RIETI Discussion Paper Series 26-E-023

Nudging Automatic Debit for Property Tax: Evidence from two natural field experiments

NISHIHATA, Masaya
Keio University / Mitsubishi UFJ Research and Consulting

KOBAYASHI, Yohei
RIETI

ISHIKAWA, Takayuki
Mitsubishi UFJ Research and Consulting

RIETI
Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 26-E-023
March 2026

Nudging Automatic Debit for Property Tax: Evidence from two natural field experiments[1]

Masaya NISHIHATA
Graduate School of Economics, Keio University / Mitsubishi UFJ Research and Consulting
Yohei KOBAYASHI
Research Institute of Economy, Trade and Industry / Mitsubishi UFJ Research and Consulting
Takayuki ISHIKAWA
Mitsubishi UFJ Research and Consulting

Abstract

This study conducted two natural field experiments in Yokohama City, Japan, to evaluate the effectiveness of behavioral nudges in promoting automatic debit registration for property tax payments. While much of the existing literature on tax compliance focuses on reminder letters, relatively little attention has been paid to payment method choice, despite its potential to reduce administrative costs associated with reminders and enforcement. We find that a nudge flyer and the inclusion of the owner code required for the application increase the probability of applying for automatic debit by 2.7 and 2.8 percentage points, respectively. When implemented together, the combined intervention increases adoption by 8.8 percentage points, suggesting complementarities between benefit-enhancing and cost-reducing components. Despite the increase in automatic debit adoption, we find no evidence that these interventions improve on-time payment within the time frame observed in our experiments. This may reflect low baseline delinquency among new taxpayers or the possibility that the interventions primarily affect taxpayers who would have paid on time even in the absence of automatic debit. Taken together, our findings highlight both the potential and the limits of behavioral nudges in improving tax administration outcomes.

Keywords: taxation, automatic debit, natural field experiment, nudge
JEL classification: C93, D91, H26, H71

[1]This study is conducted as a part of the Project "Comprehensive study to promote Evidence-Based Policy Making (EBPM) in Japan" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The draft of this paper was presented at the RIETI DP seminar for the paper. We are especially grateful to Fumio Ohtake, Daiji Kawaguchi, Eiichi Tomiura, Kyoji Fukao, and Shusaku Sasaki for their valuable comments and suggestions. We also thank participants of the RIETI DP Seminar and the 26th Experimental Social Science Conference for their helpful comments.

1. Introduction

The collection of taxes is essential for providing public services such as healthcare, education, and infrastructure. In most countries, however, tax evasion and noncompliance exist to some extent. Allingham and Sandmo (1972) theoretically analyze the decision to evade taxes and suggest that it is possible to prevent tax evasion by increasing the penalty rate and the probability of detecting tax evasion. However, when individuals intend to pay but forget to do so or have misconceptions about penalty rates and related costs, behavioral approaches such as nudges can also effectively enhance tax compliance.

In recent years, a growing body of empirical research has examined behavioral approaches to tax collection. For instance, Hallsworth et al. (2017) conducted two large-scale field experiments targeting individuals with delinquent income tax in the U.K. They find that standard reminder letters that include social norm messages increase payment rates.[1] In addition, existing studies find that deterrence messages (Castro and Scartascini, 2015; Chirico et al., 2019; Cranor et al., 2020; De Neve et al., 2021) and simplifying communication (De Neve et al., 2021) can also increase tax compliance.

While most of the literature examines how messages in reminder letters sent to individuals with delinquent payments, few studies focus on the payment method.[2] Interventions that encourage the payment of overdue taxes typically need to be repeated each time noncompliance occurs, which can be costly for tax authorities. In contrast, once taxpayers choose automatic debit as a payment method, future tax payments are automatically withdrawn from their bank accounts. This feature can reduce both administrative costs by limiting the need for repeated reminder letters and transaction costs for taxpayers, who no longer need to actively initiate each payment. This contrast highlights that payment methods can shape tax compliance not only at a single point in time, but also in a persistent manner, by reducing the need for repeated active decisions by taxpayers.

On this basis, we conducted two natural field experiments that nudged automatic debit for property tax in Yokohama City, Kanagawa, Japan. Specifically, we sent direct mail that

[1] In related work, Allcott (2011) evaluates the effectiveness of a social norm nudge using Home Energy Report programs that compare participants' electricity usage with that of their neighbors. He finds that, on average, these programs reduce energy consumption by 2.0%.

[2] Relatedly, Guttman-Kenney et al. (2025) conduct a field experiment on payment method choice in credit card repayments. By shrouding the option to automatically pay only the minimum amount each month, the share of cardholders paying exactly the minimum decreased. However, nudged cardholders often chose automatic fixed payments set only slightly above the minimum, while others opted for manual payments instead of autopay, leading to an increase in missed payments. Overall, the intervention did not lead to a significant reduction in credit card debt.

contained a flyer recommending automatic debit to new taxpayers. In the first experiment, new taxpayers were randomly assigned to different mailing conditions, including a nudge version of the flyer with a separately enclosed owner code sheet and a standard version of the flyer without the owner code. The inclusion of the owner code reduces procedural frictions by eliminating the need for taxpayers to locate the code from previous correspondence before completing the application for automatic debit. Because the first experiment bundled multiple components into a single intervention, the second experiment expanded the design to disentangle these components. Specifically, the second experiment independently varied the flyer design, the inclusion of the owner code, and the envelope design.

Our experiments demonstrate that the nudge flyer and the inclusion of the owner code each increased the application rate for automatic debit by 2.7 and 2.8 percentage points, respectively, while the combined intervention increased adoption by 8.8 percentage points, suggesting potential complementarities between the two components. By contrast, we found no evidence that a nudge version of the envelope design affected application rates. We do not find statistically significant effects of these interventions on on-time payment rates.

One interpretation is that baseline delinquency among new taxpayers is low, making changes in aggregate on-time payment behavior difficult to detect. In this case, automatic debit may nonetheless generate benefits over a longer horizon by preventing missed payments as taxpayers' attention or salience declines over time, although such longer-run or cumulative effects cannot be assessed with our data. An alternative interpretation is that the interventions disproportionately attracted taxpayers with relatively high compliance. This suggests that additional or more targeted approaches may be needed to encourage automatic debit adoption among low-compliance taxpayers.

The rest of this paper proceeds as follows. Section 2 describes the experimental design of our two natural field experiments. Section 3 presents the empirical results. Section 4 introduces a conceptual framework to interpret the findings. Finally, Section 5 concludes.

2. Background and experimental design

2.1 Institutional background

In this study, we collaborated with Yokohama City, Kanagawa, Japan, and conducted two natural field experiments to evaluate the effectiveness of nudges encouraging automatic debit

for property tax.

The amount of property tax is calculated as the assessed value of the property as determined by the city multiplied by the tax rate (1.4%), and the total amount represents approximately 30% of municipal taxes in Yokohama.[3] Tax liability is determined based on ownership of land or buildings as of January 1, and taxpayers receive tax notices in early April. Property tax is paid in four installments: April, July, December, and the following February. In addition, taxpayers can also make a single lump-sum payment for the entire year in April. Payment methods include cash, automatic debit, credit cards, and others; except for automatic debit, taxpayers must complete the payment procedure each time. If taxpayers have not completed the payment by the deadline, the city sends reminder letters approximately one month after the due date. Furthermore, if taxpayers still have not made the outstanding payment, the delinquent collection process begins.

2.2 First experiment

In the first experiment, we conducted a natural field experiment among new taxpayers (n = 3,184) in Totsuka-ku, Yokohama City. By targeting new taxpayers, we were able to make timely interventions when taxpayers had recently acquired property, making it more likely that taxpayers will choose automatic debit. Specifically, on October 21, 2020, we randomly assigned new taxpayers to three groups and sent different types of direct mail.[4] Group 1 (n = 1,200) received a nudge flyer encouraging automatic debit, together with a sheet listing the owner code required to apply for automatic debit. Without the enclosed code, applicants must locate the owner code in prior tax notices when applying for automatic debit. Group 2 (n = 1,200) received a standard flyer without the owner code. Group 3 (n = 784) received no mail.[5] Table 1 summarizes all materials included in the mailings for each group, including items other than the flyer and the owner code. The application data are administrative records collected as of January 5, 2021. This design allows us to assess the effect of providing a nudge flyer together with the owner code, relative to a standard flyer without the owner code or no mailing.

[3] Taxpayers who own land or buildings in areas designated for urbanization (areas with concentrations of houses and shops) are also subject to a city planning tax at a rate of 0.3%, in addition to the property tax. Property and city planning taxes are not levied when the total assessed value of a taxpayer's property within the same district falls below the exemption threshold, which is 300,000 JPY for land and 200,000 JPY for buildings.

[4] The number of groups and the sample size for each group are determined based on a power calculation designed to detect an effect size of three percentage points in the comparison between Groups 1 and 2.

[5] In 2020 and 2021, Yokohama City did not mail any flyers promoting automatic debit to new taxpayers. Thus, Groups 1 and 2 received only additional information, and no participants were disadvantaged by the contents of the materials sent.

Table 1: Materials included in the mailings by group in the first experiment

	Group 1	Group 2	Group 3
Flyer	Nudge	Standard	
Owner code	✓		
Application form	✓	✓	
Example of filling out	✓	✓	
Self-addressed envelope	✓	✓	
# of new taxpayers	1,200	1,200	784

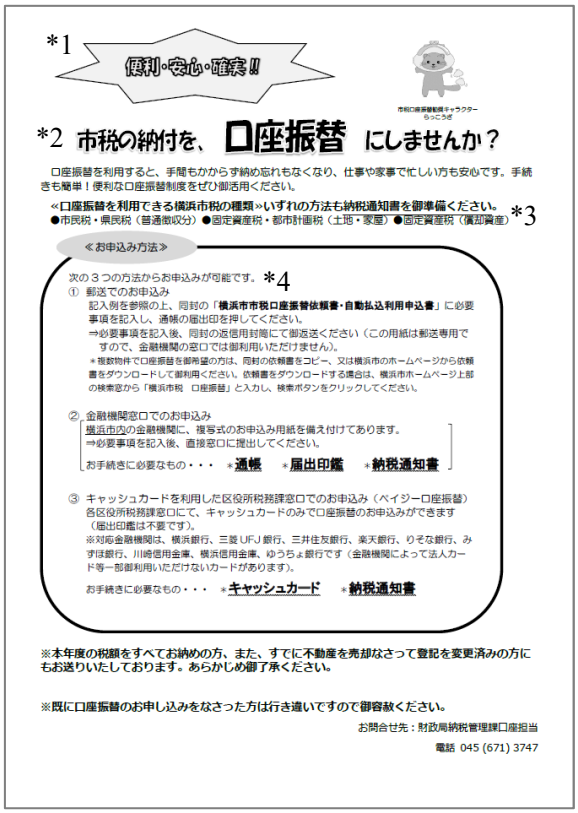
Figure 1 illustrates the design of the standard flyer. The primary message recommends automatic debit and explains the various types of taxes subject to this transfer and the application methods. Although this flyer provides sufficient detailed information, conveying the advantages of automatic debit and specific application procedures may be challenging due to the high text density and information overload.[6] By contrast, the nudge version of the flyer, shown in Figure 2, incorporates four key enhancements. First, we simplified it by reducing text density and visually presented a step-by-step application process, focusing on a single application method. As Bhargava and Manoli (2015) and De Neve et al. (2021) show, simplification can be effective. This enhancement would help flyer readers understand the content, especially in complex administrative documents. Second, the main message emphasizes penalties. The effectiveness of loss-aversive messages has been documented in numerous pieces of literature (e.g., Tversky and Kahneman, 1991; Pope and Schweitzer, 2011; and Fryer et al., 2022). Third, we stipulated the application deadline for making payment of property tax for the third period via automatic debit to prevent procrastination in applying. Dirkmaat et al. (2023) find that setting an earlier non-binding target date nudges individuals toward earlier submission. Although an application for automatic debit is optional, such a gentle deadline may encourage individuals to apply. Finally, as it was the peak of the COVID-19 pandemic in 2020, we added the timely and beneficial message that automatic debit can be a precaution against COVID-19 by reducing in-person contact at banks, convenience stores, and government offices.

To mitigate the risk of contamination, we refrained from sending different types of direct mail to the same name or address. Except for this, we employed a simple random assignment method without clustering. While our available data only allowed us to determine whether

[6] Iyengar and Lepper (2000) show, using laboratory and field experiments, that individuals are more likely to prefer a limited set of options rather than an extensive choice set.

individuals lived in Yokohama and co-owned the property with others, the resulting groups exhibited similar average characteristics, as shown in Table 2. Consequently, this experiment allows us to estimate the average treatment effect of receiving the nudge flyer together with the owner code.

Figure 1: The standard version of the flyer



English translation:

*1 Convenient, Safe, and Reliable

*2 Would you like to pay your city tax with automatic debit?

*3 The following Yokohama City taxes are eligible for automatic debit:

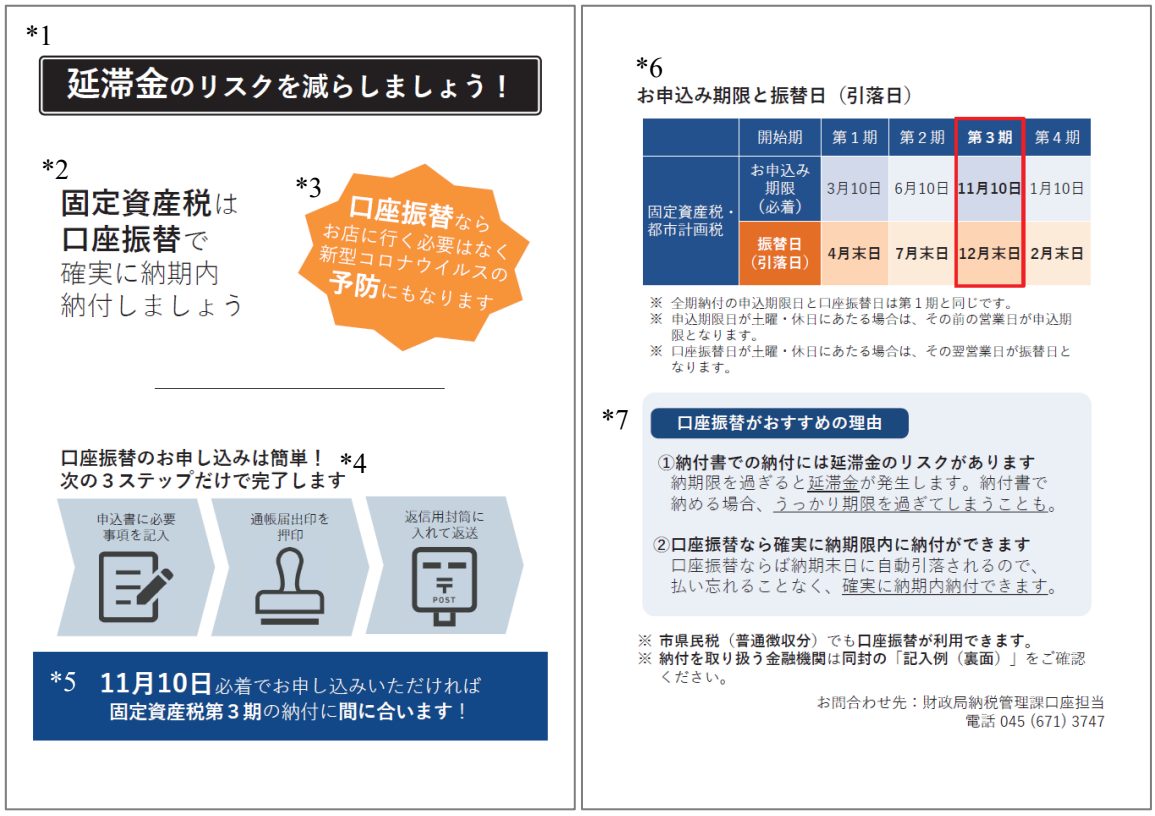
Resident and prefectural taxes, property and city planning taxes, property tax for depreciable assets

*4 Application can be submitted by one of the three methods:

By mail, at a financial institution's counter, or at a government office counter

Source: Provided by Totsuka-ku, Yokohama City.

Figure 2: The nudge version of the flyer (left: front side, right: back side)



English translation:

*1 Let's reduce the risk of penalty fees!

*2 Let's ensure on-time payment of property tax through automatic debit.

*3 With automatic debit, there is no need to visit stores, and it also helps prevent COVID-19.

*4 Applying is easy! It can be completed in just three simple steps.
(Document filling, stamping, and submission)

*5 If you apply by November 10, your property tax for the third period will be paid with automatic debit!

*6 Application deadline and transfer date

*7 Reasons to consider automatic debit

Source: Designed by Totsuka-ku and Mitsubishi UFJ Research and Consulting, with the cooperation of the Behavioural Insights Team.

Table 2: Balance check for the first experiment

	Group 1	Group 2	Group 3
Living in Yokohama	0.884	0.900	0.904
Welch's *t*-test (= Group 1)		(0.211)	(0.150)
Welch's *t*-test (= Group 2)			(0.750)
With co-owner	0.238	0.247	0.244
Welch's *t*-test (= Group 1)		(0.601)	(0.788)
Welch's *t*-test (= Group 2)			(0.844)

Notes: *p*-values are in parentheses.

2.3 Second experiment

In the second experiment, we collaborated with Konan-ku and Kanazawa-ku, in addition to Totsuka-ku, Yokohama City. As in the first experiment, we conducted a natural field experiment targeting new taxpayers (n = 7,621). The flyer designs were identical to those used in the first experiment.

In this trial, because the first experiment examined the combined intervention, we aim to estimate the average treatment effect separately for the nudge version of the flyer, the inclusion of the owner code, and the nudge version of the envelope. To achieve this, on October 20, 2021, we randomly assigned new taxpayers to five groups and sent different types of direct mail. Group 1 (n = 1,640) received the nudge flyer with the owner code in a standard envelope; Group 2 (n = 1,641) received the nudge flyer without the owner code in a standard envelope; Group 3 (n = 2,391) received the nudge flyer with the owner code in a nudge envelope; Group 4 (n = 1,641) received the standard flyer with the owner code in a standard envelope; and Group 5 (n = 308) received no mail. Table 3 displays the combination of all materials sent. The application data are administrative records collected as of January 14, 2022. Due to limitations on the number of envelopes available at the municipal level and budget constraints, we could not achieve an equal allocation across groups. This design allows us to identify the effect of the nudge flyer by comparing Group 1 and Group 4, the effect of the owner code by comparing Group 1 and Group 2, and the effect of the nudge envelope by comparing Group 3 and Group 1.

Table 3: Materials included in the mailings by group in the second experiment

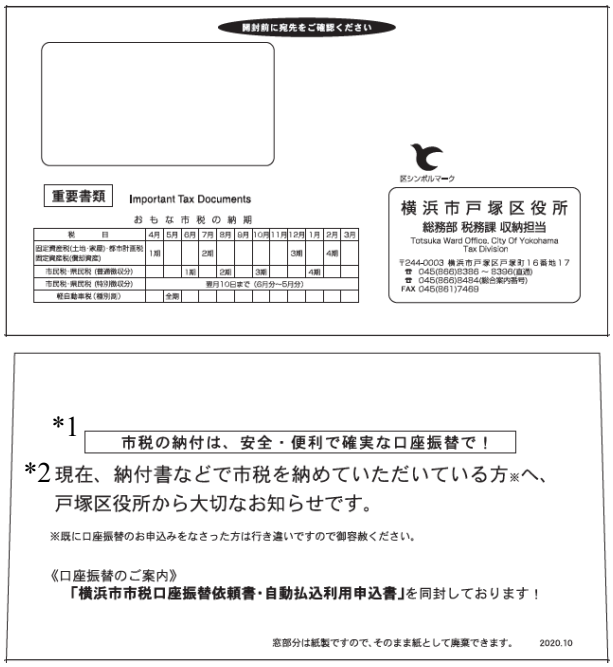
	Group 1	Group 2	Group 3	Group 4	Group 5
Flyer	Nudge	Nudge	Nudge	Standard	
Envelope	Standard	Standard	Nudge	Standard	
Owner code	✓		✓	✓	
Application form	✓	✓	✓	✓	
Example of filling out	✓	✓	✓	✓	
Self-addressed envelope	✓	✓	✓	✓	
# of new taxpayers					
Totsuka-ku	724	724	724	724	0
Konan-ku	466	467	1,000	467	308
Kanazawa-ku	450	450	667	450	0
Total	1,640	1,641	2,391	1,641	308

Figures 3 and 4 illustrate the designs of the standard and nudge versions of the envelope,

respectively. The standard envelope straightforwardly recommends secure automatic debit and emphasizes the importance of the enclosed notice on the back side. In contrast, the nudge envelope highlights the time-saving benefits of automatic debit and encourages recipients not to miss this opportunity on a sticky-note-style design on the front side. These design features intended to increase the likelihood that recipients open the envelope and, in turn, encourage applications for automatic debit.

The randomization procedure is similar to that in the first experiment. However, the allocation of individuals to each group varies by taxing district due to the limitations in the number of available envelopes at the municipal level and budget constraints. As in the first experiment, we avoid sending different types of direct mail to the same address to mitigate the risk of contamination. Table 4 indicates that the average characteristics are similar across the resulting groups. Accordingly, this design allows us to estimate the average treatment effect of the nudge flyer, the inclusion of the owner code, and the nudge envelope separately.

Figure 3: The standard version of the envelope



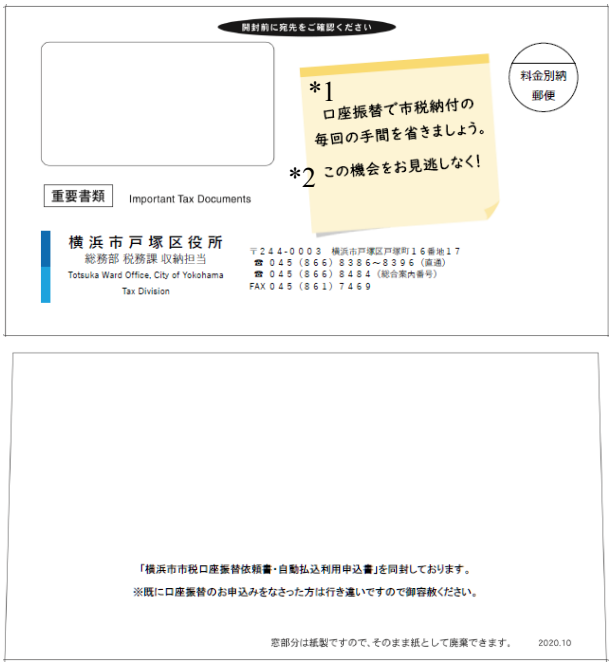
English translation:

*1 Paying city taxes is secure, convenient, and reliable with automatic debit!

*2 An important notice from the Totsuka-ku Ward Office for those currently paying city taxes using a payment slip.

Source: Provided by Totsuka-ku, Yokohama City.

Figure 4: The nudge version of the envelope



English translation:

*1 Let's save time with each city tax payment using automatic debit.

*2 Don't miss this opportunity!

Source: Designed by Totsuka-ku, Konan-ku, Kanazawa-ku, and Mitsubishi UFJ Research and Consulting, with the cooperation of the Behavioural Insights Team.

Table 4: Balance check for the second experiment

	Group 1	Group 2	Group 3	Group 4	Group 5
Living in Yokohama	0.888	0.898	0.885	0.901	0.909
Welch's *t*-test (= Group 1)		(0.334)	(0.782)	(0.231)	(0.242)
Welch's *t*-test (= Group 2)			(0.182)	(0.816)	(0.547)
Welch's *t*-test (= Group 3)				(0.112)	(0.173)
Welch's *t*-test (= Group 4)					(0.640)
With co-owner	0.238	0.240	0.250	0.235	0.218
Welch's *t*-test (= Group 1)		(0.878)	(0.371)	(0.830)	(0.432)
Welch's *t*-test (= Group 2)			(0.468)	(0.712)	(0.382)
Welch's *t*-test (= Group 3)				(0.259)	(0.196)
Welch's *t*-test (= Group 4)					(0.508)

Notes: *p*-values are in parentheses.

3. Results

3.1 First experiment

As mentioned in Section 2.2, we randomly assigned new taxpayers to three groups to examine the impact of the nudge flyer with the owner code. To estimate this effect, we employ a simple linear probability model. Specifically, we estimate the following specification:

$$Y_i = \beta_0 + \boldsymbol{Group_i}\boldsymbol{\beta_1} + \boldsymbol{X_i}\boldsymbol{\theta} + \varepsilon_i,$$

where Y_i is the binary indicator that equals one if individual i applies for automatic debit, $\boldsymbol{Group_i}$ is a vector of treatment group dummies excluding one baseline group, $\boldsymbol{X_i}$ is a vector of control variables, including indicators for living in Yokohama and jointly owning the property with a co-owner, and ε_i is an error term.

Table 5 presents the estimation results from the linear probability model for the first experiment. Columns (1) and (2) report the average treatment effect of receiving the nudge flyer together with the owner code relative to receiving the standard flyer without the owner code (Group 1 vs Group 2), while Columns (3) and (4) report the effects of receiving the standard flyer relative to no mail group (Group 2 vs Group 3). The estimated average treatment effect of the nudge flyer with the owner code is 0.088, implying an 8.8 percentage-point increase in the probability of applying for automatic debit. The corresponding effect of the standard flyer is 0.073. All estimates are statistically significant at the 1% level. The estimated effects are very similar with and without control variables, suggesting that the randomization was successful.

Table 5: Linear probability model for application in the first experiment

	Nudge flyer + Owner code		Standard flyer	
	(1)	(2)	(3)	(4)
Average treatment effect	0.088***	0.088***	0.073***	0.073***
	(0.014)	(0.014)	(0.009)	(0.009)
	[0.000]	[0.000]	[0.000]	[0.000]
Living in Yokohama		✓		✓
With co-owner		✓		✓
Observations	3184	3184	3184	3184
Adjusted R^2	0.044	0.046	0.044	0.046

Notes: The dependent variable is the application for automatic debit. All regressions include indicator variables for the remaining treatment groups, so that coefficients are estimated relative to the omitted baseline group. Robust standard errors are in parentheses. Benjamini and Hochberg's (1995) FDR-adjusted *p*-values, calculated using *p*-values of four hypothetical tests in this table, are in brackets. *** denotes significance at the 1% level.

3.2 Second experiment

In the second experiment, we estimate the effects of the nudge flyer, the inclusion of the owner code, and the nudge envelope separately. While the first experiment estimated the combined effect of nudge flyer and the owner code, the second experiment is designed to disentangle these components. As the data include three taxing districts, all specifications include taxing district fixed effects.

Table 6 presents the estimation results for the second experiment using the full sample. Columns (1) and (2) report the average treatment effect of the nudge flyer relative to the standard flyer (Group 1 vs Group 4), Columns (3) and (4) report the effect of including the owner code (Group 1 vs Group 2), and Columns (5) and (6) report the effect of the nudge envelope relative to the standard envelope (Group 3 vs Group 1). The estimated effect of the nudge flyer is 0.027, corresponding to a 2.7 percentage-point increase in the probability of applying for automatic debit, and is statistically significant at the 5% level. The estimated effect of including the owner code is 0.028 and also statistically significant at the 5% level. In contrast, the estimated effect of the nudge envelope is close to zero and statistically insignificant. As in the first experiment, the estimated effects are similar across specifications with and without additional control variables.

Table 6: Linear probability model for application in the second experiment

	Nudge flyer		Owner code		Nudge envelope	
	(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	0.026**	0.027**	0.028**	0.028**	-0.007	-0.009
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
	[0.049]	[0.049]	[0.049]	[0.049]	[0.553]	[0.521]
Living in Yokohama		✓		✓		✓
With co-owner		✓		✓		✓
Taxing district		✓		✓		✓
Observations	7621	7621	7621	7621	7621	7621
Adjusted R^2	0.007	0.010	0.007	0.010	0.007	0.010

Notes: The dependent variable is the application for automatic debit. All regressions include indicator variables for the remaining treatment groups, so that coefficients are estimated relative to the omitted baseline group. Robust standard errors are in parentheses. Benjamini and Hochberg's (1995) FDR-adjusted *p*-values, calculated using *p*-values of six hypothetical tests in this table, are in brackets. ** denotes significance at the 5% level.

To facilitate comparison with the first experiment, Table 7 reports the estimation results for the subsample of taxpayers in Totsuka-ku. The estimated effect of the nudge flyer is 0.032 and statistically significant at the 10% level. However, after applying the Benjamini and Hochberg's (1995) false discovery rate (FDR) adjustment, the null hypothesis cannot be rejected. Given the smaller sample size relative to the full sample in Table 6, the result should be interpreted with caution. The estimated effect of the owner code is positive (0.018) but statistically insignificant, and the estimated effect of the nudge envelope is close to zero and statistically insignificant. The combined effect of the nudge flyer and the owner code in Totsuka-ku is 0.050, which is smaller than the corresponding estimate in the first experiment.

Table 7: Linear probability model for application in the second experiment in Totsuka-ku

	Nudge flyer		Owner code		Nudge envelope	
	(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	0.032*	0.032*	0.018	0.018	0.007	0.007
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
	[0.225]	[0.225]	[0.482]	[0.482]	[0.713]	[0.713]
Living in Yokohama		✓		✓		✓
With co-owner		✓		✓		✓
Observations	2896	2896	2896	2896	2896	2896
Adjusted R^2	0.001	0.001	0.001	0.001	0.001	0.001

Notes: The dependent variable is the application for automatic debit. All regressions include indicator variables for the remaining treatment groups, so that coefficients are estimated relative to the omitted baseline group. Robust standard errors are in parentheses. Benjamini and Hochberg's (1995) FDR-adjusted *p*-values, calculated using *p*-values of six hypothetical tests in this table, are in brackets. * denotes significance at the 10% level.

3.3 Heterogeneous treatment effect

In this subsection, we present exploratory analyses of heterogeneous treatment effects. We focus on heterogeneity by residence in Yokohama City and by co-ownership of the property. Table 8 reports the results for the first experiment. Each column presents estimates for a specific treatment contrast, and the interaction terms capture whether corresponding average treatment effect varies with observable characteristics. In Columns (1) and (2), which report the average treatment effect of receiving the nudge flyer together with the owner code, the interaction terms with living in Yokohama and with co-owning the property are both positive, with point estimates of approximately 0.03. However, these interaction effects are not statistically significant. Columns (3) and (4), which report the heterogeneous effects of receiving the

standard flyer, show interaction terms of similar magnitude but opposite signs, and these estimates are also not statistically significant. Overall, Table 8 provides no robust evidence that the treatment effects in the first experiment differ systematically by residence in Yokohama or by co-ownership status.

Table 8: Heterogeneous treatment effect in the first experiment

	Nudge flyer + Owner code		Standard flyer	
	(1)	(2)	(3)	(4)
Average treatment effect	0.058*	0.080***	0.058***	0.079***
	(0.035)	(0.016)	(0.022)	(0.011)
ATE × Living in Yokohama	0.034		-0.034	
	(0.038)		(0.038)	
ATE × With co-owner		0.032		-0.032
		(0.030)		(0.030)
Living in Yokohama	✓	✓	✓	✓
With co-owner	✓	✓	✓	✓
Observations	3184	3184	3184	3184
Adjusted R^2	0.046	0.046	0.046	0.046

Notes: The dependent variable is the application for automatic debit. All regressions include indicator variables for all treatment groups except the omitted baseline group, as well as their interactions with the corresponding subgroup indicators. Robust standard errors are in parentheses. *** and * denote significance at the 1% and 10% level, respectively.

Table 9 presents analogous heterogeneity analyses for the second experiment. For the nudge flyer, the interaction between the average treatment effect and living in Yokohama is 0.071 in Column (1) and statistically significant at the 10% level. In contrast, the interaction between the nudge flyer and the co-ownership is close to zero. For the owner code, the interaction with living in Yokohama is negative and statistically insignificant, and for the nudge envelope, the interaction with living in Yokohama is close to zero. Similarly, the interaction terms with co-ownership are small in magnitude and statistically insignificant across treatment contrasts. Taken together, the results in Table 9 do not provide consistent evidence of heterogeneous treatment effects in the second experiment.

Table 9: Heterogeneous treatment effect in the second experiment

	Nudge flyer		Owner code		Nudge envelope	
	(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	-0.037	0.029**	0.063**	0.036**	-0.013	-0.013
	(0.038)	(0.014)	(0.031)	(0.014)	(0.031)	(0.014)
ATE × Living in Yokohama	0.071*		-0.039		0.004	
	(0.040)		(0.033)		(0.033)	
ATE × With co-owner		-0.008		-0.035		0.017
		(0.027)		(0.028)		(0.026)
Living in Yokohama	✓	✓	✓	✓	✓	✓
With co-owner	✓	✓	✓	✓	✓	✓
Taxing district	✓	✓	✓	✓	✓	✓
Observations	7621	7621	7621	7621	7621	7621
Adjusted R^2	0.010	0.009	0.010	0.009	0.010	0.009

Notes: The dependent variable is the application for automatic debit. All regressions include indicator variables for all treatment groups except the omitted baseline group, as well as their interactions with the corresponding subgroup indicators. Robust standard errors are in parentheses. ** and * denote significance at the 5% and 10% level, respectively.

3.4 The effect of the nudges on on-time payment

The primary purpose of encouraging automatic debit is not only to increase take-up but also to improve on-time payment rates and thereby reduce administrative costs associated with payment reminders and delinquent collection. To examine whether the interventions translate into higher on-time payment, we estimate specifications analogous to those in Section 3.1, replacing the dependent variable with the indicator for on-time payment.

Table 10 reports the results for the first experiment, using administrative records on on-time payment from the first period of FY2021 through the second period of FY2022. Across all periods, the estimated average treatment effects of receiving the nudge flyer together with the owner code are close to zero and statistically insignificant.

Table 10: Linear probability model for on-time payment in the first experiment

	Nudge flyer + Owner code					
	FY2021				FY2022	
	1st period	2nd period	3rd period	4th period	1st period	2nd period
	(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	-0.012	-0.009	0.001	-0.008	-0.004	-0.008
	(0.016)	(0.016)	(0.015)	(0.015)	(0.018)	(0.017)
Living in Yokohama	✓	✓	✓	✓	✓	✓
With co-owner	✓	✓	✓	✓	✓	✓
Observations	3184	3184	3184	3184	3184	3184
Adjusted R^2	0.014	0.015	0.011	0.014	0.020	0.016

Notes: The dependent variable is the indicator for on-time payment. All regressions include indicator variables for the remaining treatment groups, so that coefficients are estimated relative to the omitted baseline group. Robust standard errors are in parentheses.

Table 11 presents corresponding results for the second experiment, focusing on on-time payment in the first and second periods of FY2022. Because on-time payment data were available only for Totsuka-ku, the analysis is restricted to this subsample. Consistent with the findings from the first experiment, the estimated effects of the nudge flyer, the inclusion of the owner code, and the nudge envelope are all close to zero and statistically insignificant in both periods. Taken together, the results in Tables 10 and 11 indicate that, while the nudges increase application for automatic debit, they do not lead to a detectable improvement in on-time payment rates within the observed time frame.

Table 11: Linear probability model for on-time payment in the second experiment

	FY2022 1st period			FY2022 2nd period		
	Nudge flyer	Owner code	Nudge envelope	Nudge flyer	Owner code	Nudge envelope
	(1)	(2)	(3)	(4)	(5)	(6)
Average treatment effect	0.003	-0.018	-0.009	-0.007	-0.004	-0.009
	(0.022)	(0.021)	(0.022)	(0.020)	(0.020)	(0.020)
Living in Yokohama	✓	✓	✓	✓	✓	✓
With co-owner	✓	✓	✓	✓	✓	✓
Observations	2896	2896	2896	2896	2896	2896
Adjusted R2	0.011	0.011	0.011	0.019	0.019	0.019

Notes: The dependent variable is the indicator for on-time payment. All regressions include indicator variables for the remaining treatment groups, so that coefficients are estimated relative to the omitted baseline group. Robust standard errors are in parentheses.

4. Interpretation Framework

This section develops a simple theoretical framework to interpret why benefit-enhancing and cost-reducing interventions may exhibit complementary effects on application behavior.

Consider an individual i who decides whether to apply for an automatic debit. Let B_i denote the perceived benefit from applying, and C_i the perceived cost, including time, cognitive burden, and procedural frictions. The application decision follows a standard threshold rule:

$$Apply_i = 1\{B_i - C_i > 0\}.$$

We allow B_i and C_i to capture all individual-specific determinants of the application decision.

We consider two types of behavioral interventions corresponding to our experimental design. A benefit-enhancing intervention (flyer) increases perceived benefits by δ_{Bi}, while a cost-reducing intervention (owner code) lowers perceived costs by δ_{Ci}. The post-intervention decision rule becomes:

$$Apply_i = 1\{(B_i + \delta_{Bi}) - (C_i - \delta_{Ci}) > 0\}.$$

The intervention effects δ_{Bi} and δ_{Ci} are allowed to be heterogeneous across individuals. We assume only that the interventions do not reduce latent utility on average and that large sign reversals are absent, so that $\delta_{Bi}, \delta_{Ci} \geq 0$ for most individuals.

For expositional convenience, define the baseline latent index:

$$U_{0i} = B_i - C_i,$$

and let $G(\cdot)$ denote the cumulative distribution function of U_{0i}, with density $g(\cdot)$. We impose no parametric assumptions on this distribution and require only that it is continuous in a neighborhood of the threshold.

The application probability under interventions is given by:

$$\Pr(Apply = 1) = 1 - G(-(\delta_B + \delta_C)),$$

where δ_B and δ_C denote average shifts induced by the two interventions.

The complementarity between the two interventions can be characterized by the cross-partial derivative of the application probability with respect to δ_B and δ_C:

$$\frac{\partial^2 \Pr(Apply = 1)}{\partial \delta_B \, \partial \delta_C} = -g'(-(\delta_B + \delta_C)).$$

A sufficient condition for a positive interaction effect is therefore that $g'(x) < 0$ in a neighborhood of the threshold. That is, when the density of latent utility is decreasing around the cutoff, an increase in one intervention raises the marginal effectiveness of the other, even though the two interventions enter additively in the latent utility.

This mechanism is most relevant in settings with low baseline application rate, where the mass of the distribution lies to the left of the threshold. In contrast, when most individuals already apply, additional interventions are unlikely to exhibit strong complementarities.

In our experiment, the baseline take-up rate in the absence of any nudge intervention (the standard flyer without the owner code) is approximately 8.4 percent, indicating that the vast majority of individuals do not apply. This suggests that the mass of the latent utility distribution is likely concentrated to the left of the application threshold, making it plausible that the sufficient condition discussed above holds in our setting. Accordingly, our empirical finding that the combined effect of the nudge flyer and the owner code exceeds the sum of their individual effects is consistent with an interpretation in which the two interventions are complementary.

5. Discussion and concluding remarks

This study sheds light on the effectiveness of behavioral nudges in encouraging taxpayers to apply for automatic debit for property tax payments. Using two natural field experiments, we find that both the nudge flyer and the inclusion of the owner code increase application rates. In the second experiment, the nudge flyer and the inclusion of the owner code raise the probability of applying for automatic debit by 2.7 and 2.8 percentage points, respectively. In contrast, modifying the envelope design has no detectable effect, suggesting that official tax mailings

are likely to be opened at high rates regardless of envelope presentation.

A notable finding is the difference in the magnitude of treatment effects across the two experiments. In the first experiment, sending the nudge flyer together with the owner code increases the application rate by 8.8 percentage points, which exceeds the simple sum of the individual effects identified in the second experiment. While differences in timing and geographic coverage across the two experiments may partly account for this discrepancy, the results are also consistent with the presence of a complementary relationship between benefit-enhancing and cost-reducing interventions. As discussed in Section 4, the nudge flyer primarily increases taxpayers' perceived benefits from automatic debit, whereas the owner code reduces the costs associated with completing the application. When either component is absent, the marginal impact of the other may be limited, whereas implementing both simultaneously can lead to a larger behavioral response.

Although the primary policy objective of promoting automatic debit is to improve on-time tax payment, we do not find evidence of such effects within the time frame observed in our experiments. One interpretation is that baseline delinquency among new property taxpayers is already low, making changes in aggregate on-time payment behavior difficult to detect in the short run. In this case, automatic debit may nonetheless generate benefits over a longer horizon by preventing missed payments as taxpayers' attention or salience declines over time, although such longer-run or cumulative effects cannot be assessed with our data. An alternative interpretation is that the interventions disproportionately attracted taxpayers with relatively high compliance, who would have paid their taxes on time even in the absence of automatic debit. This suggests that additional or more targeted approaches may be required to encourage automatic debit among taxpayers with a higher risk of delinquency.

This study has several limitations. First, the nudge flyer differs from the standard flyer along multiple dimensions, making it difficult to isolate which specific design elements drive the observed effects. Second, although our findings suggest that combining benefit-enhancing and cost-reducing interventions may generate complementarities, the experimental design was not explicitly structured to test interaction effects. Designing experiments that directly vary combinations of such interventions would be a promising avenue for future research. Finally, limited access to individual-level characteristics restricts our ability to explore heterogeneity in treatment effects beyond basic observables. Richer administrative data would allow for a deeper understanding of which taxpayers respond most strongly to different types of nudges.

Declaration of competing interest

Declaration of interest: The authors declare that this research was conducted in the absence of any financial relationships with the City of Yokohama related to the study reported in this manuscript. Some authors have separately received consulting fees from different departments of the City of Yokohama for projects unrelated to the present study. These engagements had no influence on the design, conduct, analysis, or interpretation of the research reported here.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Grammarly and ChatGPT in order to proofread for grammar and spelling. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Data availability

The authors do not have permission to share data.

References

Allcott, H. (2011). Social Norms and Energy Conservation. *Journal of Public Economics*, 95(9–10), 1082–1095.

Allingham, M. G. and Sandmo, A. (1972). Income Tax Evasion: A Theoretical Analysis. *Journal of Public Economics*, 1(3–4), 323–338.

Benjamini, Y. and Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of Royal Statistical Society: Series B*, 57(1), 289–300.

Bhargava, S. and Manoli, D. (2015). Psychological Frictions and the Incomplete Take-Up of Social Benefits: Evidence from an IRS Field Experiment. *American Economic Review*, 105(11), 3489–3529.

Castro, L. and Scartascini, C. (2015). Tax Compliance and Enforcement in the Pampas Evidence from a Field Experiment. *Journal of Economic Behavior & Organization*, 116, 65–82.

Chirico, M., Inman, R., Loeffler, C., MacDonald, John, and Sieg, H. (2019). Deterring Property Tax Delinquency in Philadelphia: An Experimental Evaluation of Nudge Strategies. *National Tax Journal*, 72(3), 479–506.

Cranor, T., Goldin, J., Homonoff, T., and Moore, L. (2020). Communicating Tax Penalties to Delinquent Taxpayers: Evidence from a Field Experiment. *National Tax Journal*, 73(2), 331–360.

De Neve, J. E., Imbert, C., Spinnewijn, J., Tsankova, T., and Luts, M. (2021). How to Improve Tax Compliance? Evidence from Population-Wide Experiments in Belgium. *Journal of Political Economy*, 129(5), 1425–1463.

Dirkmaat, T., Rohde, K. I. M., van de Veer, Evelien, van Dijk, B., and Yu, X. (2023). Managing "Last Moment Behavior": Non-Binding Target Dates to Reduce the Spike in Task Completion at Deadlines. *Journal of Public Economics*, 219, 104813.

Fryer, R. G., Levitt, S. D., List, J., and Sadoff, S. (2022). Enhancing the Efficacy of Teacher Incentives through Framing: A Field Experiment. *American Economic Journal: Economic Policy*, 14(4), 269–299.

Guttman-Kenney, B., Adams, P., Hunt, S., Laibson, D., Stewart, N., and Leary, J. (2025). The Semblance of Success in Nudging Consumers to Pay Down Credit Card Debt. *American Economic Journal: Economic Policy*, 17(4), 72–105.

Hallsworth, M., List, J. A., Metcalfe, R. D., and Vlaev, I. (2017). The Behavioralist as Tax Collector: Using Natural Field Experiments to Enhance Tax Compliance. *Journal of Public Economics*, 148, 14–31.

Iyengar, S. S. and Lepper, M. R. (2000). When Choice is Demotivating: Can One Desire Too Much of Good Thing? Journal of Personality and Social Psychology, 79(6), 995–1006.

Pope, D. G. and Schweitzer, M. E. (2011). Is Tiger Woods Loss Averse? Persistent Bias in the Face of Experience, Competition, and High Stakes. *American Economic Review*, 101(1), 129–157.

Tversky, A., and Kahneman, D. (1991). Loss Aversion in Riskless Choice: A Reference-Dependent Model. *Quarterly Journal of Economics*, 106(4), 1039–1061.

Appendix

A. Full regression results

This appendix presents supplementary regression results that are not reported in the main text for brevity.

Table A1: Full regression results for the first experiment

	(1)	(2)	(3)	(4)
Group 1: Nudge flyer + Owner code	0.160***	0.161***	0.116***	0.159***
	(0.012)	(0.012)	(0.027)	(0.014)
Group 2: Standard flyer	0.073***	0.073***	0.058***	0.079***
	(0.009)	(0.009)	(0.022)	(0.011)
Group 1 × Living in Yokohama			0.050*	
			(0.030)	
Group 2 × Living in Yokohama			0.016	
			(0.024)	
Group 1 × With co-owner				0.006
				(0.026)
Group 2 × With co-owner				-0.025
				(0.017)
Living in Yokohama		✓	✓	✓
With co-owner		✓	✓	✓
Observations	3184	3184	3184	3184
Adjusted R2	0.044	0.046	0.046	0.046

Notes: The dependent variable is the application for automatic debit. Robust standard errors are in parentheses. Reference group is no mail group (Group 3). *** and * denote significance at the 1% and 10% level, respectively.

Table A2: On-time payment outcomes in the first experiment

	FY2021				FY2022	
	1st period	2nd period	3rd period	4th period	1st period	2nd period
	(1)	(2)	(3)	(4)	(5)	(6)
Group 1: Nudge flyer + Owner code	-0.021	-0.020	-0.018	-0.013	0.006	0.002
	(0.018)	(0.017)	(0.017)	(0.017)	(0.020)	(0.019)
Group 2: Standard flyer	-0.008	-0.011	-0.019	-0.005	0.010	0.010
	(0.018)	(0.017)	(0.017)	(0.017)	(0.020)	(0.019)
Living in Yokohama	✓	✓	✓	✓	✓	✓
With co-owner	✓	✓	✓	✓	✓	✓
Observations	3184	3184	3184	3184	3184	3184
Adjusted R2	0.014	0.015	0.011	0.014	0.020	0.016

Notes: The dependent variable is the indicator for on-time payment. Robust standard errors are in parentheses. Reference group is no mail group (Group 3).

Table A3: Full regression results for the second experiment

	(1)	(2)	(3)	(4)
Group 1: Nudge flyer + Owner code in Standard envelope	0.159***	0.173***	0.136***	0.182***
	(0.009)	(0.011)	(0.026)	(0.013)
Group 2: Nudge flyer in Standard envelope	0.132***	0.145***	0.073***	0.146***
	(0.008)	(0.011)	(0.020)	(0.012)
Group 3: Nudge flyer + Owner code in Nudge envelope	0.152***	0.164***	0.123***	0.169***
	(0.007)	(0.009)	(0.020)	(0.010)
Group 4: Standard flyer + Owner code in Standard envelope	0.133***	0.146***	0.173***	0.153***
	(0.008)	(0.011)	(0.030)	(0.012)
Group 1 × Living in Yokohama			0.041	
			(0.026)	
Group 2 × Living in Yokohama			0.080***	
			(0.021)	
Group 3 × Living in Yokohama			0.045**	
			(0.021)	
Group 4 × Living in Yokohama			-0.030	
			(0.030)	
Group 1 × With co-owner				-0.042**
				(0.020)
Group 2 × With co-owner				-0.007
				(0.019)
Group 3 × With co-owner				-0.025
				(0.016)
Group 4 × With co-owner				-0.034*
				(0.019)
Living in Yokohama		✓	✓	✓
With co-owner		✓	✓	✓
Taxing district		✓	✓	✓
Observations	7621	7621	7621	7621
Adjusted R2	0.007	0.010	0.010	0.009

Notes: The dependent variable is the application for automatic debit. Robust standard errors are in parentheses. Reference group is no mail group (Group 5). ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table A4: On-time payment outcomes in the second experiment

	FY2022	FY2022
	1st period	2nd period
	(1)	(2)
Group 2: Nudge flyer in Standard envelope	0.018	0.004
	(0.021)	(0.020)
Group 3: Nudge flyer + Owner code in Nudge envelope	-0.009	-0.009
	(0.022)	(0.020)
Group 4: Standard flyer + Owner code in Standard envelope	-0.003	0.007
	(0.022)	(0.020)
Living in Yokohama	✓	✓
With co-owner	✓	✓
Observations	2896	2896
Adjusted R2	0.011	0.019

Notes: The dependent variable is the indicator for on-time payment. Robust standard errors are in parentheses. Reference group is Group 1 (nudge flyer with the owner code in a standard envelope).