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Monetary Costs Versus Opportunity Costs in a Voting Experiment

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Abstract

Monetary incentives are widely used to reproduce various voting environments in the laboratory. In actual elections, however, non-monetary opportunity costs play a role in voter turnout. Our research question was two-fold; whether the effect of opportunity costs on voter turnout differs from the effect of monetary costs, and if so, to what extent they differ. To generate opportunity costs, we asked participants to work on tasks for two minutes; they were rewarded for successful task completions but lost thirty seconds if they chose to vote. Our regression analysis suggested that nearly half of the participants' decisions took account of opportunity costs as well as monetary costs, and that for such decisions, the effect of opportunity costs on voter turnout was about one-third of the effect of monetary costs. These observations attribute the "paradox of voter turnout" to the misperception and/or depreciation of voting costs.

JEL Classifications: C92, D72, D90

Keywords: Laboratory experiment, Monetary incentives, Opportunity cost, Paradox of voter turnout, Finite mixture model

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1. Introduction

Does providing monetary incentives to participants in the laboratory influence their voting behavior differently than non-monetary incentives? If the answer is yes, what is the extent thereof? As a first step towards answering these fundamental questions to experimental political science, this study focused on voting costs and examined whether imposing voting costs on participants as opportunity costs changes their behavior in comparison with the imposition of monetary costs.

In elections, voters first form their preferences regarding candidates and then select candidates collectively under each electoral system. In laboratory studies on voting, these two steps (i.e., the formation of preferences and the collective choice of candidates) are dealt with separately from each other. The former is analyzed by psychological and neuroscientific approaches (e.g., Iyengar and Kinder 1987; Kato et al. 2009) while the latter is based on an economics approach[1] (e.g., Forsythe et al. 1993; Schram and Sonnemans 1996).

When the focus is on the collective choice among voters, their preferences regarding candidates need to be fixed exogenously in advance of voting. For this purpose, the economics approach provides monetary incentives to participants. For example, if a candidate wins the laboratory election, a group of participants receive a fixed amount of money while other groups receive nothing. In such a way, a voting environment in which each candidate is supported by a group of participants is created in the laboratory.[2] In the same manner, researchers can induce participants to experience a cost of going to the polls with an instruction such that if a participant chooses to go to the poll, he/she is required to pay a fixed amount of money.

Whereas incentivization by money increases internal validity, its external validity is discussed when we deal with political decisions and behavior for which the benefits and costs to political actors are not immediately realized in the form of money but are rather ambiguous and long-term in many cases. It is possible that participants in the laboratory, where the benefits from voting outcomes are exchanged into money they receive at the end of experiments, are motivated to care more strongly about how their votes affect the election outcomes than voters in real politics. For example, in well-controlled laboratory

[1] See Blais, Laslier, and Van der Straeten (2016) for the recent development of laboratory experiments on voting.

[2] Smith's (1976, 1982) induced value theory justifies such a predetermination of each participant's preferences regarding experimental outcomes under the assumption that participants seek the larger amount of money through their participation in the experiment. It enables researchers to predict what happens theoretically under each experimental setting and to test to what extent theories explain the observations in the laboratory.

environments, the previous literature has observed that the strategic voter model explains participants' decisions successfully.[3] On the other hand, from his data analysis of the 2005 and 2009 German federal elections, Spenkuch (2018) concluded that both the strategic voter model and the expressive voter model should be rejected.[4]

It is also possible that participants in the laboratory, where voting costs are measured in monetary terms, are motivated to abstain more strongly than voters in real modern politics after poll taxes were abolished. According to previous empirical studies, the effect of monetary costs on voter turnout is estimated to be strong[5] while the effect of opportunity costs is ambiguous.[6]

The research question of this paper is two-fold; the first question is whether the effect of opportunity costs on voting is different from the effect of monetary costs; the second question is to what extent the effect of opportunity costs on voting is different from the effect of monetary costs. We have chosen to focus on opportunity costs in our experiment for several reasons. First, we can introduce opportunity costs as well as monetary costs in the laboratory more easily than introducing non-monetary benefits as well as monetary benefits. Second, we can create variations in costs among participants and between elections more easily than in the case of benefits, which helps us estimate their effects on voter turnout statistically. Finally, as mentioned above, opportunity costs are realistic as voting costs in modern politics; that is, all the voters in actual elections must spend time if they decide to go to the polls.

To generate opportunity costs in the laboratory, we asked participants to work on two-minute slider tasks developed by Gill and Prowse[7] (2012, 2015). Each success in the

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[3] See Palfrey (2009) for a survey.

[4] Spenkuch (2018) shows that the German voters cannot be neatly classified into these two types: almost two thirds of voters violate the predictions of the strategic voter model while about one third violate those of the expressive voter model.

[5] Using the questionnaire surveys conducted by the Survey Research Center of the University of Michigan in the U.S. presidential elections of 1960 and 1972, Ashenfelter and Kelley (1975) showed that a six-dollar poll tax, which was imposed in the 1960 election, had decreased each voter's probability of voting by 42%.

[6] See Green and Shapiro (1994, Ch. 4) for a discussion. Niemi (1976) claims that the effect of opportunity costs on voter turnout is negligible because people do not spend much time for voting, and because people devote their leisure time, instead of working time, to voting.

[7] Faravelli, Kalayci, and Pimienta (2017) also used slider tasks to create opportunity costs of voting in a different manner from ours. They conducted a voting experiment with the general public through Amazon's Mechanical Turk. Each participant's opportunity cost of voting was measured with his/her per-minute income in his/her own job multiplied by the estimated time for completing a fixed number of slider tasks. In the current study, the income was defined as the revenue each participant earned through slider tasks so that the opportunity cost was fully

task gave each participant a fixed amount of money, and thirty seconds were lost if he/she chose going to the poll in our experiment. The amount of money each participant could earn in thirty seconds was regarded as the opportunity cost for him/her to go to the poll. Our method to generate opportunity costs in the laboratory was sufficiently easy for each participant to calculate his/her expected loss in money when he/she went to the poll. Nonetheless, we observed that participants' reactions towards opportunity costs were much smaller than towards monetary costs. Under our experimental setting, nearly a half of voting decisions by participants were regarded to have taken account of opportunity costs. Even for such rational decisions, the effect of opportunity costs on voter turnout was one-third of the effect of monetary costs.

Our observation of the weak effect of opportunity costs on participants' behavior is consistent with the previous literature on the recognition of opportunity costs. The pioneering work by Becker, Ronen, and Sorter (1974) suggests that participants do not perceive opportunity costs as seriously as monetary costs.[8] There have been two approaches to explaining why people do not fully use the information on opportunity costs in their decision making. The first approach focuses on cognitive skills. Since the idea of opportunity costs is not easy to understand, whether to use the information on opportunity costs is dependent on how easy it is to use that information (Frederick et al. 2009; Spiller 2011). The second approach focuses on the uncertainty of forgone chance. In particular, since the value of time given up for the sake of something is ambiguous, people underestimate the impact of opportunity costs, especially when it is measured in time (Thaler 1980; Okada and Hoch 2004). In our experiment, as mentioned above, the opportunity costs were sufficiently easy for participants to recognize. Furthermore, the value of time given up for the sake of voting was sufficiently easy for participants to calculate.

This paper also contributes to the literature on the paradox of voter turnout (Downs 1957). While the expected gain from casting a vote is nearly zero because each individual vote hardly affects the outcomes in large elections, going to the polls requires a strictly

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determined in the laboratory. The purpose of Faravelli et al. (2017) was to test whether the results obtained in the previous literature (e.g., Levine and Palfrey 2007) were replicated in a large-scale (i.e., 300-voter) real-effort experiment.

[8] In their experiment, participants were asked to make a selection between two investment projects whose margins were equal if opportunity costs were taken into account. They found that participants tended to choose projects with higher opportunity costs, instead of being equally likely to choose either project. Although their experimental framework has been widely used in the field of accounting research (Neumann and Friedman 1978; Friedman and Neumann 1980), it provides neither monetary incentives nor non-monetary incentives to participants.

positive cost. Hence, the cost seems to exceed the expected gain, but many people do go to the polls in actual elections. Various explanations to the question why people vote have been provided, as reviewed by Aldrich (1993), Blais (2000, 2006), Dhillon and Peralta (2002), Mueller (2003, Ch. 14), Feddersen (2004), Dowding (2005), Geys (2006a, 2006b), and Goldfarb and Sigelman (2010). The impact of pivot probability is one of the focuses that have attracted many empirical studies with aggregate data, as summarized by Mueller (2003, 316–17, Table 14.2). Recently, misperception of pivot probability was analyzed with individual data obtained in a field experiment by Hoffman, Morgan, and Raymond (2013). They applied the misperceptions of extremely unlikely events, which have been found in psychology and behavioral economics, to voting decisions, and showed that voters inflate their pivot probabilities. However, they also showed that voters' decisions on whether to go to the polls or abstain are not affected by their beliefs about pivotality, which implies that misperception of pivot probability does not successfully explain why people vote. This study focused on the misperception and/or depreciation of the opportunity cost of voting.

This paper is organized as follows. Section 2 describes the design of our experiment. We prepared three types of sessions according to the amount of revenue each participant obtained from each success in the slider task. Section 3 introduces our finite mixture probit model, which enables us to distinguish four types of voting behavior. Whether to use the information on opportunity costs is one of our focuses. Section 4 reports the estimation results and summarizes for what proportions of decisions/participants opportunity costs matter and to what extent they decrease voter turnout in comparison with monetary costs. Section 5 concludes.

2. Experimental design

2.1 Theory

We designed our experiment on the basis of the rational voter theory (Riker and Ordeshook 1968). In the model, whether a voter goes to the poll or abstains is determined by whether the net payoff from voting,

$$PB - C + D, \tag{1}$$

is positive or not. The first term of equation (1), PB, is the expected gain from voting, where P represents the voter's subjective probability that his/her vote changes the winner (pivot probability), and B represents the extra gain he/she obtains when the winner changes in his/her favor. For rational voters, PB is supposed to have a positive effect on turnout. Duffy and Tavits (2008) observed in their laboratory experiment that the higher pivot probabilities participants estimated, the more likely they voted.

The second term C is the cost of voting. In this paper, we suppose that it consists of monetary cost CM and opportunity cost CO (i.e., $C = CM + CO$). Monetary costs are supposed to have a negative effect on voter turnout. Our main focus is on whether opportunity costs have the same degree of negative effect on turnout.

The last term D indicates the utility each voter feels by going to the poll due to the sense of civic duty to vote. The stronger the sense of civic duty to vote, the larger utility he/she feels if he/she goes to the poll. Hence, D is supposed to have a positive effect on turnout. Campbell, Gurin, and Miller (1954) showed in their questionnaire surveys that the more strongly voters expressed their sense of civic duty to vote, the more likely they voted in the 1952 U.S. presidential election.

Among the above determinants of voter turnout, B and CM were given to participants exogenously in our experiment. To obtain the information on P, we asked each participant to report his/her subjective pivot probability in advance of each election. Opportunity cost CO was determined by the revenue per success given exogenously and the number of successes each participant achieved in slider tasks. Finally, a question which measured each participant's D was included in the post-experiment questionnaires. In such a way, we controlled terms PB and D in our data analysis so that we could extract the effects of CM and CO on voter turnout.

2.2 Procedures of the experiment

We conducted a computerized experiment with software z-Tree (Fischbacher 2007) in April and May 2017 in the Social Science Laboratory at Kochi University of Technology, Japan. We recruited 144 undergraduate students from various academic disciplines using our online recruitment system. The majority of them were freshmen. Female participants constituted exactly one-third of the participants. Each participant joined only one session.

Each session consisted of 12, 18, or 24 participants. When participants entered the laboratory, each of them drew a lot to determine his/her PC terminal. The terminals were separated from each other by boards.[9] In the beginning, the instructions for the first three rounds were provided, in which it was also mentioned that the experiment consisted of 13

[9] Participants could not see each other's faces but could see the tops of the heads of those sitting in front of them. Hence, they could recognize the presence of other participants.

rounds in total as well as post-experiment questionnaires.[10]

In the first three rounds, participants worked on two-minute slider tasks developed by Gill and Prowse[11] (2012, 2015). These rounds were prepared to measure the ability of each participant in the slider task. In each round, 48 sliders appeared on each participant's PC screens, as illustrated in Figure 1. Each slider was set at position 0 at the beginning and could be moved with a PC mouse between 0 and 100. The task for each participant was to move and stop each slider at 50 in two minutes. The number of sliders stopped at 50 determined the payoff for each participant.

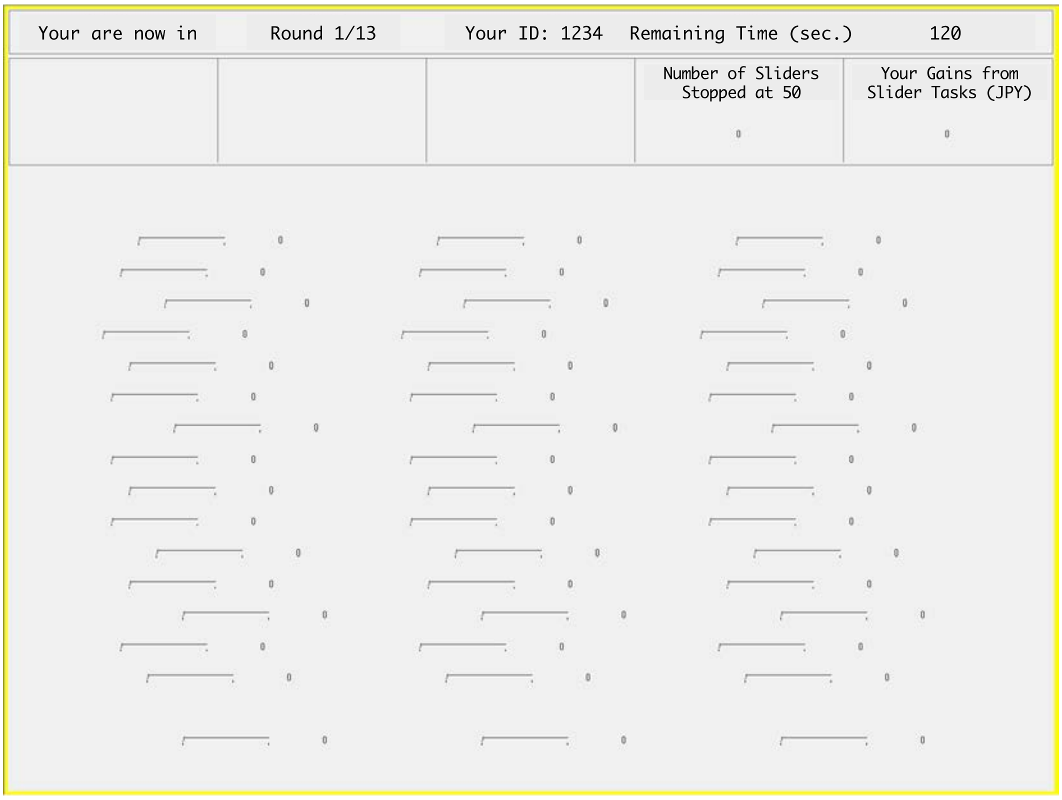

Figure 1. Screenshot of Slider Task in the First Three Rounds

After the third round, additional instructions were provided for the next ten rounds. In each of the ten rounds, participants voted and then worked on the slider tasks. For voting, participants were divided into six people randomly round by round. Each round consisted of the conjecture on pivot probabilities, voting decisions, and slider tasks. The details are as follows.

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[10] The instructions to the participants in our experiment are provided in Appendix 1.
[11] We used the z-Tree code file for the slider task provided on Prowse's webpage, accessed October 26, 2018, https://www.vprowse.org/research.

2.2.1 Voting decisions

Six people were randomly divided into two three-person groups, *A* and *B*. Each participant was informed of only his/her group assignment and could not identify other members. Voting was held between groups *A* and *B*. Each participant chose either voting or abstaining (figure 2). If he/she chose to vote, he/she lost a fixed amount of money shown on his/her PC screen and 30 seconds for the slider task. The monetary cost of voting was a random variable drawn from a uniform distribution.[12] The amount of money each participant could earn in 30 seconds working on the slider task was regarded as his/her opportunity cost of voting. On the other hand, if he/she chose to abstain, he/she suffered neither monetary costs nor opportunity costs.

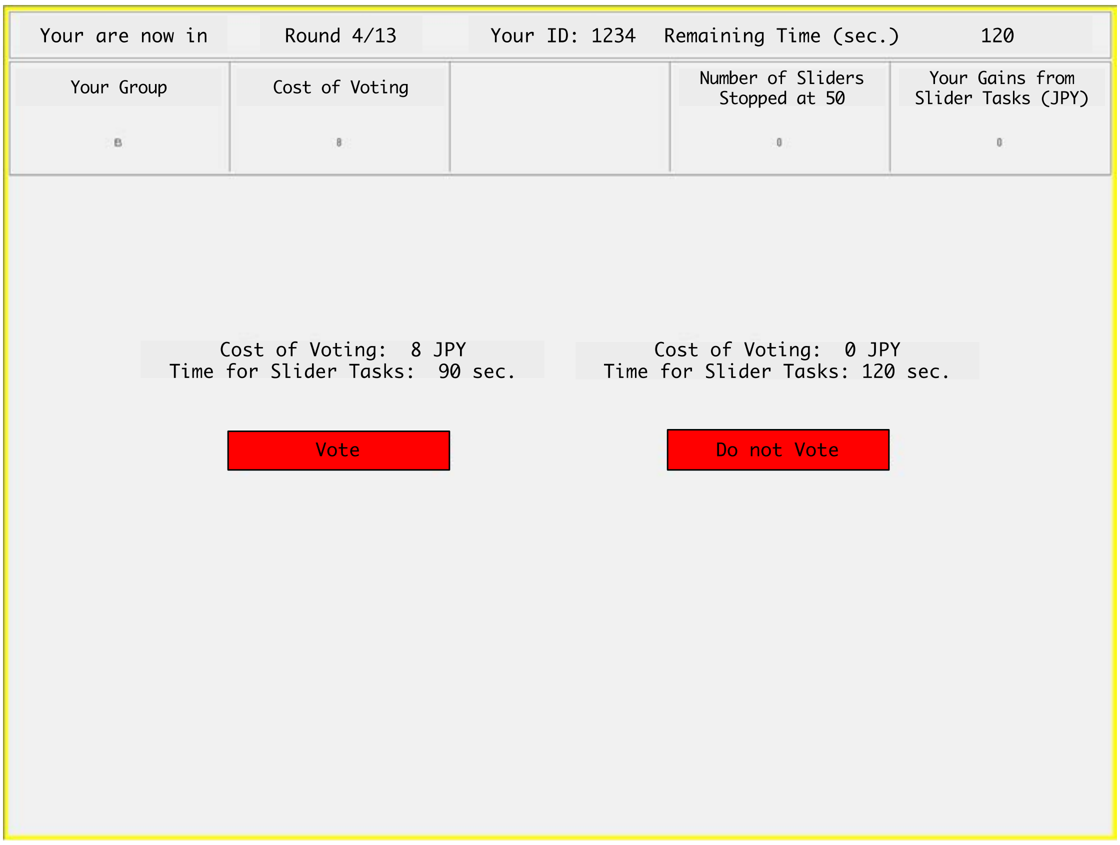

Figure 2. Screenshot of Voting Stage

[12] This setting follows Levine and Palfrey (2007). However, since our experiment focused on how individual participants behave rather than whether game-theoretic equilibria are realized among participants, we did not mention the distributional form. We merely explained that each participant's monetary cost was determined randomly round by round; it was enough to collect data on subjective pivot probabilities. Changing group members round by round also eliminated group-specific effects.

The winning group was determined by the majority rule. For example, group A won if the number of participants in group A who had chosen to vote was greater than the number in group B. All three members of the winning group, whether they voted or abstained, received a fixed amount of money.[13] The winner in the case of a tie was determined and announced to participants in advance of the voting decisions. This predetermination of the winner in the case of a tie made it easy for each participant to understand the effect of his/her vote on voting outcomes.

2.2.2 Conjecture on pivot probabilities

In order to control each participant's expected gain from voting in our data analysis, we asked him/her to conjecture his/her pivot probability. At the beginning of each round, each participant entered his/her subjective pivot probability on his/her PC screen (Figure 3). They could enter up to two decimal digits. This procedure was designed on the basis of the instructions of Duffy and Tavits[14] (2008), except for the scoring rule; we used Hossain and Okui's (2013) binarized scoring rule, instead of Brier's (1950) quadratic scoring rule, in the determination of payoffs from the conjecture.[15] Specifically, suppose that a participant entered a probability p. If his/her vote was pivotal, he/she earned a fixed amount of money with probability $1-(1-p)^2$ but lost another fixed amount of money with probability $(1-p)^2$. On the other hand, if his/her vote was not pivotal, he/she earned the fixed amount with probability $1-p^2$ but lost another amount with probability p^2.

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[13] The actual amount of money is summarized in Table 1 in section 2.2.5.

[14] We thank John Duffy for his provision of their instructions.

[15] Under the binarized scoring rule, entering his/her truthful conjecture maximizes his/her expected payoffs regardless of his/her attitude toward risk.

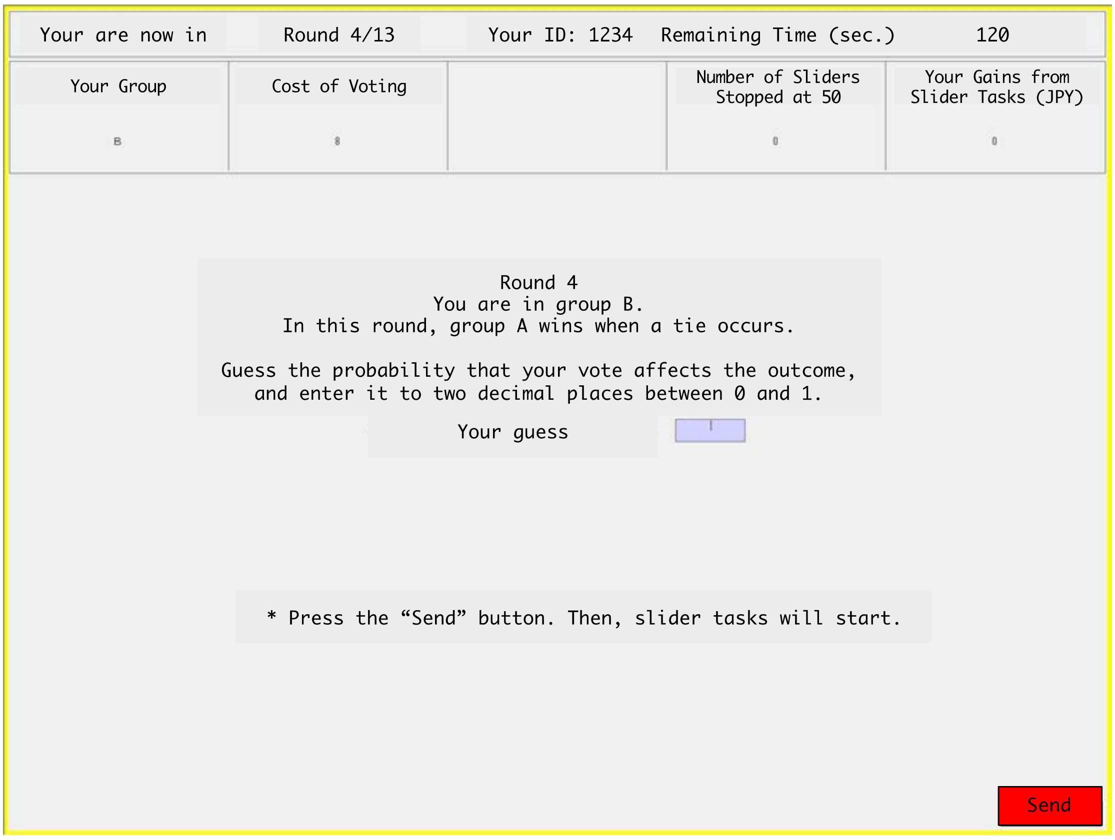

Figure 3. Screenshot of the Conjecture on Pivot Probabilities

In the instructions, pivot probabilities for each participant's vote were explained as probabilities with which his/her vote would affect voting outcomes. Affecting voting outcomes was explained as one of the following two cases happening among the five people except him/her (i.e., two members of his/her group except him/her and three members of the opponent group). First, in rounds in which his/her group is predetermined as the winner in the case of a tie, it is the case that the number of members who have voted in his/her group is one fewer than the number of members who have voted in the opponent group (i.e., 0 vs. 1, 1 vs. 2, or 2 vs. 3). Second, in rounds in which the opponent group is predetermined as the winner in the case of a tie, it is the case that the number of participants who have voted is the same between the two groups (i.e., 0 vs. 0, 1 vs. 1, or 2 vs. 2). In both cases, if his/her vote is added to his/her group, the winner changes from the opponent group to his/her group.

2.2.3 Slider tasks

After voting decisions, participants started slider tasks simultaneously, but the time for those who have voted expired 30 seconds earlier than that of the abstainers. Except for one type of session, the revenue per success in stopping sliders at 50 changed between the first eight rounds (i.e., three rounds without voting and five rounds with voting) and the remaining five rounds.[16] After the slider tasks, all the results in that round appeared on the PC screen, including the numbers of votes cast in groups *A* and *B*, the winning group, his/her gain from the voting outcome, his/her monetary cost, whether his/her vote has been pivotal or not, his/her payoff from the conjecture on his/her pivot probability, the number of successes in the slider task, his/her revenue from the slider task, and his/her total amount of money earned in that round.

2.2.4 Sense of civic duty to vote

In order to measure the strength of the sense of civic duty to vote, we asked participants whether to agree or disagree with the following four statements in our post-experiment questionnaire:[17]

1. *It has no meaning to vote when the winning probability of the party/candidate you support is low.*
2. *Most local elections are not important enough to bother with.*
3. *So many voters vote in national elections that your vote has no possibility to affect the outcomes.*
4. *If a person is not interested in the voting outcome, he/she should not vote from the first.*

We counted each participant's number of disagreements with these four statements. The larger the number of disagreements, the more strongly he/she is regarded to have a sense of civic duty to vote.[18]

2.2.5 Parameter values

Table 1 summarizes the parameter values used in each of our three types of sessions. We first arranged condition (*a*). Under this condition, monetary costs followed a uniform distribution

[16] This change created the variation in opportunity costs for each participant.
[17] We modified the statements from Campbell et al. (1954) in the questionnaire survey of the 1952 U.S. presidential election.
[18] Our third statement is regarded to mention pivot probabilities. In fact, whether to agree or disagree with this statement is correlated with subjective pivot probabilities in our data. For a robustness check, we also conducted the same regression analysis as this paper with another measure of the strength of the sense of civic duty to vote which has eliminated this statement. However, it did not affect our main argument in this paper.

with a range of 0 to 40 Japanese yen.[19] Every member of the winning group got 100 yen. The payoff from the conjecture on pivot probabilities was 5 or -3 yen. We employed the Accumulated Payoff Mechanism (APM); that is, earnings obtained over the 13 rounds were accumulated and paid to participants.

Table 1. Summary of Experimental Settings

	(*a*)	(*b*)	(*c*)
Number of participants	48	48	48
Revenue per slider success (yen)	First 5, then 10	First 10, then 5	50
Monetary costs (yen)	0 to 40	0 to 40	0 to 400
Winners' payoff in elections (yen)	100	100	1000
Payoffs from the conjecture on pivot prob. (yen)	5 or -3	5 or -3	50 or -30
Payment scheme	APM	APM	RRPM

In order to balance the order effect, we next arranged condition (*b*), which was the same as condition (*a*) except for the order of two levels of revenue per success in the slider task, 5 and 10 yen. Under condition (*a*), the revenue was 5 yen in the first eight rounds, and then it changed to 10 yen in the remaining five rounds. Under condition (*b*), it changed from 10 yen to 5 yen.

To examine how the payment scheme affected the behavior of participants, we also arranged condition (*c*).[20] Under this condition, the revenue per success in slider task was fixed at 50 yen throughout the 13 rounds, and only one of the 13 rounds was selected randomly to determine the rewards each participant received, which is called Random Round Payoff Mechanism (RRPM). Every payoff in each round under condition (*c*) was ten times as large as that of the rounds with 5 yen per success in the slider task under the other two conditions.

3. Model

In this section, we introduce our finite mixture probit model with tremble parameters, which is based on Bardsley and Moffatt (2006). It is often the case that simple probit models, which

[19] One Japanese yen equaled approximately 0.009 U.S. dollars on April 24, 2017.
[20] As is often the case in experiments on the voluntary provision of public goods, participants tend to free ride more severely under the APM as rounds proceed (Lee and Lima 2004).

suppose that all participants follow the same behavioral rule, fail to detect behavioral determinants of interest because participants may follow different behavioral rules from each other; some participants may behave in accordance with the rational voter theory while others may behave habitually (Gerber, Green, and Shachar 2003). The finite mixture model prepares several hypotheses regarding the behavior of participants and allows us to determine the degree to which the data obtained in the laboratory are consistent with each of the hypotheses at the population level. If we add a further analysis, it also allows us to identify with which hypothesis the ten voting decisions of each participant are consistent at the individual level.

We prepared the following four hypotheses regarding the behavior of participants. The first hypothesis is labeled as *fully rational voter hypothesis*, which is in accordance with the rational voter theory (i.e., equation (1)). It takes both monetary costs and opportunity costs into account. The second hypothesis is labeled as *partially rational voter hypothesis*, which is almost the same as the previous one but neglects opportunity costs. The third hypothesis is labeled as *naïve voter hypothesis*, under which participants always go to the polls regardless of the potential determinants of voter turnout. The last hypothesis is labeled as *free rider hypothesis*, under which participants always abstain. The last two hypotheses assume habitual behavior of participants.

Our first research question, whether opportunity costs are recognized in voting decisions, is answered by the classification of subject behavior between fully rational and the others. Our second research question, to what extent opportunity costs affect voting behavior in comparison with monetary costs if they are recognized, is answered by the estimates of fully rational voters.

Our data consist of a panel of $N = 144$ participants over $T = 10$ elections in $K = 13$ rounds. We label $t = 1$ for the first election in round $k = 4$, and $t = 10$ for the last election in round $k = 13$ as no elections were held in rounds $k = 1, 2, 3$.

3.1 Hypotheses on voting behavior

Fully rational voter hypothesis

We first describe the regression model of fully rational voter hypothesis. This fully rational voter hypothesis assumes that participants care about both monetary costs and opportunity costs. More precisely, the underlying willingness of participant i to vote in election t, Y_{it}^*, is defined as:

$$Y_{it}^* = X'_{it}\beta_{full} + \varepsilon_{full,it} \tag{2}$$

$$= \beta_{full,0} + \beta_{full,1}PB_{it} + \beta_{full,2}CM_{it} + \beta_{full,3}CO_{it} + \beta_{full,4}D_i + \beta_{full,5}RRPM_i + \varepsilon_{full,it},$$
$$\varepsilon_{full,it} \sim N(0, \sigma^2_{full}),$$

where PB_{it} is participant i's expected gain from voting in election t, while CM_{it} and CO_{it} are participant i's monetary and opportunity costs of voting in election t, respectively. Term D_i is the strength of the sense of civic duty of participant i to vote. The term $RRPM_i$ is a dummy variable which takes 1 if participant i is assigned to condition (c) in Table 1 while 0 otherwise. The vectors of these variables and their coefficients are represented by X_{it} and β_{full}, respectively. Error term $\varepsilon_{full,it}$ is assumed to follow the normal distribution with mean 0 and variance σ^2_{full}.

Under the fully rational voter hypothesis, participant i is assumed to vote in election t if $Y^*_{it} \geq 0$ and abstain otherwise. Formally, for $i \in S_{full}$:

$$Y_{it} = 1 \; if \; Y^*_{it} \geq 0, \qquad (3)$$
$$Y_{it} = 0 \; if \; Y^*_{it} < 0,$$

where S_j indicates the set of participants classified into type $j \in \{full, part, naïv, free\}$ while Y_{it} indicates the observed decision by participant i in election t: it takes 1 if he/she has voted while 0 if abstained.

Partially rational voter hypothesis

We next describe the partially rational voter hypothesis. As in the case of fully rational voter hypothesis, we assume that Y^*_{it} is linearly dependent on explanatory variables. The model is almost the same as the one under the fully rational voter hypothesis, but it does not include the term of opportunity costs:

$$Y^*_{it} = X'_{it}\beta_{part} + \varepsilon_{part,it}$$
$$= \beta_{part,0} + \beta_{part,1}PB_{it} + \beta_{part,2}CM_{it} + \beta_{part,3}D_i + \beta_{part,4}RRPM_i + \varepsilon_{part,it}, \qquad (4)$$
$$\varepsilon_{part,it} \sim N(0, \sigma^2_{part}).$$

We assume that the relationship between Y^*_{it} and Y_{it} for $i \in S_{part}$ is the same as in equation (3).

Naïve voter hypothesis

Naïve voters always go to the polls, and hence their behavior is formally described as, for $i \in S_{naïv}$,

$$Y_{it} = 1 \; \forall t.$$

Free rider hypothesis

Free riders always abstain, and hence their behavior is formally described as, for $i \in S_{free}$,

$$Y_{it} = 0 \; \forall t.$$

3.2 Tremble parameters

Following Bardsley and Moffatt (2006), we introduce tremble parameters in our finite mixture model. We assume that each participant chooses what he/she supposes to choose with probability $1 - \omega_{it}$ and chooses voting and abstaining equally likely with probability ω_{it}. The chance of such a tremble is assumed to diminish as rounds proceed:

$$\omega_{it} = \omega_0 \exp[\omega_1 (t-1)], \tag{5}$$

where ω_0 indicates the initial probability of tremble while ω_1 indicates the rate of decay of the tremble.

Without tremble parameters, any deviation from the naïve voter hypothesis and the free rider hypothesis must be explained by the fully and/or partially rational voter hypotheses. However, a part of such deviations might not fit these rational voter hypotheses which require participants to react to the change in expected gains and costs. Tremble parameters allow deviations such as trial and error under any behavioral hypothesis. The next subsection explains how the tremble parameters are installed into our finite mixture model.

3.3 Estimation strategy

Now we are ready to describe the probabilities of voting and abstaining under each hypothesis. Under the fully rational voter hypothesis, we have:

$$P\left(Y_{it} = 1 \middle| i \in S_{full}\right) = (1 - \omega_{it}) \Phi\left(\frac{X'_{it} \beta_{full}}{\sigma_{full}}\right) + \frac{\omega_{it}}{2}, \tag{6a}$$

$$P\left(Y_{it}=0\middle|i\in S_{full}\right)=(1-\omega_{it})\Phi\left(-\frac{X'_{it}\beta_{full}}{\sigma_{full}}\right)+\frac{\omega_{it}}{2}, \tag{6b}$$

where $\Phi(.)$ is the standard normal cumulative distribution function. We normalize σ_{full} to unity for the purpose of the identification of parameters.

Likewise, under the partially rational voter hypothesis, we have:

$$P\left(Y_{it}=1\middle|i\in S_{part}\right)=(1-\omega_{it})\Phi\left(\frac{X'_{it}\beta_{part}}{\sigma_{part}}\right)+\frac{\omega_{it}}{2}, \tag{7a}$$

$$P\left(Y_{it}=0\middle|i\in S_{part}\right)=(1-\omega_{it})\Phi\left(-\frac{X'_{it}\beta_{part}}{\sigma_{part}}\right)+\frac{\omega_{it}}{2}. \tag{7b}$$

We also normalize σ_{part} to unity. Under the naïve voter hypothesis, we have:

$$P(Y_{it}=1|i\in S_{naïv})=(1-\omega_{it})\cdot 1+\frac{\omega_{it}}{2}=1-\frac{\omega_{it}}{2},$$

$$P(Y_{it}=0|i\in S_{naïv})=(1-\omega_{it})\cdot 0+\frac{\omega_{it}}{2}=\frac{\omega_{it}}{2}.$$

Finally, under the free rider hypothesis, we have:

$$P\left(Y_{it}=1\middle|i\in S_{free}\right)=(1-\omega_{it})\cdot 0+\frac{\omega_{it}}{2}=\frac{\omega_{it}}{2},$$

$$P\left(Y_{it}=0\middle|i\in S_{free}\right)=(1-\omega_{it})\cdot 1+\frac{\omega_{it}}{2}=1-\frac{\omega_{it}}{2}.$$

Now we define the likelihood contribution for participant i as:

$$L_i = p_{full} \prod_{t=1}^{10} P\big(Y_{it} = 1 \big| i \in S_{full}\big)^{\boldsymbol{I}_{Y_{it}=1}} \cdot P\big(Y_{it} = 0 \big| i \in S_{full}\big)^{\boldsymbol{I}_{Y_{it}=0}}$$

$$+ p_{part} \prod_{t=1}^{10} P\big(Y_{it} = 1 \big| i \in S_{part}\big)^{\boldsymbol{I}_{Y_{it}=1}} \cdot P\big(Y_{it} = 0 \big| i \in S_{part}\big)^{\boldsymbol{I}_{Y_{it}=0}}$$

$$+ p_{naïv} \prod_{t=1}^{10} P(Y_{it} = 1 | i \in S_{naïv})^{\boldsymbol{I}_{Y_{it}=1}} \cdot P(Y_{it} = 0 | i \in S_{naïv})^{\boldsymbol{I}_{Y_{it}=0}} \qquad (8)$$

$$+ p_{free} \prod_{t=1}^{10} P\big(Y_{it} = 1 \big| i \in S_{free}\big)^{\boldsymbol{I}_{Y_{it}=1}} \cdot P\big(Y_{it} = 0 \big| i \in S_{free}\big)^{\boldsymbol{I}_{Y_{it}=0}},$$

where $\boldsymbol{I}_{Y_{it}=1}$ ($\boldsymbol{I}_{Y_{it}=0}$, respectively) is the indicator function which takes 1 if $Y_{it} = 1$ ($Y_{it} = 0$) and 0 otherwise. Parameters p_{full}, p_{part}, $p_{naïv}$, and p_{free} are "mixing proportions" corresponding to each hypothesis. These proportions express the degree to which the data are consistent with each hypothesis at the population level.

Then we take the logarithm of equation (8) and sum it up for all participants to obtain the log-likelihood function:

$$Log\ L = \sum_{i=1}^{N} \ln(L_i)\,. \qquad (9)$$

This function contains two tremble parameters from equation (5), six parameters from equations (2) and (6), five parameters from equations (4) and (7), and three free parameters of the mixing proportions in equation (8). These sixteen parameters are determined so that equation (9) is maximized.

3.4 Opportunity costs

Figure 4 illustrates how many successes each participant achieved per round in two-minute slider tasks through the first three rounds without voting. The average among all participants was 19.51, which is slightly fewer than Gill and Prowse's (2012) result.[21] The large variation

[21] Note that how many sliders participants can stop at 50 in two minutes depends on not only

in the number of successes among participants indicates a large variation in opportunity cost among them for the subsequent rounds.

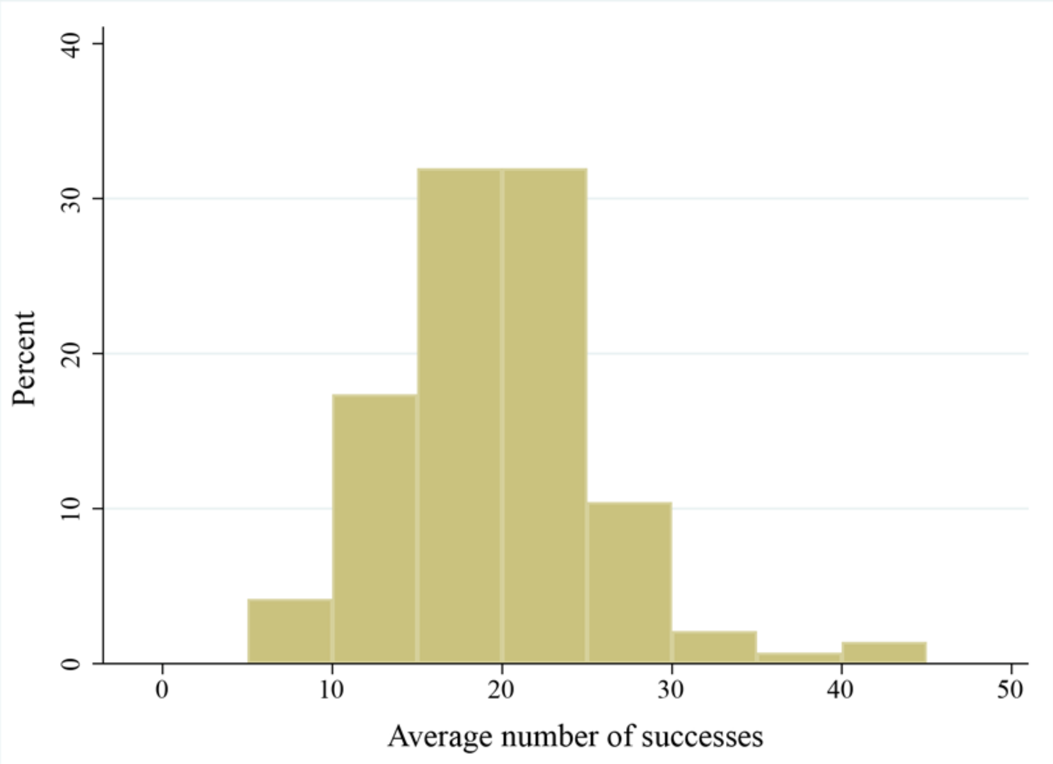

Figure 4. Distribution of the Average Number of Successes in the First Three Rounds

Note: The bandwidth of the histogram is 5.

Let e_{ik} denote the number of successes in the slider task participant i has achieved per second in round k.[22] We define the opportunity cost of voting for participant i in election t as:

$$CO_{it} = \frac{1}{3}(e_{i1} + e_{i2} + e_{i3}) \cdot 30 \cdot R_t, \tag{10}$$

where R_t represents the revenue per success in the slider task after election t. This

each participant's ability in slider task but also the ease of the use of the PC mouse in each laboratory.

[22] Let E_{ik} denote the total number of successes in the slider task participant i has achieved in round k. Then, $e_{ik} = \frac{1}{90}E_{ik}$ if the participant votes, while $e_{ik} = \frac{1}{120}E_{ik}$ if he/she abstains or $k = 1, 2, 3$, where the denominators are the seconds available for the participant to do his/her slider task in round k.

definition supposes that each participant recognizes his/her ability in the slider task through the first three rounds without voting, and that his/her recognition never changes over the remaining 10 rounds. According to this definition, the opportunity cost for each participant is constant through 5 or 10 elections unless R_t changes, although it can differ among participants.

In order to examine the robustness of the results obtained from the model with definition (10), we also defined two alternative measures of opportunity costs of voting. One measure is to use each participant's performance in the previous round. Formally,

$$CO_{it}^{*} = e_{i,t+2} \cdot 30 \cdot R_t. \tag{11}$$

Note that we conduct election t in round $k = t + 3$ as there are no elections in rounds $k = 1,2,3$. Hence, the performance in the previous round is denoted as $e_{i,t+2}$ at the time of election t. This definition supposes that each participant updates his/her recognition of his/her ability in the slider task round by round according to their performance in the previous round.

Another measure is the average performance each participant has experienced in all the previous rounds. Formally,

$$CO_{it}^{**} = \frac{1}{t+2} \sum_{k=1}^{t+2} e_{ik} \cdot 30 \cdot R_t. \tag{12}$$

Again, note that participants have experienced $t + 2$ previous rounds as of election t. Hence, the average performance before election t is the summation of the performances from e_{i1} to $e_{i,t+2}$ divided by the number of rounds $t + 2$. Under this definition, the update of the recognition of ability is gradual.

We label the original definition of opportunity cost in equation (10) as "opportunity cost 1," and the corresponding model as "model 1." We also label the first and the second alternatives in equations (11) and (12) as "opportunity cost 2" and "opportunity cost 3," with the corresponding models as "model 2" and "model 3," respectively. Table 2 summarizes the means and standard deviations of independent variables defined so far. Among the three definitions of opportunity costs, the mean is the largest for opportunity cost 2, second largest for opportunity cost 3, and the smallest for opportunity cost 1. This rank-order means that participants became better at the slider task as the rounds proceeded.

Table 2. Summary Statistics of Independent Variables

	Accumulated payoff mechanism			Random round payoff mechanism		
Variables	Observations	Mean	SD	Observations	Mean	SD
Expected gain	960	38.25	31.99	480	408.29	290.31
C (monetary)	960	19.93	11.62	480	203.33	114.45
C (opportunity 1) †	960	36.22	16.13	480	248.44	90.82
C (opportunity 2)	960	42.74	19.85	480	293.29	114.51
C (opportunity 3)	960	41.45	18.92	480	284.32	105.47
Sense of civic duty †	960	2.95	0.96	480	2.71	1.28

Note: Variables marked † take the same values through ten rounds for each participant.

4. Results

This section provides the results of our finite mixture probit regressions. Our main focuses were on ascertaining what proportion of data are consistent with the fully rational voter hypothesis at the population level and on comparing the effect of opportunity costs on voter turnout with the effect of monetary costs. A further analysis is added to find what proportion of participants are regarded to have followed each of the four hypotheses at the individual level.

4.1 Fully rational voter hypothesis

Table 3 summarizes the estimation results.[23] We have three models, depending on the definition of opportunity cost. The estimated proportions of fully rational behavior are 49.7% in model 1, 47.5% in model 2, and 48.1% in model 3, all of which are highly significant ($p<0.001$). The fact that nearly half of the data are consistent with the fully rational voter hypothesis is more or less surprising because participants had difficulty in understanding the idea of opportunity cost in our post-experiment questionnaires.[24] Thus, the answer to our first research question is constrained; that is, almost half of voting behaviors take account of opportunity costs.

[23] Robustness checks of the estimated parameters are performed in Appendix 2.

[24] In our post-experiment questionnaires, we included four two-alternative choice problems, which were based on Becker et al. (1974), to measure to what extent participants have understood the concept of opportunity cost. We found that more than one-third of participants could not choose any correct answer (35.00%), and another one-third could answer only one question correctly (33.33%).

Table 3. Estimation Results of Finite Mixture Models

Independent Variables	Model 1	Model 2	Model 3
Mixing Proportions			
P of fully rational voter	0.497 ***	0.475 ***	0.481 ***
	0.067	0.066	0.065
P of partially rational voter	0.355 ***	0.372 ***	0.370 ***
	0.067	0.068	0.066
P of naïve voter	0.039	0.045	0.043
	0.025	0.023	0.024
P of free rider	0.108 **	0.108 **	0.106 **
	0.034	0.034	0.034
Fully Rational Voter			
Expected gain	0.039 ***	0.042 ***	0.040 ***
	0.007	0.009	0.007
C (monetary)	-0.062 ***	-0.064 ***	-0.063 ***
	0.011	0.013	0.011
C (opportunity 1)	-0.020 **		
	0.006		
C (opportunity 2)		-0.019 **	
		0.006	
C (opportunity 3)			-0.019 **
			0.006
Sense of civic duty	0.190	0.194	0.183
	0.143	0.141	0.144
RRPM dummy	-9.895 ***	-10.745 ***	-9.574 ***
	2.246	2.775	2.315
Constant	-0.198	-0.194	-0.091
	0.457	0.437	0.453
Partially Rational Voter			
Expected gain	0.001 *	0.001 *	0.001 *
	0.001	0.001	0.001
C (monetary)	-0.006 **	-0.006 **	-0.006 **
	0.002	0.002	0.002
Sense of civic duty	0.186	0.116	0.140
	0.179	0.125	0.147
RRPM dummy	1.315 *	1.193 *	1.189 *
	0.631	0.511	0.519
Constant	-0.558	-0.335	-0.431
	0.617	0.412	0.509
Tremble Parameters			
ω_0	0.501 ***	0.482 ***	0.482 ***
	0.099	0.101	0.100
ω_1	-0.241 ***	-0.246 ***	-0.251 ***
	0.069	0.070	0.070
Log L	-816.802	-815.812	-815.972
AIC	1665.603	1663.624	1663.945
BIC	1749.962	1747.982	1748.303

Note: Table entries are probit coefficients with standard errors.
The dependent variable is whether to have voted (1) or abstained (0).
*p<0.05, **p<0.01, ***p<0.001

How large was the effect of opportunity costs on turnout in comparison with monetary costs? Under the fully rational voter hypothesis, both monetary costs and opportunity costs had negative effects on turnout in all the three models with significance levels of 0.1% and 1%, respectively. We calculated the marginal rate of substitution (MRS) between monetary costs and opportunity costs under the fully rational voter hypothesis (i.e., $\beta_{full,3}/\beta_{full,2}$). Table 4 summarizes the results. The rates are 0.320 with a 95% confidence interval of (0.161, 0.478) in model 1, 0.292 with (0.149, 0.435) in model 2, and 0.306 with (0.165, 0.447) in model 3. These values suggest that, even under the fully rational voter hypothesis, the effect of opportunity costs on turnout is about one-third of the effect of monetary costs, which is the answer to our second research question. The weaker effect of opportunity costs also provides an answer to the paradox of voter turnout in terms of the misperception and/or depreciation of opportunity costs.

Table 4. Estimated MRS Between Monetary and Opportunity Costs
Under the Fully Rational Voter Hypothesis

	MRS	SE	[95% Confidence Interval]	
Model 1	0.320	0.081	0.161	0.478
Model 2	0.292	0.073	0.149	0.435
Model 3	0.306	0.072	0.165	0.447

4.2 Partially rational voter hypothesis

The estimated proportions of partially rational voter hypothesis are second largest, which are 35.5% in model 1, 37.2% in model 2, and 37.0% in model 3. All of them are highly significant ($p<0.001$). Under this partially rational voter hypothesis, monetary costs also have negative effects on turnout with high significance levels ($p<0.01$) in all three models (Table 3).

We can conclude that about 85% of data are either fully or partially consistent with the rational voter hypothesis. Under either rational voter hypothesis, the effect of expected gain is also significantly positive ($p<0.001$). These facts are favorable to the rational voter theory in which voters are assumed to calculate gains and costs in their voting decisions.

4.3 Other findings

We also obtain the following three observations from Table 3. First, only a small proportion of data are regarded to be consistent with the naïve voter and free rider hypotheses. The estimated proportion of naïve voter hypothesis is not significantly different from 0% in all three models. On the other hand, the proportions of free rider hypothesis are 10.8% in models 1 and 2, and 10.6% in model 3, all of which are highly significant (p<0.01).

Second, the estimated coefficients of the strength of the sense of civic duty to vote are insignificant under both the fully and partially rational voter hypotheses in any model. One interpretation from the viewpoint of controlled laboratory experiments is that our experiment has succeeded in eliminating such motivation participants bring from outside the laboratory. Another interpretation is that we should have operationalized the sense of civic duty to vote differently from the four statements that modified Campbell et al. (1954). For example, civic duty might be also defined as peer pressure among voters rather than an intrinsic characteristic of each voter (e.g., Gerber, Green, and Larimer 2008).

Finally, the estimates of the initial probability of tremble ω_0 have significantly positive signs in all three models (p<0.001), while the estimates of the rate of decay of tremble ω_1 have significantly negative signs (p<0.001). These facts suggest that the probability of tremble diminishes as participants experience more elections. We conducted likelihood-ratio tests and found that the introduction of these tremble parameters had improved the fitness of all models with high significance levels (p<0.001). The same tests also confirmed that the introduction of dummy variable regarding the payment scheme (i.e., RRPM dummy) into the equations for the fully and partially rational voter hypotheses had improved the fitness of all models with high significance levels (p<0.001).

4.4. Classification of voting behavior by participant

So far, we have focused on the fitness of each behavioral hypothesis to the data at the population level. In this subsection, we classify each participant into one of the four behavioral types according to his/her 10 voting decisions. This classification at the individual level not only reexamines how well our finite mixture model fits the data, but also helps us understand how each type of participant behaved.

Using each participant's 10 decision data, we first calculated his/her posterior probabilities for each of the four types, which are defined as:

$$P\left(i \in S_{full} \middle| Y_{i1,}Y_{i2,\dots,}Y_{i10}\right) = \frac{p_{full}\prod_{t=1}^{10} P\left(Y_{it}=1|i \in S_{full}\right)^{I_{Y_{it}=1}} \cdot P\left(Y_{it}=0|i \in S_{full}\right)^{I_{Y_{it}=0}}}{L_i},$$

$$P\left(i \in S_{part} \middle| Y_{i1,}Y_{i2,\dots,}Y_{i10}\right) = \frac{p_{part}\prod_{t=1}^{10} P\left(Y_{it}=1|i\in S_{part}\right)^{I_{Y_{it}=1}} \cdot P\left(Y_{it}=0|i\in S_{part}\right)^{I_{Y_{it}=0}}}{L_i},$$

$$P\left(i \in S_{naïv} \middle| Y_{i1,}Y_{i2,\dots,}Y_{i10}\right) = \frac{p_{naïv}\prod_{t=1}^{10} P\left(Y_{it}=1|i\in S_{naïv}\right)^{I_{Y_{it}=1}} \cdot P\left(Y_{it}=0|i\in S_{naïv}\right)^{I_{Y_{it}=0}}}{L_i},$$

$$P\left(i \in S_{free} \middle| Y_{i1,}Y_{i2,\dots,}Y_{i10}\right) = \frac{p_{free}\prod_{t=1}^{10} P\left(Y_{it}=1|i\in S_{free}\right)^{I_{Y_{it}=1}} \cdot P\left(Y_{it}=0|i\in S_{free}\right)^{I_{Y_{it}=0}}}{L_i}.$$

We then classified him/her into a particular type that gives the highest posterior probability; this classification criterion is based on Bardsley and Moffatt (2006).[25]

Table 5 summarizes the results. If we accept model 1, we identified 80 fully rational voters (55.56%), 45 partially rational voters (31.25%), 5 naïve voters (3.47%), and 14 free riders (9.72%). If we accept other models, we could still identify about half participants as fully rational voters (50.00% in model 2; 50.69% in model 3), and about one-third of participants as partially rational voters (36.11% in model 2; 34.72% in model 3). It is worth noticing that these percentages are similar to the mixing proportions at the population level in Table 3.

Table 5. Type Classification of Participants

	Fully Rational	Partially Rational	Naïve Voter	Free Rider	Total
Model 1	80	45	5	14	144
%	55.56%	31.25%	3.47%	9.72%	100.00%
Model 2	72	52	5	15	144
%	50.00%	36.11%	3.47%	10.42%	100.00%
Model 3	73	50	5	16	144
%	50.69%	34.72%	3.47%	11.11%	100.00%

Figure 5 draws the locally weighted scatter plot smoother (LOWESS) of voting decision (on the vertical axis; vote (1) or abstain (0)) against net payoff from voting (on the horizontal axis; equation (1) where *C* consists of monetary costs and opportunity costs) estimated by a form of nonparametric regression (Cleveland 1979) on the scatterplot of each type in model 1.[26] If the smoother is vertical at 0, and horizontal at height 0 to its left and horizontal at height 1 to its right, then such voters are strictly rational as in the rational voter theory. If it is horizontal over the whole range, on the other hand, such voters are insensitive

[25] This simple method of classification is as good as more elaborate methods in terms of predictive power. See Appendices 3 and 4.
[26] Graphs of other models are presented in Appendix 4.

to the change in net payoff from voting.

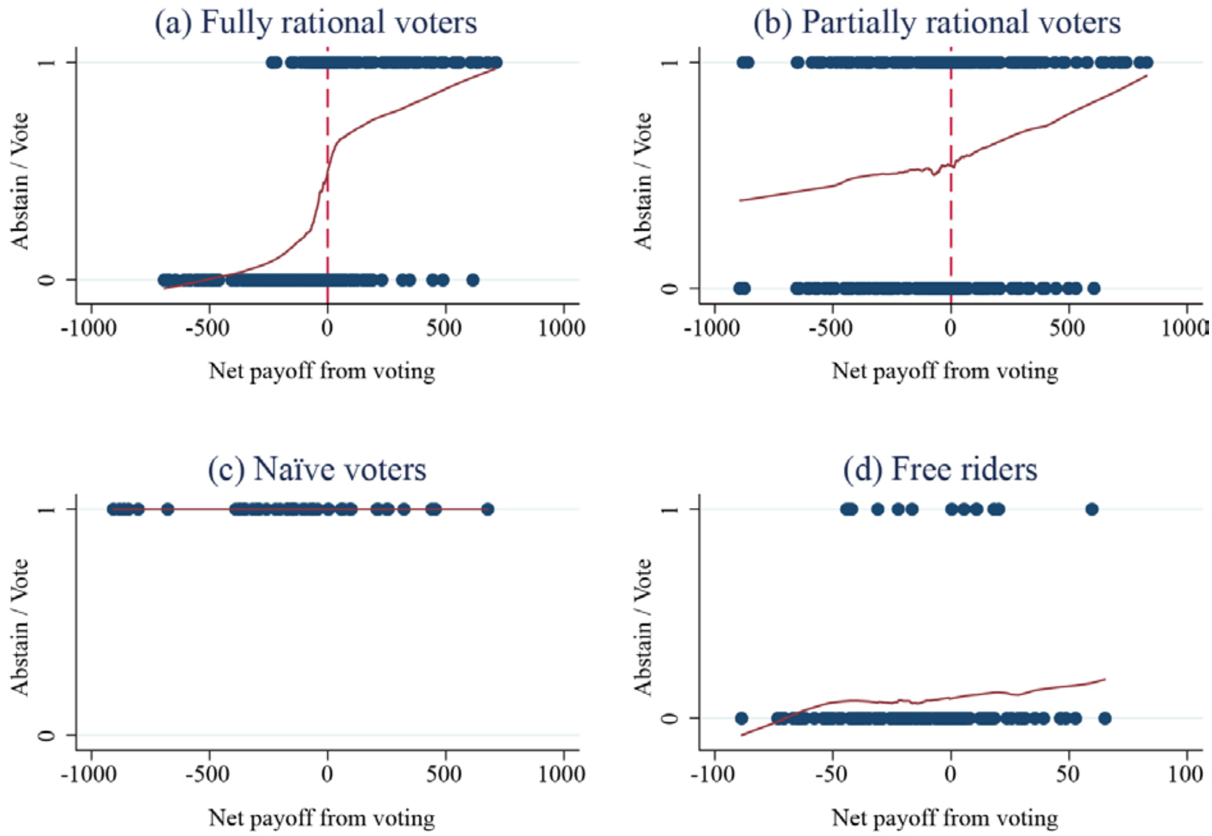

Figure 5. Scatterplot and LOWESS of Voting Decision Against the Net Payoff from Voting

Note: The bandwidth of LOWESS is 0.8. Since all of the 14 free riders are from APM sessions, the horizontal axis of panel (d) ranges from -100 to 100.

Panel (a) is created from the 800 decisions of 80 fully rational voters. The smoother rises sharply to the right at zero. Although they are not perfectly rational around the zero net payoff, the shape of their smoother shows their sufficient rationality. Also, in panel (b), partially rational voters are likely to abstain when the net payoff is negative while vote when it is positive. However, their switch from abstention to voting is not as clear as fully rational voters. The smoothers in panels (c) and (d) are flat at height 1 and height 0, respectively; their decisions are consistent with our behavioral hypotheses for naïve voters and free riders. These four panels show that the type classification at the individual level obtains the results consistent with those obtained by the finite mixture probit regression at the population level.

5. Conclusion

In this study, we examined whether participants vote differently in the standard framework of voting experiment depending on whether they face monetary costs or opportunity costs of voting. Monetary costs have been widely used as a proxy of opportunity costs in voting experiments. However, previous experimental studies in behavioral science suggest that participants have difficulty in understanding opportunity costs. Therefore, our first question was whether participants take account of opportunity costs when they face voting decisions. Our second question was to what extent they react to opportunity costs in comparison with monetary costs if they take account of opportunity costs.

We created opportunity costs in the laboratory by asking participants to work on two-minute slider tasks in which they could earn money depending on their performances. If a participant chose to go to the poll, he/she lost both a fixed amount of money and thirty seconds for his/her slider task. We also asked each participant to conjecture his/her pivot probability in order to control for their expected gains from voting.

From our data, we obtained the following two main findings. First, for decisions that are consistent with the fully rational voter hypothesis, the effect of opportunity costs on voter turnout is about one-third of the effect of monetary costs. This finding implies that such a stronger effect of monetary costs in comparison with opportunity costs should be taken into account when we apply observations from laboratory experiments to real politics. The weaker effect of opportunity costs also provides an answer to the paradox of voter turnout in terms of the misperception and/or depreciation of opportunity costs.

Second, the degree to which the fully rational voter hypothesis is consistent with the data is nearly 50% at the population level. If we also include the partially rational voter hypothesis, under which participants react to monetary costs but ignore opportunity costs, then about 85% of our data are consistent with the rational voter theory. At the individual level, we found that over 50% of participants were classified as fully rational voters, and about one-third of participants were partially rational voters. Naïve voters and free riders made up less than or about 10% of participants. These findings imply that the rational voter theory explains a sufficiently large proportion of participants' behavior in the laboratory despite the weak recognition of opportunity costs in post-experiment questionnaires.

Future studies should address the following issues to increase the accuracy of measuring opportunity costs. First, in our experiment, we measured each participant's opportunity cost as the earnings he/she would have obtained if he/she spent 30 seconds longer on slider tasks. However, tackling slider tasks for 30 seconds longer might have been tiring for participants, although it might have been rather enjoyable or neither. One way to control such possible costs or benefits associated with the longer time for tackling slider tasks is to give the same working time to participants who voted and those who abstained, but to subtract 30 seconds worth of successes in slider tasks from the participants who voted.

Second, in our experiment, monetary costs were determined in advance of voting while opportunity costs were determined in the slider task done after voting. It means that our opportunity costs included uncertainty; at the time of voting, participants did not know how much money they would earn for the 30 seconds if they abstained, although they could expect it from their experiences in the previous rounds. We know that opportunity costs are inherently accompanied by uncertainty because they are calculated from the choices not actually taken; uncertainty might be regarded as a part of the concept of opportunity cost. Nonetheless, we can control such uncertainty in the laboratory if we predetermine how many sliders participants must work on, if we employ any other task for which the number of successes is much less uncertain, or if we add the same degree of uncertainty to monetary costs.[27]

[27] The idea of adding uncertainty to monetary costs is similar to the experimental design taken by Andreoni and Sprenger (2012). They added uncertainty to immediate rewards to control the uncertainty accompanied by later rewards in measuring participants' time preferences.

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Appendix 1. Sample instructions for voting experiment participants

This section presents the instructions given to participants under condition (*a*), shown in Table 1. The instructions are composed of two parts that correspond to A1.1 and A1.2.

A1.1 Instructions

In your hands, there are:

● Instructions (this booklet)

● Participant number card

● Ballpoint pen

Please raise your hand if any of the above is missing.

Before we start today's experiment

Talking with others is prohibited until today's experiment ends and you leave this laboratory. Please turn off your mobile phone.

About today's experiment

This experiment is being conducted for research on decision making. The rewards you receive today are determined by the experimental outcomes. You will receive a cash reward at the end of the experiment.

Participant number

In your hands, you have a card that reads "Your participant number is (   )." This is your participant number. You need this number to collect your earnings. Please keep it on hand so that you do not lose it. The experiment is being conducted anonymously using participant numbers instead of names. Your decisions and rewards will never be known to the other participants.

Now, you are going to enter your participant number on your computer screen. Please follow the experimenters' instructions exactly. If the instruction "Please enter your participant number in the box below" appears on your computer screen, please enter your participant number as requested and click the "Confirm" button at the bottom right of your screen. On the next screen, please do not click anything yet.

Organization of the experiment

This experiment consists of 13 rounds, namely Round 1 through to Round 13. Each round is independent of the other rounds. That is, the results of the previous rounds are not carried forward to the next round. After Round 13, you will answer multiple-choice questions and complete another questionnaire.

What to do in Rounds 1, 2, and 3

There are 48 sliders on the computer screen. Initially, all sliders were set at position 0. If you move the cursor to each slider with the mouse and drag it (i.e., move the mouse while left clicking), the slider can be moved freely between 0 and 100. Your task is to move the sliders one by one and stop each at 50. You can begin with any slider. **The time limit is 2 minutes. You will receive 5 yen per slider stopped at 50** when 2 minutes have passed. This 2-minute task is to be repeated for three rounds.

Practice

For practice, let us try to move sliders. The results of this practice exercise are not counted in your rewards. The time allotted for practice is 1 minute. Please click the “Start Practice” button in the lower right of your screen and move the sliders as you like. When the message “Please wait for a moment” appears, please follow that instruction. Your screen will automatically proceed to the next screen after the other participants have finished clicking the button.

After 1 minute, your computer screen will display the results of your practice exercise. Please confirm the results and click the “Confirm” button at the bottom right. On the next screen, please do not click anything yet.

What to do during and after Round 4

You will also perform the slider task during and after Round 4. However, what you need to do changes slightly. We will give you detailed instructions after Round 3.

Earnings

You will obtain rewards in each round. The sum of the rewards you obtain from Rounds 1 to 13 will be paid in cash at the end of the experiment. You will also have an opportunity to obtain rewards for solving multiple-choice problems after Round 13.

This is the end of the instructions for Rounds 1, 2, and 3. If you have any questions, please raise your hand and an experimenter will come to your assistance.

A1.2 Instructions (continuation)

In your hands, please find the following:

● Instructions (continuation) (this booklet)

Please raise your hand if this material is missing.

What to do during and after Round 4

■ Grouping

From Rounds 4 to 13, participants are divided into groups of six. Each group of six is then further divided into two three-member groups (i.e., Group *A* and Group *B*). These six people and the two three-member groups are shuffled randomly in every round. In each round, you can see the group that you belong in the upper left of your computer screen. However, you will never know which groups the other participants in the laboratory belong.

What to do in each round

■ Things common to Round 3 and earlier rounds

As in Round 3 and earlier rounds, you will perform slider tasks. You have 2 minutes for the task, and you will receive 5 yen per success from Rounds 4 to 8. Each round is independent of the other rounds. That is, the results of the previous rounds are not carried forward to the next round.

■ Things that are different from those in Round 3 and earlier rounds

The things that are different between Round 3 (and earlier rounds) and Round 4 (and subsequent rounds) are as follows. [1] In addition to the slider task, **a vote is held between Groups *A* and *B***: you can also obtain rewards for voting. [2] **During and after Round 9, you will earn 10 yen per success in the slider task.** We will now explain [1], that is, how to vote and how voting outcomes and rewards are determined.

■ How to vote

Before going into the slider task, buttons labeled “Vote” and “Do not vote” will appear on your computer screen. Please click the “Vote” button if you are going to vote and the “Do not vote” button if you are not going to vote. You must click one of the buttons.

Clicking the “Vote” button is accompanied by the following two steps:

(1) **You will lose an amount of money as your voting cost.** The amount of money that you

will lose is displayed as “Voting cost” in the upper left of your computer screen. This cost changes every round for each participant.

(2) **You will lose 30 seconds of your working time for the slider task.** That is, your time will be shortened from 2 minutes to 1 minute and 30 seconds.

Clicking the “Do not vote” button is not accompanied by these two steps.

■ Determination of voting outcomes and rewards

Your gain from the vote depends on which group has a larger number of voting members: Group *A* (three members), or Group *B* (three members). More precisely, **each member of the group that has a larger number of members who have voted earns 100 yen, while each member of the other group earns 0 yen**. For instance, suppose that two members have voted in Group *A*, while only one member has voted in Group *B*. Then, regardless of your individual choice (i.e., to vote or abstain), you will earn 100 yen if you belong to Group *A* but 0 yen if you belong to Group *B*. Note that, as mentioned above, if you vote, you lose your voting cost and 30 seconds of your working time for the slider task.

To prepare for the possibility of a tie, at the beginning of each round, we predetermine which group will earn 100 yen in the event that a tie occurs. This information will be displayed at the top of the screen in each round, e.g., “In this round, in case the number of members who have voted is the same between the two groups, group (   ) will earn 100 yen,” where either *A* or *B* will be in the parentheses.

■ Conjecture on the probability that your vote will affect the voting outcome

At the beginning of each round, before undertaking the voting decision and the slider task, you will conjecture as to the probability that your vote will affect the voting outcome. Depending on how accurate your conjecture is, you will earn additional rewards. The sentence “Your vote affects the voting outcome” means that one of the following cases occurs **among five people, excluding you (i.e., two members of your group, besides yourself, and three members of the other group)**:

● **In rounds where your group earns 100 yen if the number of members who have voted is the same between the two groups, the number of members who have voted in your group is one fewer than that in the other group.** In other words, this is when the number of members who have voted in your group and in the other group is 0-1, 1-2, or 2-3. In this case, if you do not vote, your group earns 0 yen. On the other hand, if you do vote, the number of members who have voted becomes the same between the two groups, and your group earns 100 yen. Hence, we can say that your vote affects the voting outcome (i.e., whether your group earns 0 yen or 100 yen).

● **In rounds where your group earns 0 yen if the number of members who have voted is the same in the two groups, the number of voting members is the same in both groups.** Specifically, this is when the number of members who have voted in your group and the other group is 0-0, 1-1, or 2-2. In this case, if you do not vote, your group earns 0 yen. On the other hand, if you do vote, the number of members who have voted in your group exceeds that in the other group, and your group earns 100 yen. Hence, we can say that your vote affects the voting outcome (i.e., whether your group earns 0 yen or 100 yen).

In cases other than the above, your vote does not affect the voting outcome because the voting outcome does not change regardless of whether you vote or abstain. For instance, suppose that the other two members in your group do not vote, while all three members of the other group do vote. Under such a circumstance, even if you vote, the number of voting members in your group and the other group is 1 and 3, respectively, and your group still earns 0 yen.

At the beginning of each round, the following instruction will appear on your computer screen: "Please conjecture as to the probability that your vote will affect the voting outcome and enter a value between 0 and 1" (this range is inclusive of both 0 and 1). You can enter a number with up to two decimal places, such as 0.01.

■ The determination of your rewards based on your conjecture as to the probability that your vote will affect the voting outcomes

Your rewards from your conjecture as to the probability that your vote will affect the voting outcomes are determined as follows.

Suppose that you enter "p" in the box for the conjecture on the probability. Note that p is a number with up to two decimal places between 0 and 1 (including 0 and 1). **If your vote has affected the voting outcome, you earn 5 yen with probability $1-(1-p)^2$ but lose 3 yen with probability $(1-p)^2$. If your vote has not affected the voting outcome, you earn 5 yen with probability $1-p^2$ but lose 3 yen with probability p^2.** The computer determines whether you earn 5 yen or lose 3 yen based on these probabilities. The decision is displayed on your computer screen.

■ **The flow of each round**

The flow of each round is summarized as follows:

(1) Make your conjecture and enter the probability that your vote will affect the voting outcome.

(2) Choose either “Vote” or “Do not vote.”

(3) Work on the slider task. You have 1 minute and 30 seconds to complete it if you have chosen to vote and 2 minutes if you have chosen not to vote.

(4) After finishing the slider task, the following six results will be displayed on your computer screen:

1. Voting outcome (i.e., the number of members who have voted in each group)
2. The rewards you have earned from your conjecture on the probability that your vote will affect the voting outcome (i.e., whether you have gained 5 yen or lost 3 yen)
3. The rewards you have earned from the voting outcome (i.e., either 100 yen or 0 yen)
4. The amount of money you have lost as your voting cost (i.e., the amount of money displayed in the box labeled “Voting cost” if you have voted and 0 yen if you have not voted)
5. The rewards you have earned from the slider task (i.e., 5 yen per success from Rounds 4 to 8 and 10 yen per success from Rounds 9 to 13)
6. The sum of Numbers 2 to 5 in this list (i.e., the total rewards you have earned in the round)

We repeat the above flow for ten rounds from Rounds 4 to 13. Note that the reward per success in the slider task is 5 yen during and prior to Round 8 and 10 yen during and after Round 9. Each round is independent of the other rounds. That is, the results of the previous rounds are not carried forward to the next round. After Round 13, you will do multiple-choice problems and complete a questionnaire.

This is the end of the instructions for Round 4 and later rounds. If you have any questions, please raise your hand and an experimenter will come to your assistance.

Appendix 2. Monte Carlo simulation of the estimated parameters

To determine the robustness of the estimated parameters shown in Table 3, we conduct in-sample Monte Carlo simulations. We replicate 1,000 datasets from the estimated parameters and the actual data. We then estimate the parameter sets, assuming models 1, 2, and 3.

Figure A2.1 shows the distributions of such simulated mixing proportions based on model 1. The vertical line in each pane indicates the estimated mixing proportion shown in Table 3. Similarly, Figure A2.2 shows the distributions of the simulated coefficients of fully rational voters' monetary costs and opportunity costs, and partially rational voters' monetary costs, assuming model 1. The means and standard errors of the simulated mixing proportions and the coefficients of three kinds of costs are summarized in Table A2.1. Figures A2.3 and A2.4 and Table A2.2 correspond to model 2, while Figures A2.5 and A2.6 and Table A2.3 correspond to model 3. Figure A2.7 shows the distributions of simulated marginal rate of substitution (MRS) based on the three models. Their means and standard errors are summarized in Table A2.4. We confirm that the estimated parameters in table 3 and the MRS in table 4 are both consistent and unbiased.

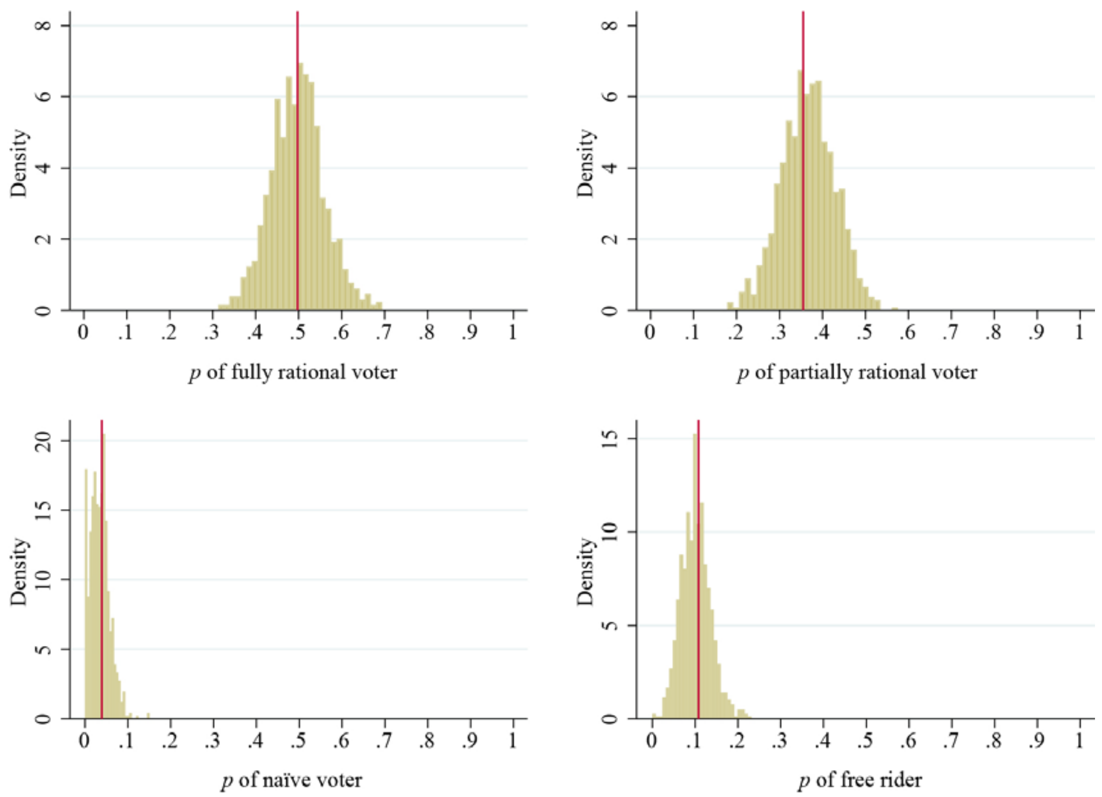

Figure A2.1 Simulated Mixing Proportions of Each Type (Model 1)

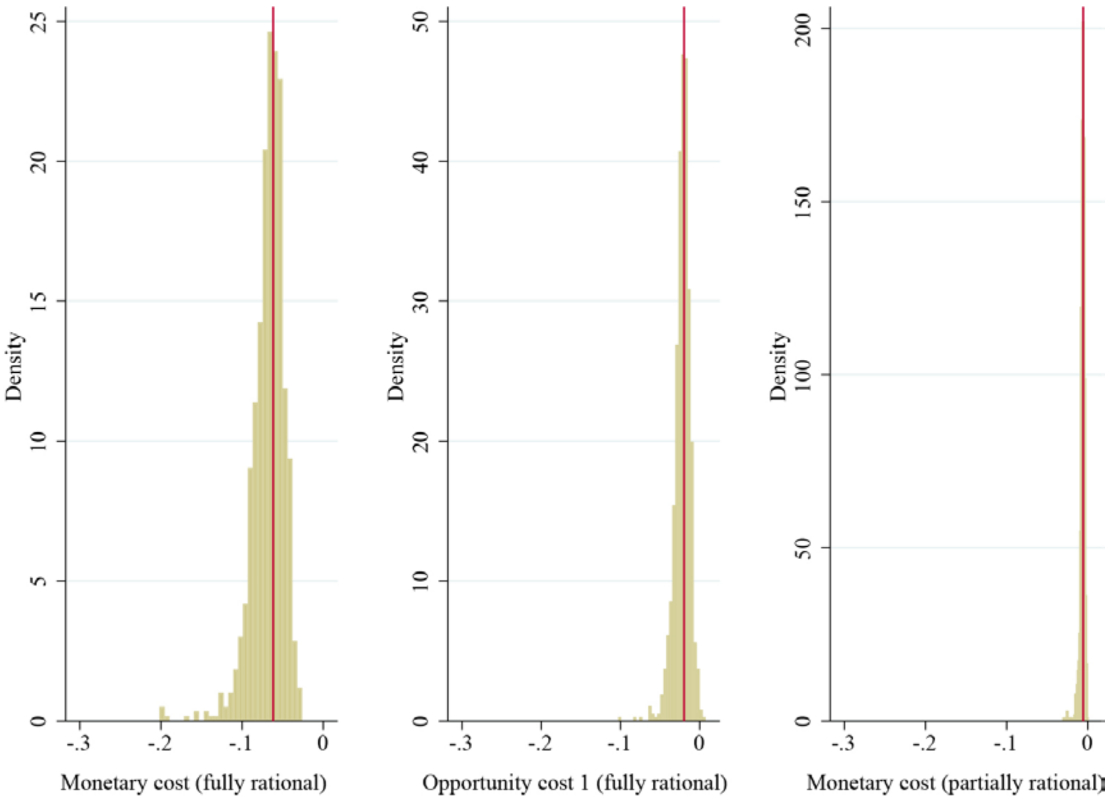

Figure A4.2 Simulated Coefficients (Model 1)

Table A2.1 Summary of Simulated Coefficients (Model 1)

			Number of obs =	987
	Mean	SE	[95% Confidence	Interval]
Mixing Proportions				
P of fully rational voter	0.498	0.002	0.494	0.502
P of partially rational voter	0.366	0.002	0.362	0.370
P of naïve voter	0.035	0.001	0.033	0.036
P of free rider	0.101	0.001	0.099	0.104
Fully Rational Voter				
C (monetary)	-0.068	0.001	-0.069	-0.066
C (opportunity 1)	-0.022	0.000	-0.023	-0.021
Partially Rational Voter				
C (monetary)	-0.007	0.000	-0.007	-0.006

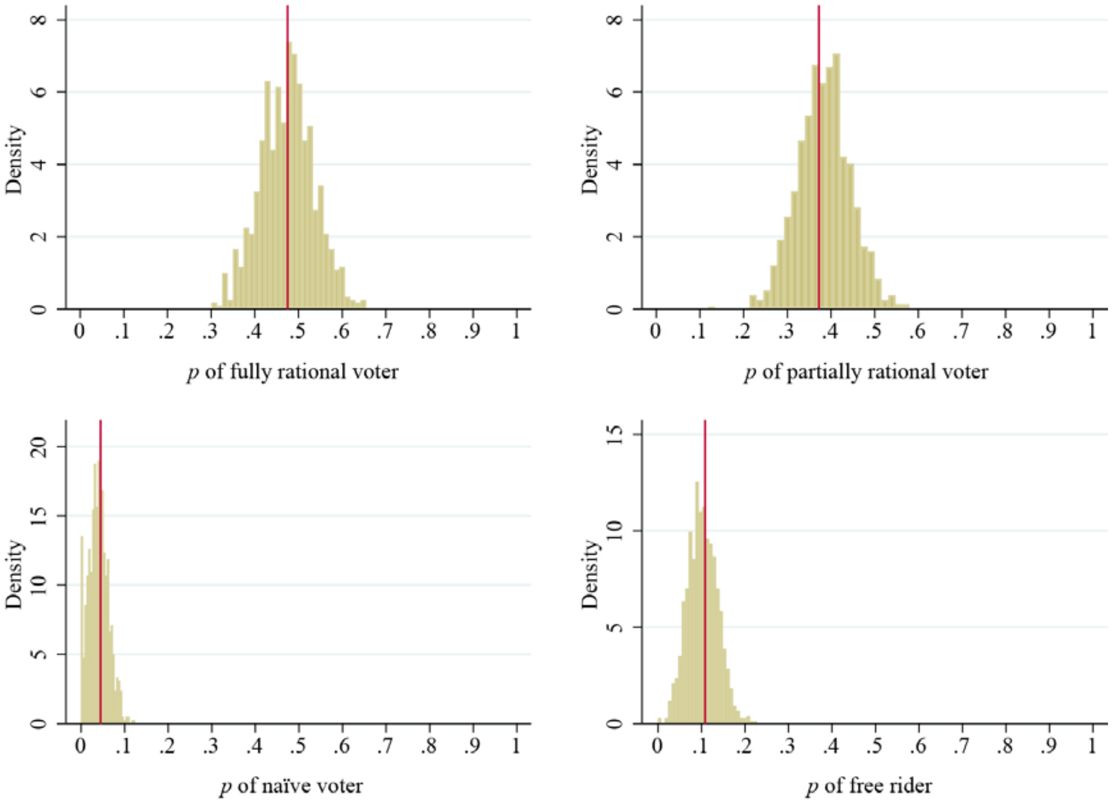

Figure A2.3 Simulated Mixing Proportions of Each Type (Model 2)

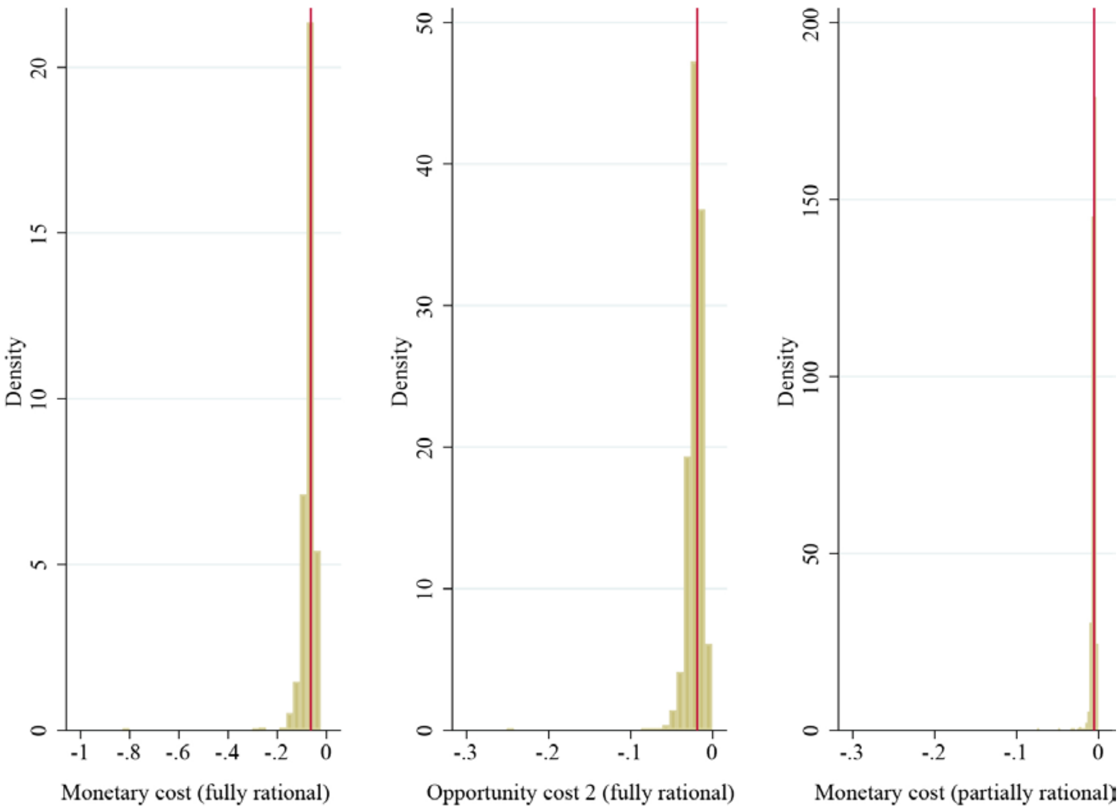

Figure A5.4 Simulated Coefficients (Model 2)

Table A2.2 Summary of Simulated Coefficients (Model 2)

			Number of obs =	988
	Mean	SE	[95% Confidence	Interval]
Mixing Proportions				
P of fully rational voter	0.474	0.002	0.470	0.478
P of partially rational voter	0.384	0.002	0.380	0.387
P of naïve voter	0.040	0.001	0.039	0.042
P of free rider	0.102	0.001	0.100	0.104
Fully Rational Voter				
C (monetary)	-0.073	0.001	-0.075	-0.070
C (opportunity 2)	-0.021	0.000	-0.022	-0.021
Partially Rational Voter				
C (monetary)	-0.006	0.000	-0.007	-0.006

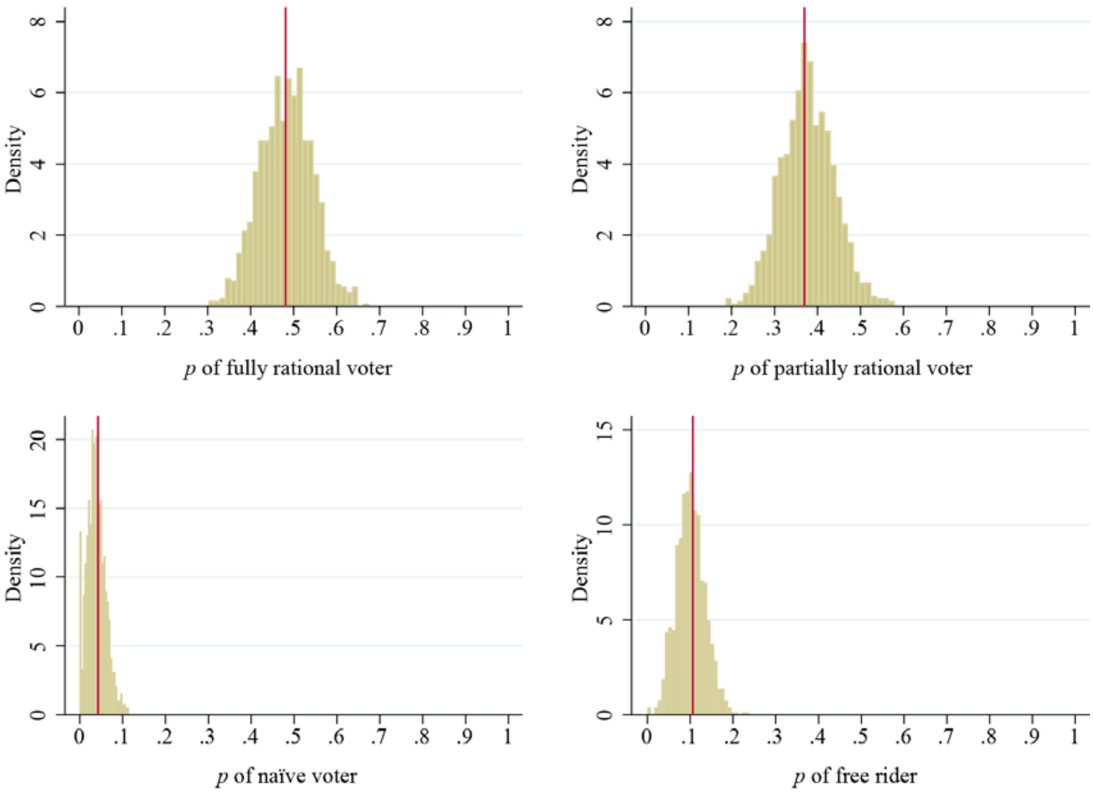

Figure A2.5 Simulated Mixing Proportions of Each Type (Model 3)

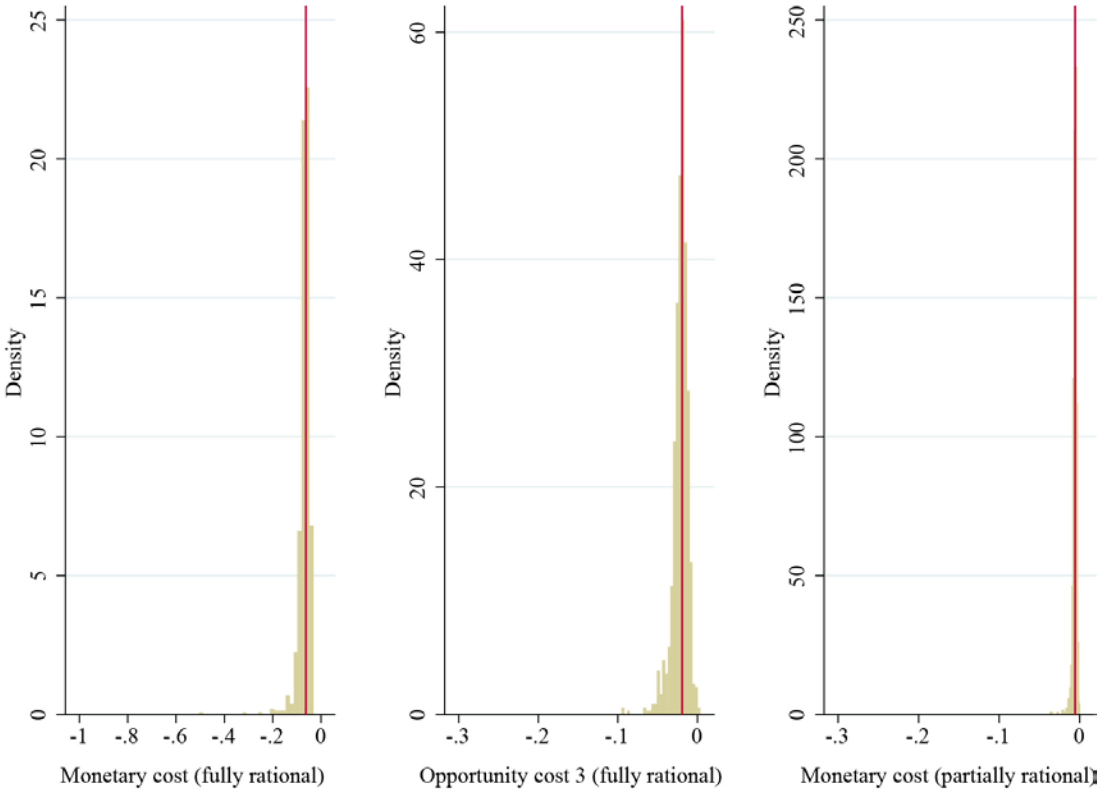

Figure A6.6 Simulated Coefficients (Model 3)

Table A2.3 Summary of Simulated Coefficients (Model 3)

			Number of obs =	987
	Mean	SE	[95% Confidence	Interval]
Mixing Proportions				
P of fully rational voter	0.482	0.002	0.479	0.486
P of partially rational voter	0.378	0.002	0.374	0.382
P of naïve voter	0.039	0.001	0.037	0.040
P of free rider	0.101	0.001	0.099	0.103
Fully Rational Voter				
C (monetary)	-0.069	0.001	-0.071	-0.067
C (opportunity 3)	-0.021	0.000	-0.022	-0.021
Partially Rational Voter				
C (monetary)	-0.006	0.000	-0.006	-0.006

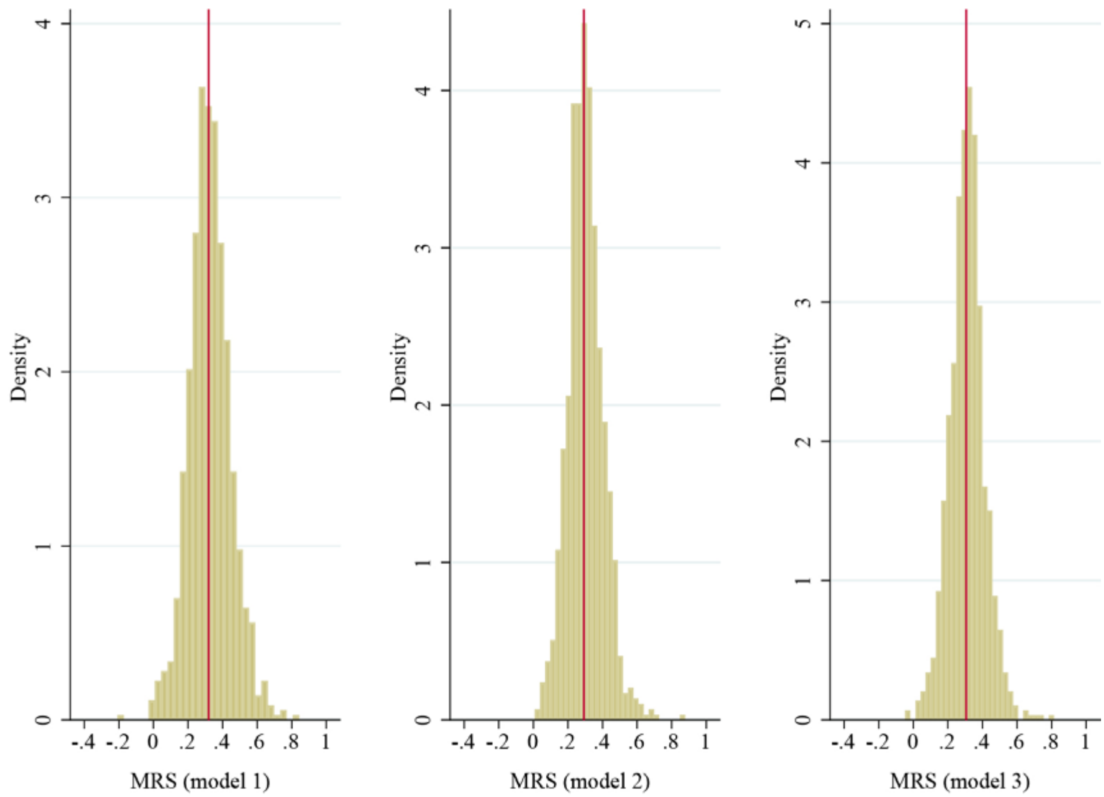

Figure A7.7 Simulated MRS

Table A2.4 Summary of Simulated MRS

	Mean	SE	[95% Confidence	Interval]
MRS (model 1)	0.327	0.004	0.320	0.335
MRS (model 2)	0.302	0.003	0.296	0.309
MRS (model 3)	0.312	0.003	0.306	0.318

Appendix 3. Identification of voter type using the false discovery rate

We calculate four posterior type probabilities for each participant, and then classify each participant into a particular type (e.g., fully rational voter) if their posterior probability of the corresponding type exceeds a threshold λ (e.g., $P\left(i \in S_{full} \middle| Y_{i1,}Y_{i2,\ldots,}Y_{i10}\right) > \lambda$). The next step is to determine an appropriate threshold value. The problem here is that if we set the value too low, participants may be classified into more than one type; on the contrary, if we set the value too high, many participants will not be classified into any specific type. Thus, following Imai and Tingley (2011), we use the following optimal value for the threshold:

$$\lambda^* = inf\left\{\lambda\left|\frac{\sum_{i=1}^{N}\sum_{j\in\{full,part,naïv,free\}}(1-P_{ij})I_{P_{ij}>\lambda}}{\sum_{i=1}^{N}\sum_{j\in\{full,part,naïv,free\}}I_{P_{ij}>\lambda}+\prod_{i=1}^{N}\prod_{j\in\{full,part,naïv,free\}}I_{P_{ij}\leq\lambda}} \leq \alpha\right.\right\},$$

where P_{ij} is the abbreviation of posterior probability $P\left(i \in S_j \middle| Y_{i1,}Y_{i2,\ldots,}Y_{i10}\right)$, and $I_{P_{ij}>\lambda}$ is an indicator function that takes 1 if $P_{ij} > \lambda$ and 0 otherwise. The left-hand side of the inequality in the braces is the expected value of the false discovery rate (FDR), while α in the right-hand side is a significance level. The basic idea is that we set the threshold value as low as possible while keeping the expected FDR lower than α. For the type classification, we arrange three levels of significance: $\alpha = 0.05$, $\alpha = 0.01$, and $\alpha = 0.001$.

Table A3.1 Participants' Type Classification Using the FDR ($\boldsymbol{\alpha = 0.05}$)

	Fully Rational	Partially Rational	Naïve Voter	Free Rider	Not Classified	Total
Model 1	36	23	2	7	76	144
%	25.00%	15.97%	1.39%	4.86%	52.78%	100.00%
Model 2	37	25	4	6	72	144
%	25.69%	17.36%	2.78%	4.17%	50.00%	100.00%
Model 3	36	25	4	7	72	144
%	25.00%	17.36%	2.78%	4.86%	50.00%	100.00%

Table A3.2 Participants' Type Classification Using the FDR ($\boldsymbol{\alpha = 0.01}$)

	Fully Rational	Partially Rational	Naïve Voter	Free Rider	Not Classified	Total
Model 1	8	13	1	3	119	144
%	5.56%	9.03%	0.69%	2.08%	82.64%	100.00%
Model 2	7	13	1	2	121	144
%	4.86%	9.03%	0.69%	1.39%	84.03%	100.00%
Model 3	7	13	1	2	121	144
%	4.86%	9.03%	0.69%	1.39%	84.03%	100.00%

Table A3.3 Participants' Type Classification Using the FDR ($\boldsymbol{\alpha = 0.001}$)

	Fully Rational	Partially Rational	Naïve Voter	Free Rider	Not Classified	Total
Model 1	**0**	**0**	**0**	**0**	**144**	**144**
%	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**100.00%**	**100.00%**
Model 2	**0**	**1**	**0**	**0**	**143**	**144**
%	**0.00%**	**0.69%**	**0.00%**	**0.00%**	**99.31%**	**100.00%**
Model 3	**0**	**1**	**0**	**0**	**143**	**144**
%	**0.00%**	**0.69%**	**0.00%**	**0.00%**	**99.31%**	**100.00%**

Tables A3.1 to A3.3 summarize the number of participants classified into each type using the FDR with different levels of significance. If we accept a 5% significance level (i.e., $\alpha = 0.05$), about 25% of the participants are classified as fully rational voters, and 15% to 17% are classified as partially rational voters based on models 1, 2, and 3. However, if we accept a 1% significance level, only seven or eight participants can be classified as fully rational voters (5.56% in model 1; 4.86% in models 2 and 3). If we accept a 0.1% significance level, it becomes difficult to classify most of the participants into any type.

Appendix 4. Assessing the goodness of fit of type classifications

To assess the goodness of fit of the type classifications, we conduct in-sample simulations based on types assigned by different methods. We simulate 1,000 datasets from the estimated parameters and the actual data, and cross-tabulate the simulated voting decisions with actual decisions, type by type. If a participant is "not classified," we randomly assign a type using posterior probabilities.

We compared four different classification methods: the simple method of classifying participants into their most probable type, and the methods using the FDR with significance levels of 5%, 1%, and 0.1%. Table A4.1 summarizes the results based on model 1. Each column corresponds to the actual voting behavior, while each row corresponds to the simulations for each type. The percentages in each cell represent the extent to which the actual and simulated behavior by each method (column) match or do not match.

For the classification made via the simple method, instances where participants classified as "fully rational" actually abstained and were predicted to abstain in the simulation occupy 23.49%. Likewise, instances where they actually voted and were predicted to vote accounted for 15.49%. In these two cases, the "fully rational" model accurately explains participants' voting decisions. On the other hand, cases in which participants classified as "fully rational" actually abstained but were predicted to vote in the simulation occupy 8.31%. Likewise, cases in which they actually voted but were predicted to abstain accounted for 8.26%. In these two cases, the type classification fails to explain the participants' voting decisions.

We then take the sum of the percentages representing consistent cases and find that the actual and simulated voting decisions are consistent in 67.50% cases when we apply the simple method. When we applied the FDR methods, the percentages of consistent cases were 66.97%, 66.66%, and 66.67% when we set the significance levels at 5%, 1%, and 0.1%, respectively. It can therefore be said that the simple method is as effective as the methods using the FDR.

Tables A4.2 and A4.3 correspond to models 2 and 3. We also present the smoothers derived from locally weighted scatterplot smoother (LOWESS) for voting decisions in models 2 and 3, which are compatible with Figure 5.

Table A4.1 Cross Tables of Simulated and Actual Decisions by Type (Model 1)

	Simple		FDR (α = 0.05)		FDR (α = 0.01)		FDR (α = 0.001)	
	Abstain	Vote	Abstain	Vote	Abstain	Vote	Abstain	Vote
Fully rational								
abstain in simulation	23.49%	8.26%	11.02%	2.88%	2.63%	0.46%	0.00%	0.00%
vote in simulation	8.31%	15.49%	3.15%	7.95%	0.50%	1.97%	0.00%	0.00%
Partially rational								
abstain in simulation	6.92%	7.16%	3.28%	3.69%	1.75%	2.04%	0.00%	0.00%
vote in simulation	6.76%	10.41%	3.25%	5.75%	1.72%	3.51%	0.00%	0.00%
Naïve voter								
abstain in simulation	0.00%	0.37%	0.00%	0.14%	0.00%	0.07%	0.00%	0.00%
vote in simulation	0.00%	3.10%	0.00%	1.25%	0.00%	0.62%	0.00%	0.00%
Free rider								
abstain in simulation	7.94%	0.76%	4.08%	0.27%	1.81%	0.05%	0.00%	0.00%
vote in simulation	0.88%	0.15%	0.44%	0.08%	0.21%	0.02%	0.00%	0.00%
Not classified								
abstain in simulation			19.75%	9.86%	31.77%	14.36%	37.95%	16.98%
vote in simulation			9.35%	13.82%	13.92%	22.59%	16.35%	28.71%
Total	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%
	100.00%		100.00%		100.00%		100.00%	
Consistent	67.50%		66.97%		66.66%		66.67%	
Inconsistent	32.50%		33.03%		33.34%		33.33%	

Table A4.2 Cross Tables of Simulated and Actual Decisions by Type (Model 2)

	Simple		FDR (α = 0.05)		FDR (α = 0.01)		FDR (α = 0.001)	
	Abstain	Vote	Abstain	Vote	Abstain	Vote	Abstain	Vote
Fully rational								
abstain in simulation	21.88%	7.01%	11.26%	2.99%	2.36%	0.40%	0.00%	0.00%
vote in simulation	6.94%	14.18%	3.05%	8.40%	0.42%	1.68%	0.00%	0.00%
Partially rational								
abstain in simulation	8.24%	8.61%	3.63%	4.03%	1.80%	2.11%	0.16%	0.12%
vote in simulation	7.80%	11.46%	3.59%	6.11%	1.67%	3.45%	0.18%	0.23%
Naïve voter								
abstain in simulation	0.00%	0.35%	0.00%	0.28%	0.00%	0.07%	0.00%	0.00%
vote in simulation	0.00%	3.13%	0.00%	2.50%	0.00%	0.63%	0.00%	0.00%
Free rider								
abstain in simulation	8.54%	0.82%	3.53%	0.22%	1.25%	0.00%	0.00%	0.00%
vote in simulation	0.91%	0.16%	0.36%	0.06%	0.14%	0.00%	0.00%	0.00%
Not classified								
abstain in simulation			19.75%	9.20%	32.58%	14.28%	37.81%	16.74%
vote in simulation			9.14%	11.91%	14.09%	23.08%	16.15%	28.61%
Total	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%
	100.00%		100.00%		100.00%		100.00%	
Consistent	67.57%		67.14%		66.83%		66.81%	
Inconsistent	32.43%		32.86%		33.17%		33.19%	

Table A4.3 Cross Tables of Simulated and Actual Decisions by Type (Model 3)

	Simple		FDR (α=0.05)		FDR (α=0.01)		FDR (α=0.001)	
	Abstain	Vote	Abstain	Vote	Abstain	Vote	Abstain	Vote
Fully rational								
abstain in simulation	21.77%	7.23%	10.94%	2.96%	2.34%	0.40%	0.00%	0.00%
vote in simulation	7.12%	14.58%	2.88%	8.22%	0.44%	1.68%	0.00%	0.00%
Partially rational								
abstain in simulation	7.87%	8.32%	3.51%	4.06%	1.79%	2.11%	0.16%	0.11%
vote in simulation	7.47%	11.05%	3.64%	6.15%	1.68%	3.44%	0.19%	0.23%
Naïve voter								
abstain in simulation	0.00%	0.36%	0.00%	0.28%	0.00%	0.07%	0.00%	0.00%
vote in simulation	0.00%	3.12%	0.00%	2.50%	0.00%	0.63%	0.00%	0.00%
Free rider								
abstain in simulation	9.11%	0.88%	4.10%	0.28%	1.25%	0.00%	0.00%	0.00%
vote in simulation	0.96%	0.16%	0.41%	0.07%	0.14%	0.00%	0.00%	0.00%
Not classified								
abstain in simulation			19.52%	9.13%	32.51%	14.28%	37.79%	16.74%
vote in simulation			9.30%	12.05%	14.16%	23.08%	16.17%	28.61%
Total	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%	54.31%	45.69%
	100.00%		100.00%		100.00%		100.00%	
Consistent	67.66%		67.07%		66.73%		66.79%	
Inconsistent	32.34%		32.93%		33.27%		33.21%	

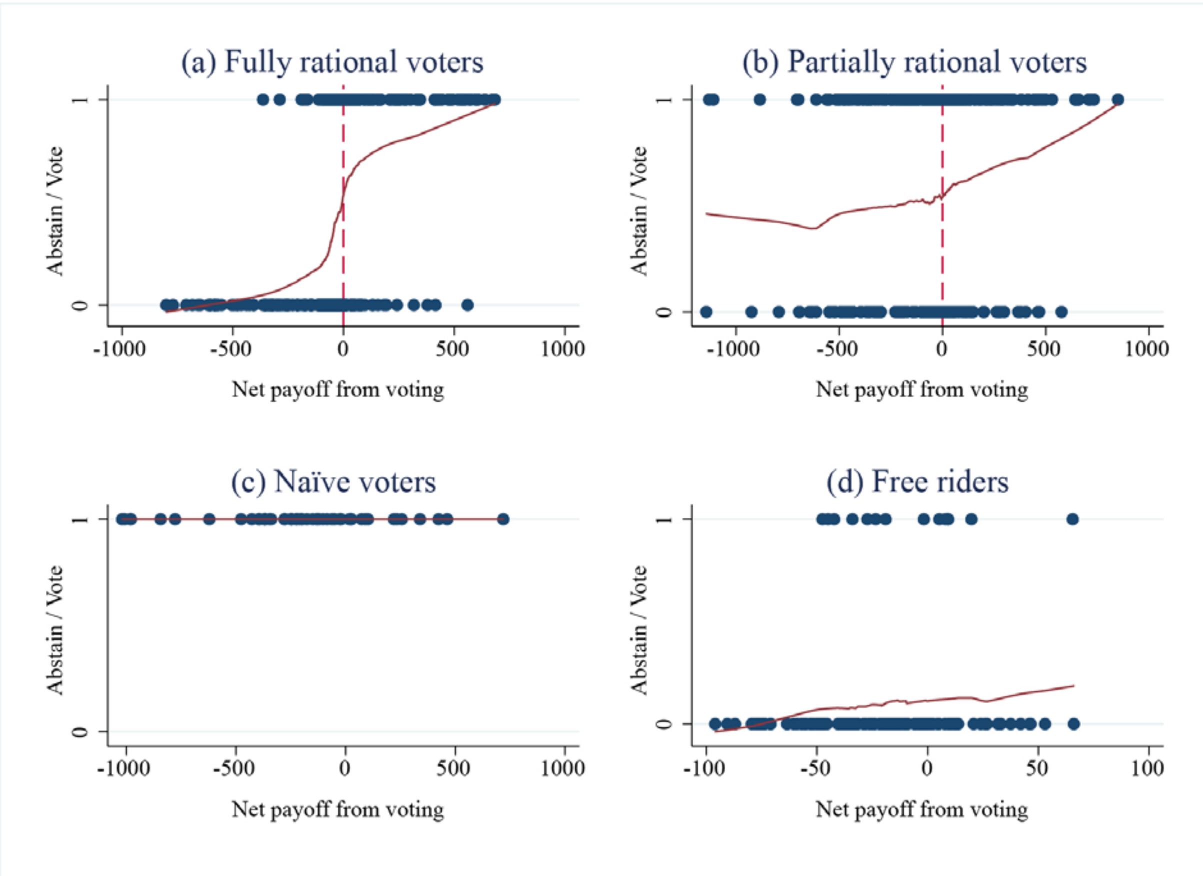

Figure A4.1 Scatterplot and LOWESS of Voting Decision Against the Net Payoff from Voting (Model 2)

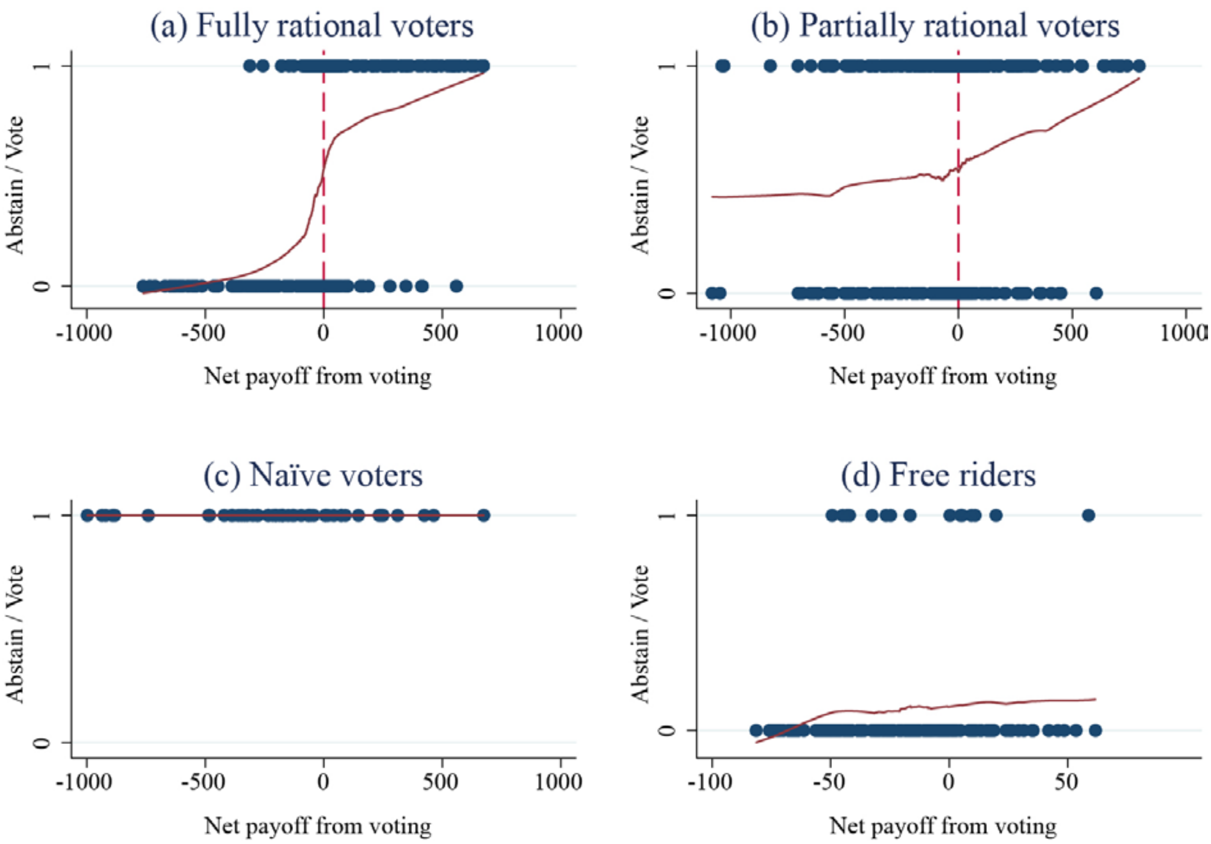

Figure A4.2 Scatterplot and LOWESS of Voting Decision Against the Net Payoff from Voting (Model 3)