and future health damage. This explains the positive correlation between time preference rate and smoking probability. Besides, it is reasonable that those who practice risk aversion avoid smoking because it is widely known to increase health risks. Our finding that smokers are more impatient than nonsmokers 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). On the other hand, 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). Our simultaneous measurements of the time preference rate and risk aversion coefficient indicate that smokers are more time-impatient and more risk-prone than nonsmokers.

At this point, a reservation must be mentioned. Since this research only investigated the relationship between smoking and time/risk preferences, we reserve judgment about causality because we cannot determine whether an impulsive person tends to smoke or whether a smoker tends to become impulsive. A detailed study of causality lies outside the scope of this paper. This is the most crucial area for future research¹¹.

The second hypothesis is established for the elasticities of smoking probability with time and risk consistency indexes.

Hypothesis 2: time anomaly, risk anomaly, and smoking probability

The higher the time consistency index, the lower is the smoking probability. Similarly, the higher the risk consistency index, the lower is the smoking probability.

We obtained the following result.

Result 2: Hypothesis 2 is verified.

A 1% increase in the time consistency index significantly decreased the smoking probability by 0.7497%. Moreover, a 1% increase in the risk consistency index significantly decreased the smoking probability by 1.2606%.

Therefore, both the time and risk consistency indexes successfully account for

¹¹Becker and Mulligan (1997) and Orphanides and Zervos (1998) suggested a variant of the rational addiction approach where the time preference rate was *endogenously* generated. On the other hand, Loewenstein et al. (2003) pointed out the *projection bias*, which suggests that a person was wrongly convinced that her/his current preference would last for a long period.

smoking decisions. Note that the impact of the risk consistency index is larger than that of the time consistency index. If we suppose that smoking results from anomalies of the discounted or expected utility models, 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 individuals failed to recognize the true difficulty of quitting and sought self-control devices to help them quit. Kan (2007) empirically studied time-inconsistent preferences in the context of cigarette smoking behavior and concluded that a smoker who wanted to quit had a demand for control devices, e.g., smoking bans in public areas or hikes in cigarette taxes.

Next, the elasticities of nicotine dependence with respect to economic-psychological parameters are displayed in Table 5. A third hypothesis is established about the elasticities of nicotine dependence with the time preference rate and the risk aversion coefficient.

<Table 5>

Hypothesis 3: time preference rate, risk aversion coefficient, and nicotine dependence
The higher the time preference rate, the higher is the nicotine dependence. On the other hand, the higher the risk aversion coefficient, the lower is the nicotine dependence.

We tested the above hypothesis by considering the main effects and interaction terms, and obtained the following result.

Result 3: Hypothesis 3 is confirmed only for the time preference rate.

A 1% increase in the time preference rate significantly increased the FTND score by 0.1540%. On the other hand, contrary to our expectation, a 1% increase in the risk aversion coefficient increased the FTND score by 0.1013%.

As such, only the time preference rate accounts for 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. On the other hand, the risk aversion coefficient is unexpectedly positively associated with nicotine dependence. Note that Mitchell (1999), Reynolds et al. (2003), and Ohmura et al. (2005) reported negligible correlations between smoking and risk-prone preferences. The reason why the results of risk preference appear to be so complicated in comparison with those obtained from time preference remains unclear.

The fourth hypothesis is established for the elasticities of nicotine dependence with time and risk consistency indexes.

Hypothesis 4: time anomaly, risk anomaly, and nicotine dependence

The higher the time consistency index, the lower is the nicotine dependence. Similarly, the higher the risk consistency index, the lower is the nicotine dependence.

We obtained the following result.

Result 4: Hypothesis 3 is confirmed only for the time consistency index.

A 1% increase in the time consistency index significantly decreased the FTND score by 0.5901%. On the other hand, contrary to our expectation, a 1% increase in the risk consistency index increased the FTND score by 0.4597%.

Only the time consistency index 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 imposed 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.

Next, the risk consistency index, like the risk aversion coefficient, is unexpectedly positively associated with nicotine dependence. Interestingly, our result is connected

with Yi et al. (2006), who compared smokers and nonsmokers using a probability discounting procedure. When these data were fit to a hyperbolic discounting model, significant group differences were not observed; further, indifference points obtained from high probabilities were lower for heavy cigarette smokers as compared to nonsmokers.

In conclusion, both the time preference rate and the time consistency index can suitably account for smoking and nicotine dependence. On the other hand, the risk aversion coefficient and the risk consistency index only predict the decision to smoke, not nicotine dependence. This partial discrepancy between time and risk preferences suggests that they share certain common elements with regard to the decision to smoke but differ with regard to nicotine dependence.

VI. Conclusion

This paper investigated smoking status, including nicotine dependence, on the basis of four economic-psychological parameters. Two of them are rational addiction parameters—time preference rate and risk aversion coefficient—while the other two are the time consistency index and risk consistency index. First, when analyzing whether economic-psychological parameters are associated with smoking, it was found that the time preference rate significantly increased smoking probability; on the other hand, the risk aversion coefficient significantly decreased smoking probability. Furthermore, the higher the time consistency index, the lower is the smoking probability, and the higher the risk consistency index, the lower is the smoking probability. Second, when investigating how economic-psychological parameters can elucidate nicotine dependence, we discovered unexpected results: the risk aversion coefficient and the risk consistency index are positively associated with nicotine dependence. Thus, it becomes clear that economic-psychological parameters function as good predictors of smoking status on the whole, although exceptions were discovered with regard to risk preference. These exceptions can be attributed to nicotine dependence.

The above results mark a breakthrough in smoking research. However, some unsolved problems remain. Since this research only investigated the relationship between smoking and time/risk preferences, we reserve judgment about causality

because we cannot determine whether an impulsive person tends to smoke or whether a smoker tends to become impulsive. A detailed study of causality lies outside the scope of this paper. However, this area is crucial for future research. Furthermore, we assumed that delay and risk were distinguished by our questionnaires. However, the literature, including Rachlin et al. (1991) and Sozou (1998), 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 both time and probability discounting are different and dissociable processes. We consider these issues as potential topics for future research.

APPENDIX ML Model

Assuming that parameter β_n is distributed with density function $f(\beta_n)$ (Train 2003, Louviere et al. 2000), 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. 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 $j=1, \dots, J$ in choice situations $t = 1, \dots, T$. Therefore, 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

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

where x_{nit} and z_{nit} denote observable variables, γ denotes a fixed parameter vector, 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). We can also calculate the estimator of the conditional mean of the random parameters, conditioned on individual specific choice profile y_n , given as

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

Here, we assume that preference parameters regarding time and risk follow normal distribution:

TIME (rate of time preference)

RISK (coefficient of relative risk aversion represented by 1-*RISK*).

The random utility that person n obtains from choosing alternative i in choice situation t can be written as follows:

$$U_{nit} = -\alpha * TIME * timedelay_{nit} + \alpha * \ln probability_{nit} + \alpha * RISK * \ln reward_{nit} + \varepsilon_{nit},$$

where α is a scale parameter that is not separately identified from free parameters and is normalized to one (Hensher, Rose, and Green 2005, p. 536)¹².

¹² Louviere, Hensher, and Swait (2000, pp. 142–143) showed that variance is an inverse function of the scale, $\sigma^2 = \pi^2 / 6\alpha^2$. Therefore, associated variance σ^2 becomes 1.645.

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TABLE 1: Basic Demographics

	SAMPLE NO.	FEMALE RATIO	AGE	UNIVERSITY GRADUATION	HOUSEHOLD INCOME
NON-SMOKER	182	0.5659	35.26	0.5714	6,052,198
SMOKER	253	0.3636	40.48	0.3874	5,950,593
L-SMOKER	97	0.4845	38.30	0.3918	5,737,113
M-SMOKER	111	0.3151	40.86	0.3964	6,301,802
H-SMOKER	45	0.2222	44.22	0.3556	5,544,444

TABLE 2: Time Preference Rates, Risk Aversion Coefficients, Time Anomaly Indices, and Risk Anomaly Indices

		TIME	1-RISK	TIME CONSISTENCY	RISK CONSISTENCY
NON-SMOKER	MEAN	0.0505	0.1069	0.8375	0.8905
	S.E.	0.0009	0.0091	0.0201	0.0120
SMOKER	MEAN	0.0697	0.0385	0.7971	0.8756
	S.E.	0.0019	0.0183	0.0187	0.0104
L-SMOKER	MEAN	0.0555	0.0557	0.8196	0.8681
	S.E.	0.0019	0.0191	0.0279	0.0168
M-SMOKER	MEAN	0.0771	0.0423	0.8070	0.8667
	S.E.	0.0027	0.0376	0.0286	0.0166
H-SMOKER	MEAN	0.0821	-0.0079	0.7241	0.9137
	S.E.	0.0064	0.0164	0.0483	0.0205

TABLE 3: Estimation Results

SAMPLE NO.	435		
LOG LIKELIHOOD	-755.7586		
	Coefficient	S.E.	
BINOMIAL PROBIT MODEL			
CONSTANT	0.54822	0.72913	
GENDER	-0.60959	0.18182	***
AGE	0.01370	0.00714	*
SCHOOL	-0.15282	0.06274	**
INCOME	0.01087	0.06078	
TIME	-7.48861	4.74093	
1-RISK	9.63221	4.68444	**
TIME CONSISTENCY	-1.71441	0.44788	***
RISK CONSISTENCY	1.20829	0.82424	
TIME*(TIME CONSISTENCY)	21.19997	5.87867	***
(1-RISK)*(RISK CONSISTENCY)	-9.82897	4.73522	**
ORDERED PROBIT MODEL			
CONSTANT	1.19453	0.73867	
GENDER	-0.57642	0.14542	***
AGE	0.01921	0.00581	***
SCHOOL	-0.22632	0.05315	***
INCOME	-0.04187	0.05645	
TIME	-1.09825	7.40304	
1-RISK	-8.62954	2.41216	***
TIME CONSISTENCY	-1.04281	0.67158	
RISK CONSISTENCY	-1.52671	0.44624	***
TIME*(TIME CONSISTENCY)	21.08610	11.04321	*
(1-RISK)*(RISK CONSISTENCY)	8.60068	2.47468	***
Cor[u, ε]			
ρ	0.53681	0.46596	

Note: *** 1% significant level, ** 5% significant level, * 10% significant level

TABLE 4: Probabilities Elasticities for Binomial Probit Model

	Elasticity	S.E.	
TIME	0.7089	0.1420	***
1-RISK	-0.2031	0.0605	***
TIME CONSISTENCY	-0.7497	0.3364	**
RISK CONSISTENCY	-1.2606	0.3553	***

Note: *** 1% significant level, ** 5% significant level

TABLE 5: FTND Elasticities for Ordered Probit Model

	Elasticity	S.E.	
TIME	0.1540	0.0534	***
1-RISK	0.1013	0.0211	***
TIME CONSISTENCY	-0.5901	0.1958	***
RISK CONSISTENCY	0.4597	0.0807	***

Note: *** 1% significant level