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Abstract

This study examines the effects of combining financial incentives with nudges to promote rubella antibody testing and vaccination. To increase the rubella antibodies uptake rate among 40-to-57-year-old men, the Japanese government began providing vouchers for free testing and vaccination in the fiscal year 2019. During this year, the government initially mailed vouchers only to those aged 40–46 years. Although the remaining males aged 47–57 received vouchers via mail in FY2020, they could have obtained vouchers and received testing and vaccination also in FY2019 by completing the application process. We focus on this policy distinction and conduct a late-FY2019 online field experiment with 40-to-57-year-old men living throughout Japan. We randomly send reminders with nudge-based messages recommending antibody testing and vaccination, and then track self-reported behavior until the end of FY2019. We find that one nudge-based reminder with an altruistic message, which highlights the negative impact on the fetus caused by infection from the men to pregnant women, significantly promotes antibody testing and vaccination among those who have already received vouchers as a financial incentive. For the other group that must apply for vouchers, any nudge-based reminder has no promoting impact.

JEL: D90, I12, I18
Key words: Rubella, Vaccination, Antibody Test, Text Messages, Reminders, Free Vouchers

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1 Introduction

Vaccination is an essential countermeasure against infectious diseases, including COVID-19, seasonal influenza, and rubella. Vaccination enables individuals to voluntarily acquire antibodies and immunity. They can thus prevent the onset of infectious diseases and even infection itself.

Vaccination has positive externalities and benefits for the vaccinated individuals, surrounding community, and society. For example, vaccination lowers the risk of developing an infectious disease or becoming severely ill. It also reduces the risk of the health-care delivery system becoming strained. Vaccination with infection-preventive effects, including the rubella vaccine, reduces the risk of infection for the vaccinated and the risk of spreading the infection. Vaccination can contribute to social stability during pandemics and the acquisition of herd immunity via these positive externalities.

However, economic theories suggest that vaccination rates may not reach the socially optimal level due to the positive externalities (Brito et al., 1991; Francis, 1997; Stiglitz, 2000). With the externalities, the marginal individual benefit of vaccination becomes lower than the marginal social benefit, and this feature discourages vaccination by those with selfish motives. Even if people are altruistic and gain utility from the social benefits of their vaccinations reducing the infection probability of others, they still have an incentive to free-ride on others' vaccinations and not receive the vaccines themselves, because the infection probability is lowered by the others' vaccinations. We find empirical studies reporting that others' increased vaccination rates reduce the likelihood of people being vaccinated (Hershey et al., 1994; Ibuka et al., 2014).

To overcome the challenge of vaccine coverage not achieving socially optimal levels, governments have used a variety of interventions, including monetary and non-monetary interventions (nudges in behavioral economics). Many countries subsidize COVID-19 vaccinations, making them free. Some local governments set subsidies above and beyond the amount required to make vaccination free, giving vaccinated people the right to join a lottery, and recent studies have confirmed the effectiveness of these measures (Barber and West, 2022; Brehm et al., 2022). Nudge-based interventions include recommending a predetermined vaccination date, sending a reminder message, and changing message wording (Chapman et al., 2010; Sasaki et al., 2022; Yokum et al., 2018).[1]

This study explores the possibility of combining financial incentives with nudges in vaccina-

[1] In the context of vaccines for seasonal influenza and COVID-19, some studies found that messages stimulating people's ownership, "A vaccine dose is reserved for you," promotes their vaccination uptake (Dai et al., 2021; Milkman et al., 2021).

tion and antibody acquisition. Many previous studies estimated or compared these two as independent or substitutive. However, Richard Thaler and Cass Sunstein define nudges as "an aspect of choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler and Sunstein, 2009, p. 6). As mentioned, "without significantly altering economic incentives," nudges include devising wordings and expressions for existing financial incentives. They further explain that nudges adjust the salience of financial incentives so that the incentives have the expected effect.[2] In other words, nudges and financial incentives are complementary in their original definition.

Recently, more studies have examined the two combinations in non-vaccination contexts. For example, Burtch et al. (2018) found that combining a nudge emphasizing social norms with a financial incentive improves the length and quality of online market reviews more than either intervention alone. Thorndike et al. (2016) reported similar results regarding healthy food choices in a hospital cafeteria. Meanwhile, in the study of Kullgren et al. (2014), combining nudges and financial incentives does not increase outdoor exercise among older adults. Furthermore, Pellerano et al. (2017) reported that adding a financial incentive to a social norm nudge undermines the energy-saving effect of the nudge-based intervention alone.[3] We can expect relatively large facilitating effects in combining nudges and financial incentives, while in practice, the effects' direction and extent depend on contexts. Before applying the combinations to policies, we must confirm their effects empirically.

To the best of our knowledge, no study has focused on the combination of financial incentives and nudges in the context of vaccination. As previously stated, many previous studies have separately estimated the effects of financial incentives (Banerjee et al., 2010; Barber and West, 2022; Barham and Maluccio, 2009; Brehm et al., 2022) and nudges (Dai et al., 2021; Chapman et al., 2010; Milkman et al., 2021; Sasaki et al., 2022) as stand-alone measures. Although some studies focused on both, they compared the effects of the two interventions, examined which is larger, and seemed to regard the two as substitutive. For example, Bronchetti et al. (2015) conducted a randomized controlled trial with college students in Pennsylvania and found that a financial incentive increases their seasonal influenza vaccination rate. In this experiment, a peer-related nudge increases vaccine information exposure but does not increase vaccination rates. Campos-Mercade

[2]They mention "iNcentives," "Understand mappings," "Defaults," "Give feedback," "Expect error," and "Structure complex choices" as the six principles of "NUDGES" for creating a good choice architecture. The first principle, "iNcentives," explains the complementary relationship between financial incentives and nudges.

[3]Besides field experimental studies, some laboratory experimental studies have also tested the effects of the combination; Chen et al. (2021) show that combining a financial incentive with an informational nudge induces cooperative behaviors in a prisoner's dilemma game among intrinsically motivated individuals.

et al. (2021) reported that a € 20 financial incentive increases vaccination rates by 4 percentage points (pp) in a Swedish field experiment and emphasized that some nudge-based interventions have little promotional effect.

We add new insights to the literature on the combination of financial incentives and nudges, by focusing on Japan's policy on rubella antibody testing and vaccination and conducting a nationwide online field experiment. We estimate the effect of providing nudge-based messages in each of the situation where people can easily obtain financial incentives and where they must incur additional transaction costs to obtain the incentives. In the former situation, financial incentives and nudges are more closely combined.

In Japan, men born between April 2, 1962, and April 1, 1979 (aged 40–57 years as of 2019) have historically been excluded from routine rubella immunization (see Section 2 for details). Consequently, men in this age group have lower antibody prevalence than their female counterparts. Therefore, Japan has yet to achieve herd immunity against rubella. Unlike flu and COVID-19 vaccinations, rubella vaccine-induced immunity is long-lasting, and people without antibodies must receive a single vaccination to achieve herd immunity against rubella. The Ministry of Health, Labor, and Welfare (MHLW) then initiated an additional measure for routine rubella vaccination in FY2019 by mailing vouchers covering the costs of the rubella antibody test (approximately 5,000 JPY, which is equal to 45 US dollars) and vaccination (approximately 10,000 JPY) to men aged 40–57 years, to confirm whether they have an antibody and then encourage vaccination for those without.

Free vouchers were distributed progressively through local governments: vouchers were mailed to men aged 40–46 in FY2019 and those aged 47–57 years in FY2020. Men aged 47–57 years had to apply to their local government to receive the vouchers during FY2019. That is, in FY2019, men aged 40–46 years received the free vouchers as financial incentives by default, whereas men aged 47–57 years had to opt-in to receive the vouchers, incurring transaction costs.

We conducted an online field experiment in February–March 2020 (at the end of FY2019) with men aged 40–57 years living throughout Japan, including the aforementioned two age groups. In this study, we use a randomized controlled trial (RCT) and send reminders with nudge-based messages to encourage the uptake of antibody testing and vaccination. We ascertain their intentions to receive the test and vaccine, and their self-reported behaviors to receive them in a follow-up survey.

By focusing on the sample aged 40–46 years, we can capture the effects of providing additional reminders with nudged messages in one situation where they already obtained the vouchers as financial incentives. Meanwhile, we can capture the effects of providing reminders in another situation where they must incur transaction costs and opt-in to obtain financial incentives with the sample aged 47–57 years. The main finding reveals that a reminder with an altruistic message is effective in promoting antibody testing and vaccination behaviors only in the former group. This altruistic message emphasizes the negative impact on newborns caused by infection from the men to pregnant women.

This study contributes to the literature exploring the conditions under which nudges work effectively. Evidence for the effectiveness of nudges has been mixed in recent years; according to a meta-analysis by DellaVigna and Linos (2022), nudges are not large in reality, and their effectiveness depends on various conditions, including topics and channels. This study focuses on the combination of financial incentives and nudges, which have often been treated as mutually substitutive measures, and demonstrates that nudges can be effective when given to a group that has already obtained financial incentives. This result is also consistent with the original definition of the two being complementary.

This research also contributes to acquiring global herd immunity against rubella; according to the World Health Organization, 101 of 194 countries have not yet eliminated rubella, accounting for 52% (Zimmerman et al., 2022). Specifically, in the Eastern Mediterranean, South-East Asia, and Western Pacific regions, the proportion of countries that have not yet achieved herd immunity is high. As cross-border traffic increases toward the end of the COVID-19 pandemic, achieving herd immunity against rubella will become increasingly important for the remaining countries. Japan is extremely close to achieving herd immunity. The nudge-based strategy used in such a country to acquire that last mile will be useful for many other countries in the future.

The rest of this paper is structured as follows. Section 2 provides an overview of rubella in Japan. Section 3 describes the experimental design and Section 4 presents the results. Finally, Section 5 concludes the paper.

2 Background of Rubella Vaccination in Japan

Rubella is a highly contagious disease spread through droplet transmission. The most common symptoms are fever and rashes.In addition to serious symptoms for both men and women, women infected with rubella during early pregnancy may have children with congenital rubella syndrome (CRS), which includes eye and ear defects. Because the spread of rubella tends to increase the CRS incidence, the Japanese government has designated rubella as a disease requiring immunization to

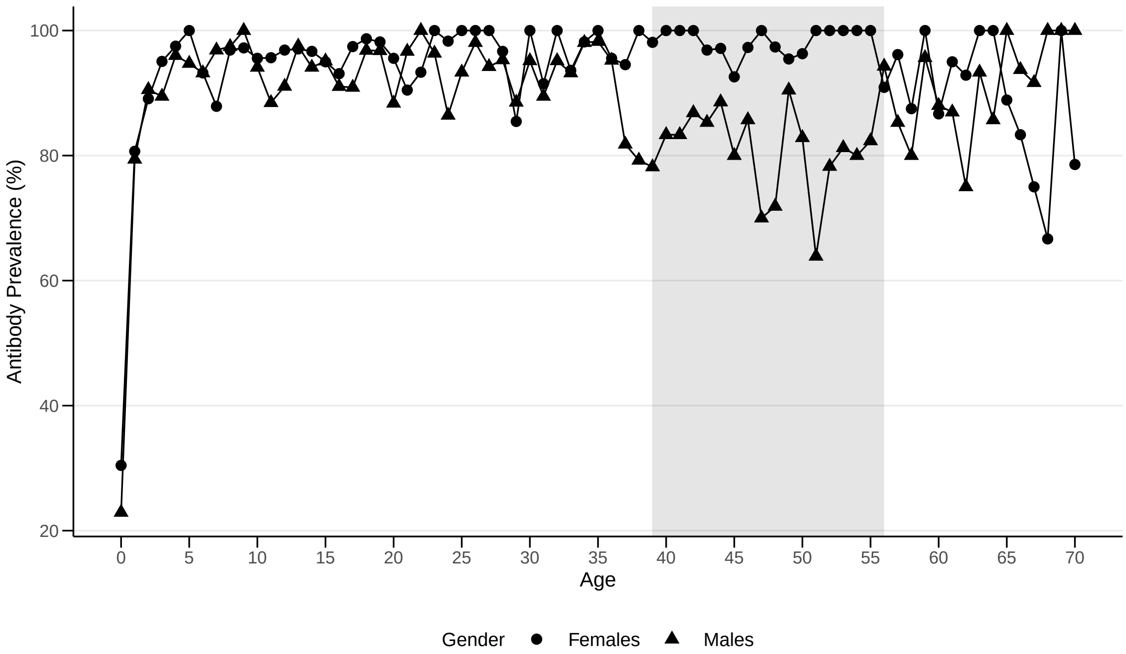

Figure 1: Prevalence of Rubella Antibodies by Age and Gender. Data: NIID ”2018 National Epidemiological Surveillance of Vaccine-Preventable Diseases (NESVPD).

prevent its spread. According to Kinoshita and Nishiura (2016), Japan can obtain herd immunity against rubella if the antibody prevalence exceeds 90% in all generations.[4]

However, due to low antibody prevalence among men in their 40s and 50s, Japan has not achieved herd immunity to rubella. Fig. 1 plots the prevalence of rubella antibodies by age and gender from the National Institute of Infectious Diseases (NIID) “2018 Infectious Disease Epidemic Prediction Survey.” The antibody prevalence among men aged 39–56 years is approximately 81.5%, which is lower than that of women of the same generation (about 97.9%) and other generations because they have not received routine rubella vaccination and have not had less opportunity to infect naturally.[5] The prevalence of antibodies in men and women aged 57 and older is 91.1% and 89.3%, respectively. Despite not having received routine vaccination, men and women aged 57 and older grew up during a time when rubella was common and people are likely to have antibodies from natural infection. The antibody prevalence of men and women aged 38 years and younger is 91.3% and 94.0%, respectively. They have had at least one dose of rubella vaccine administered as part of routine immunization. We give a detailed background of routine vaccination

[4] According to Plans-Rubió (2012), antibody prevalence of 83% to 95% achieves herd immunity against rubella. Nishiura et al. (2015) found that the antibody prevalence for herd immunity is 83.6%.

[5] Using this data, we predict antibody prevalence by a saturated model for three age groups (38 years and younger, 39-– 56 years, and 57 years and older) and a female dummy. The difference in antibody prevalence between men and women in the 39–56 age group is 0.164 (se = 0.034; $p < 0.01$). The difference in antibody prevalence between men aged 39 to 56 years and men aged 57 years and older is 0.96 (se = 0.036; $p < 0.01$).

against rubella in Appendix A.

To achieve herd immunity against rubella, Japan must raise the antibody prevalence among men in their 40s and 50s from 80% to 90%. To achieve this goal, MHLW has provided the rubella vaccine as an additional free routine immunization for men aged 40–57 years (as of 2019) between April 2019 and March 2022.[6] For efficient utilization of vaccination, eligible men must first get antibody testing. Men who have a negative test can then be vaccinated against rubella.

Following the Immunization Act, eligible men can receive free antibody testing and vaccinations. MHLW requested local governments to send free vouchers for a rubella antibody test and vaccine to eligible men over a three-year period. Concerning whether they receive the voucher automatically in FY2019, we can divide eligible men into the following two age groups:

1. 40–46 years old: they automatically received the free voucher in FY2019;

2. 47–57 years old: they automatically received the free voucher after FY2020 but had to apply to obtain it in FY2019.

Thus, transaction costs for monetary incentives in FY2019 differ between the two age groups. In particular, 40-to-46-year-old men have no transaction costs because they obtained monetary incentives by default in the form of free vouchers in FY2019. However, 47-to-57-year-old men have high transaction costs because they must contact their local government to obtain the free vouchers in FY2019 (opt-in incentives).

Although men aged 40–46 years automatically received monetary incentives, the uptake rate of antibody testing with vouchers remained as low as 18% as of January 2020.[7] Given adequate financial incentives, non-monetary interventions should be considered to increase antibody testing. Therefore, we developed behavioral science-based text message reminders for those who were not tested and vaccinated. Using a nationwide online survey, we tested how well those reminders improve antibody testing and vaccination rates among default voucher recipients (and the effect on those who incur a transaction cost to obtain them).

[6]More precisely, eligible men were born between April 2, 1962, and April 1, 1979.

[7]More than half of eligible men are 40–46 years old (6.46 million). They received the free vouchers from April 2019 to March 2020. According to interviews conducted by the MHLW, approximately 96% of local governments planned to send them by October 2019. The cumulative number of antibody tests using vouchers through January 2019 was 1.17 million. We calculate antibody testing uptake by dividing the cumulative number of antibody tests using vouchers up to January 2019 (1.17 million) by the population of 40-to-46-year-old men (6.46 million).

3 Nationwide Online Survey Experiment

In collaboration with MHLW, we commissioned MyVoiceCome Co. Ltd. to conduct two nationwide online surveys at the end of FY2019. On February 15–17, 2020, we conducted the first survey (wave 1) of 4,200 Japanese men aged 40–59 years living throughout Japan. Wave 1 randomizes seven text messages to test how they affect antibody testing and vaccination intentions. On March 17–25, 2020, we surveyed wave 1 respondents again for the second survey (wave 2). We received responses from 3,963 individuals (attrition rate = 5.64%).[8] Wave 2 aims to test how the randomly assigned text messages in wave 1 affect the actual uptake of antibody testing and vaccination.

Appendix B contains detailed information about the survey. We obtained prior approval from the IRB of the Graduate School of Economics, Osaka University (IRB approval number: R020114) for conducting the RCT on the online survey.

3.1 Wave 1: Treatments and Outcome Variables on Intention

We randomly sent one of the text messages in Table 1. The *MHLW (Control)* message is the control. Using this message, MHLW promotes antibody testing and rubella vaccination against rubella on its website (*business-as-usual control*). We developed six additional text messages based on the MHLW (Control) message to explore what elements to use and how to emphasize them. Recent behavioral science research has increasingly investigated the efficacy of multiple candidate messages (e.g. Dai et al., 2021; Milkman et al., 2021), similar to this study.

The six treated text messages alter the MHLW (Control) message to (1) a simple age expression and (2) behavioral economics content. In addition to the precise target age for the additional rubella measures, the *MHLW (Age)* message includes the simple phrase "men in their 40s and 50s," which helps the reader understand if they are eligible for vaccination and pay attention to the message. The MHLW (Age) message only changed the age expression; the message's content is identical to the control. The other five messages both add simplified age expressions and change message content based on behavioral economics.

The *Altruistic* message describes how one's infection can harm others, particularly pregnant women and their children. As previously stated, vaccination has positive externalities. In the case of rubella, having antibodies through vaccination prevents infection in pregnant women, thus protecting their children. The Altruistic message is the inverse of this positive externality, emphasizing the negative externality of not being vaccinated. This message is intended to help altruistic

[8]The seven experimental arms have similar attrition rates. We linearly regress an attrition dummy on treatment group dummies. F-test for joint null hypothesis is statistically insignificant (F-value = 1.434; p-value = 0.197).

Table 1: List of Text Message Reminders

			Age (as of Apr 2019)				
Message	Contents		39	40–46	47–56	57–59	All
MHLW (Control)	Dear all men born between 1962 and 1979. Get rubella antibody testing and be vaccinated to protect yourself and the upcoming generation!	N	20	210	321	49	600
MHLW (Age)	Dear men in their 40s and 50s (all men born between 1962 and 1979). Get rubella antibody testing and be vaccinated to protect yourself and the upcoming generation!	N	23	205	309	63	600
Altruistic	Dear men in their 40s and 50s (all men born between 1962 and 1979). If you get a pregnant woman infected with rubella, she may give birth to a child with a serious disability. Get rubella antibody testing and be vaccinated!	N	24	214	296	66	600
Selfish	Dear men in their 40s and 50s (all men born between 1962 and 1979). Rubella infection in adult men may have serious complications such as encephalitis and thrombocytopenic purpura. Get rubella antibody testing and be vaccinated!	N	16	225	302	57	600
Social Comparison	Dear men in their 40s and 50s (all men born between 1962 and 1979). Compared to other generations, more than twice as many people in your generation can get rubella because one in five of you does not have rubella antibodies. Get rubella antibody testing and be vaccinated!	N	18	204	321	57	600
Deadline	Dear men in their 40s and 50s (all men born between 1962 and 1979). The voucher for a free rubella antibody test and vaccine is valid on March 31, 2020. Get rubella antibody testing and be vaccinated!	N	18	216	299	67	600
Convenient	Dear men in their 40s and 50s (all men born between 1962 and 1979). You can use your coupon for a rubella antibody test at a growing number of workplaces and government agencies, in addition to your usual health examinations. Get rubella antibody testing and be vaccinated!	N	19	213	307	61	600

readers imagine the negative externalities caused by the infection and change their behavior.[9]

The *Selfish* message and *Social Comparison* message aim to change behavior by increasing the importance of having rubella antibodies. The Selfish one describes in detail the damage caused by the infection to the individual, making it easier for the reader to imagine it. Meanwhile, the Social Comparison informs the reader that antibody prevalence is low and reminds them that they are susceptible to infection. This message can help people avoid underestimating the likelihood of infection and undervaluing vaccination.

The *Deadline* message and *Convenient* message describe the routine vaccination system. Deadline emphasizes that the FY2019 vouchers are valid until the end of March. This message aims to prevent people from postponing antibody testing and vaccination due to the present bias, which is one of behavioral economics' key findings. Meanwhile, Convenient states that some people can get antibody testing as part of a regular health examination and emphasizes its convenience. This message aims to reduce the subjective cost of antibody testing.

We employed stratified randomization. The survey firm divided respondents into four age groups (40–44, 45–49, 50–54, and 55–59) and assigned messages to each group equally. The sample size for each group is 1,050, with 150 for one experimental arm within each group. Thus, the sample size for one experimental group is 600.[10]

In wave 1, after viewing a randomly assigned message, participants expressed their intention to get antibody testing and vaccinated on a 5-point Likert scale (5 = definitely yes; 1 = absolutely no). The question of willingness to take antibody testing is, "Are you willing to take an antibody test for rubella now?" Meanwhile, the intention to get vaccinated question asks, "If the antibody testing reveals that you have no antibodies, are you willing to get vaccinated?" We create a binary variable taking the value of 1 if the participant responds 4 or 5 for each question and use it as the outcome variable for intentions.

3.2 Wave 2: Outcome Variables on Behavior

Wave 2 investigates actual antibody testing and vaccination behavior since wave 1. We present exact questions and choices about antibody testing and vaccination in Appendix B. We create a binary variable taking 1 if the respondent has taken antibody testing since the end of wave 1.

To receive rubella vaccination through routine immunization, eligible men must first undergo

[9]We define an altruistic person as someone who considers social benefits, including externalities.

[10]The ages shown in Table 1 are as of April 2019, calculated using the year and month of respondents' birth. Men aged 40–56 years as of April 2019 are eligible for the MHLW's additional measures. Those aged 40–46 years automatically receive coupons for the first year. We assume that those born in April have not yet reached their birthday. Also, some men aged 39 years as of April 2019 were 40 years old at the time of the survey.

antibody testing. However, they may have been vaccinated against rubella at their own expense without having their antibodies tested. To eliminate this possibility, we create a binary variable taking 1 if respondents have been tested and vaccinated since the end of wave 1.Then, we use it as the outcome variable on vaccination coverage.

4 Results

4.1 Study Population

Our study population consists of men who did not have antibody testing or vaccinations prior to wave 1. We estimate the effect on intention using wave 1 data that exclude respondents who stated in wave 1 that they had already received either antibody testing or vaccination (hereinafter, *Wave 1 study sample*). In addition to this criterion, we estimate the effect on behavior using wave 2 data without respondents who report in wave 2 that they had either antibody testing or were vaccinated prior to wave 1 (hereinafter, *Wave 2 study sample*).[11]

Furthermore, we aim to estimate the effect of text messages in situations where men received monetary incentives as vouchers by default and where they had to incur transaction costs to obtain them. To accomplish this, we create a subsample of men aged 40–46 years and another of men aged 47–56 years. Men in the former subsample automatically received the free vouchers (*default incentive* group). Meanwhile, men in the latter subsample received no incentives or required a costly procedure to get it (*opt-in incentive* group). We believe that most men aged 47–56 years did not receive free vouchers in FY2019 because 77.5% of respondents in wave 1 did not know that rubella routine immunization began in FY2019. Thus, in the default incentive group, monetary incentives and text message reminders are more closely combined than in the opt-in incentive group.

4.2 Effect of Text Messages on Intentions

This subsection estimates the effect of text messages on intentions using the wave 1 study sample. We find that individuals' observable characteristics are balanced across experimental arms in both subsamples (Appendix C). Thus, we report the difference-in-mean test (t-test) here and present the regression analysis in Appendix D. We also calculate the minimum size of the effect for the two-sided hypothesis test with a statistical significance of 0.05 and statistical power of 0.8. An absolute

[11] Differences could exist in responses between the first and second waves, for example, by checking one's vaccination history after the first survey. Hence, we exclude respondents who stated in either wave that they had received either antibody testing or vaccination prior to wave 1.

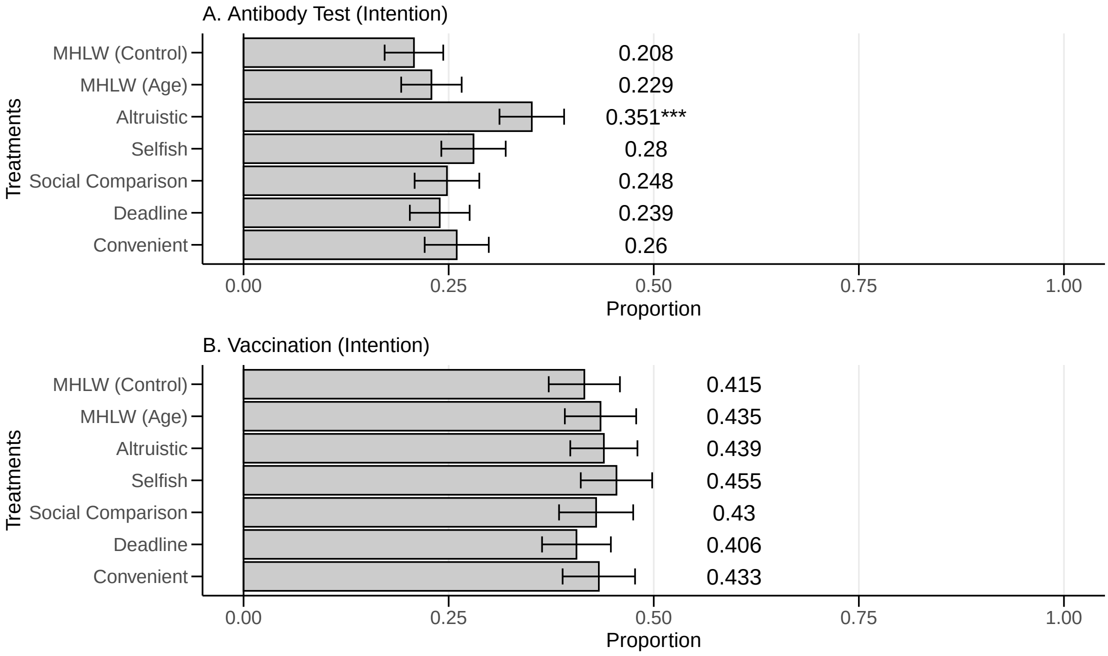

Figure 2: Effect of Text Messages on Intentions for Default Incentive Group ($N = 927$). Data: Men aged 40–46 years in wave 1 study sample. Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * p < 0.1, ** p < 0.05, *** p < 0.01.

minimum difference is 6.7 pp when we use the subsample of men aged 40–46 years ($N = 927$). However, it is 5 pp when using the subsample of men aged 47–56 years ($N = 1,688$).

First, using a subsample of men aged 40–46 years who already have free vouchers in FY2019, we show the proportion of intention for antibody testing (Panel A) and vaccination (Panel B) in each experimental arm in Fig. 2. The results show that the Altruistic message increases the intention for antibody testing compared to the MHLW (control) message. The intention ratio of antibody testing in the MHLW (control) message group and the Altruistic message group is about 20.8% and 35.1%, respectively. Thus, compared to the MHLW (control) message, the Altruistic message increases the intention for antibody testing by about 14.3 pp, which is statistically significant at the 1% level and is above the required minimum detectable effect size (6.7 pp).

Meanwhile, compared to the MHLW (control), all other text messages do not statistically and significantly increase the intention to get vaccinated. Note that the intention ratio of vaccination in all experimental arms is higher than that of antibody testing. This result may be explained by the stimulus of the question eliciting the vaccination intention. We asked respondents to report their willingness to vaccinate if they did not have antibodies. This condition may strongly stimulate the need for vaccination. Thus, when assessed by actual behavior, the results may differ.

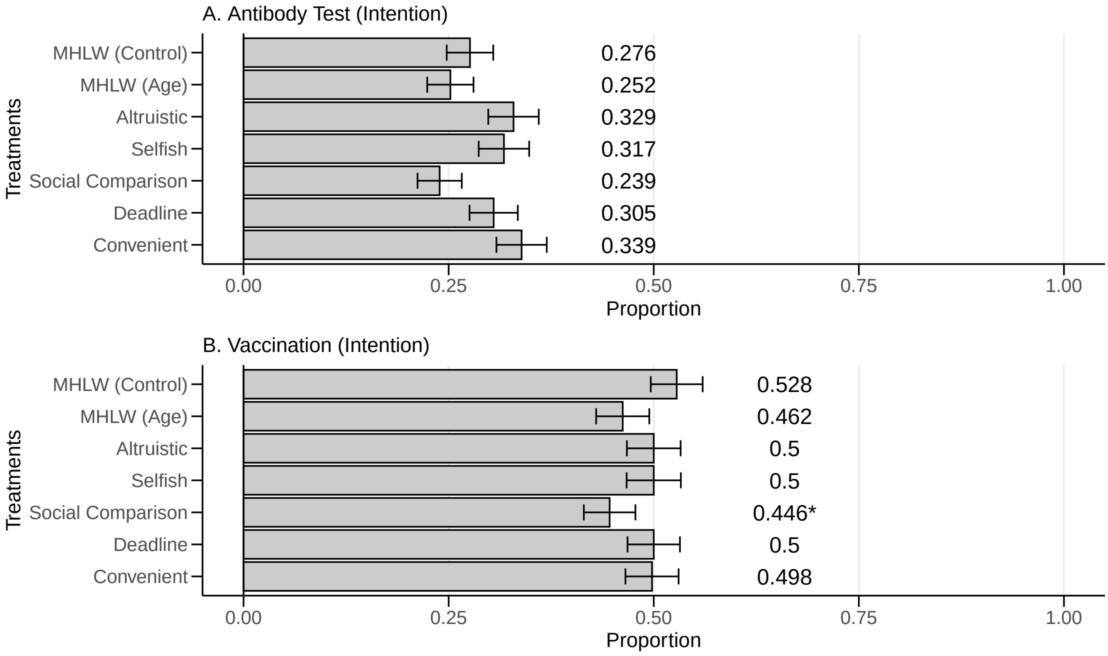

Figure 3: Effect of Text Messages on Intentions for Opt-in Incentive Group ($N = 1,688$). Data: Men aged 47–56 years in the first wave study sample. Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * p < 0.1, ** p < 0.05, *** p < 0.01.

Fig. 3 depicts the proportions of intention for antibody testing (Panel A) and vaccination (Panel B) , using a subsample of men aged 47–56 years who required costly procedures to obtain the free vouchers in FY2019. The results indicate that in comparison to the MHLW (control), none of the other text messages, including the Altruistic message, significantly increase the intention to undergo antibody testing.

In contrast, the Social Comparison message may lower vaccination intention than the MHLW (control) message. In the MHLW (control) message group and the Social Comparison message group, the vaccination intention ratio is approximately 52.8% and 44.6%, respectively.[12] Thus, compared to the MHLW (control), the Social Comparison message reduces vaccination intention by 8.2 pp, which is statistically significant at the 10% level. The behavior of free-riding explains this result. The Social Comparison message emphasizes that "one in five people do not have antibodies." Conversely, four out of five individuals have antibodies. The readers of such a message may have believed that even if they lacked rubella antibodies, the likelihood of infection would be low because 80% of the population possesses them. When eligible men were required to undergo

[12]Similar to the results with the subsample of men aged 40–46 years who automatically received free vouchers in FY2019, the vaccination intention ratio is higher than the antibody testing intention ratio for all experimental arms. This result may be due to the stimulation of questions designed to elicit vaccination intent.

costly procedures to receive free vouchers, this belief may have made vaccination less beneficial, resulting in a lower vaccination intention than the MHLW (control).

Since age determines whether eligible men received the free vouchers automatically in FY2019, the different effect of text messages for two subsamples is influenced by the presence or absence of monetary incentives, and by the age group differences between the two subsamples. We estimate a linear probability model that directly controls for the effect of age. The outcome variables consist of the intention to get antibody testing or vaccination. The explanatory variables consist of treatment dummies, the interaction term between treatment dummies, a binary variable indicating age 40–46, and covariates including age. The estimated model produces the same result described previously (see Appendix D for details).

4.3 Effect of Text Messages on Behaviors

Using wave 2 study sample, we estimate the effect of text messages on behavior. We tested a balance of individual characteristics again because a few respondents dropped out between waves 1 and 2. The results show that the observable characteristics are balanced across experimental arms in both subsamples (see Appendix C). Therefore, we only present the difference-in-mean test (t-test) here and the regression analysis in Appendix D. We also compute the minimum size of the effect for the two-sided hypothesis test at 0.05 statistical significance and 0.8 statistical power. An absolute minimum difference is 7.2 pp when the subsample of men aged 40–46 years ($N = 805$) is used. Meanwhile, 5.3 pp is required when the subsample of men aged 47–56 years ($N = 1,467$) is used.

Using a subsample of men aged 40–46 years who already received the free vouchers in FY2019, we show the uptake rate of antibody testing (Panel A) and vaccination rates (Panel B) for each experimental arm in Fig. 4.[13] We find that, as in the intention case, the Altruistic message increases the actual antibody test uptake rate compared to the MHLW (control) message. The uptake rate of antibody testing in the MHLW (control) and Altruistic message group is 3.5% and 10.9%, respectively. Thus, the Altruistic message increases the actual uptake rate of antibody testing by 7.4 pp, which is statistically significant at the 5% level and slightly larger than the minimum detectable effect size (7.2 pp). Altruism may also boost vaccination rates. This arm's vaccination rate is 4.7%, which is 3.8% points higher than MHLW (control) (0.9%) at the 10% significance level.

Selfish messages may boost antibody testing uptake. Moreover, Social Comparison may in-

[13] Vaccination is a dummy variable that takes the value of 1 if respondents have been tested and vaccinated. Thus, the vaccination rate can be regarded as the proportion of newly acquired antibodies through vaccination. This outcome variable matches MHLW's policy goal.

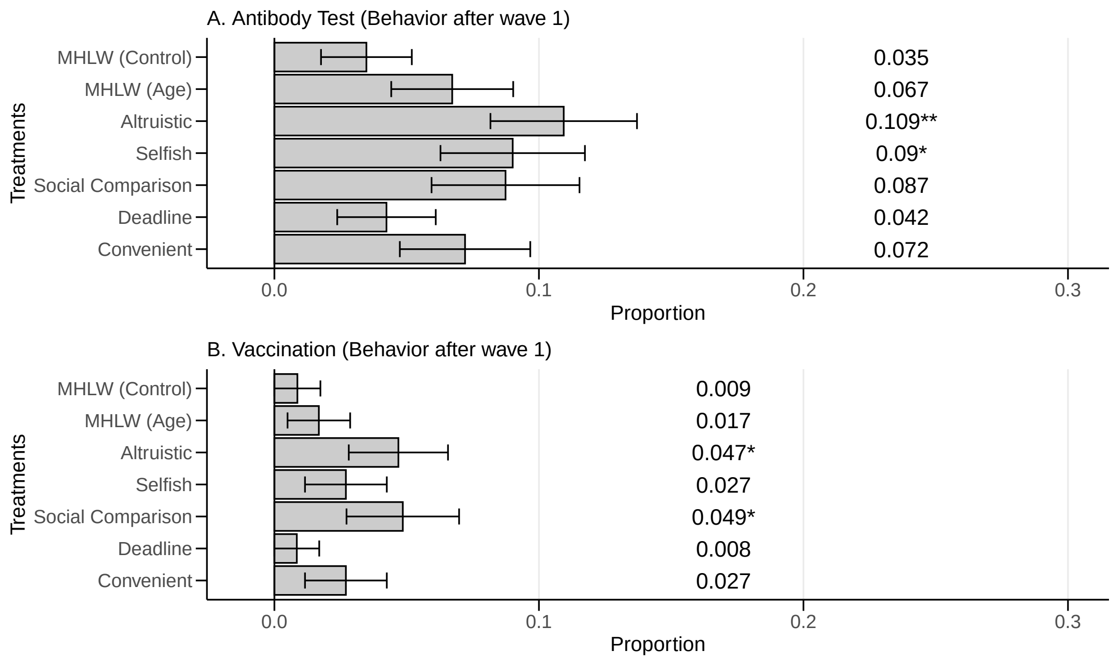

Figure 4: Effect of Text Messages on Behavior for Default Incentive Group (N = 805). Data: Men aged 40–46 years in wave 2 study sample. Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

crease vaccination rates. Selfish message groups' antibody testing uptake is 9%, 5.5 pp higher than MHLW (control) (3.5%), which is statistically significant at the 10% level. In addition, Social Comparison's vaccination rate is 4.9%, 4 pp higher than MHLW (control) (0.9%), which is statistically significant at the 10% level.

Fig. 5shows the uptake rate of antibody testing (Panel A) and vaccination rates (Panel B) for each experimental arm using a subsample of men aged 47–56 who needed costly procedures to obtain free vouchers in FY2019. Social Comparison may increase antibody testing uptake rate, but not vaccination rate. In the MHLW (control) and Social Comparison message groups, antibody testing uptake is 0.5% and 2.8%, respectively. However, none got vaccinated in both groups. The Social Comparison message increases antibody testing by 2.3 pp compared to the MHLW (control) message, which is statistically significant at the 10% level. However, the effect on vaccination rates is zero.

We estimate a linear probability model directly controlling for age differences and obtain the same results (see Appendix D). Among men aged 40–46, the Social Comparison message increases antibody testing uptake by 5.7 pp compared to the MHLW (control) message, which is statistically significant at the 10% level. In sum, the Altruistic message (and possibly the Social comparison

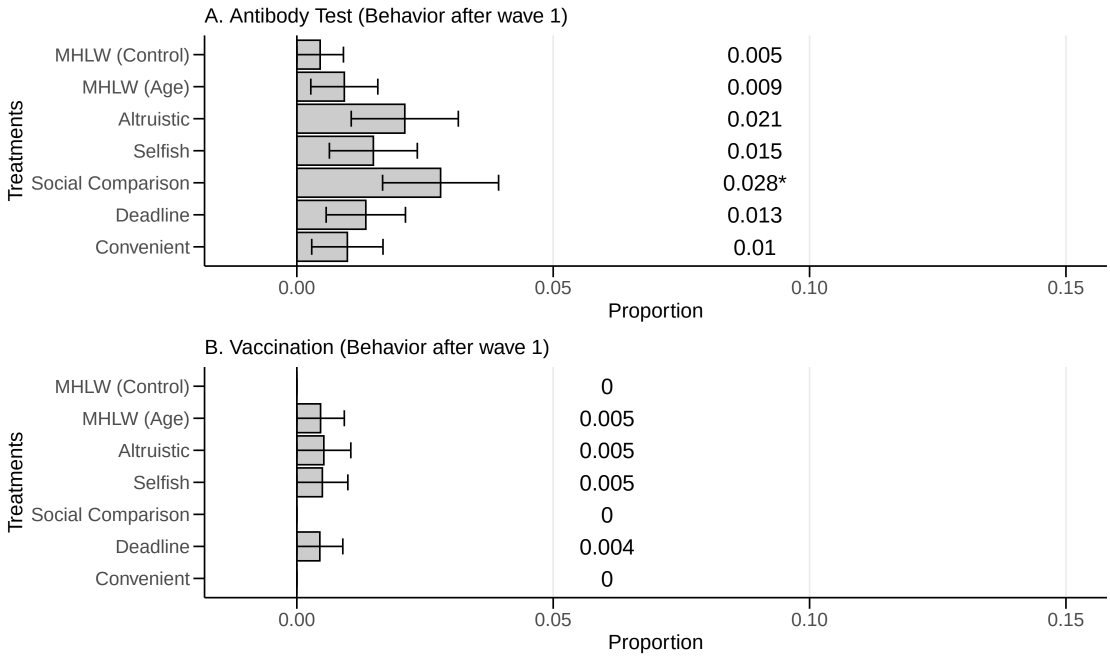

Figure 5: Effect of Text Messages on Behaviors for Opt-in Incentive Group (N = 1,467). Data: Men aged 47–56 years in wave 2 study sample. Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

message) increases antibody testing and vaccination rates among men aged 40–46 who received free vouchers by default.

4.4 Mechanism of Difference of Uptake Rate between Antibody Testing and Vaccination

Vaccination rates are lower than antibody testing uptake rates in all experimental arms, regardless of whether eligible men already received free vouchers. This may not be due to the large number of people who tested negative for antibodies but were not vaccinated, but rather to an exogenous factor in which fewer people should be vaccinated because the majority of those who took the test already had antibodies. To check this point, we compute the number of people who had antibody testing, who had a negative antibody test, and who were vaccinated in each experimental arm (Table 2).

This table shows that most of those with negative antibody test results were vaccinated in all experimental arms, regardless of whether eligible men were automatically given free vouchers.[14]

[14]The vaccination rate of negatives is 87.5% ($= 21/24$) among men who received free vouchers automatically in FY2019. The 95% confidence interval using 1,000 bootstrap samples is $[75.0\%, 100.0\%]$. Similarly, the vaccination coverage of the negatives is 66.7% ($= 4/6$) among men who require expensive procedures to receive the free coupons

Table 2: Classification of Antibody Test Takers

Text messages	Default Incentive Group			Opt-in Incentive Group		
	Antibody test	Negatives	Vaccination	Antibody test	Negatives	Vaccination
MHLW (Control)	4	1	1	1	0	0
MHLW (Age)	8	2	2	2	2	1
Altruistic	14	7	6	4	1	1
Selfish	10	3	3	3	1	1
Social Comparison	9	5	5	6	1	0
Deadline	5	1	1	3	1	1
Convenient	8	5	3	2	0	0
Fisher's exact test (p-value)		0.53	0.66		0.47	1.00

Note: Fisher's exact test was used to test the null hypothesis that the number of negative antibody tests does not differ between experimental arms. It was also used to test the null hypothesis that the number of vaccinations would not differ between experimental arms.

The negatives who received a monetary incentive automatically have been vaccinated in all messages except the Altruistic and Convenient messages. In the Altruistic and Convenient messages, a few negatives have not been vaccinated. Similarly, the negatives who required expensive procedures to obtain the incentive were vaccinated in all message groups except MHLW (age) and Social Comparison.

Furthermore, the number of negative antibody tests varied between experimental arms. The 25% ($= 1/4$) antibody tests are negative in eligible men in the MHLW (Control) group who received the free vouchers automatically. In contrast, given men who automatically received the free vouchers, the negative ratios of antibody tests for the Altruistic and Social comparison messages, which have a positive effect on vaccination, are 50% ($= 7/14$) and 55% ($= 5/9$), respectively. The negative ratio of antibody testing for the Selfish message, which is only effective for antibody test uptake, is 30% ($= 3/10$). This value is similar to the MHLW (control) message. Thus, the experimental arms with higher vaccination rates have a greater negative ratio, resulting in a positive effect on vaccination.

However, the variation in the negative ratio of antibody tests across experimental arms is most likely due to statistical error. A Fisher's exact test is used to test the null hypothesis that the number of negative antibody tests does not differ across message groups. Consequently, regardless of whether men automatically received free vouchers or not, we cannot reject this null hypothesis. Our data show that the negative ratio of antibody tests varies across experimental arms but not in the population.[15]

in FY2019. Its 95% confidence interval, calculated using 1,000 bootstrap samples, is [33.3%, 100.0%].

[15] A competing hypothesis is that after reading the Altruistic or Social Comparison messages, men who automatically received the free vouchers believed they did not have antibodies against rubella and thus had their antibodies tested. We

4.5 Monetary Value of Text Messages

Altruistic (and possibly Social comparison) messages encourage men who received free vouchers by default to obtain antibody testing and be vaccinated. This implies that text messages complement financial incentives. If the MHLW only uses financial incentives without text messages, how much should it pay to eligible men? We use willingness to pay (WTP) for rubella vaccination to calculate monetary values.[16]

We elicit the WTP for vaccination in the first wave before participants read messages. If the vaccination costs 5,000 JPY, we ask respondents if they will get it if the local government pays s_j. The subsidy amounts are $s_j \in \{0, 1000, 2000, \ldots, 10000\}$. Let s_i^{min} be the lowest subsidy at which respondents indicate that they would vaccinate. Let s_i^{max} be the highest subsidy that respondents indicate they would not vaccinate. We can identify the WTP for vaccination within the range $[5000 - s_i^{\text{max}}, 5000 - s_i^{\text{min}})$.[17] Thus, assuming that the true WTP is uniformly distributed within the range $[5000 - s_i^{\text{max}}, 5000 - s_i^{\text{min}})$, we draw the demand curve for vaccination (see Appendix E for details).

We calculate the monetary value of the messages by examining the change in WTP when the vaccination rate increases from baseline by the message's effects. Baseline immunization rate is the sum of free vaccinations and antibody testing in MHLW (Control) message group. We examine

estimate the uptake rate of antibody testing among the negatives to test this hypothesis. We cannot directly recover it from the data since some negatives did not get antibody testing. Using Bayes' theorem, we can thus estimate the uptake rate of antibody testing among the negatives indirectly. Consider the negative event A, and the antibody test uptake event B. The overall uptake rate of antibody testing is $P(B)$, and the negative ratio of antibody testing is $P(A|B)$, which we can directly estimate from the data. By Bayes' theorem, the negative rate of antibody testing is as follows:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)},$$

where $P(A)$ is the proportion of the negatives, which is 0.2 from NIID's data on antibody prevalence. The probability $P(B|A)$ is the antibody testing uptake rate conditional on the negatives, the parameter of interest. Thus, we can estimate the update rate of antibody testing conditional on the negatives as follows:

$$\hat{P}(B|A) = \frac{\hat{P}(A|B) \cdot \hat{P}(B)}{0.2}.$$

In the Altruistic message group, $\hat{P}(A|B) = 0.5$ and $\hat{P}(B) = 0.109$, so $\hat{P}(B|A) = 0.273$ (95% confidence interval constructed on 1,000 bootstrap samples is $[0.117, 0.469]$). Furthermore, we test the null hypothesis that the event of being negative (event A) is independent of the event of taking the antibody test (event B) to determine whether the selection for antibody testing is dependent on being negative. If the 95% confidence interval for $P(B|A) - P(B)$ does not contain zero, the null hypothesis can be rejected at the 5% significance level. Therefore, we can reject the null hypothesis because the 95% confidence interval for $P(B|A) - P(B)$ is $[0.016, 0.336]$. Similarly, the 95% confidence interval for $P(B|A) - P(B)$ in the Social Comparison message group is $[0.000, 0.350]$. Thus, the negatives in the Altruistic and Social Comparison messages are more likely to get antibody testing.

[16] Several studies calculate the monetary value of text messages. For example,Bursztyn et al. (2019) calculated it using the two relative effects of financial incentives and text message treatment groups. Moriwaki et al. (2020) also surveyed WTP amounts and calculated monetary value. The latter study is similar to our approach.

[17] If respondents indicated that they would not vaccinate at all subsidy amounts, then $s_i^{\text{max}} = 10000$. However, we cannot define s_i^{min} in the data. Therefore, we assume $s_i^{\text{min}} = 11000$. This assumption does not affect the monetary value of the messages.

Table 3: Estimated Monetary Value of Text Message Reminders

			Monetary value (JPY)		Monetary value (USD)	
Text messages	Size of effect	Baseline + size of effect	pp	total	pp	total
MHLW (Age)	0.032	0.732	367.854	1.946	3.344	17.690
Altruistic	0.075	0.774	2037.553	10.779	18.523	97.988
Selfish	0.055	0.755	744.045	3.936	6.764	35.782
Social Comparison	0.053	0.752	596.335	3.155	5.421	28.678
Deadline	0.008	0.707	86.059	0.455	0.782	4.139
Convenient	0.037	0.737	422.789	2.237	3.844	20.332

Note: We use the effect size of each text message reminder on antibody testing. Baseline is the sum of the rate of antibody test in the control and the free vaccination rates. The monetary value is the amount per person multiplied by the number of people who received the coupon in 2019 but did not use it until January 2020 (5.29 million). We valued it in Japanese Yen and US Dollars (1USD = 110JPY). The unit of monetary value per person is 1 JPY and 1 USD, respectively. The unit of total monetary value is 1 billion JPY and 1 million USD, respectively.

the message's impact on men who received free vouchers. Since they were vaccinated for free, the vaccine supply curve is horizontal at zero, and the equilibrium is part of the baseline. Adding the MHLW(Control) antibody testing uptake rate to the baseline vaccination rate removes the effect of the message in our survey. Baseline vaccination rate is 70%, and the corresponding WTP is -394 JPY.

We use the text messages' effects on antibody test uptake. As shown in Table 2, most people with negative antibody tests are vaccinated. This suggests that antibody test takers are willing to be vaccinated. Text messages' effect on antibody test uptake can be viewed as an effect on (true) vaccination intention inferred from behavior.

Table 3 shows the estimated message value. The per capita value in the fourth column is the absolute change in WTP when vaccination rate is increased from baseline by the message effect (third column). Therefore, the Altruistic and Social Comparison message, which promotes antibody testing, value about 2,000 JPY (about 18 USD) and 600 JPY (about 5.5 USD), respectively. The total monetary value is the product of the per capita value and the number of people who have not yet used the free vouchers issued in FY2019 (5.29 million as of January 2020). In the fifth column, the Altruistic and Social Comparison messages are worth 10 billion JPY (about 98 million USD) and 3 billion JPY (about 28 million USD), respectively.

5 Discussion and Conclusion

This study uses RCTs to investigate effective messages for promoting rubella antibody testing and vaccination. The main results reveal that the Altruistic message, which emphasizes the negative externality of infection, increases antibody testing uptake by 7.5 pp, equating to a 2,000 JPY subsidy (about 18 USD if 1USD = 110JPY) among men who received free coupons by default in FY2019. However, this message is less effective for men aged 47–57 years who need costly procedures to obtain financial incentives.

This finding suggests that text message reminders are effective when financial incentives and reminders are closely combined; that is, text message reminders and financial incentives are complementary. The regression analysis also shows that the positive difference in the effect of the Altruistic message on antibody testing by proximity to financial incentives is statistically significant, albeit at the lower end of the scale at 10% level (see Appendix D).

Our messages are ineffective among men who required costly procedures to obtain financial incentives because there is low awareness of additional rubella routine immunization beginning in FY2019. Before presenting the messages, we inquire about the MHLW's policy in the wave 1 survey. As a result, approximately 77.5% are unaware of the rubella immunization program. Even if they read the messages and realized the importance of rubella antibody testing and vaccination, they would believe they had to pay for these preventive actions. Our messages may not increase the value of antibody testing and vaccination sufficiently to outweigh their cost. In addition, the fact that many people are unaware of the additional routine rubella vaccinations precludes the possibility that they stopped getting antibody testing and were vaccinated in the first year (FY2019) because they expected to automatically receive the voucher the following year.

Furthermore, we discover that the Selfish and the Social comparison message may encourage antibody testing among men who received vouchers by default. A simple difference-in-means test reveals that, albeit with low statistical significance, the Selfish message encourages antibody testing. A linear probability model that accounts for individual characteristics shows that the Selfish and Social comparison messages promote antibody testing, although the statistical significance is weak (see Appendix D). Furthermore, we estimate the message effect in comparison to the Altruistic message using a linear probability model (also see Appendix D). The findings reveal that the antibody testing uptake rates for the Selfish and Social comparison messages are not statistically and significantly different from the Altruistic message. In this sense, the Selfish and Social Comparison message may also encourage antibody testing. However, the effect size is not large enough to maintain statistical power, requiring a reexamination with a larger sample size.

The fact that all behavior-related outcomes were self-reported limits the scope of this study. The estimated effects are biased if the outcome variables contain recall bias or incorrect responses. We assume no misreporting of whether respondents receive antibody testing and get vaccinated or not. This assumption becomes more valid as the timing of antibody tests and vaccination approaches the time of wave 2 responses. Therefore, we can have some confidence in the results of the antibody testing and vaccination decisions made after wave 1. We also estimate the effects on non-timing-related behaviors. The results show that the Altruistic message encourages antibody testing among default coupon recipients in FY2019, although the magnitude, monetary value, and statistical significance vary (see Appendix F for details). Objective indicators, such as administrative data, must be used to completely eliminate self-reporting issues. This solution is one future research direction.

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Appendix A Background on Routine Rubella Vaccination in Japan

Vaccinations are of two types: "voluntary vaccination" and "routine vaccination." Voluntary vaccinations incur costs, but routine vaccinations are free under the Immunization Act.

Since August 1977, Japan has vaccinated pregnant women against rubella. Junior high girls were required to receive a single routine rubella vaccination. Meanwhile, male and female infants aged 12–72 months received the measles, mumps, and rubella (MMR) vaccine in April 1989. In April 1993, routine MMR vaccination was suspended due to aseptic meningitis.

The 1994 Immunization Act revision made routine vaccination voluntary. In April 1995, men and women aged 12–90 months became the target population for routine rubella vaccination. This change aimed to end the rubella epidemic and achieve herd immunity. The government also made transitional measures for generations who had not received rubella or MMR vaccines. Transitional measures apply to (1) boys and girls under 90 months and first- and second-graders in 1995, (2) first-graders in 1996–1999, and (3) junior high school students who were born between April 2, 1979, and October 1, 1987, from April 1995 to September 2003. Two routine Measles and Rubella (MR) vaccinations have been given since 2006. The first dose is administered to 12-to-24-month-olds, and the second is one year before elementary school.

In 2007, there was a nationwide measles outbreak among teens and people in their 20s. From April 2008 to March 2013, the government gave first-year junior high and third-year high school students the second dose of the MR vaccine.

Due to Japan's history of routine vaccinations, two generations lack the rubella vaccine: (1) men and women born before April 2, 1962; (2) men born between April 2, 1962, and April 1, 1979. The first generation graduated from junior high school before the routine rubella vaccination started in 1977. The second generation's rubella vaccination was limited to junior high girls. In 1995, this generation's men were not eligible for transitional measures. Men and women born after April 2, 1979, are eligible for routine vaccination, including transitional measures.

Rubella antibodies can be acquired through vaccination and infection. The first generation had lived through a period when rubella was widespread and thus possessed antibodies from natural rubella infection. Rubella antibodies are less common in men born between April 2, 1962, and April 1, 1979.

As described in the main manuscript, in April 2019, MHLW in Japan started additional measures for routine rubella vaccination for the second group, men born between April 2, 1962, and April 1, 1979. This additional measure aims to increase this group's antibody coverage from 80%

Figure A.1: Sample of Voucher for Free Rubella Antibody Test and Vaccination

to 90% by March 2022. If this goal is achieved, Japan can achieve herd immunity against rubella.

Under this additional measure, local governments mail vouchers to men in the target generation vouchers for free antibody testing and vaccination against rubella (Fig. A.1). They first use the voucher to receive a free antibody test. Those without antibodies will receive a free vaccine.

Appendix B Additional Tables and Figures about Online Survey Experiment

This section overviews our online surveys. We commissioned an Internet research firm, MyVoice-Com Co. Ltd., and conducted two experiments. Fig. B.1 shows experiment flow.

Wave 1 experiment was conducted on February 15–17, 2020. For the first survey, we surveyed 4,200 Japanese men ages 40–59 years residing throughout Japan. Wave 1 experiment randomly assigns nudge-based reminders to test how they influence rubella antibody testing and vaccination intentions. Before viewing nudge-based reminders, first-wave participants will be asked about daily health behaviors, rubella knowledge, rubella infection history, and vaccination history (Questionnaire A). Table B.1 shows covariates used in regression analysis and balance checks.

Table B.1: List of Covariates

	Description	Mean	Std.Dev.
age	(Wave1) Age as of April 2019 based on year of birth and month of birth.	48.66	5.69
coupon2019	(Wave1) Dummy variable taking one if 40 to 46 years old as of April 2019.	0.35	0.48
married	(Wave1) Dummy variable taking one if a respondent is married.	0.58	0.49
education	(Wave1) Years of education.	14.75	2.31
income	(Wave1) Household income. For those who did not respond with household income, the overall average was substituted.	684.90	375.74
noinfo_income	(Wave1) Dummy variable taking one if a respondent did not answer household income.	0.15	0.36
exercise_w1	(Wave1) Dummy variable taking one if a respondent exercises or plays sports more than once a week.	0.22	0.42
health_check	(Wave1) Dummy variable taking one if a respondent has had a medical examination at his/her city or place of employment in the past year from the time of the wave 1.	0.68	0.46
flushot	(Wave1) Dummy variable taking one if a respondent is vaccinated against influenza every year.	0.27	0.45
handwash	(Wave2) Five-point Likert scale for the question ”I wash my hands and gargle frequently during the period from the end of the previous questionnaire response to today.”	3.91	1.04
temp_check	(Wave2) Five-point Likert scale for the question ”I take my temperature frequently during the period from the end of the previous questionnaire response to today.”	2.26	1.22
avoid_out	(Wave2) Five-point Likert scale for the question ”I am refraining from going out during the end of the previous questionnaire response to today.”	2.96	1.20
avoid_crowd	(Wave2) Five-point Likert scale for the question ”I avoid crowded places when I go out from the end of the previous questionnaire response to today.”	3.38	1.10
wear_mask	(Wave2) Five-point Likert scale for the question ”I always wear a medical mask when I go out or meet people during the period from the end of the previous questionnaire response to today.”	3.14	1.38

Next, one of seven text messages is randomly displayed. Participants complete Questionnaire B after viewing the message. This questionnaire asks about willingness to receive rubella antibody testing, willingness to receive a rubella vaccine, birth year and month, marital status, and years of

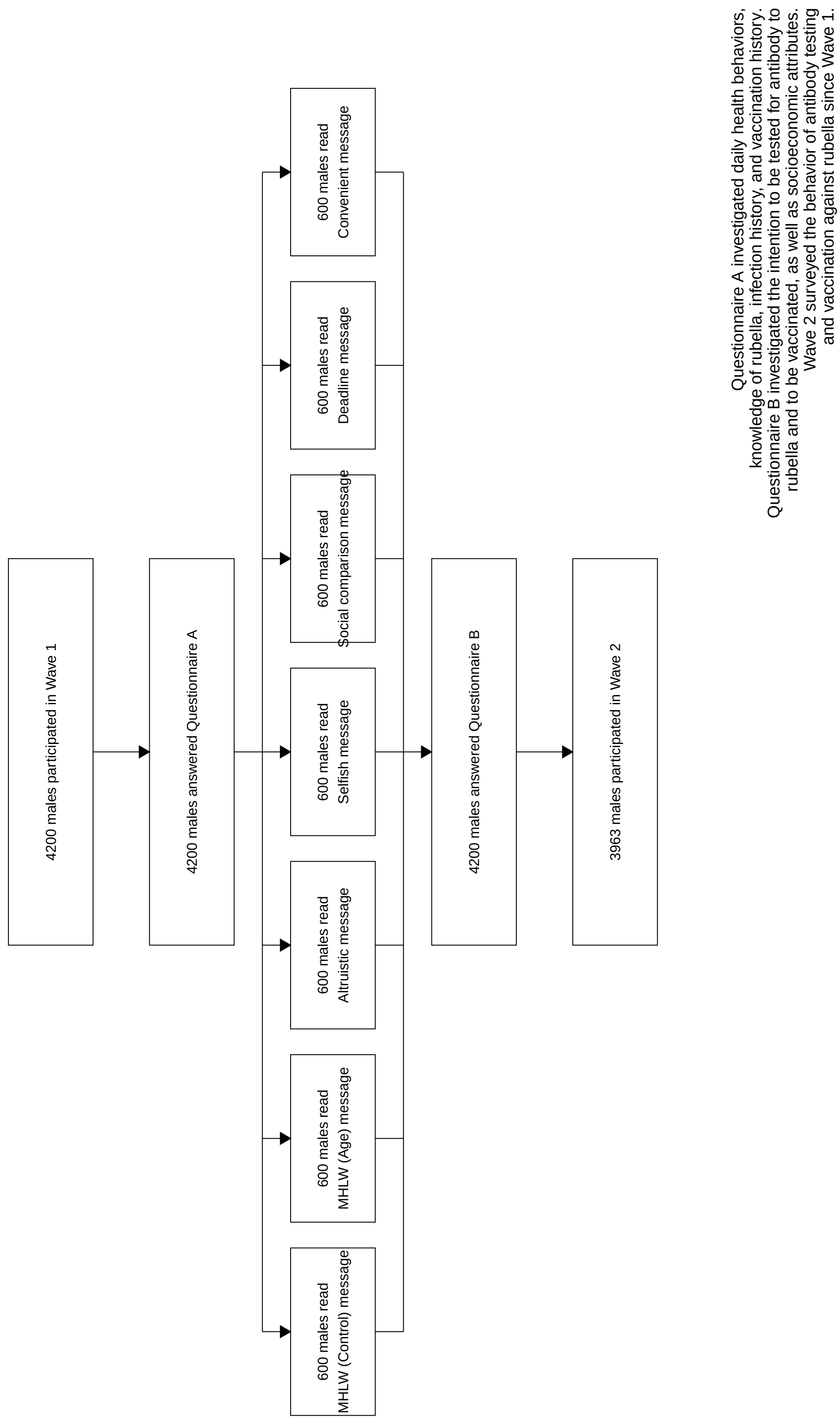

Figure B.1: Overview of Online Survey Experiment education. Table B.1 contains descriptive statistics, including marital status and age from birth year and month.

Wave 2 is a follow-up to wave 1. From March 17, 2020, to March 25, 2020, we surveyed all first-wave participants and received 3,963 responses. The attrition rate is 5.64% across all seven groups. Also, the seven experimental arms have similar attrition rates. We linearly regress an attrition dummy on treatment group dummies. F-test for joint null hypothesis is statistically insignificant (F-value = 1.434; p-value = 0.197). Wave 2 tests how randomly assigned nudge-based reminders affect the actual behaviors of receiving rubella antibody testing and vaccination.

In wave 2, participants are asked if they have had antibody testing and vaccination since wave 1. The antibody testing question asks, "Have you had rubella antibody testing since the end of the last survey?" Participants were given the following choices:

- (a) Yes, I have taken antibody testing;
- (b) No, I have not taken antibody testing;
- (c) I have taken antibody testing before the last survey.

Meanwhile, the vaccination question is "Have you been vaccinated against rubella since the end of the last survey?" Respondents were given one of five options:

- (a) I have been vaccinated;
- (b) I do not need the vaccine due to a positive test or infection experience;
- (c) I have taken antibody testing but have not been vaccinated yet;
- (d) I have not taken antibody testing or gotten vaccinated;
- (e) I have been vaccinated before the last survey.

In the main manuscript, we create a binary variable taking 1 if the respondent chooses option (a) and use it as an outcome variable for the uptake rate of antibody testing. Moreover, we create a binary variable taking 1 if the participant chooses option (a) for both the antibody testing and vaccination questions. Then, we use it as the outcome variable on vaccination.

Wave 2 also includes questions on daily infection prevention, such as handwashing and avoiding crowds, in light of the 2020 COVID-19 outbreak. Balance test and regression analysis also use daily infection prevention behaviors. Table B.1 shows variable descriptive statistics.

Appendix C Results of Balance Test

Each covariate's linear model was estimated as a balancing test. The MHLW message group is the reference group in this model. The F-test tests whether all estimated coefficients are zero.

Table C.1 shows the balance test results for men aged 40 −-46 in the wave 1 study sample (default incentive group). Table C.2 shows the result of a balance test for men aged 47–57 in the wave 1 study sample (opt-in incentive group). Table C.3 shows the default incentive group's balance test using the wave 2 study sample. Table C.4 shows the opt-in incentive group's second wave balance test. Each table's right column shows p-values of the F-test.

Table C.1: Balance Test for Default Incentive Group in First Wave Study Sample

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	42.862	43.046	43.135	43.045	42.909	42.906	42.866	0.874
education	14.654	14.473	14.595	14.205	14.099	14.348	14.575	0.446
exercise_w1	0.246	0.176	0.277	0.189	0.165	0.217	0.213	0.285
flushot	0.238	0.260	0.203	0.144	0.140	0.239	0.236	0.055
health_check	0.654	0.626	0.696	0.538	0.603	0.674	0.614	0.150
income	557.562	645.556	613.156	623.542	569.530	590.422	633.487	0.149
married	0.408	0.458	0.412	0.417	0.455	0.478	0.480	0.785
noinfo_income	0.162	0.168	0.203	0.197	0.157	0.130	0.181	0.706

Note: Description of variables is shown in Table B.1. The wave 1 study sample includes men aged 40–46 years who received free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table C.2: Balance Test for Opt-in Incentive Group in First Wave Study Sample

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	51.632	51.408	51.226	51.657	51.582	51.545	51.502	0.712
education	14.572	14.655	14.530	14.830	14.566	14.634	14.393	0.578
exercise_w1	0.156	0.193	0.239	0.230	0.183	0.203	0.218	0.252
flushot	0.228	0.244	0.197	0.270	0.275	0.228	0.251	0.433
health_check	0.632	0.664	0.701	0.683	0.653	0.659	0.644	0.742
income	712.622	707.190	687.764	677.141	656.419	707.708	710.713	0.540
married	0.600	0.588	0.628	0.657	0.602	0.549	0.619	0.334
noinfo_income	0.184	0.164	0.145	0.117	0.155	0.163	0.205	0.211

Note: Table B.1 describes variables. The wave 1 study sample includes men aged 47–57 who needed expensive procedures to get free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table C.3: Balance Test for Default Incentive Group in Second Wave Study Sample

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	42.861	43.059	43.102	43.036	42.893	42.898	42.964	0.953
avoid_crowd	3.296	3.336	3.273	3.234	3.350	3.305	3.324	0.990
avoid_out	3.096	3.034	3.047	2.793	2.932	3.025	2.928	0.544
education	14.496	14.471	14.547	14.126	14.010	14.407	14.595	0.474
exercise_w1	0.252	0.185	0.266	0.171	0.165	0.195	0.225	0.375
flushot	0.235	0.261	0.227	0.135	0.146	0.246	0.207	0.082
handwash	3.861	3.916	3.797	3.757	3.767	3.915	3.829	0.835
health_check	0.643	0.639	0.680	0.532	0.631	0.661	0.640	0.391
income	548.244	649.778	614.512	599.124	555.083	591.597	637.056	0.102
married	0.391	0.454	0.391	0.360	0.437	0.466	0.477	0.467
noinfo_income	0.174	0.126	0.203	0.207	0.146	0.136	0.171	0.522
temp_check	2.139	2.235	2.414	2.126	2.204	2.203	2.117	0.535
wear_mask	2.930	3.076	3.109	3.009	3.010	3.144	3.207	0.794

Note: Description of variables is shown in Table B.1. The wave 2 study sample includes men aged 40–46 years who received free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-values of the joint null hypothesis (F-test).

Table C.4: Balance Test for Opt-in Incentive Group in Second Wave Study Sample

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	51.695	51.394	51.179	51.662	51.421	51.605	51.512	0.564
avoid_crowd	3.295	3.361	3.447	3.239	3.313	3.309	3.433	0.437
avoid_out	2.886	2.889	2.932	2.866	2.855	2.964	2.941	0.960
education	14.505	14.620	14.553	14.876	14.593	14.610	14.345	0.472
exercise_w1	0.159	0.194	0.232	0.229	0.173	0.211	0.202	0.432
flushot	0.223	0.245	0.189	0.264	0.280	0.215	0.241	0.376
handwash	3.823	3.889	3.926	3.751	3.836	3.861	3.867	0.769
health_check	0.632	0.667	0.684	0.677	0.645	0.673	0.631	0.849
income	712.165	707.809	686.355	671.407	644.798	699.289	718.575	0.370
married	0.591	0.560	0.611	0.652	0.598	0.547	0.596	0.407
noinfo_income	0.173	0.157	0.137	0.114	0.159	0.166	0.222	0.142
temp_check	2.095	2.204	2.221	2.100	2.136	2.085	2.182	0.841
wear_mask	3.082	3.176	3.116	3.144	2.977	2.942	3.010	0.533

Note: Description of variables is shown in Table B.1. The wave 2 study sample includes men aged 47–57 years who needed expensive procedures to get free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-values of the joint null hypothesis (F-test).

Appendix D Estimation Results of Linear Probability Model

As age determines whether eligible men automatically got the free vouchers, the different effect of the text messages for the two subsamples (men aged 40–46 years and aged 47-56 years) is influenced by whether to receive the vouchers automatically or not and by the age difference between the two subsamples. After eliminating this issue, we will test whether the message's effect differs between age groups. We estimate a linear probability model of intent:

$$Y_{ij} = \alpha + \sum_j \beta_j \text{Message}_j + \sum_j \gamma_j (\text{Message}_j \times \text{Coupon}_i) + \delta \text{Coupon}_i + \lambda X'_{ij} + \epsilon_{ij}, \quad (1)$$

where where Message_j is a treatment dummy (the control group is MHLW(Control) message), Coupon_i is a binary variable indicating 40-46 years old (who automatically received the free vouchers), and X is a set of covariates including age.

Our parameter of interest is β_j and γ_j. The parameter β_j represents a text message effect among men who needed a costly procedure to get the free vouchers. The linear combination of parameters, $\beta_j + \gamma_j$, is a text message effect among men who already obtained monetary incentives as vouchers. The parameter γ_j shows a difference in the message effect between the two age groups.

Table D.1 is the estimated result of the linear probability model of intentions. The linear probability model is used to represent a text message effect for two age groups in Table D.2. The altruistic message effect on the intention to get antibody testing is statistically significant among men who automatically received the vouchers in FY2019, similar to the t-test results. However, among men who required costly procedures to obtain incentives, its effect is statistically insignificant. It should be noted that the difference in effect between the two groups is not statistically significant (see Table D.1).

Similar to the t-test results, the effect of Social Comparison messages on vaccination intention is statistically non-significant among men who received free vouchers in FY2019. The Social Comparison message discourages men who underwent expensive procedures to get vaccinated. It is -9.8 pp. This is bigger than difference-in-mean. Furthermore, Table D.1 shows that the difference between the two effects is statistically significant at the 10% level.

Table D.3 compares the effect of the message with that of the Altruistic message. In FY2019, the message effect among men who required a costly procedure to receive free vouchers is a linear combination of parameters $\beta_j - \beta_{\text{Altruistic}}$. The message effect among men who received vouchers automatically represents a linear combination of parameters $(\beta_j + \gamma_j) - (\beta_{\text{Altruistic}} + \gamma_{\text{Altruistic}})$. Among men who have already received monetary incentives, the intention to get antibody testing

Table D.1: Linear Probability Model of Intentions

	Antibody Test	Vaccination
	(1)	(2)
MHLW (Age)	−0.033	−0.075*
	(0.038)	(0.043)
Altruistic	0.044	−0.040
	(0.041)	(0.044)
Selfish	0.014	−0.058
	(0.040)	(0.044)
Social Comparison	−0.050	−0.095**
	(0.038)	(0.043)
Deadline	0.024	−0.033
	(0.039)	(0.043)
Convenient	0.056	−0.035
	(0.041)	(0.044)
Coupon	−0.080	−0.075
	(0.051)	(0.062)
Coupon×MHLW (Age)	0.057	0.102
	(0.063)	(0.075)
Coupon×Altruistic	0.105	0.066
	(0.065)	(0.073)
Coupon×Selfish	0.093	0.135*
	(0.065)	(0.075)
Coupon×Social Comparison	0.120*	0.138*
	(0.063)	(0.075)
Coupon×Deadline	0.005	0.023
	(0.062)	(0.073)
Coupon×Convenient	−0.002	0.059
	(0.064)	(0.075)
Num.Obs.	2615	2615
R2	0.337	0.502
R2 Adj.	0.331	0.497
Covariates	X	X

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors. We use the wave 2 study sample and control for covariates. The list of covariates is presented in Table B.1.

Table D.2: Effects of Text Message on Intentions for Two Groups Using Linear Probability Model Estimates

		Antibody testing			Vaccination		
Group	Text messages	estimate	std.error	p.value	estimate	std.error	p.value
Opt-in incentive	MHLW (Age)	−0.033	0.038	0.380	−0.075	0.043	0.084
	Altruistic	0.044	0.041	0.292	−0.040	0.044	0.360
	Selfish	0.014	0.040	0.727	−0.058	0.044	0.189
	Social Comparison	−0.050	0.038	0.186	−0.095	0.043	0.026
	Deadline	0.024	0.039	0.536	−0.033	0.043	0.440
	Convenient	0.056	0.041	0.165	−0.035	0.044	0.421
default incentive	MHLW (Age)	0.024	0.050	0.630	0.027	0.061	0.660
	Altruistic	0.149	0.050	0.003	0.026	0.058	0.662
	Selfish	0.107	0.051	0.034	0.077	0.061	0.209
	Social Comparison	0.070	0.051	0.172	0.043	0.062	0.483
	Deadline	0.030	0.048	0.541	−0.011	0.059	0.855
	Convenient	0.055	0.050	0.272	0.024	0.060	0.688

Note: We estimate the effect for the default incentive group (men aged 40–46) and the opt-in incentive group (men aged 47–57 years) using Table D.1. The effect for the opt-in incentive group is the estimate β_j. The effect for the default incentive group is a linear combination of the estimates, $\beta_j + \gamma_j$. F-test is used for linear combination null hypothesis. Robust standard errors.

Table D.3: Effects of Text Message on Intentions for Two Groups Using Linear Probability Model Estimates (Baseline: Altruistic Message)

		Antibody testing			Vaccination		
Group	Text messages	estimate	std.error	p.value	estimate	std.error	p.value
Opt-in incentive	MHLW (Age)	−0.077	0.041	0.059	−0.035	0.045	0.440
	Selfish	−0.030	0.043	0.490	−0.018	0.046	0.697
	Social Comparison	−0.093	0.040	0.021	−0.055	0.044	0.216
	Deadline	−0.019	0.042	0.648	0.007	0.045	0.875
	Convenient	0.013	0.043	0.766	0.005	0.045	0.907
default incentive	MHLW (Age)	−0.125	0.052	0.017	0.001	0.058	0.982
	Selfish	−0.042	0.053	0.435	0.051	0.058	0.377
	Social Comparison	−0.079	0.054	0.142	0.018	0.059	0.762
	Deadline	−0.119	0.051	0.020	−0.036	0.056	0.518
	Convenient	−0.094	0.052	0.072	−0.001	0.057	0.983

Note: We estimate the effect for the default incentive group (men aged 40–46) and the opt-in incentive group (men aged 47–57 years) using Table D.1. The effect for the opt-in incentive group is a linear combination of the estimates, $\beta_j - \beta_{\text{Altruistic}}$. The effect for the default incentive group is a linear combination of the estimates, $\beta_j + \gamma_j - (\beta_{\text{Altruistic}} + \gamma_{\text{Altruistic}})$. F-test is used for linear combination null hypothesis. Robust standard errors.

Table D.4: Linear Probability Model of Behaviors

	Antibody Test	Vaccination
	(1)	(2)
MHLW (Age)	0.003	0.004
	(0.008)	(0.005)
Altruistic	0.016	0.005
	(0.011)	(0.005)
Selfish	0.007	0.005
	(0.010)	(0.005)
Social Comparison	0.022*	0.000
	(0.013)	(0.001)
Deadline	0.009	0.005
	(0.009)	(0.005)
Convenient	0.007	0.000
	(0.009)	(0.001)
Coupon	0.019	0.003
	(0.020)	(0.011)
Coupon×MHLW (Age)	0.026	0.002
	(0.030)	(0.015)
Coupon×Altruistic	0.057*	0.032
	(0.034)	(0.021)
Coupon×Selfish	0.054	0.013
	(0.033)	(0.018)
Coupon×Social Comparison	0.034	0.039*
	(0.035)	(0.023)
Coupon×Deadline	−0.003	−0.006
	(0.026)	(0.013)
Coupon×Convenient	0.031	0.018
	(0.031)	(0.018)
Num.Obs.	2272	2272
R2	0.080	0.040
R2 Adj.	0.069	0.028
Covariates	X	X

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust Standard errors. We use the wave 2 study sample. We use waves 1 and 2 covariates. The list of covariates is presented in Table B.1.

for the Selfish and Social Comparison messages is not statistically significantly different from that of the Altruistic message group. In this sense, the Selfish message and Social Comparison may encourage people to test for antibodies. However, these differences are insufficient to maintain sufficient power. We should conduct another study with a larger sample size.

As with intention, we estimate a linear probability model of behavior. Table D.4 shows linear probability model results. Table D.5 shows message effects using linear probability model estimates. Similar to a difference-in-mean test, statistically significant at the 10% level, the Social Comparison message increased antibody testing uptake by 5.7 pp among men who received free vouchers automatically in FY2019.Table D.4 also shows that the Altruistic message effect on antibody test uptake and the Social Comparison message effect on vaccination uptake are statistically significant at the 10% level.

Table D.5: Effects of Text Messages on Behaviors for Two Groups Using Linear Probability Model Estimates

		Antibody testing			Vaccination		
Group	Text messages	estimate	std.error	p.value	estimate	std.error	p.value
Opt-in incentive	MHLW (Age)	0.003	0.008	0.755	0.004	0.005	0.436
	Altruistic	0.016	0.011	0.159	0.005	0.005	0.381
	Selfish	0.007	0.010	0.501	0.005	0.005	0.301
	Social Comparison	0.022	0.013	0.082	0.000	0.001	0.920
	Deadline	0.009	0.009	0.346	0.005	0.005	0.318
	Convenient	0.007	0.009	0.430	0.000	0.001	0.876
Default incentive	MHLW (Age)	0.029	0.028	0.307	0.006	0.015	0.702
	Altruistic	0.073	0.032	0.023	0.037	0.020	0.071
	Selfish	0.061	0.032	0.055	0.018	0.017	0.292
	Social Comparison	0.056	0.032	0.084	0.040	0.023	0.084
	Deadline	0.005	0.025	0.833	−0.002	0.012	0.897
	Convenient	0.038	0.029	0.202	0.018	0.018	0.311

Note: We estimate the effect for the default incentive group (men aged 40–46 years) and the opt-in incentive group (men aged 47–57) using results of the linear probability model presented in D.4. The effect for the opt-in incentive group is the estimate β_j. The effect for the default incentive group is a linear combination of the estimates, $\beta_j + \gamma_j$. F-test is used for linear combination null hypothesis. Robust standard errors.

Table D.6: Effects of Text-Based Nudges on Behaviors for Two Groups Using Linear Probability Model Estimates (Baseline: Altruistic Message)

		Antibody Test			Vaccination		
Group	Text messages	estimate	std.error	p.value	estimate	std.error	p.value
Costly procedure	MHLW (Age)	−0.013	0.012	0.287	−0.001	0.007	0.898
	Selfish	−0.009	0.013	0.501	0.001	0.008	0.927
	Social Comparison	0.006	0.015	0.693	−0.005	0.006	0.405
	Deadline	−0.007	0.013	0.569	0.000	0.007	0.999
	Convenient	−0.009	0.012	0.476	−0.005	0.005	0.369
Automatic receiving	MHLW (Age)	−0.044	0.036	0.218	−0.031	0.022	0.158
	Selfish	−0.012	0.038	0.749	−0.018	0.024	0.438
	Social Comparison	−0.017	0.039	0.662	0.003	0.028	0.923
	Deadline	−0.068	0.033	0.039	−0.038	0.020	0.058
	Convenient	−0.035	0.036	0.330	−0.019	0.024	0.429

Note: We estimate the effect for the default incentive group (men aged 40–46) and the opt-in incentive group (men aged 47–57) using results of the linear probability model presented in D.4. The effect for the opt-in incentive group is a linear combination of the estimates, $\beta_j - \beta_{\text{Altruistic}}$. The effect for the default incentive group is a linear combination of the estimates, $\beta_j + \gamma_j - (\beta_{\text{Altruistic}} + \gamma_{\text{Altruistic}})$. F-test is used for linear combination null hypothesis. Robust standard errors.

Table D.6 compares the effect of the message with that of the Altruistic message. Other text message groups' antibody testing uptake rates do not differ significantly from those of the Altruistic message group. In this sense, text messages other than the Altruistic message may also promote antibody test uptake; however, the difference is insufficient to maintain sufficient power.

Appendix E Elicitation of WTP for Rubella Vaccination and Estimation of Demand Curve

	Vaccine	Not Vaccinated
Subsidy is 0 JPY, you pay 5,000 JPY	○	○
Subsidy is 1,000 JPY, you pay 4,000 JPY	○	○
Subsidy is 2,000 JPY, you pay 3,000 JPY	○	○
Subsidy is 3,000 JPY, you pay 2,000 JPY	○	○
Subsidy is 4,000 JPY, you pay 1,000 JPY	○	○
Subsidy is 5,000 JPY, you pay 0 JPY	○	○
Subsidy is 6,000 JPY, you receive 1,000 JPY	○	○
Subsidy is 7,000 JPY, you receive 2,000 JPY	○	○
Subsidy is 8,000 JPY, you receive 3,000 JPY	○	○
Subsidy is 9,000 JPY, you receive 4,000 JPY	○	○
Subsidy is 10,000 JPY, you receive 5,000 JPY	○	○
	Vaccine	Not Vaccinated

Figure E.1: Elicitation of Willingness-to-Pay for Rubella Vaccination.

To evaluate the effect of the text messages in monetary terms, we use the rubella vaccination willingness to pay. Before presenting text messages, the first wave survey elicits the willingness-to-pay amount using the multiple price list method (see Figure E.1 for the survey screen). We ask respondents to indicate their intention to get vaccinated when the local government's subsidy is 5,000 JPY. s_j. The subsidy amounts are $s_j \in \{0, 1000, 2000, \dots, 10000\}$. Let $s_i^{\min}$ be the lowest subsidy at which respondents indicate that they would vaccinate. Let $s_i^{\max}$ be the highest subsidy

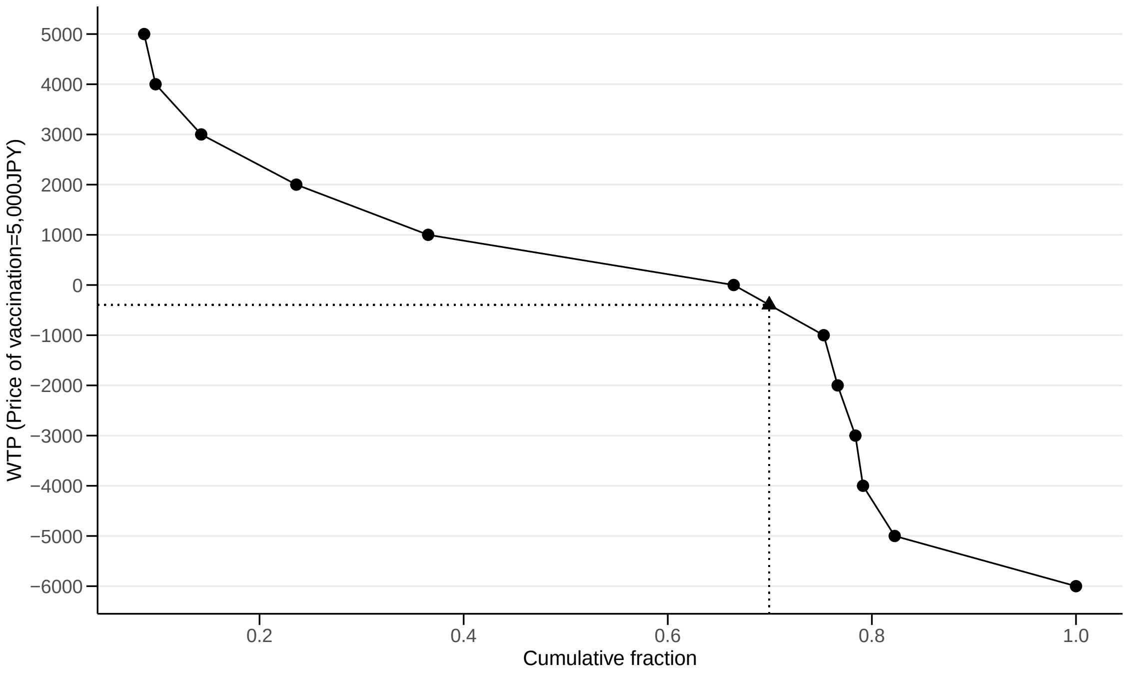

Figure E.2: Demand Curve of Rubella Vaccination for Default Incentive Group. Data source: Men aged 40–46 years in the second wave analysis sample. Note: Black triangles indicate the sum of the percentage of vaccination when vaccination costs are free and the percentage of antibody test uptake in the MHLW message combined, and the corresponding WTP.

at which respondents indicate they would not vaccinate. If respondents indicated that they would not vaccinate at all subsidy amounts, then $s_i^{\max} = 10000$. However, we cannot define $s_i^{\min}$ in the data. Therefore, we assume $s_i^{\min} = 11000$.

We can identify the willingness to pay for vaccination within the range $[5000 - s_i^{\max}, 5000 - s_i^{\min})$. Thus, without additional assumptions, the demand curve is step-wise, and we estimate the monetary value of the message effect with bounds.

To estimate the monetary value, we assume true willingness to pay for vaccination is uniformly distributed between $[[5000 - s_i^{\min}, 5000 - s_i^{\max})$. The vaccination demand curve can then be linearly interpolated. Figure E.2 shows a linear-interpolated demand curve for men aged 40–46 who received vouchers in FY2019 but had not gotten antibody testing or vaccination at the wave 1 survey.

Appendix F Analysis to Address Recall Bias Associated with Self-Reporting of Behavior

In this section, we show results that account for recall bias in second-wave antibody testing and vaccination behaviors. The second wave asks about antibody testing and vaccinations before wave 1. If these responses are subject to recall bias, we should not exclude those who got antibody testing or were vaccinated before wave 1 in the second wave (criterion of the wave 2 analysis sample). We estimate the effect of text messages on behavior by excluding men who have already been tested or vaccinated at response of wave 1 (the same criterion as in the wave 1 analysis sample). Thus, we include those who report in wave 2 getting antibody testing or vaccinated only before wave 1.

Table F.1: Balance Test for Default Incentive Group

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	42.869	43.063	43.099	43.016	42.948	42.901	42.893	0.948
avoid_crowd	3.328	3.331	3.261	3.211	3.339	3.336	3.273	0.958
avoid_out	3.082	3.047	3.028	2.805	2.896	3.038	2.926	0.509
education	14.598	14.457	14.592	14.236	14.130	14.267	14.603	0.530
exercise_w1	0.262	0.181	0.289	0.179	0.165	0.198	0.215	0.161
flushot	0.238	0.268	0.211	0.130	0.148	0.244	0.215	0.040
handwash	3.885	3.866	3.824	3.764	3.748	3.954	3.744	0.624
health_check	0.656	0.638	0.683	0.528	0.617	0.664	0.620	0.236
income	556.952	652.347	611.214	625.226	564.594	588.881	640.231	0.096
married	0.402	0.465	0.408	0.415	0.452	0.473	0.479	0.765
noinfo_income	0.164	0.157	0.190	0.187	0.157	0.130	0.182	0.840
temp_check	2.180	2.260	2.380	2.179	2.226	2.145	2.157	0.735
wear_mask	2.951	3.063	3.113	3.033	2.965	3.115	3.174	0.852

Note: Description of variables is shown in Table B.1. We use men aged 40–46 received free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-values of the joint null hypothesis (F-test).

We estimate the message effects using two subsamples, dividing the sample by automatically receiving vouchers in FY2019 (aged 40-46 years or not). Tables F.1 and F.2 show balance tests. We confirm that treatment arms have balanced observables.

We calculate the smallest effect size required to maintain 80% power and 5% significance. When using the subsample of men who received free vouchers automatically in FY2019, we require at least a 6.8 percentage point difference. When we use the subsample of men who required costly procedures to obtain monetary incentives such as vouchers, the minimum difference is 5.2 percentage points.

We alter the outcome variables. The outcome variable of antibody test uptake in the main paper is a binary variable that takes one if the respondent received antibody testing after the first wave

Table F.2: Balance Test for Opt-in Incentive Group

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	p-value
age	51.664	51.396	51.210	51.602	51.454	51.567	51.536	0.722
avoid_crowd	3.307	3.378	3.429	3.250	3.306	3.296	3.455	0.354
avoid_out	2.903	2.917	2.919	2.884	2.825	2.966	2.982	0.848
education	14.542	14.652	14.533	14.833	14.576	14.609	14.378	0.589
exercise_w1	0.160	0.196	0.248	0.231	0.188	0.206	0.216	0.304
flushot	0.223	0.243	0.200	0.264	0.284	0.223	0.248	0.453
handwash	3.803	3.883	3.900	3.778	3.817	3.833	3.892	0.827
health_check	0.634	0.661	0.690	0.685	0.651	0.670	0.649	0.872
income	709.184	711.202	688.773	673.323	645.225	712.130	713.246	0.326
married	0.588	0.578	0.624	0.662	0.603	0.554	0.608	0.337
noinfo_income	0.185	0.165	0.129	0.111	0.157	0.163	0.212	0.076
temp_check	2.139	2.248	2.210	2.083	2.192	2.086	2.270	0.490
wear_mask	3.071	3.191	3.157	3.148	2.961	2.966	3.068	0.447

Note: Description of variables is shown in Table B.1. We use men aged 40–46 years who needed expensive procedures to get free vouchers in FY2019. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-values of the joint null hypothesis (F-test).

survey. The vaccination outcome variable is a dummy variable that takes one if the respondent received antibody testing after the first wave and also received the vaccination. In contrast, in this supplement, the antibody test uptake is a dummy variable that takes one if the respondent reported getting antibody testing in the second wave, regardless of timing. Furthermore, vaccination uptake is a dummy variable that takes one if the participant responded in the second wave that they received antibody testing and vaccination regardless of timing.

Using a subsample of men who received free vouchers in FY2019, we present in Fig. F.1 the uptake rate of antibody taking (Panel A) and vaccination (Panel B) for each experimental arm. The Altruistic message encourages antibody testing. MHLW (Control) and Altruistic antibody testing uptake rates are 6.6% and 14.1%, respectively. The Altruistic message increased antibody testing by 7.5 percentage points, which is statistically significant at the 5% level. The result is consistent with the main paper. The altruistic message effect on vaccination is insignificant.

Fig. F.2 shows the uptake rate of antibody testing (Panel A) and vaccination (Panel B) for each experimental arm among men who required costly procedures to obtain vouchers in FY2019. Altruistic and Convenient messages encourage antibody testing, but only Convenient boosts vaccination rates. The MHLW (Control) message group's antibody testing uptake rate is 2.5%, while the Altruistic and Convenient messages are 5.7% and 6.8%, respectively. Thus, the Altruistic and Convenient messages increase antibody testing uptake by 3.2 and 4.3 percentage points, respectively. MHLW (Control) and Convenient have 1.7% and 5% vaccination coverage, respectively. The Convenient message effect on vaccination coverage is 3.3

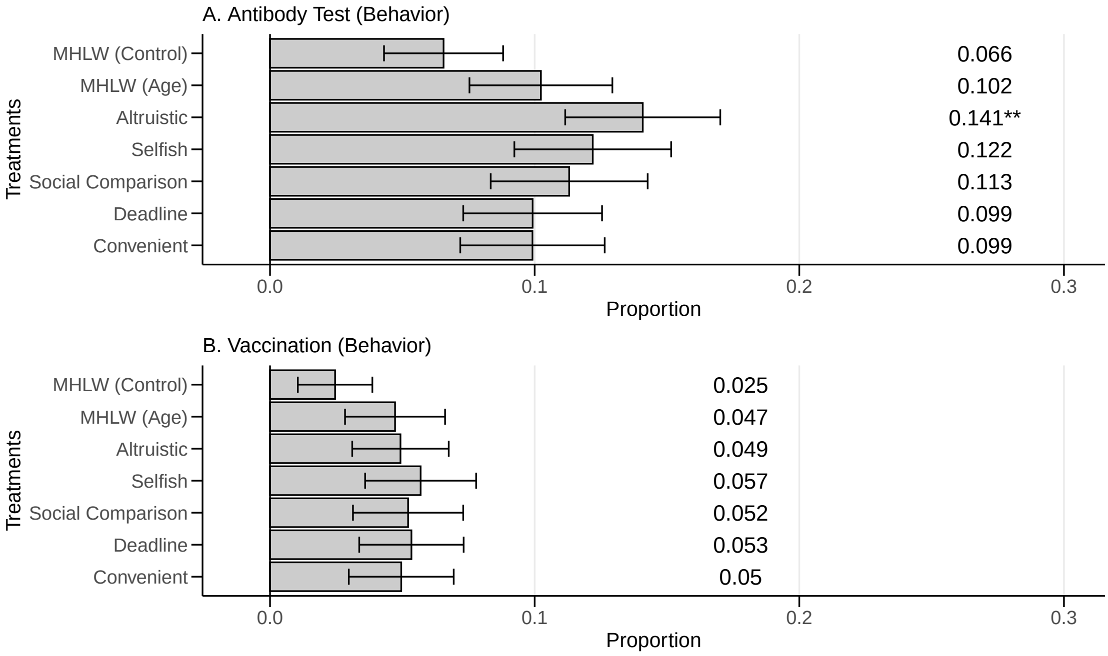

Figure F.1: Effect of Text Messages on Behavior for Default Incentive Group (N = 881). Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values for t-tests of the difference in means from the MHLW message group: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

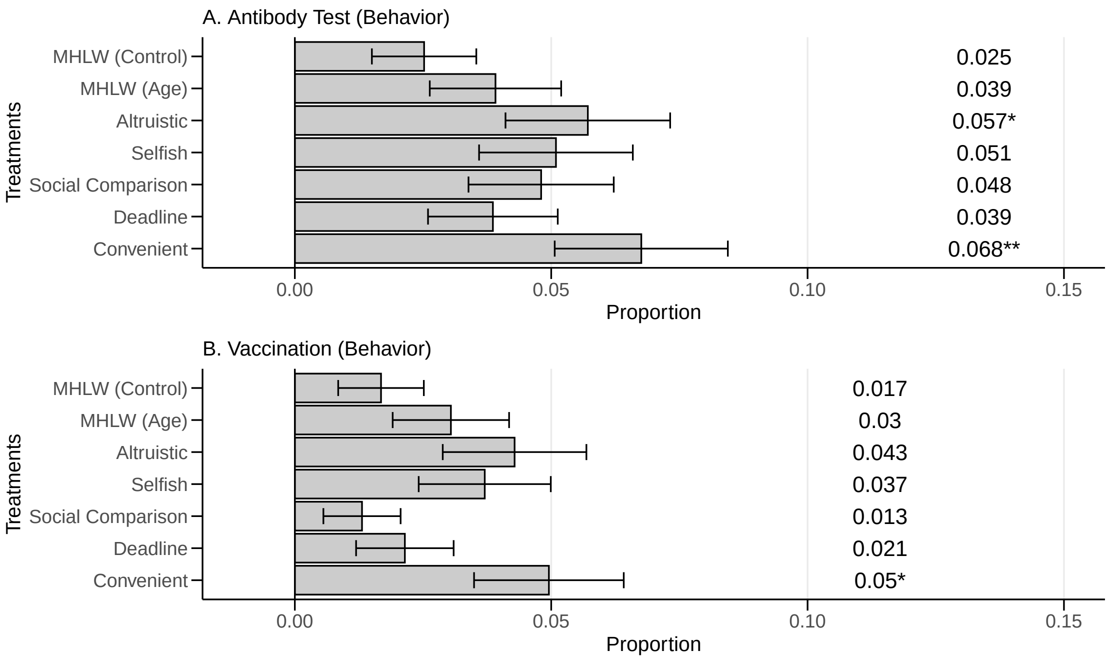

Figure F.2: Effect of Text Messages on Behaviors for Opt-in Incentive Group (N = 1,578). Note: Numbers in the figure indicate the proportion of each group. Error bars indicate the standard error of the mean. Asterisks are p-values for t-tests of the difference in means from the MHLW message group: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table F.3: Linear Probability Model of Behaviors

	Antibody Test	Vaccination
	(1)	(2)
MHLW (Age)	0.010	0.012
	(0.017)	(0.014)
Altruistic	0.028	0.023
	(0.019)	(0.016)
Selfish	0.020	0.019
	(0.018)	(0.015)
Social Comparison	0.020	−0.005
	(0.018)	(0.011)
Deadline	0.013	0.005
	(0.016)	(0.013)
Convenient	0.041**	0.031*
	(0.020)	(0.017)
Coupon	0.019	−0.014
	(0.028)	(0.021)
Coupon×MHLW (Age)	0.025	0.010
	(0.038)	(0.027)
Coupon×Altruistic	0.046	0.000
	(0.041)	(0.028)
Coupon×Selfish	0.042	0.015
	(0.041)	(0.029)
Coupon×Social Comparison	0.031	0.032
	(0.041)	(0.027)
Coupon×Deadline	0.019	0.023
	(0.038)	(0.027)
Coupon×Convenient	−0.006	−0.006
	(0.040)	(0.029)
Num.Obs.	2459	2459
R2	0.096	0.052
R2 Adj.	0.086	0.042
Covariates	X	X

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors.. We also control for covariates obtained in waves 1 and 2. The list of covariates is presented in Table B.1.

Table F.4: Effects of Text Messages on Behaviors for Two Groups Using Linear Probability Model Estimates

		Antibody testing			Vaccination		
How to get coupons	Text-based nudges	estimate	std.error	p.value	estimate	std.error	p.value
Opt-in incentive	MHLW (Age)	0.010	0.017	0.530	0.012	0.014	0.404
	Altruistic	0.028	0.019	0.146	0.023	0.016	0.152
	Selfish	0.020	0.018	0.270	0.019	0.015	0.213
	Social Comparison	0.020	0.018	0.275	−0.005	0.011	0.668
	Deadline	0.013	0.016	0.436	0.005	0.013	0.688
	Convenient	0.041	0.020	0.039	0.031	0.017	0.065
Default incentive	MHLW (Age)	0.035	0.035	0.308	0.022	0.023	0.354
	Altruistic	0.074	0.036	0.043	0.023	0.023	0.306
	Selfish	0.062	0.037	0.088	0.034	0.025	0.175
	Social Comparison	0.051	0.037	0.166	0.027	0.025	0.278
	Deadline	0.032	0.034	0.347	0.028	0.024	0.246
	Convenient	0.035	0.035	0.322	0.025	0.024	0.296

Note: We estimate the effect for the default incentive group (men aged 40–46) and the opt-in incentive group (men aged 47–57) using F.3. The effect for the opt-in incentive group is the estimate β_j. The effect for the default incentive group is a linear combination of the estimates, $\beta_j + \gamma_j$. F-test is used for linear combination null hypothesis. Robust standard errors.

We estimate a linear probability model because the difference in effects between two subsamples is affected not only by whether or not the free vouchers are automatically distributed but also by differences in age groups. Regression analysis produces the same results. Furthermore, Table F.4 shows that the effect of the Selfish message on antibody testing uptake rate is 6.2 percentage points among men who automatically received coupons in FY 2019, which is statistically significant at the 10% level. Even though the effect size remains unchanged, the effect of Altruistic messages on antibody testing is statistically insignificant among men who required a costly procedure to receive the free vouchers. Furthermore, Table F.3 shows that the heterogeneous message effects are statistically insignificant.

Table F.5 shows the number of people who had antibody testing, the number of people who had a negative antibody test, and the number of people who were vaccinated in each experimental arm. As stated in the main paper, most negatives receive vaccination in all experimental arms, regardless of whether eligible men received vouchers automatically. As a result, the message effects on vaccination are strongly influenced by the negative ratio of antibody testing. The Convenient message has a negative rate of 87% ($= 13/15$) among eligible men who needed costly procedures to get vouchers. As a result of this, the Convenient message has a statistically significant positive effect on vaccination rates. The variation in negative rates across experimental arms, on the other hand, is most likely a statistical error. A Fisher's exact test is used to test the null hypothesis that

Table F.5: Classification of Antibody Test Takers

Text messages	Default incentive group: Antibody test	Default incentive group: Negatives	Default incentive group: Vaccination	Opt-in incentive group: Antibody test	Opt-in incentive group: Negatives	Opt-in incentive group: Vaccination
MHLW (Control)	8	3	3	6	4	4
MHLW (Age)	13	6	6	9	9	7
Altruistic	20	8	7	12	9	9
Selfish	15	7	7	11	8	8
Social Comparison	13	7	6	11	5	3
Deadline	13	7	7	9	6	5
Convenient	12	8	6	15	13	11
Fisher's exact test (p-value)		0.83	0.76		0.12	0.31

Note: Fisher's exact test was used to test the null hypothesis that the number of negative antibody tests and vaccinations does not differ between experimental arms.

Table F.6: Estimated Monetary Value of Text Message Reminders

Text-based nudge	Size of effect	Baseline + size of effect	Monetary value (JPY): pp	Monetary value (JPY): total	Monetary value (USD): pp	Monetary value (USD): total
MHLW (Age)	0.037	0.766	1528.377	8.085	13.894	73.501
Altruistic	0.075	0.805	3925.285	20.765	35.684	188.771
Selfish	0.056	0.786	3285.074	17.378	29.864	157.982
Social Comparison	0.047	0.777	2200.534	11.641	20.005	105.826
Deadline	0.034	0.763	1331.690	7.045	12.106	64.042
Convenient	0.034	0.763	1327.720	7.024	12.070	63.851

Note: We use the effect size of each text message reminder on antibody testing. Baseline is the sum of the rate of antibody test in the control and the free vaccination rates. The monetary value is the amount per person multiplied by the number of people who received the coupon in 2019 but did not use it until January 2020 (5.29 million). We valued it in Japanese Yen and US Dollars (1USD = 110JPY). The unit of monetary value per person is 1 JPY and 1 USD, respectively. The unit of total monetary value is 1 billion JPY and 1 million USD, respectively.

the number of negative antibody tests is the same across experimental arms. As a result, in two subsamples, we cannot reject the null hypothesis.

In terms of monetary value, we attempt to assess the impact of text messages among those who automatically received free vouchers in FY2019. Fig. F.3 draws the demand curve for rubella vaccinations using men who automatically received monetary incentives as vouchers in FY2019, using the method presented in the main paper and Appendix E. The vaccination rate is 0.664 when the vaccination price is zero.

Using the message effects on the uptake rate of antibody testing, Table F.6 shows the economic value of text messages. The per capita value displayed in the fourth column represents the absolute change in WTP when vaccination rate is increased from baseline by the message effect (third column). The value per person of the Altruistic message is approximately 3,900 JPY (about 35 USD). The total value is equal to the product of the per capita value and the number of people who

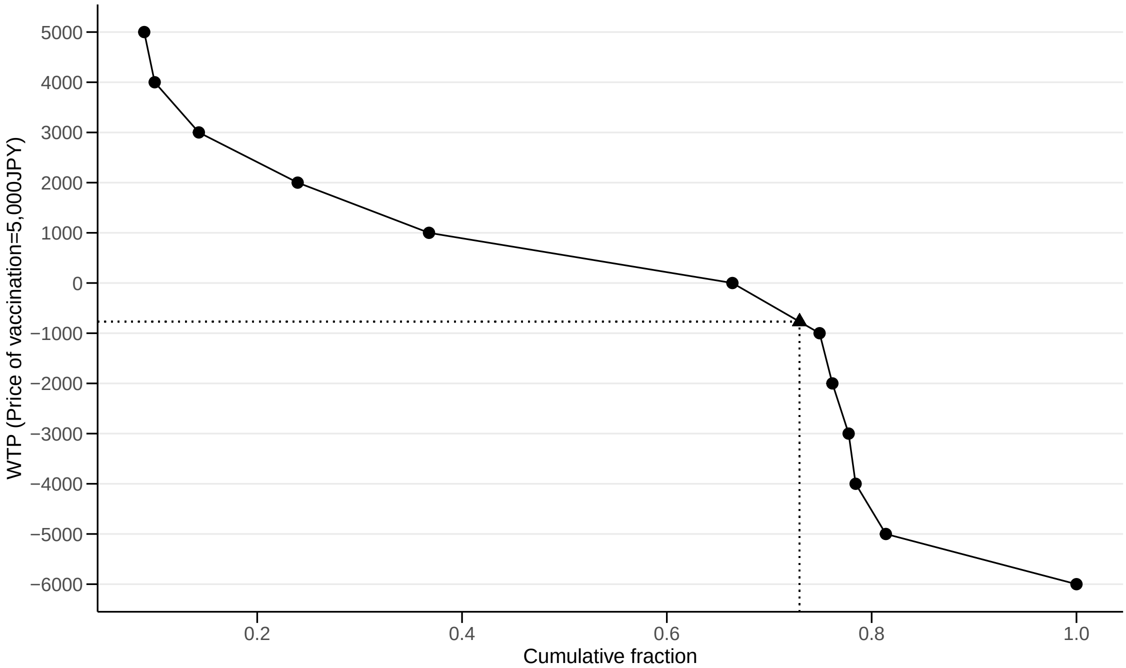

Figure F.3: Demand Curve of Rubella Vaccination for Default Incentive Group. Note: Black triangles indicate the sum of the percentage of vaccination when vaccination costs are free and the percentage of antibody test uptake in the MHLW message combined, and the corresponding WTP.

have not yet redeemed their free vouchers for FY2019 (5.29 million as of January 2020). The total monetary value of the Altruistic message is 20 billion JPY in the fifth column (about 189 million USD).