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Economic and Behavioral Factors in an Individual's Decision to Take the Influenza Vaccination in Japan

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ECONOMIC AND BEHAVIORAL FACTORS IN AN INDIVIDUAL'S DECISION TO TAKE THE INFLUENZA VACCINATION IN JAPAN[†]

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ABSTRACT

In this paper, we investigate what people in Japan consider when deciding to take the influenza vaccination. We develop an economic model to explain the mechanism by which people decide to take the influenza vaccination. Using our model and the data obtained from a large-scale survey we conducted in Japan, we demonstrated that people make rational decisions about vaccinations after considering its cost and benefits. People consider the probability of infection, severity of the disease, and the vaccination's effectiveness and side effects. The time discount rate is another consideration because the timing of costs and benefits of the vaccination differ. Risk aversion (fearing the contraction of the flu and vaccination's side effects) also affects the decision. People also deviate from rationality—altruism and status quo bias play important roles in the decision-making. Overconfidence indirectly affects the decision via perception variables such as the subjective probability of infection and assessment of influenza's severity. The decision also depends on attributes such as gender, age, and marital status. If the general perception of flu and vaccination is inaccurate, supplying accurate information regarding those may increase or decrease the vaccination rate, depending on whether this perception is, respectively, higher or lower than the objective rates. Thus, we examine whether the general perception is biased. Our survey suggests that disseminating information on the vaccination's effectiveness may increase the rate of vaccination, whereas that on the probability of infection may have the opposite effect.

KEY WORDS: influenza; inoculation; survey; time preference; Japan

JEL Classification Numbers: I19

Running head: Decision to take influenza vaccination in Japan

1. INTRODUCTION

Influenza can be a serious disease in modern societies. As a serious pandemic, it can cause *morbidity and mortality, as in 2009 with the swine flu. Since vaccination against flu can* potentially prevent it, a study of the factors that are considered when making the decision to take or not to take the influenza vaccine can help prevent outbreaks of the disease. The objective of the current study is to examine how willingness to take the influenza vaccination depends on economic aspects such as costs and benefits as well as behavioral aspects including perceptions of influenza and the vaccination against it, preference parameters, and personal attributes. To achieve this aim, we use the behavioral economic model and results of a large data survey in Japan.

The study takes an economic approach and determines the relationship between vaccine taking and the costs/benefits of vaccination from utility-maximizing behavior. Based on the classic expected utility framework, we assume that people compare the benefits and costs of taking the vaccine, and choose to be vaccinated if the benefits exceed the costs. Our model predicts that the decision to be vaccinated depends on the perceived probability of infection, severity of the disease, side effects of vaccination, and inoculation costs.

The economic approach has been used to examine individual decisions regarding whether or not to take the vaccine [4, 9, 11]. Nevertheless, the theoretical framework of Shahrabani *et al*. [11] show that the decision to take the vaccine based on objective factors can differ from that based on subjective or psychological factors. Their results show that values of objective factors predict a very high vaccination rate, implying that an individual's perceptions and beliefs do not accurately reflect actual values; further, it predicts that behavioral factors may be important in the decision. For example, perceived risks of infection may affect an individual's propensity to be immunized [9]. Thus, psychological factors, in addition to economic variables, should be considered to fully understand the reasons for the vaccination rate.

The Health Belief Model (HBM) developed by Rosenstock *et al*. [10] is a traditional psychological approach to explaining and predicting preventive health behavior. HBM has been used to explore a variety of health behaviors, including vaccination [3, 6, 8, 12, 14]. According to the HBM, the acceptance of an influenza vaccine depends on the following predictors: perception of susceptibility to influenza, beliefs about the severity of influenza, perceived benefits of the vaccine in preventing influenza, and perceived barriers to accepting a vaccine [3, 5].

The factors that explain vaccination behavior according to utility-maximizing behavior are very similar to those of the HBM. However, our theory predicts that an individual's time discount and risk aversion also play important roles in the decision to take a vaccination or not. We hypothesize that people choose to take a flu vaccination when the benefits exceed the costs (specified as benchmark equations in section 2.1), but introduce an extended model that takes into account behavioral aspects which may affect the decision to be vaccinated. In particular, we examine whether psychological factors such as altruism, overconfidence, and the status quo effect play an important role in the decision.

We designed questions concerned with a respondent's beliefs and preferences with regard to influenza and vaccination, and conducted a large-scale survey in Japan to test our theoretical hypothesis. Thus, although we rely on the economic approach, we actually use perception or belief variables, as does the HBM, so that our results are immune to the critique of [11].

The current study contributes to existing literature by (a) theoretically and empirically elucidating the important role of time discounting and risk aversion in the decision to take a vaccination, (b) expanding the behavioral economic model to include the impact of altruism on the willingness to be vaccinated; (c) presenting empirical results of the model using a large-scale survey in Japan; (d) applying the results to derive policy implications with regard to dissemination of information on influenza and the vaccination against it; and (e) comparing factors affecting the willingness among Japanese people to be vaccinated to factors affecting the population in the USA as reported in previous studies [14].

The paper is organized as follows. In section 2, we explain the analytical framework including the basic model and extended model. In subsections 2.1 and 2.2, we develop a model based on rationality, while in subsection 2.3, we introduce behavioral variables to the basic model. Section 3 explains the methods and describes the survey in Japan. Section 4 is devoted to the results. Section 5 summarizes the study and concludes by showing how the inoculation rate can be increased.

2. ANALYTICAL FRAMEWORK

2.1. Model

Benefits: The benefits of vaccination are (a) improving current and future health and (b) reducing the degree of inconvenience to one's family and friends when one is infected with flu. These benefits are realized a couple of months after being vaccinated. Thus, the magnitude of the benefits depends on how one perceives (1) the seriousness of the disease, (2) how the vaccination relieves the condition, and (3) the probability of infection, as well as his/her time discount rate, and risk aversion. Time discounting matters because the benefits of vaccination are received in the future, while the costs are paid earlier. Risk aversion involves assessing the risk of contracting flu and the side effects of the vaccination.

We denote the probability of contracting flu by *PROB*, the effectiveness of the vaccination by *EFFECT*, and the damage of contracting flu by *DAMAGE*. Thus, the damage of contracting flu is reduced to $(1-EFFECT)\times DAMAGE$, where *EFFECT* is assumed to take on a value between zero and one.

Costs: The cost of vaccination (*COST*) consists of the fee for inoculation (*FEE*), opportunity, and psychological costs of taking the vaccination, and perceived side effects of vaccination (*SIDEEFFECT*). We assume that people suffer these costs at the time of vaccination.

Decision to be vaccinated: The utility of the individual in our model is defined over consumption in two periods, x_1 and x_2. In period 1, the individual decides whether he/she wants to take the vaccine, and in period 2, the individual may be infected by influenza. Thus, the expected utility in the case of taking vaccination is:

$$u(x_1-COST)+\theta\left[(1-PROB)\times u(x_2)+PROB\times u(x_2-(1-EFFECT)\times DAMAGE)\right] \quad (1)$$

while the expected utility of not taking vaccination is:

$$u(x_1)+\theta\left[(1-PROB)\times u(x_2)+PROB\times u(x_2-DAMAGE)\right] \quad (2)$$

where θ is the discount factor. A person will take the vaccination if the value of Equation (1) is larger than the value of Equation (2).

Assuming that $x_1 \approx x_2 >> COST$ and *DAMAGE*, and expanding the utility function to the second order, we find that people take the vaccination, if:

$$
\begin{aligned}
&-COST+\theta PROB\times EFFECT\times DAMAGE \\
&-\frac{1}{2}\alpha\left[COST^2-\theta\times PROB\times EFFECT\times(2-EFFECT)\times DAMAGE^2\right]>0
\end{aligned} \tag{3}
$$

where α stands for the absolute risk aversion, $-\frac{u''}{u'}$. This inequality implies that people are more likely to take the vaccination when (a) *PROB*, (b) *EFFECT*, or (c) *DAMAGE* is greater, (d) *COST* or (e) time discount rate ($\frac{1}{\theta}-1$) is smaller, or (f) risk aversion (α) is higher (lower, respectively), in the case where the fear of getting the flu is greater (smaller) than the fear of side effects, i.e., $COST^2$ < (>) $\theta\times PROB\times EFFECT\times(2-EFFECT)\times DAMAGE^2$ (see Appendix 1). Conditions (a) to (d) conform to the results of the HBM.

Assuming a linear function, (a) to (f) are described in Equation (4), which is the basic equation for estimating willingness to take the vaccination (*WTVACCIN*).

$$
\begin{aligned}
&WTVACCIN_i=a_0+a_1PROB_i+a_2EFFECT_i+a_3DAMAGE_i+a_5COST_i \\
&+a_6\theta_i+a_7\alpha_i+u_i
\end{aligned} \tag{4}
$$

where the subscript *i* stands for the individual *i*. It is straightforward to prove that $a_1, a_2>0$ and $a_3, a_5, a_6<0$, and a_7 will be positive when *DAMAGE* dominates *SIDEEFFECT*.

To identify the channels through which risk aversion affects *WTVACCIN*, we adopt cross terms of risk aversion and *COST*, and risk aversion and *DAMAGE*, using the following equation.

$$
\begin{aligned}
&WTVACCIN_i=a_0+a_1PROB_i+a_2EFFECT_i+a_3DAMAGE_i+a_5COST_i+a_6\theta_i \\
&+a_8\alpha_iDAMAGE+a_9\alpha_iCOST_i+u_i
\end{aligned} \tag{5}
$$

where it is demonstrated that $a_8>0$ and $a_9<0$.

2.2. Variables in the basic equation

Willingness to get the vaccination: *WTVACCIN* is the respondent's intention to take the vaccination within 12 months.

Probability of infection: *PROB* is the respondent's assessment of the probability of being infected with flu within 12 months, expressed as a percentage.

Damage of flu: *DAMAGE* is the respondent's assessment of the damage suffered if he/she contracts flu. It consists of two elements: *SEVERITY*, the respondent's assessment of the potential severity of the disease; and *BOTHER*, the respondent's assessment of the degree to which his/her family and friends would be inconvenienced if the respondent were infected.

Effectiveness of vaccination is denoted as *EFFECT*.

Cost of vaccination: We examine *COST* using the following: (a) the respondent's assessment of the seriousness of the side effects of a flu shot, *SIDEEFFECT*, (b) the monetary cost of the shot, and (c) the psychological costs. Variables relating to the monetary cost include the inoculation fee, *FEE*, and per capita income, *INCOME*, used to normalize the *FEE*. Variables associated with the opportunity costs of taking the injection include wage and regional dummies, which include factors such as the cost of transportation to the administering hospital.

Preferences: Preferences include time discount rate, *TDR*, and absolute risk aversion, *ARA*. To determine *TDR*, we ask respondents which option they prefer: an earlier receipt with a smaller reward or a later receipt with a larger reward. To determine *ARA*, we ask respondents which option they prefer: lower wage with lower risk or higher wage with higher risk, following the method of Barsky *et al*. [2]. Definitions of all the variables we used are presented in Appendix 2.

Using these notations of the variables, our basic Equation (4) is now described as

$$\begin{aligned} WTVACCIN_i &= b_0 + b_1 PROB_i + b_2 EFFECT_i + b_3 SEVERITY_i + b_4 BOTHER \\ &+ b_5 FEE + b_6 SIDEEFFECT + b_7 INCOME_i + b_8 TDR + b_9 ARA_i + u_i \end{aligned} \tag{6}$$

2.3. Extension of the model considering behavioral variables

Our basic model assumes that rational individuals decide whether they want to take the vaccination based only on the costs and benefits of vaccination. However, other variables representing behavioral preferences and attributes may also affect the decision. In this subsection, we present an extended model that incorporates behavioral preferences and socio-economic variables into the basic Equation (6).

Our extended model takes into consideration an individual's altruism, overconfidence, anxiety regarding his/her health, and experiences of vaccination and flu, i.e., behavioral preferences that are often disregarded in traditional economics.

Altruism: Those who are more altruistic and caring may be more likely to take a vaccine because they want to avoid troubling other people. If so, the degree of altruism, *ALTRUISM*, has a positive effect on taking a vaccination. To examine this, we insert $(b_4 + b_{22} ALTRUISM) BOTHER$ or $b_{10} ALTRUISM + b_4 BOTHER$ instead of $b_4 BOTHER$ in the regression, where b_4 and b_{22} represent concern for family and friends, and b_{10} for the public. We expect b_4 and b_{22}>0. In addition, b_{10}>0 if a respondent believes that vaccination will mitigate flu epidemics and improve social welfare.

Overconfidence: Overconfidence may lower a respondent's assessment of the potential level of *PROB*, *SEVERITY*, *SIDEEFFECT*, or *BOTHER*. However, these variables are already included in the regression. To examine whether or not overconfidence affects vaccination behavior through some other channel not already specified in the regression, we add a variable for overconfidence, *OVERCON*.

Anxiety over health condition: Those who are concerned about their health will tend to take the vaccination. Thus, we take into account three variables: the degree of their health anxiety, *UNHEALTH*, and whether they undergo blood tests periodically, *TESTP*, or when disease is suspected, *TESTS*.

Psychological costs: Status quo bias means that people are reluctant to try new things [7]. Accordingly, people who have never been vaccinated may resist taking the vaccination while those who are accustomed to being vaccinated every year may be reluctant to stop being vaccinated. We measure this psychological cost of taking the vaccination by the respondent's experience with flu vaccination, *EXVACCIN*. Those vaccinated in recent years are more likely to be vaccinated again.

Past experience of catching flu: Past experience of being ill with the flu, *EXFLU*, is also expected to influence *WTVACCIN*. Those seriously affected in the past will tend to take the vaccination, while those who experienced a mild infection may think that inoculation is unnecessary. Those seriously affected would have clearer memories of their illness and *EXFLU* is expected to be positive.

Attributes: We include gender, age, marital status, whether or not the respondent has children, and level of education in our extended regression Equation (7):

$$
\begin{aligned}
WTVACCIN_i &= b_0 + b_1 PROB_i + b_2 EFFECT_i + b_3 SEVERITY_i + b_4 BOTHER_i + b_5 FEE_i \\
&+ b_6 SIDEEFFECT_i + b_7 INCOME_i + b_8 TDR_i\,(HOMEWORK_i) + b_9 ARA_i\,(UMBRELLA_i) \\
&+ b_{10} ALTRUISM_i + b_{11} OVERCON_i + b_{12} HEALTH_i + b_{13} TESTP_i + b_{14} TESTS_i \\
&+ b_{15} EXVACCIN_i + b_{16} EXFLU_i + b_{17} MALE_i + b_{18} AGE_i + b_{19} UNMARRY_i + b_{20} NOCHILD_i \\
&+ b_{21} SCHOOL_i + b_{22} ALTRUISM_i \times BOTHER_i + u_i
\end{aligned} \tag{7}
$$

3. DATA AND THE ESTIMATION METHOD

3.1. Data

Data used in this paper were obtained from a survey conducted by the COE (Center of Excellence) project of Osaka University in February 2005 with 4300 people from throughout Japan, randomly selected by the double stratified random sampling method.[1] The selected participants were visited in their homes and given a questionnaire. Several days later, the filled-out questionnaires were picked up from their homes; 2987 questionnaires (70%) were returned. The range, means, and standard deviations of the main variables used for the analysis are presented in Table 1.

Place Table 1 here

3.2. Estimation method

Since willingness to get the vaccination, *WTVACCIN*, is an ordered variable from 1 to 5, we estimate Equation (6) by ordered probit. A problem with this estimation is that those who decide to take the vaccination usually assess *PROB* to be lower than those who choose not to be vaccinated do. Thus, a reverse causality between *WTVACCIN* and *PROB* exists, making *PROB* an endogenous variable.

This conjecture has some support. *WTVACCIN* among 60--70-year-old respondents is significantly higher than among 20--50-year-olds.[2] In contrast, *PROB* decreases with age, probably because elderly people are more likely to take the flu vaccination than younger people and believe that they are protected against the flu.

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[1] The questionnaire (in Japanese) is found at http://www2.econ.osaka-u.ac.jp/coe/project/survey-0502.pdf.

[2] The *t* statistic of the difference of means test between over- and under-60 groups is 10.2, rejecting the hypothesis of equal means at very low probability. Thus, those over 60 are more willing to be vaccinated than those under 60. Experience of vaccination, *EXVACCIN*, is also higher for over- 60s.

Since all the subjective variables, including *WTVACCIN*, may be endogenous, we check to see if results that do not correct the endogeneity biases are robust. We eliminate this endogeneity by regressing each subjective variable over the exogenous variables to estimate a reduced form. In the case of *PROB*, we construct the fitted value, *FITTTED_PROB*, as in regression Equation (8). Using *FITTED_PROB* instead of *PROB* in Equation (7) will correct the endogeneity biases.[3]

$$\begin{aligned} PROB_i &= c_0 + c_7 INCOME_i + c_9 TDR_i\ (HOMEWORK_i) + c_{10} ARA_i (UMBRELLA_i) \\ &+ c_{11} ALTRUISM_i + c_{12} OVERCON_i + c_{13} HEALTH_i + c_{14} TESTP_i + c_{15} TESTS_i \\ &+ c_8 EXVACCIN_i + c_{16} EXFLU_i + c_{17} MALE_i + c_{18} AGE + c_{19} UNMARRY_i \\ &+ c_{20} NOCHILD_i + c_{21} SCHOOL_i + u_i \end{aligned} \tag{8}$$

By the same token, *SEVERITY* and *BOTHER* may be affected by *WTVACCIN*. Thus, we estimate Equation (8) for these two variables and construct the fitted values, *FITTED_SEVERITY* and *FITTED_BOTHER*.

4. RESULTS

4.1. Results of basic Equation (6)

Estimates of basic Equation (6) are presented in the left-hand columns of Table 2. Because the dependent variable, *WTVACCIN*, is denoted in integers from 1 to 5, and larger values indicate stronger willingness, we estimate the equation with ordered probit. However, we do not try to correct endogeneity biases here. Pseudo R^2 is around 0.11, high for a cross-sectional regression with a large number of samples. Most of the estimates are significant and show the expected sign, suggesting that basic Equation (6), assuming rational choice, explains vaccination behavior well.

Place Table 2 here

PROB, EFFECT, SEVERITY, BOTHER, and *SIDEEFFECT* are highly significant, showing a positive sign as expected. *FEE* is not significant, implying that monetary cost is not important in Japan. However, per capita household income has a positive sign and is significant at the 5% level, suggesting that higher income promotes *WTVACCIN*. This may be because the fee is of less

[3] Equation (8) is identified by the absence of the insignificant variables present in Equation (7).

importance to households with a higher income.

To save space, we do not show the results associated with opportunity costs in this regression in Table 2. Therefore, the following is a brief report on the effect of opportunity costs. Important opportunity costs include those for transportation and lost revenue. Direct data are not available for transportation costs, so we make do with dummy variables dependant on the size of the respondent's city and region. Lost revenue is defined as the time required to take the vaccination multiplied by the wage rate. In the questionnaire, we ask respondents how many hours they work per week, how many days per year, and how much income they receive for their labor. Thus, *WAGE* is calculated as labor income/(work hours × work days/7). We add *WAGE* and regional and city-size dummies (proxies for lost time) to Equation (6). Although *WAGE* was expected to negatively affect *WTVACCIN*, the estimate is not significant. Likewise, none of the regional and city-size dummies were significant at the 5% level. However, while we found no evidence that opportunity costs significantly affect vaccination behavior, this may not necessarily imply that opportunity costs are unimportant since our data regarding opportunity costs are far from perfect.

TDR, the time discount rate for the immediate future, has a significant negative sign, as predicted in our model, implying that those who heavily discount the expected benefits of vaccination are less likely to take the vaccination. Discount rates over a long time horizon, such as one year, however, are not significant, implying that time discounting for the immediate future is crucial for *WTVACCIN* (results not shown to save space).

ARA has a significant positive sign, suggesting that fear of contracting flu dominates any fear of side effects from the vaccination. Thus, risk aversion promotes taking the vaccination.

4.2. Results of extended Equation (7)

Results of the extended model Equation (7), including *ALTRUISM* in the regression, are presented in the middle columns of Table 2. The fit of this specification is good. The adjusted R^2 is much improved, compared to the basic Equation (6).[4] The estimates of the variables included in basic Equation (6) are almost the same.

The coefficient of *ALTRUISM*, b_{10}, is significant at the 0.1% level, suggesting that those who

[4] This is partly due to the inclusion of experience of vaccination, *EXVACCIN*.

are altruistic tend to take vaccinations in order to avoid flu epidemics in the society. *UNHEALTH* has a significant positive sign, as expected. However, *TESTP* and *TESTS* are insignificant, even though they have positive signs. *OVERCON* is insignificant, suggesting that it does not affect vaccination behavior through channels other than those specified in the regression, such as *PROB*.

EXVACCIN is highly significant, indicating that having been vaccinated in the past reduces the psychological costs of taking a vaccination. The large coefficient suggests that psychological costs carry great weight in the decision to be vaccinated, supporting the "status quo bias" hypothesis that human beings are reluctant to change. *EXFLU* is positive but insignificant, suggesting that painful memories of previous experiences with flu dominate relatively pleasant memories, but only slightly.

Among attributes, females, the elderly, the unmarried, and those who have children are more likely to take a vaccination. Schooling does not affect vaccination behavior.

When *ALTRUISM*BOTHER* replaces *ALTRUISM* in the equation (right-hand columns of Table 2), the cross term is highly significant with a positive sign, implying that those who are altruistic tend to take the vaccination to avoid troubling their families and not only in consideration of avoiding flu epidemics in the society.[5]

4.3. Examination of time discount rate (*TDR*) and risk aversion (*ARA*)

While the total number of responses to the survey was 2987, only 1849 observations were available for estimating Equation (6), partly because many respondents did not answer questions on *TDR* and *ARA*.[6] Thus, to check the robustness of the results, we present the results using qualitative data associated with *TDR* and *ARA* in the left-hand columns of Table 3. There, *HOMEWORK* is data relating to when the respondent did his/her homework as a child (those who made it a rule to do homework, which symbolized an unpleasant obligation, early in the school holiday are regarded as more patient or more future-oriented). *UMBRELLA* is determined by asking how high the probability of rain has to be to motivate the respondent to carry an umbrella

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[5] However, neither is significant when both terms are included at the same time.

[6] The number of observations was also limited by the fact that many respondents did not answer the question regarding income.

(those who report that a low probability is sufficient are regarded as more risk-averse). In this case, 2173 observations are available. *UMBRELLA* is positive and significant at the 0.1% level, and *HOMEWORK* is negative and significant at the 5% level, confirming the results for *TDR* and *ARA*. Estimates of other variables are almost unchanged from those presented in the left-hand columns of Table 2, indicating that our results are robust for the sample size.[7]

Place Table 3 here

In the middle and right-hand columns of Table 3, we show the estimation results of Equation (5), which examines two channels through which risk aversion impacts *WTVACCIN*. When cross terms for risk aversion and severity (representing *DAMAGE*), *ARA*SEVERITY*, and risk aversion and side effects (representing *COST*), *ARA*SIDEEFFECT*, are used, the coefficient of the former, i.e. a_8 in equation (5), is positive and significant at the 1% level, and that of the latter, i.e. a_9 in equation (5), is negative and significant at the 5% level (middle columns). This result supports our hypothesis that risk aversion operates through the fear of getting the flu, which is stronger than the fear of side effects of the vaccination. When a cross term for risk aversion, severity, and effect, *ARA*SEVERITY*EFFECT*, is used instead of *ARA*SEVERITY*, the results are unchanged (right-hand columns).[8] This result is consistent with the result that risk aversion, in general, negatively affects *WTVACCIN*.

4.4. Perception variables

Estimation of the auxiliary Equation (8) reveals that *OVERCON* negatively affects *PROB* at the 10% significance level, *SEVERITY* at the 0.1% level, and *BOTHER* at the 10% level (the results are not shown to save space). The dummy variable for being male, *MALE*, has the same signs as those of *OVERCON* in all the estimations.[9] As expected, *UNHEALTH* positively affects *PROB*,

[7] However, estimates of the coefficients of variables associated with the cost of vaccination changed from those in Table 2. This is because the psychological cost, *EXVACCIN*, is not included in basic Equation (6). When *EXVACCIN* is included, the coefficients of *SIDEEFFECT*, *INCOME*, and *FEE* are almost unchanged.

[8] See footnote 7.

[9] Barber and Odean [1] argue that males are more overconfident than females and use a male dummy as a proxy of overconfidence.

SEVERITY, and *BOTHER*. A dummy variable for having no children, *NOCHILD,* understandably has a negative coefficient in the *BOTHER* equation. *AGE* is highly significant with a negative sign in *PROB* and *BOTHER* equations. *SCHOOL* is significantly negative for *SEVERITY* and positive for *BOTHER*, but insignificant for *PROB.*

4.5. Results of Equation (7) using fitted values

To correct for possible endogeneity biases, we estimate Equation (7) using fitted values of *PROB*, *SEVERITY*, and *BOTHER* (Table 4).[10] The fitted values are used one by one because they are highly correlated (the correlation coefficient is around 0.5), which seems to cause multicolinear problems when all three are used at the same time.

Place Table 4 here

When *PROB* is substituted by *FITTED_PROB*, most of the estimates are unchanged from those in Table 2, suggesting that the subjective assessment of the probability of infection causes the decision for taking the vaccination. *FITTED_SEVERITY* is significantly positive and most estimates are similar to those in Table 2, suggesting that *SEVERITY* also causes *WTVACCIN*. *FITTED_BOTHER*, however, is insignificant, casting a doubt on whether *BOTHER* really affects *WTVACCIN*. The causality may be reverse, and it may be that those who plan to take the vaccination believe that they will bother their family less by doing so.

5. DISCUSSION AND CONCLUSION

This paper develops an economic model to explain the mechanism by which people in Japan decide whether or not to take the influenza vaccination. Using our model and data obtained from a large-scale survey we conducted in Japan, we demonstrate that people rationally make the decision considering the costs and benefits of vaccination. People take into account the probability of infection, severity of the disease, and effectiveness and side effects of the vaccination. Time

[10] *OVERCON* and *EXFLU*, which are insignificant in the middle column of Table 2, are excluded from this regression.

discount rate matters because the timing of costs and benefits of vaccination differs. Risk aversion also affects the decision through the fear of contracting the flu and the fear of side effects of the vaccination. However, we found no evidence that monetary cost is important in making the decision.[11] The results of this Japanese sample are compatible with the findings of Tsutsui *et al*. [14] with respect to their USA sample.

Yet, people also deviate from rationality. Altruism, a behavioral variable, plays an important role in making the decision. To the best of our knowledge, the effect of altruism on the willingness to be vaccinated has not yet been examined. The status quo bias is clearly recognized, in that people who have never been vaccinated tend to avoid taking the vaccination. Overconfidence affects the decision indirectly via perception variables such as the subjective probability of infection and assessment of the severity of influenza, similar to findings in the USA sample [14]. The decision also depends on attributes such as gender, age, and marital status.

The results of this paper have interesting implications. First, raising the inoculation rate is often thought to be socially desirable because taking a vaccination has strong externality. However, we found that the degree of altruism affects the willingness to take vaccination not only through the channel of concern for one's family and friends (the coefficient of *ALTRUISM*, b_{22}, in Table 2), but also through a channel of caring about a wider range of people (the coefficient of *ALTRUISM*BOTHER*, b_{10}, in Table 2). Therefore, if most Japanese people are altruistic, the vaccination rate will not differ substantially from the social optimum. However, our survey indicates that 44% of Japanese respondents show no altruism, suggesting that it is desirable for the society to raise the vaccination rate to a level higher than the rate that people choose spontaneously.[12]

Second, if the general perception of flu and vaccination is inaccurate, supplying accurate information on the illness, its possible complications, and the effectiveness of the vaccination will probably raise or lower the vaccination rate, depending on whether this perception is higher or lower than the objective rates. Thus, we examine whether the general perception is biased, although our caveat is that the following assessment is crude. *WTVACCIN* depends on six

[11] However, since previous studies, such as Steiner *et al*. [13], found that monetary cost has an impact on the decision to take a vaccination, our results should be examined further from various aspects.
[12] In the USA, only 24% are not altruistic based on our survey results.

perceptions: *PROB*, *SEVERITY*, *BOTHER*, *EFFECT*, *SIDEEFFECT*, and *FEE*. The mean *PROB* is 24%, which is very high considering the fact that according to the website of "global security" (http:// ww.globalsecurity.org/security/ops /hsc-scen-3_flu-pandemic-deaths.htm), the influenza infection rate is 5%–15% (except during pandemic periods). Although there are no statistics on the total number of flu cases in Japan, based on the 1.56 million infections reported in 2005 from 4700 hospitals, the probability of infection is only 1.5% (A website of National Infectious Disease Surveillance Center: http:// dsc.nih.go.jp/idwr/ydata/report-Jb.html). This number, of course, underestimates the true rate because it is based on reports from the limited number of hospitals. More reliable information can be derived from our survey. Some 10.5% of our respondents indicated that they were infected with flu during the previous two years, reflecting a yearly probability of infection of about 5%.[13] Since this rate is still substantially lower than the subjective probability of being infected (24%), providing information on the probability of contracting flu would probably reduce the average vaccination rate.[14]

However, the infection rates differ between different age groups and between those who took the vaccine and those who did not take it. Therefore, we examined the subjective infection rates and the infection rates in the following sub-samples: male vs. female, over-60s vs. under-60s, those who took the flu shot during the past two years vs. those who did not take it.

Our results (not shown in the paper) indicate that the subjective probability differs between the sub-groups: female-25.5% vs. male-22.5%; people under 60 years-25.6% vs. people over 60 years-20.0%; those who took the vaccine during the last two years-26.4% vs. those who did not take the vaccine during this period-23.3%. Nonetheless, in all sub-groups we found that the subjective probability was substantially higher than the experienced flu rate during the last two years.

Most of the other perception variables are qualitative and not easy to compare with actual figures. For *FEE*, 55% chose "the fee is 2000-5000 yen," and for *SEVERITY*, 60% chose "a

[13] Yet, it could be that this number reflects also "flu-like" symptoms which are sometimes wrongly attributed to the influenza illness.

[14] One may argue that the flu rate varies substantially from year to year, so that we should not compare the subjective probability of 2005 with experienced probability for the past two years. According to the statistics reported by the National Infectious Disease Surveillance Center, the number of influenza infections reported by the hospitals designated to report the infection in 2005 was almost double the number reported in 2004, and 1.3 times the number reported in 2003. Thus, the actual rate of infection is probably larger than 5%. Yet, there is no reason to believe that this rate exceeds 10%.

disease from which it takes about a week to recover," both of which do not seem to radically contradict the facts. However, with regard to the effectiveness of the vaccination, while 60% of the respondents correctly answered "the shot can prevent certain types of flu," 20% selected "despite the flu shot, a high possibility of getting the flu remains," which contradicts the truth and underestimates the effectiveness of vaccination. With reference to the side effects of vaccination, although 50% accurately answered that "side effects have little influence," about 10% selected "very serious side effects that could cause after-effects" and 5% selected "extremely serious side effects that could cause death," which overestimate potential side effects of flu vaccination.

In sum, although the comparisons are crude, they seem to suggest that Japanese people evaluate the effectiveness of vaccination as too low and the side effects as too high in number and level of severity. In this case, dissemination of information on the effectiveness of vaccination may help raise the vaccination rate. On the other hand, they seem to perceive too high a probability of getting the flu. If this is true, provision of correct information on the probability of infection may mitigate their willingness to be vaccinated. These conclusions are the same as those of [14] with respect to the USA, which are derived by an econometric analysis.

Appendix 1 Derivation of Equation (3) and the expected sign of the coefficients

For simplicity, let us assume that x_1 and x_2 are independent of the decision on vaccination and they are much larger than the costs and benefits due to vaccination. Then, expanding the utility (1) and (2) around x_1 and x_2 respectively, we obtain,

$$\begin{aligned}&-u'(x_1)COST+\frac{1}{2}u''(x_1)COST^2\\&+\theta PROB\times EFFECT\times DAMAGE\times\left[u'(x_2)+\frac{1}{2}u''(x_2)\times DAMAGE\times(EFFECT-2)\right]>0\end{aligned}, \quad \text{(A1)}$$

Assuming that $x_1 = x_2$, and denoting $-\frac{u''}{u'}$, the absolute risk aversion, as α, Equation (3) is derived.

Denoting the left side of (A1) as Ω, a larger Ω implies more willingness to take the vaccination. Therefore, the derivative of Ω to these elements implies the effect of each element of the equation on the willingness to be vaccinated against flu. Differentiating Ω from each term, we obtain

$$\frac{d\Omega}{dCOST} = -\alpha \times COST \ -1 < 0$$

$$\frac{d\Omega}{dDAMAGE} = \theta \times PROB \times EFFECT \times [1+\alpha \times DAMAGE \times (2-EFFECT)] > 0$$

$$\frac{d\Omega}{dPROB} = \theta \times EFFECT \times DAMAGE \times [1+\alpha \times DAMAGE \times (2-EFFECT)] > 0$$

$$\frac{d\Omega}{dEFFECT} = \theta \times PROB \times DAMAGE \times [1+\alpha \times DAMAGE \times (1-EFFECT)] > 0$$

$$\frac{d\Omega}{d\theta} = PROB \times EFFECT \times DAMAGE \times \left[1+\frac{1}{2}\alpha \times DAMAGE \times (2-EFFECT)\right] > 0$$

$$\frac{d\Omega}{d\alpha} = -\frac{1}{2}\left[COST^2 - \theta \times PROB \times EFFECT \times (2-EFFECT)) \times DAMAGE^2\right]$$

$\frac{d\Omega}{d\alpha} > 0$, if $DAMAGE$ is sufficiently larger than $COST$,

which prove a) to f) in the text.

Appendix 2 Definition of the data

In this appendix, we explain the variables used in the analysis.

WTVACCIN: Willingness to take the vaccination, which is defined as 6 minus the answer to the question “Do you intend to receive the flu shot in the next 12 months?” The answer is given on a five-point scale from “1 Yes, certainly” to “5 No, certainly not.” A larger *WTVACCIN* implies greater willingness to take vaccination.

PROB: Subject probability of infection (*PROB*) is defined as the answer (%) to the question “Estimate your chances of being infected with the flu during the next 12 months.”

EFFECT: With reference to the effectiveness of a flu shot, we asked, “How effective do you think the flu shot is?” and define a variable *EFFECT* as 6 minus the answer to this question, which is any one of five options on a scale from “1 The shot can completely prevent the flu” to “5 The shot is never effective.”

SEVERITY: For seriousness of the disease, we define *SEVERITY* as 7 minus the answer to the question “How serious a disease do you think the flu is?” which is one of six options on a scale from “1 An extremely serious disease which could cause death” to “6 A disease which has little influence.”

BOTHER: With regard to the degree of bother for one’s family and friends when one is infected, we defined *BOTHER* as the answer to the question “When you are infected with the flu, to what extent do you bother your family and friends?” which is one of four options on a scale from “1 I bother them tremendously” to “4 I hardly bother them.”

SIDEEFECT: With regard to the seriousness of the side effects of a flu shot, we defined *SIDEEFFECT* as 8 minus the answer to the question “How serious do you think the side effects caused by a flu shot are?” This is one of the seven options on a scale from “1 Extremely serious side effects which could cause death” to “7 There are no side effects.”

FEE: For the injection fee, we defined *FEE* as the answer to the question “How much do you think a flu shot costs?” which is any of six options on a scale from “1 free” to “6 more than $50.00.”

TDR: Discount rates are estimated from the following questions: “Which would you choose, receiving $100 in 2 days or in 9 days?” Eight different pairs of options that correspond to different interest rates ranging from -10% to 300% are presented. Respondents are requested to choose earlier or later receipt in these eight cases. Most respondents rationally chose earlier options during low interest rates, switched to a later option at some interest rate, and kept choosing it for higher interest rates. We define a variable *TDR* as the interest rate at which they switch.

ARA: Risk aversion is measured using a question that asks what payment pattern is preferred. The options are: 1 Your monthly income has a 50% chance of increasing by 30%, but also has a 50% chance of decreasing by 10% ***or*** 2 Your monthly income is guaranteed to increase by 5%. Those who choose 1 are asked the question in which the increasing rate is altered from 30% to 20%. Those who choose 2 are asked the question in which the increasing rate is altered from 30% to

50%. From these answers, we classify all the respondents into four groups, and assuming constant relative risk aversion utility function, we calculate relative risk aversion for each group, which is named *RRA* following Barsky *et al.* [2]. Dividing *RRA* by their household income, we calculate the absolute risk aversion, *ARA*.

ALTRUISM: Altruism is measured using the question "Suppose that you found a well-known charity that gave financial help to people who typically had about one-fifth of your family income per person. Up to how much of your own family income per month would you be willing to give the charity if you knew the money would go directly to benefit these people?" We define a dummy variable where "No help at all" =1 and 0 otherwise.

OVERCON: A variable measuring overconfidence of respondents is defined by the responses to the statement "I will never be robbed." *OVERCON* is defined as 6 when the answers are five options on a scale from "1 It is particularly true for you" to "5 It doesn't hold true for you at all."[15]

UNHEALTH: We define a variable *UNHEALTH* from the response to the statement "I am anxious about my health," which is any of five options on a scale from "1 It is particularly true for you" to "5 It doesn't hold true for you at all." Larger *UNHEALH* implies greater anxiety for health.

TESTP and *TESTS*: *TESTP* takes on unity if respondents took a periodic blood test in the previous 12 months and zero otherwise. *TESTS* takes on unity if respondents took a blood test because of suspicion of disease in the last 12 months and zero otherwise.

EXVACCIN: We define *EXVACCIN* that takes unity if the answer to the question "Have you ever received a flu shot?" is yes and zero otherwise.

EXFLU: We define *EXFLU* that takes unity if the answer to the question "Have you been infected by the flu during the last two years?" is yes and zero otherwise.

MALE: A dummy variable with male=1 and female=0.

AGE: Age of the respondent.

UNMRRY: A dummy variable with unmarried=1and 0 otherwise.

NOCHILD: A dummy variable with those who have no children=1 and 0 otherwise.

SCHOOL: School career, which is defined by "the highest level of education completed" from "1 Grade school" to "11 Doctorial degree."

WAGE: Wage is defined based on the following three questions as $\frac{Q62}{Q35\times(Q36/7)}$.

Q35. About how many hours per week do you work for pay in a typical week?

Q36. About how many days do you work for pay per year?

Q62. How much was your annual income earned for 2004?

[15] The confidence of "never be robbed" may exist for good reasons for some people. They might be too poor to be robbed. Or they might have taken the most foolproof measures for security. Or they live in safer places. In order to adjust these elements, we regress *OVERCON* over financial wealth of respondents and variables representing size of city where respondents live and 10 regions of Japan and define *OVERCON2* as the constant term plus estimated residuals. However, no explanatory variables of the regression were significant and the regression as a whole was insignificant by F-test (p-value was 0.8). Thus, we report only the results with *OVERCON*.

Sixty-nine percent answered “yes” to the question “Are you currently employed?” so that we got only 1147 observations for the equation including *WAGE*.

HOMEWORK: This is a proxy for time discounting, since those who finish unpleasant tasks earlier are considered to be more patient, or more future-oriented. *HOMEWORK* is defined using the answers to the following question: When you were a child, if you were given an assignment in school, when did you usually do the assignment? 1 Got it done right away 2 Tended to get it done early, before the due date 3 Worked on it daily up until the due date 4 Tended to get it done toward the end 5 Got it done at the last minute

UMBRELLA: This is a proxy for risk aversion and is defined as an answer to the following question: When you usually go out, how high does the probability of rain have to be **before** you take an umbrella? (Percentages between 0 and 100).

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Table 1. Definitions and mean values of variables in the study

		Range			
Variable	Definition	Min	Max	Mean	Std error
WTVACCIN	Willingness to be vaccinated	1	5	2.712	0.029
PROB	Subject assessment of probability of getting flu (%)	0	100	23.868	0.469
SEVERITY	Self-assessment of seriousness of flu	1	6	3.260	0.026
BOTHER	Degree of bothering one's family and friends if infected	1	4	2.874	0.018
EFFECT	Effectiveness of vaccination	1	5	2.950	0.016
SIDEEFFECT	Seriousness of side effects of vaccination	1	7	3.055	0.039
FEE	Fee for inoculation	1	6	4.539	0.021
INCOME	Annual income per family member (ten thousand yen)	8.333	1500	222.807	3.632
TDR	Time discount rate	-0.562	26.890	7.904	0.272
ARA	Absolute risk aversion	0.000	0.444	0.036	0.001
OVERCON	Degree of overconfidence	1	5	2.784	0.022
UNHEALTH	Anxiety regarding health	1	5	3.223	0.025
ALTRUISM	Degree of altruism	0	1	0.551	0.012
EXVACCIN	Experience of flu vaccination	0	1	0.521	0.012
EXFLU	Experience of contracting flu	0	1	0.113	0.008
TESTP	Had a periodic blood test in the last 12 months	0	1	0.652	0.011
TESTS	Had a blood test because of suspected disease in the last 1	0	1	0.096	0.007
DMAN	A dummy variable where male = 1, female = 0	0	1	0.492	0.012
AGE	Age of respondent	22	72	49.215	0.302
UNMARRY	A dummy variable where unmarried = 1, otherwise = 0	0	1	0.128	0.008
NOCHILD	A dummy variable where no children = 1, otherwise = 0	0	1	0.192	0.009
SCHOOL	Level of education where 1 = lowest and 11 = highest	1	11	4.081	0.048

Table 2. Results of basic Equation (6) and extended regression Equation (7) for estimating vaccination behavior, *WTVACCIN*[a]

		Equation (6)		Equation (7) using *ALTRUISM*		Equation (7) using *ALTRUISM* **BOTHER*	
Variable		Estimate	*p*-value	Estimate	*p*-value	Estimate	*p*-value
CONSTANT		-0.978	0.000	-2.445	0.000	-2.34	0.000
PROB		0.008	0.000	0.008	0.000	0.008	0.000
DAMAGE	*SEVERITY*	0.134	0.000	0.111	0.000	0.112	0.000
	BOTHER	0.236	0.000	0.26	0.000	0.22	0.000
EFFECT		0.251	0.000	0.228	0.000	0.227	0.001
COST	*SIDEEFFECT*	-0.046	0.004	-0.057	0.001	-0.057	0.204
	FEE	0.015	0.594	0.038	0.202	0.038	0.045
	INCOME	0.0004	0.030	0.0004	0.051	0.0004	0.027
TDR		-0.005	0.019	-0.005	0.029	-0.005	0.038
ARA		1.1	0.014	1.033	0.038	1.034	0.852
Behavioral variables	*OVERCON*	-	-	0.004	0.893	0.005	0.027
	UNHEALTH	-	-	0.057	0.026	0.057	0.000
	ALTRUISM	-	-	0.217	0.000	-	-
	ALTRUISM BOTHER*	-	-	-	-	0.076	0.000
	EXVACCIN	-	-	0.877	0.000	0.878	0.156
	EXFLU	-	-	0.116	0.164	0.118	0.108
	TESTP	-	-	0.099	0.111	0.1	0.250
	TESTS	-	-	0.116	0.248	0.115	0.004
	MALE	-	-	-0.153	0.004	-0.154	0.000
	AGE	-	-	0.018	0.000	0.018	0.082
	UNMARRY	-	-	0.217	0.085	0.219	0.006
	NOCHILD	-	-	-0.292	0.006	-0.293	0.384
	SCHOOL	-	-	-0.012	0.374	-0.012	0.000
Boundary values	μ_3	1.069	0.000	1.174	0.000	1.174	0.000
	μ_4	1.747	0.000	1.964	0.000	1.964	0.000
	μ_5	2.347	0.000	2.686	0.000	2.688	0.000
Pseudo R^2		0.111		0.291		0.292	
Number of observations		1849		1752		1752	

[a]The first column contains the variables that determine *WTVACCIN*. When the variable in the first column consists of multiple variables, those are shown in the second column. The estimation method is ordered probit.

Table 3. Examination of time discounting and risk aversion[a]

		Equation (6) using *HOMEWORK* and *UMBRELLA*		Equation (5) using *ARA*SEVERITY* and *ARA*SIDEEFFFECT*		Equation (5) using *ARA*EFFECT*SEVERITY*	
Variable		Estimate	p-value	Estimate	p-value	Estimate	p-value
CONSTANT		-0.863	0.000	-0.912	0.000	-0.834	0.000
PROB		0.007	0.000	0.008	0.000	0.008	0.000
DAMAGE	*SEVERITY*	0.13	0.000	0.105	0.000	0.11	0.000
	BOTHER	0.229	0.000	0.235	0.000	0.234	0.000
EFFECT		0.254	0.000	0.249	0.000	0.222	0.000
COST	*SIDEEFFECT*	-0.0002	0.993	0.015	0.588	0.016	0.570
	FEE	0.0002	0.249	0.0003	0.058	0.0003	0.059
	INCOME	-0.045	0.003	-0.025	0.191	-0.029	0.107
Time discount	*TDR*	-	-	-0.005	0.016	-0.005	0.016
	HOMEWORK	-0.035	0.045	-	-	-	-
Risk aversion	*ARA*	-	-	-	-	-	-
	UMBRELLA	0.004	0.001	-	-	-	-
	*ARA*SEVERITY*	-	-	0.77	0.003	-	-
	*ARA*EFFECT*SEVERITY*	-	-	-	-	0.219	0.003
	*ARA*SIDEEFFFECT*	-	-	-0.605	0.028	-0.46	0.050
Boundary value	μ_3	1.069	0.000	1.07	0.000	1.07	0.000
	μ_4	1.748	0.000	1.748	0.000	1.748	0.000
	μ_5	2.33	0.000	2.349	0.000	2.349	0.000
Pseudo R^2		0.109	-	0.113	-	0.113	-
Number of observations		2173	-	1849	-	1849	-

[a]The first column indicates the variables that determine *WTVACCIN*. When the variable in the first column consists of multiple variables, those are shown in the second column. The estimation method is ordered probit.

Table 4. Results of extended regression Equation (7) for estimating vaccination behavior, *WTVACCIN* using fitted values from auxiliary Equation (8)

	FITTED_PROB		*FITTED_SEVERITY*		*FITTED_BOTHER*	
Parameter	Estimate	P-value	Estimate	P-value	Estimate	P-value
Constant	-2.792	0.000	-2.786	0.001	-0.682	0.800
FITTED_PROB	0.016	0.007	.	.	.	.
PROB	.	.	0.009	0.000	0.009	0.000
FITTED_SEVERITY	.	.	0.145	0.000	.	.
SEVERITY	0.115	0.000	.	.	0.151	0.000
FITTED_BOTHER	.	.	.	.	-0.331	0.671
BOTHER	0.269	0.000	0.294	0.592	.	.
EFFECT	0.216	0.000	0.236	0.000	0.238	0.000
SIDEEFFECT	-0.049	0.003	-0.039	0.000	-0.048	0.004
FEE	0.048	0.110	0.049	0.015	0.057	0.058
INCOME	0.0004	0.032	0.0004	0.101	0.0002	0.479
TDR	-0.005	0.040	-0.005	0.064	-0.005	0.025
ARA	0.947	0.058	1.041	0.033	0.795	0.158
UNHEALTH	0.043	0.113	0.049	0.037	0.086	0.107
ALTRUISM	0.213	0.000	0.212	0.212	0.218	0.000
EXVACCIN	0.863	0.000	0.865	0.000	0.886	0.000
TESTP	0.094	0.130	0.100	0.000	0.110	0.083
TESTS	0.110	0.269	0.113	0.136	0.230	0.197
MALE	-0.128	0.018	-0.134	0.277	-0.208	0.056
AGE	0.020	0.000	0.018	0.068	0.010	0.306
UNMARRY	0.263	0.044	0.231	0.000	0.083	0.716
NOCHILD	-0.286	0.007	-0.290	0.070	-0.396	0.023
SCHOOL	-0.012	0.395	-0.012	0.017	-0.010	0.494
μ_3	1.157	0.000	1.165	0.454	1.159	0.000
μ_4	1.935	0.000	1.950	0.000	1.937	0.000
μ_5	2.652	0.000	2.669	0.000	2.642	0.000
Pseudo R^2	0.274	-	0.282	0.000	0.268	-
Number of observations	1752	-	1752	-	1752	-