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3 Abstract

Abstract

Quadratic Voting (QV) is a promising technique for improving group decision-making by accounting for preference intensities. QV is a social choice mechanism in which voters buy votes for or against a proposal at a quadratic cost and the outcome with the most votes wins. In some cases, individuals are asymmetrically informed about the effects of legislation and therefore their valuations of legislation. For instance, anti-corruption legislation is the most beneficial to taxpayers and the most detrimental to corrupt officials when corruption opportunities are plentiful, but government officials have better information than taxpayers about how many corruption opportunities exist. I provide an example of a setting in a large population where QV does not achieve approximate efficiency despite majority voting achieving full efficiency. In this example, a society considers an anti-corruption policy that protects taxpayers from corruption by deterring corruption. Officials know whether corruption opportunities exist, but taxpayers are uncertain about whether corruption opportunities exist. I present surprising experimental results showing that in one case where theory predicts QV will perform poorly and majority voting will perform relatively well, QV performs much better than expected and is about as efficient as majority voting.

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4 Introduction

Referenda are commonly used to make political decisions. Majority voting is widely used for collective decisions, even though it sometimes makes decisions that are seriously harmful to minorities. Quadratic Voting (QV) is one possible alternative that can avoid this failure of majority voting. QV is a decision-making mechanism where voters purchase votes for or against each option at a cost that is equal to the square of the number of votes purchased for that option that can solve this problem by allowing minorities that are seriously harmed by proposed legislation to cast extra votes against it. QV was first proposed by Weyl (2012). Lalley and Weyl (2019) show QV is approximately efficient in large populations when voters have independent private values. Furthermore, QV is reasonably resilient to collusion and fraud (Weyl 2017). Politicians had a positive experience with QV when using it to aggregate their preferences. In 2019, the Democratic caucus of the Colorado State House of Representatives used QV to decide which bills were most important for them to fund and reported that QV gave them a better signal than the mechanism they used the previous year (Rogers 2019). It is possible that enhancing the power of minorities may allow special interests to influence collective decisions in a way that is harmful to society as a whole. When special interests have an informational advantage over the majority of citizens, there is a danger that QV results in decisions that are beneficial to those special interests and harmful to society. I investigate whether QV will result in inefficient outcomes when a better-informed special interest may favor decisions that are harmful to society.

Anti-corruption legislation is one domain where asymmetric information about the effects of the policy could cause poor decision-making. In 2018, Colombia faced a corruption problem that cost the country $17 billion, or 5.3% of GDP, per year (Al Jazeera 2018). In an attempt to address this problem, activists added seven anti-corruption proposals to the ballot. None of the seven proposals received enough votes to pass. It was unclear whether the proposals would have been cost-effective. One proposal was to remove parole for corruption convicts. An opponent of the proposal expressed concern that the extra spending the proposal would require would have little effect on corruption.

The information structure surrounding this proposal could be problematic for making this decision with QV. Suppose that the general public is uncertain about whether the probability of convicting a corrupt official is high enough for a full prison sentence to effectively deter corruption. From the public's perspective, the probability of conviction could be either high or low. If the probability of conviction is high, the increased punishment will effectively deter corruption and therefore deliver large benefits to the public and impose large costs on corrupt officials. If the probability of conviction is low, the increased punishment will not do much to deter corruption and will therefore be costly to the public and impose small costs on corrupt officials. If corrupt officials are aware of the probability of corruption, QV will tend to make inefficient outcomes because the corrupt officials will be most likely to block the proposal when the probability of conviction is high and the proposal is beneficial to society. The proposal could pass more often when it is a waste of money than when it is socially beneficial.

Even if all measures were known to be at least somewhat effective against corruption, QV could also struggle to make efficient decisions when activists propose multiple measures to fight corruption. If the general public is uncertain about which measures most effectively fight corruption while corrupt officials are aware of which measures are most effective, the corrupt officials might be able to block the most effective measures. If there were only uninformed taxpayers and informed corrupt officials, the taxpayers would realize the defeated measures must have been their most effective tools against corruption and could attempt to pass them next election. Proposers could avoid this problem by bundling all the measures together. However, the best measures may never pass if not all measures are socially desirable and some taxpayers know which measures are socially desirable but are unable to credibly convey their information. Given that fake news was common in Colombia prior to this referendum, the likelihood that informed voters would be unable to credibly convey their information to the rest of the electorate is reasonably high. In this case, when proposals fail, uninformed taxpayers know that there is a chance that informed taxpayers were responsible for blocking the measure and therefore may be reluctant to support it again. In that case, measures blocked by corrupt officials may never pass. It is relatively common for referenda to feature multiple proposals to reduce corruption. For instance, Peru voted on four proposals to reduce corruption in 2018 (Taj and Cespedes 2018).

In order to answer this research question, I perform a theoretical analysis and an experiment. I build models of QV games in order analyze equilibrium outcomes. I find examples where QV is inefficient because special interests have better information than most voters. Surprisingly, my experimental results show that QV and majority voting have comparable efficiency in an asymmetric-information setting in which theory predicts QV will perform worse.

In my model, society must decide whether to pass anti-corruption legislation to prevent a corruption from a government that may have corruption opportunities. Government officials know whether government opportunities exist, but taxpayers only know that corruption opportunities may exist. As a result, if corruption opportunities exist, taxpayer support for anti-corruption legislation is weakened by their lack of information and government officials are often able to block anti-corruption legislation when corruption opportunities exist. In one example, the election is close only when corruption opportunities exist. The proposal usually fails when corruption opportunities exist and usually passes when corruption opportunities do not exist. This outcome is worse than simply ignoring the corruption problem and never auditing the government.

Despite the aggregate behavior of taxpayers ultimately harming taxpayers, it is rational for each taxpayer to support an audit because an individual taxpayer's support of auditing has a much higher probability of causing an audit when corruption opportunities exist than causing an audit when corruption opportunities do not exist. I assume corruption is inefficient because it reduces the welfare of taxpayers more than it increases the welfare of corrupt officials. Another issue is that taxpayer efforts to pass anti-corruption legislation lead to excessive monitoring of the government when corruption opportunities do not exist. Unnecessary monitoring of the government when corruption opportunities do not exist reduces social welfare when monitoring is costly. Next, I empirically test my predictions.

I run an online experiment on Amazon Mechanical Turk in order to test theoretical predictions. Participants use both majority voting and QV to determine whether a government that may have corruption opportunities should be audited. Using QV, participants buy votes with money and the expenditures of one participant are distributed evenly between the other two group members. One of the participants is an official who may have corruption opportunities and the other participants are taxpayers. Taxpayers are unaware whether the official has corruption opportunities. Auditing is harmful if the official is clean but protects taxpayers from corruption if corruption opportunities exist. If corruption opportunities exist, the official steals money from taxpayers. Participants are later allowed to choose which mechanism they would like to use. Theory predicts that majority voting will outperform QV in this setting.

Surprisingly, QV performs about as well as majority voting and some groups choose to use QV. 67% (6 out of 9) groups choose majority voting. QV performs well because some officials do not buy many votes against auditing when corruption opportunities existed. In fact, some officials even reduced their own monetary payoffs by supporting auditing when corruption opportunities existed (when corruption opportunities existed, taxpayers automatically lost money and the official automatically gained money if no audit was performed). Because each participant plays multiple rounds with the same group and QV vote totals for and against auditing are displayed to participants after each round, participants might help other group members in the hope of receiving help in return in a later round. When corruption opportunities did not exist, some officials also displayed the cooperative behavior of spending more points voting against an audit than an audit would have cost them.

4.1 Related Work

To define efficiency, I introduce the terminology of Holmström and Myerson (1983). Efficiency can be evaluated before agents have learned private information (*ex ante* efficiency), after each agent has learned his own private information but before the private information of other agents has been revealed (*interim* efficiency), or after each agent has learned the private information of all other agents (*ex post* efficiency). QV holds promise as a practical, approximately *ex ante* efficient system for making social decisions. Desirable features of QV include budget-balance, simplicity, and the minimal amount of information it requires the designer to have (Eguia et al. 2019). Budget-balance means that the mechanism runs without external funding. Simplicity means that people facing time constraints can participate. Theoretical results prove QV is approximately efficient in many settings. Chandar and Weyl (2019) finds QV performs reasonably well in finite populations. Weyl (2017) finds that QV is robust to a number of deviations to the independent private values Bayes-Nash model such as aggregate uncertainty. To the best of my knowledge, there is no private-value theoretical example where the welfare loss of QV is more than 10%. Eguia et al. (2019) show that QV approaches efficiency as the population size gets large in a full-information setting with multiple alternatives. Posner and Weyl (2017) prove the best equilibrium of QV dominates the best equilibrium of plurality voting in pure common-interest settings.

Empirical tests of QV confirm it has a relatively high *ex post* efficacy in private-value settings. Firstly, a lab experiment confirms QV is close to efficient in an independent private value setting. Goeree and Zhang (2017) study the performance of QV in a lab experiment in an independent private value setting and find QV outperforms majority voting. Groups of participants were allowed to choose between the two mechanisms for the final rounds and 73% of the groups chose QV. Casella and Sanchez (2019) run an experiment and find that QV has the potential to improve political decision-making. It is important to determine how generally QV is efficient. In this work, I explore an example with asymmetric information about policy effects that shows QV can be quite inefficient. In the proceeding analysis, I emphasize the *ex ante* inefficiency of QV and the *ex ante* efficiency of majority voting. In some cases, the policy decision is not important. The reason QV is much worse than majority voting in next example is that majority voting always makes the right decision when the policy is important while QV rarely does so.

5 QV Can Be Inefficient With Asymmetric Information

I start with an example showing that there is a theoretical possibility that QV can perform poorly.

5.1 Model

I use a model that is a special case of the model of Eguia et al. (2019). A society considers an anti-corruption proposal. The anti-corruption proposal prevents corruption from occurring if it passes. There are two states: one in which corruption opportunities are not available to the government (the corruptible state) and one in which corruption opportunities are available to the government (the incorruptible state). The state is known to government officials but only the prior distribution of the state is known to taxpayers. Let p be the prior probability that corruption opportunities exist. If corruption opportunities exist and the anti-corruption proposal fails, government officials steal money from taxpayers. Each government official steals a total of s. A loss of $\theta s N_g$ is divided evenly among all taxpayers, where $\theta > 1$. θ includes the money stolen, the efficiency cost of raising public funds with distortionary taxes, harm inflicted by cuts to cost-effective public services, and the cost of wasteful corrupt activities.

There are a finite number of individuals N in the society: $N_t > 0$ taxpayers and $N_g > 0$ government officials. Let $k = \frac{N_t}{N_g}$ denote the ratio of taxpayers to government officials. No anti-corruption proposal is the status quo. Voter i chooses an action a_i. Positive values of a_i can be interpreted as the number of votes purchased for the proposal. Negative values of a_i correspond to buying $|a_i|$ votes against the proposal. A monetary payment of a_i^2 is required for an action of a_i: $|a_i|$ votes have a cost of a_i^2. Let A be an indicator for the passage of the alternative.

The probability that the alternative passes is $\frac{e^{\phi \sum_{i=1}^{N} a_i}}{1+e^{\phi \sum_{i=1}^{N} a_i}}$, where $\phi > 0$. Importantly, this probability is increasing in $\sum_{i=1}^{N} a_i$. This probabilistic passage of the proposal is primarily a tractable way to approximate a deterministic decision rule that passes the alternative when the alternative gets a positive number of net votes and fails the alternative when the alternative gets a negative number of net votes. When ϕ becomes large, this passing probability closely approximates the deterministic rule. This functional form for the probability of an alternative's victory is also used in Eguia et al. (2019). Lalley and Weyl (2019) also assume that the payoff is a continuous function of the vote total. In addition, this model is an accurate description of reality if the system for counting votes sometimes makes errors and the probability that the wrong winner is declared is higher when the election is close. There is some evidence that errors sometimes occur in real elections. For instance, Keating (2002) finds that Al Gore would have won the 2000 presidential election if votes had been counted accurately, but George Bush won according to the initial count and a court order prevented a complete recount. Furthermore, the election was close: there were 105,372,669 votes that were officially valid and Gore needed only 538 more votes in Florida to win. The revenue raised from a voter is redistributed evenly among all other voters. Next, I state the payoffs of the agents.

I normalize the utility of neither losing or gaining money to 0. Let S be an indicator for whether corruption opportunities exist. The utility of taxpayer i is

$$-\left(1-\frac{e^{\phi\sum_{j=1}^{N}a_j}}{1+e^{\phi\sum_{j=1}^{N}a_j}}\right)\frac{S\theta s}{k}-a_i^2+\frac{1}{N-1}\sum_{j\neq i}a_j^2.$$

The utility of government official i is

$$\left(1-\frac{e^{\phi\sum_{j=1}^{N}a_j}}{1+e^{\phi\sum_{j=1}^{N}a_j}}\right)Ss-a_i^2+\frac{1}{N-1}\sum_{j\neq i}a_j^2.$$

5.2 An example of inefficiency in large populations

In Appendix 1, I show that the vote total for the proposal if corruption opportunities exist is $(p\theta-1)\,N_g s\phi\frac{e^{\phi\left(N_g a_g(1)+N_t a_t\right)}}{2\left(1+e^{\phi\left(N_g a_g(1)+N_t a_t\right)}\right)^2}$. If $p<\frac{1}{\theta}$, then $p\theta-1<0$, so the vote total for the proposal is negative and the proposal is likely to fail when corruption opportunities exist even though the unique efficient social choice when corruption opportunities exist is for the proposal to succeed. The anti-corruption proposal is likely to pass only when corruption opportunities do not exist. *Expected inefficiency*, defined following Lalley and Weyl (2019) to be the unique negative linear function of expected utility that lies in the unit interval, is

$$EI=\frac{e^{\phi(p\theta-1)N_g s\phi\frac{e^{\phi\left(N_g a_g(1)+N_t a_t\right)}}{2\left(1+e^{\phi\left(N_g a_g(1)+N_t a_t\right)}\right)^2}}}{1+e^{\phi(p\theta-1)N_g s\phi\frac{e^{\phi\left(N_g a_g(1)+N_t a_t\right)}}{2\left(1+e^{\phi\left(N_g a_g(1)+N_t a_t\right)}\right)^2}}} \tag{1}$$

$$=\frac{e^{\frac{\phi^2(p\theta-1)N_g s e^{\phi\left(N_g a_g(1)+N_t a_t\right)}}{2\left(1+e^{\phi\left(N_g a_g(1)+N_t a_t\right)}\right)^2}}}{1+e^{\frac{\phi^2(p\theta-1)N_g s e^{\phi\left(N_g a_g(1)+N_t a_t\right)}}{2\left(1+e^{\phi\left(N_g a_g(1)+N_t a_t\right)}\right)^2}}}. \tag{2}$$

This definition of efficiency defines a 0% efficient decision to be the decision that gives the lowest utilitarian social welfare and a 100% efficient decision that gives the highest possible social welfare. A mechanism is $X\%$ efficient if using it instead of making the worst possible decision realizes $X\%$ of the surplus that could have been gained from switching from the worst possible decision to the best possible decision. In this context, expected inefficiency is the probability that the proposal fails when corruption opportunities exist. If $k > 1$, then majority voting implements the socially optimal outcome. So, when $p\theta - 1 < 0$ and $k > 1$, QV achieves less than 50% efficiency but majority voting achieves 100% efficiency (in the equilibrium in which no player uses a weakly dominated strategy). Note that the low efficiency of QV persists in this case even when the population is large. One can also verify from this example that when there is uncertainty about the effects of a policy, it is possible in some states data about voters' expected values for a policy are not informative about the efficiency of such a policy because the better-informed voters have more accurate expectations. If corruption opportunities exist and $p < \frac{1}{\theta}$, the total valuation of the officials for the policy is $-sN_g$ while the total expected valuation of taxpayers for the policy is $p\theta sN_g$ so the sum of all voters' expected valuations for the policy is negative despite the policy being efficient in that case.

5.3 When Does QV Outperform Majority Voting?

For some parameter values, QV will outperform majority voting. QV will select the efficient outcome most of the time if $p > \frac{1}{\theta}$. Majority voting will be inefficient if $N_g > N_t$. Therefore, QV significantly outperforms majority voting when $p > \frac{1}{\theta}$ and $N_g > N_t$. This model reinforces the point made in other QV papers such as Weyl (2017) that QV will outperform majority voting when the majority of voters support a policy that voters are fairly certain is inefficient.

5.4 A Costly Anti-Corruption Policy

Next, I add a cost to the anti-corruption policy. This cost represents expenditures on activities such as auditing and monitoring to ensure corruption does not occur. The *ex ante* expected welfare loss due to corruption is $(\theta - 1)\, sN_g$. Let c be the cost of the anti-corruption policy. I assume that c is evenly distributed among all individuals. Let $a_g(0)$ denote the action of a government officials when corruption opportunities do not exist The utility of taxpayer i is

$$p\left(1 - \frac{e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}}{1+e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}}\right)\frac{-\theta s}{k}$$
$$-\left(p\frac{e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}}{1+e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}} + (1-p)\frac{e^{\phi(a_i+(N_t-1)a_t+N_g a_g(0))}}{1+e^{\phi(a_i+(N_t-1)a_t+N_g a_g(0))}}\right)\frac{c}{N} - a_i^2 + \frac{1}{N-1}\sum_{j\neq i} a_j^2.$$

When corruption opportunities exist, the utility of government official i is

$$\left(1 - \frac{e^{\phi(a_i+(N_g-1)a_g(1)+N_t a_t)}}{1+e^{(a_i+(N_g-1)a_g(1)+N_t a_t)}}\right)s - \frac{e^{\phi(a_i+(N_g-1)a_g(1)+N_t a_t)}}{1+e^{(a_i+(N_g-1)a_g(1)+N_t a_t)}}\frac{c}{N} - a_i^2 + \frac{1}{N-1}\sum_{j\neq i} a_j^2.$$

When corruption opportunities do not exist, the utility of government official i is

$$-\frac{e^{\phi(a_i+(N_g-1)a_g(0)+N_t a_t)}}{1+e^{\phi(a_i+(N_g-1)a_g(0)+N_t a_t)}}\frac{c}{N} - a_i^2 + \frac{1}{N-1}\sum_{j\neq i} a_j^2.$$

I find equilibria by solving the first-order conditions and checking that each player's strategy is a best response. When corruption opportunities exist, government officials vote against the anti-corruption proposal because they wish to steal money and avoid paying the cost of enforcing the anti-corruption proposal. When corruption opportunities do not exist, government officials also vote against the anti-corruption proposal because they wish to avoid paying the cost of the proposal. Taxpayers may vote for the proposal because they hope to pass it when corruption opportunities exist but may also vote against it because they do not want to pay the proposal's cost. I consider a numerical example based on corruption and auditing in rural Indonesia. Indonesian government officials were responsible for building roads that could provide massive benefits to society if constructed honestly. Unfortunately, these officials sometimes exploited opportunities to commit corruption by stealing money that was supposed to be spent on the road. In order to prevent this theft, the village could spend more money auditing the project. I assume a village with 2500 voters, including 7 officials, votes on whether to increase auditing expenditures by \$500. Taxpayers in the village believe that there is a 50% chance that corruption opportunities exist. If corruption opportunities exist, officials steal \$763 from the project and reduce the value of the road to society by \$1969 if auditing expenditures are not increased. I set $\phi = 15.9$ in order to create reasonably accurate elections while still allowing an equilibrium similar to the one in the game in the experiment to exist. The values of the parameters are $N_t = 2493$, $N_g = 7$, $c = 500$, $s = 109$, $\theta = 2.58$, $p = 0.5$, and $\phi = 15.9$. Three equilibria are summarized in the table below.

	Equilibrium 1	Equilibrium 2	Equilibrium 3
Efficiency	0.0208%	41.4630%	0.1003%
a_t	0.0002	-0.0002	0.0040
$a_g(0)$	-0.0004	-0.0005	-1×10^{-69}
$a_g(1)$	-0.1525	-0.0232	-1.4858
P(more audits|incorruptible)	0.9997	0.0003	1.0000
P(more audits|corruptible)	0.0002	3×10^{-5}	0.0017
Taxpayer payoff	-0.4947	-0.3948	-0.4912
Incorruptible official payoff	-0.1999	-7×10^{-5}	-0.2000
Corruptible official payoff	108.9576	108.9966	106.6104
P(corruptible|taxpayer is pivotal)	0.4091	0.746	1.0000

Table 1: Summary of Equilibria

I first discuss equilibria 1 and 3. Officials are rarely audited when corruption opportunities exist and usually audited when corruption opportunities do not exist. Efficiency is worse than both the efficiency of the status quo (41.48%) and the efficiency of increasing auditing expenditures (58.52%). These equilibria are similar to an equilibrium of the game implemented in the experiment where officials vote against auditing when corruption opportunities exist and abstain when corruption opportunities do not exist and taxpayers vote for auditing. These equilibria make some accurate qualitative predictions about behavior in the experiment: they accurately predicts that, on average, officials vote against auditing when corruption opportunities exist and abstain when corruption opportunities do not exist and taxpayers vote for auditing. In equilibrium 3, each taxpayer anticipates that other taxpayers are going to buy more than enough votes to pass the proposal with very high probability if corruption opportunities do not exist, but they will only buy enough votes to have a small chance of passing the proposal if corruption opportunities exist. In equilibrium 1, because corruption is much more costly to taxpayers than an unnecessary audit, taxpayers vote for an audit because they are primarily concerned about the possibility of corruption. Importantly, taxpayers lack complete information about the existence of corruption opportunities. The reason that efficiency is not achieved is that the information about the existence of corruption opportunities is only available to the voters who can profit from exploiting corruption opportunities. When corruption opportunities exist, the only voters that know action against corruption is socially desirable are unwilling to take action against corruption because they wish to profit from corruption. Voting for the proposal is very unlikely to make a difference if corruption opportunities do not exist but has a much more significant effect on the chance of passing the proposal if corruption opportunities exist, so the taxpayer has an incentive to buy votes for the proposal.

In contrast, in equilibrium 2, the vote total is close to zero when the government is clean and far from zero when the government is corrupt. As a result, taxpayers do not wish to marginally increase auditing expenditures. Because the probability of more audits decreases as opposition to more auditing increase even when everyone votes against more audits, taxpayers have an incentive to vote against more audits. The efficiency of never auditing is 41.48% and the efficiency of always auditing is 58.52%. Notably, all equilibria of QV achieve a lower efficiency by dictatorship by any individual.

An extension to the model in the spirit of Patty and Penn (2017) would require proposed policies to be written by some member of society. I model the proposal process as a simultaneous game. Each member of society decides whether or not to propose this policy. The policy is considered if it has been proposed by at least one individual. The number of government officials proposing the policy is observable. Taxpayers have no incentive to propose this policy since they do poorly under QV when the proposal is introduced. There is an equilibrium where no government officials submit proposals. In this equilibrium, taxpayers believe that a proposal from the government official means the corruption opportunities do not exist. In that case, the taxpayers do not make QV payments that are larger than those made by government officials, so government officials do not gain any benefit from making the proposal. In practice, it is plausible that nobody in the village has an incentive to make this proposal. The auditor might have an interest in ensuring plenty of audits are done, but in this context the auditor is not a resident of the village. Furthermore, the benefits to individual workers of reducing the theft of wages through audits are also small. Hence, a lack of proposal incentives mitigates the poor performance of QV on this proposal.

6 Experimental Design, Procedures. and Hypotheses

6.1 Design

Next, I perform an experimental test of QV. I evaluate the performance of majority voting and QV in a corruption setting where the payoff to taxpayers depends on the official's type. I base my experiment off the costly anti-corruption policy model above. I set $c = 6$, $\theta = \frac{8}{3}$, $N_g = 1$, $N_t = 2$, and $s = 6$. I require participants to spend a whole number of experimental points on each vote purchase. To solve for the equilibrium of the discrete game, I first use Gambit (McKelvey et al., 2016) compute the equilibria of the restricted game where officials are only allowed to abstain or spend 1 points opposing the proposal if corruption opportunities do not exist, officials are only allowed to abstain or spend 1-5 points opposing the proposal if corruption opportunities exist, and taxpayers are only allowed to abstain or spend 1-2 points supporting the proposal. Simplical subdivision yields a symmetric equilibrium in which officials abstain when corruption opportunities do not exist, officials spend 2 points opposing the proposal with probability 0.549 and 4 points opposing the proposal with probability 0.451 if corruption opportunities exist, and taxpayers abstain with probability 0.4226 and spend 1 point supporting the proposal with probability 0.5774. Officials have an average payoff of -1.244 when corruption opportunities do not exist and 1.9107 when corruption opportunities exist and each taxpayer has an average payoff of -3.7745.

I now verify this strategy profile is also an equilibrium of the full game. First, I consider alternative strategies for a official when corruption opportunities do not exist. Supporting the policy is dominated by abstaining. Spending 2 or more points opposing the policy also yields a payoff that is worse than the equilibrium payoff, so an official has no profitable deviations to strategies outside the restricted set when corruption opportunities do not exist. Next, I consider alternative strategies for an official when corruption opportunities are available. Supporting the policy is dominated by abstaining. Given the equilibrium strategies of the taxpayers, spending 6 or more points supporting the policy is worse than spending 5 points supporting the policy, so an official has no profitable deviations to strategies outside the restricted set when corruption opportunities are available.

Finally, I consider alternative strategies for a taxpayer. The average transfer that a taxpayer receives is $\frac{1}{2} \times 0.5774 + \frac{1}{4}(2 \times 0.549 + 4 \times 0.451) = 0.76715$. Spending 5 or more points is therefore not optimal. The best policy outcome for a taxpayer is an audit of corrupt governments and no audits of clean governments, resulting in an expected loss of 1.

Therefore, spending 4 points is not profitable: if it achieved the preferred policy outcomes, the payoff would be $-4 - 1 + 0.76715 = -4.23285$. A taxpayer gains less from opposing the proposal than a clean official, so therefore taxpayers must not oppose the proposal. The only benefit from spending 3 points supporting the proposal instead of 2 points supporting the proposal is that when corruption opportunities are available, officials are audited with certainty instead of probability $\frac{1}{2}$ when the official spends 2 points opposing the proposal and the other taxpayer abstains. When corruption opportunities are available, a certain audit of an official instead of a $\frac{1}{2}$ probability of auditing an official is worth $\frac{-3+8}{2} = \frac{5}{2}$. The expected benefit from spending 3 points is therefore $\frac{5}{2} \times \frac{1}{2} \times 0.4226 \times 0.549 = 0.29$, which is less than the cost. Therefore, spending 3 points opposing the proposal is not optimal.

Under QV, welfare is $2 \times (-3.7745) + \frac{1}{2} \times (-1.244) + \frac{1}{2} \times 1.9107 = -7.21565$. Under majority voting, the proposal passes. Welfare is -6, so majority voting is more efficient than QV in this case. Under majority voting, all participants receive a payoff of -2. The probability that the proposal passes when corruption opportunities are available is $(1 - 0.5774)^2 + \frac{1}{2} \times 0.5774^2 \times 0.451 = 0.2538$. The probability that the proposal passes when no corruption opportunities are available is $1 - 0.4226^2 \times \frac{1}{2} = 0.9107$. The best welfare is -3 and the worst welfare is $-3 - 5 = -8$, so the efficiency of QV is $\frac{-7.21565-(-8)}{5} = 15.687\%$.

The difference between the payoffs of the best and worst policy outcomes is 2 for when no corruption opportunities are available, 8 for officials when corruption opportunities are available, and 6 for taxpayers. In order to protect participants from bankruptcy, I limit spending per round to 8 points. Larger amounts of spending per round are strictly dominated by abstaining, so I have not eliminated any strategies that could be played in equilibrium. Participants receive 24 points at the start of each of the first 20 rounds and 16 points at the start of each of the last 20 rounds.

Two possible equilibrium outcomes of majority voting are an audit of both types of government and an audit of neither type of government. An audit of both types of government is supported strategy profiles in which both types of taxpayer vote for auditing. If p is the probability that an official votes for auditing when no corruption opportunities are available and q is the probability that an official votes for auditing when corruption opportunities are available, then given that the other taxpayer is voting for auditing, a taxpayer gets an expected payoff of -2 from voting for auditing and an expected payoff of

$$\begin{aligned} 0.5 \times (-2)p + 0.5 \times (-2)q + 0.5 \times (-10)(1-q) &= -p - q - 5 + 5q \\ &= -5 - p + 4q \end{aligned}$$

from voting against auditing. Therefore, a taxpayer has no profitable deviations if

$$-2 \geq -5 - p + 4q.$$

Therefore, a taxpayer has no profitable deviations if $3 \geq -p+4q$. Officials have no profitable deviations in either state so it is an equilibrium for taxpayers to vote for auditing, officials to vote for an audit with probability p when no corruption opportunities are available and government officials to vote for an audit with probability q when corruption opportunities are available as long as $p, q \in [0, 1]$ and $4q - p \leq 3$. If both types of government are audited, the total group payoff is -6. An audit of neither type of government is supported by both taxpayers voting against auditing. If p is the probability that an official votes for auditing when no corruption opportunities are available and q is the probability that an official votes for auditing when corruption opportunities are available, then given that the other taxpayer is voting against auditing, a taxpayer gets an expected payoff of $-p - q$ from voting for auditing and an expected payoff of $0.5 \times (-10)q = -5q$ from voting against auditing. Thus, it is necessary that $-5q \geq -p - q$ or $p \geq 6q$. Therefore, it is an equilibrium for both taxpayers to vote against auditing, officials to vote for an audit with probability p when no corruption opportunities are available, and officials to vote for an audit with probability q when corruption opportunities are available, as long as $p, q \in [0, 1]$ and $p \geq 6q$. If neither type of government is audited, the expected group payoff is -5. I expect majority voting to result in a group payoff of -6 since the taxpayers are able to control the group decision and on average, auditing the government is better than not auditing the government for the taxpayers. Myerson (1978) argues that the proper equilibria of the game are the most plausible. Taxpayers must vote for auditing in any proper equilibrium. Therefore, an audit of the government is the most plausible outcome of majority voting.

6.2 Procedures

Subjects were recruited through Amazon Mechanical Turk and Turker Nation. Amazon Mechanical Turk is an online labor market and Turker Nation is a community of Amazon Mechanical Turk users. Nine groups consisting of a total of 27 participants finished the experiment. Participants played a total of 40 rounds. Part 1 consists of 20 paid rounds. In part 1, subjects made choices for both majority voting and QV and will receive the sum of both payoffs. In part 2, subjects decided via majority voting which mechanism to use in the last 20 rounds of the scenario and used that mechanism for the last 20 rounds. Subjects were not informed about part 2 prior to completing part 1. Before playing the game, participants read the instructions for part 1 and completed a comprehension test on the game. Participants were required to answer the comprehension test correctly in order to advance but could try again after answering incorrectly. I used a conversion rate of 50 points per dollar. Participants who dropped out early were paid for the portion of the study they did complete, since it would be unfair to not pay a participant if circumstances out of his or her control such as internet problems prevented him or her from finishing the experiment. Participants who finished the experiment spent an average of 48 minutes completing the study. These participants earned an average of $16.58, including $3 in show-up fees. Earnings ranged from $14.01 to $18.16. Subjects had the opportunity to state a reason for their choice of mechanism at the end of the experiment.

6.3 Hypotheses

Based off equilibrium predictions, I state hypotheses:

Hypothesis 1. QV yields lower payoffs than majority voting.

Hypothesis 2. Participants choose majority voting.

7 Experimental Results

7.1 Efficiency

I first conduct analysis on the first 20 rounds played by the 10 groups that finished the first 20 rounds. In order to remove the influence of tiebreaker realizations from payoffs, I calculate expected group payoffs by setting the expected group payoff of any round that was decided by a tiebreaker equal to the average of the two possible outcomes. The table below compares the observed group payoffs with the expected group payoffs conditional on the number of officials that were corrupt.

	Majority Voting	Quadratic Voting
Observed	-6.280	-6.205
Expected	-6	-7.256

Table 2: Mean Expected Group Payoffs Per Round

Surprisingly, QV performs slightly better than majority voting in this experiment. However, the difference is not statistically significant according to a two-sided Wilcoxon signed-rank test on average group efficiencies ($p = 0.8784$). Testing was conducted in R (R Core

Team 2020). Theory predicts that the chance that QV is unlikely to achieve expected payoffs this high: the chance of achieving expected payoffs at least this high in equilibrium is less than 1%.

7.2 Voting Outcomes Under QV

In equilibrium, the probability of auditing an official is 0.258 when corruption opportunities are available and 0.911 when no corruption opportunities are available. In the experiment, the probability of auditing an official was 0.535 when corruption opportunities were available and 0.7714 when no corruption opportunities were available. Inference on small sample sizes can be challenging because the Central Limit Theorem only guarantees approximate normality of sample means for large sample sizes. Following Shearer (2004), I use 10,000 bootstrap replicates to test for significance. Testing was conducted using MKinfer (Kohl 2020). When corruption opportunities were available, the average audit probability of corrupt officials at the group level differed significantly from the equilibrium audit probability ($p = 0.0062$). More audits of officials when corruption opportunities were available improved expected efficiency relative to equilibrium levels. When no corruption opportunities were available the average audit probability of officials at the group level significantly differed from the equilibrium audit probability. ($p = 0.0482$).

7.3 Voting Behavior Under QV

In equilibrium, taxpayers cast an average of 0.5774 votes in favor of auditing and officials cast an average of 1.678 against auditing when corruption opportunities were available and abstain when no corruption opportunities are available. In the remainder of this paragraph, I discuss the behavior of officials when corruption opportunities were available. In 10 of 101 cases, officials with access to corruption opportunities played the strictly dominated strategy of casting votes in favor of auditing. On average, each official with access to corruption opportunities decreased the vote total in favor of auditing by -0.997. In instances where the official had access to corruption opportunities and did not vote for auditing, the average number of votes purchased against auditing was 1.278. The strategies of officials with access to corruption opportunities contribute to the higher efficiency of QV observed in practice: If these officials played equilibrium strategies and other types did not change their strategies, 18% of the gap between observed and equilibrium efficiencies would disappear. These officials would have gained an average of 0.364 points per round by switching to the equilibrium strategy. On average, corruptible officials who spent supported auditing, abstained, or spent only 1 point opposing auditing would have gained 0.467 points per round by switching to the equilibrium strategy. Using a bootstrap test on group-level averages, I find evidence that the average effect on the vote total of these officials differs from its equilibrium level ($p = 0.0002$). In equilibrium, officials spend an average of $0.451 \times 4 + 0.549 \times 2 = 2.902$ points buying votes when they have access to corruption opportunities. In the experiment, officials who had access to corruption opportunities spent an average of 2.782 points buying votes. Next, I discuss the behavior of officials who did not have access to corruption opportunities.

Officials sometimes played dominated strategies when no corruption opportunities were available. In 15 of 99 cases, officials played the dominated strategy of spending more than 2 points voting against auditing when no corruption opportunities were available. In 35 of 99 cases, officials played the dominated strategy of voting for auditing when no corruption opportunities were available. This behavior could reduce group payoffs. On average, officials voted for audits when no corruption opportunities were available: on average, these officials increased the vote total for auditing by 0.097. Surprisingly, the strategies used by these officials actually increased efficiency relative to equilibrium strategies. If these officials played equilibrium strategies and other types did not change their strategies, 17% of the gap between observed and equilibrium efficiencies would disappear. Cases where these officials spent many points voting against an audit had the biggest impact on efficiency because audits would otherwise have been more common. A one-sided bootstrap test assuming unequal variances testing whether the group-level average strategy of officials with access to corruption opportunities was less than the group-level average strategy of officials without access to corruption opportunities finds evidence supporting the prediction that officials oppose auditing more strongly when they have access to corruption opportunities ($p = 0.0039$). Using a bootstrap test on group-level averages, I find no evidence that the average strategy of officials without corruption opportunities differs from its equilibrium level ($p = 0.561$). These officials spent an average of 1.244 points on votes. These officials would have earned an extra 1.192 points per round by using the equilibrium strategy. Next, I discuss the behavior of taxpayers.

On average, each taxpayer increased the vote total for auditing by 0.865. The gap between observed and equilibrium payoffs would decrease by 69% if taxpayers used equilibrium strategies rather than observed strategies. Additional votes for auditing by taxpayers can reduce welfare by causing additional audits of clean officials. Using a bootstrap test on group-level averages, I find no significant evidence that the average contribution of taxpayers to the vote total differs from its equilibrium level ($p = 0.089$). A taxpayer would gain an average of 0.984 points per round by using the equilibrium strategy. Taxpayers who spent more than 1 point opposing an audit would have gained an average of 1.912 points per round by using the equilibrium strategy. I conclude that efficiency is high because corrupt officials supported auditing or did not strongly oppose auditing, clean officials strongly opposed auditing, and taxpayers strongly supported auditing. A t-test on the group-level averages of the gain to unilaterally switching to the equilibrium strategy finds statistically significant evidence that switching to the equilibrium strategy improves payoffs ($p = 6 \times 10^{-5}$). I therefore conclude that the original strategy profiles of participants were not an equilibrium.

7.4 Responsiveness of Participants to Incentives

Use of the equilibrium strategy rather than the average observed strategy would result in an expected gain of $\frac{0.364\times101+1.192\times99+400\times0.984}{600}\times 2 = 2$ cents per round. Although the monetary gains from additional strategic optimization were small on average, a couple factors made a fixed monetary gain more important for some participants. Firstly, some participants were from India, a country with 31 times less GDP per capita than the US. Secondly, some participants reported that economic disruptions caused by COVID-19 meant that earning income from the experiment was particularly important. Some participants expressed a strong desire to earn money by messaging me after the experiment to express a desire for more work. The statistically significant dependence of audit probabilities on the presence of opportunities for corruption confirms that participants were responsive to the incentives offered in this experiment. Whether participants would play strategies that were more similar to equilibrium strategies if incentive levels were increased is an interesting topic for future research.

7.5 Institution Choice

Three of the nine groups that finished the experiment chose QV. The choice of QV is inconsistent with the theoretical prediction that groups will always choose majority voting because majority voting performs better in theory. The choice of QV was not always caused by monetary considerations. One participant reported choosing majority voting due to a perception that it would "pay out better". Due to the limited sample size, I lack the power to produce a precise estimate of the probability a group chooses QV.

7.6 What Explains the Results?

Since I observe participants making choices that lead to low individual payoffs and high group payoffs, it is plausible that my participants are altruistic.

7.6.1 Logit Quantal Response Equiilibrium Model

In order to determine whether altruism is consistent with the observed behavior, I now allow for altruism and estimate preferences from a logit quantal response equilibrium (QRE) model (Mckelvey and Palfrey 1995). The logit equilbrium model is a commonly used variant of the QRE model. The logit equilibrium model combines the extreme value (logit) preference shocks that are commonly used in discrete choice models with an equilibrium framework. A player's utility is the sum of his or her von Neumann-Morgenstern utility and his or her extreme value preference shock. An equilibrium of this model is a distribution of actions that is consistent with maximization for each player. Let $\mathcal{S}_g$ represent the set of possible strategies in game g and let $\mathcal{T}$ represent the set of possible types. A strategy $\mathbf{S}_g\left(s_g \mid t\right)$ for game g is a measure that assigns a probability to every strategy s_g given a type t. In order for the strategy to be a well-defined probability measure, no strategy can have less than zero probability and conditional on any type t, the probabilities of all strategies must sum to 1:

$$\forall t \in \mathcal{T} \text{ and } s_g \in \mathcal{S}_g, \mathbf{S}_g\left(s_g \mid t\right) \geq 0 \tag{3}$$

and

$$\forall t \in \mathcal{T}, \sum_{s_g \in \mathcal{S}} \mathbf{S}_g\left(s_g \mid t\right) = 1. \tag{4}$$

Suppose all players follow the strategy $\mathbf{S}_g\left(s_g \mid t\right)$. Let $Q_o\left(s_g\right)$ be the empirical probability of an audit when an official uses strategy s_g. Let $Q_{t,corruptible}\left(s_g\right)$ be the empirical probability of an audit when a taxpayer chooses strategy s_g and the official has corruption opportunities. Let $Q_{t,incorruptible}\left(s_g\right)$ be the empirical probability of an audit when a taxpayer chooses strategy s_g and the official has no corruption opportunities. The probability that QV causes an audit if an official uses strategy s_{QV} is

$$
\begin{aligned}
& Q_{o,QV}\left(s_{QV}\right) \\
= & \sum_{s_{1,QV}\in\mathcal{S}_{QV}}\sum_{s_{2,QV}\in\mathcal{S}_{QV}} \mathbf{S}_{QV}(s_{1,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{2,QV} \mid taxpayer) \\
& \mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{\left|s_{QV}\right|}+\operatorname{sgn}\left(s_{1,QV}\right)\sqrt{\left|s_{1,QV}\right|}+\operatorname{sgn}\left(s_{2,QV}\right)\sqrt{\left|s_{2,QV}\right|}>0} \\
& + .5\mathbf{S}_{QV}(s_{1,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{2,QV} \mid taxpayer) \\
& \mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{\left|s_{QV}\right|}+\operatorname{sgn}\left(s_{1,QV}\right)\sqrt{\left|s_{1,QV}\right|}+\operatorname{sgn}\left(s_{2,QV}\right)\sqrt{\left|s_{2,QV}\right|}=0}.
\end{aligned}
$$

The probability that QV causes an audit if a taxpayer uses strategy s_{QV} and the official has no corruption opportunities is

$$
\begin{aligned}
& Q_{t,incorruptible,QV}\left(s_{QV}\right) \\
= & \sum_{s_{t,QV}\in\mathcal{S}_{QV}}\sum_{s_{o,QV}\in\mathcal{S}_{QV}} \mathbf{S}_{QV}(s_{t,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{o,QV} \mid incorruptible) \\
& \mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{\left|s_{QV}\right|}+\operatorname{sgn}\left(s_{t,QV}\right)\sqrt{\left|s_{t,QV}\right|}+\operatorname{sgn}\left(s_{o,QV}\right)\sqrt{\left|s_{o,QV}\right|}>0} \\
& + .5\mathbf{S}_{QV}(s_{t,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{o,QV} \mid incorruptible) \\
& \mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{\left|s_{QV}\right|}+\operatorname{sgn}\left(s_{t,QV}\right)\sqrt{\left|s_{t,QV}\right|}+\operatorname{sgn}\left(s_{o,QV}\right)\sqrt{\left|s_{o,QV}\right|}=0}.
\end{aligned}
$$

The probability that QV causes an audit if a taxpayer uses strategy s and the official is corrupt is

$$
\begin{aligned}
&Q_{t,corruptible,QV}\left(s_{QV}\right) \\
= &\sum_{s_{t,QV}\in\mathcal{S}_{QV}} \sum_{s_{o,QV}\in\mathcal{S}_{QV}} \mathbf{S}_{QV}(s_{t,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{o,QV} \mid corruptible) \\
&\mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{\left|s_{QV}\right|}+\operatorname{sgn}\left(s_{t,QV}\right)\sqrt{\left|s_{t,QV}\right|}+\operatorname{sgn}\left(s_{o,QV}\right)\sqrt{\left|s_{o,QV}\right|}>0} \\
&+ .5\mathbf{S}_{QV}(s_{t,QV} \mid taxpayer)\mathbf{S}_{QV}(s_{o,QV} \mid corruptible) \\
&\mathbb{I}_{\operatorname{sgn}\left(s_{QV}\right)\sqrt{|s|}+\operatorname{sgn}(s_{t,g})\sqrt{|s_{t,g}|}+\operatorname{sgn}(s_{o,g})\sqrt{|s_{o,g}|}=0}.
\end{aligned}
$$

Denote the strategy of voting for an audit as $s_{MV} = 1$ and the strategy of voting against an audit by $s_{MV} = 0$. The probability that majority voting causes an audit if an official uses strategy s_{MV} is

$$
\begin{aligned}
Q_{o,MV} = &\sum_{s_{1,MV}\in\mathcal{S}_{MV}} \sum_{s_{2,MV}\in\mathcal{S}_{MV}} \mathbf{S}_{MV}\left(s_{1,MV} \mid taxpayer\right)\mathbf{S}_{MV}\left(s_{2,MV} \mid taxpayer\right) \\
&\mathbb{I}_{s_{MV}+s_{1,MV}+s_{2,MV}>1}.
\end{aligned}
$$

The probability that majority voting causes an audit if a taxpayer uses strategy s_{MV} and the official is clean is

$$
\begin{aligned}
Q_{t,clean,MV} = &\sum_{s_{t,MV}\in\mathcal{S}_{MV}} \sum_{s_{o,MV}\in\mathcal{S}_{MV}} \mathbf{S}_{MV}\left(s_{t,MV} \mid taxpayer\right)\mathbf{S}_{MV}\left(s_{o,MV} \mid clean\right) \\
&\mathbb{I}_{s_{MV}+s_{t,MV}+s_{o,MV}>1}.
\end{aligned}
$$

The probability that majority voting if causes an audit a taxpayer uses strategy s_{MV} and the official is corrupt is

$$Q_{t,corrupt,MV} = \sum_{s_{t,MV} \in \mathcal{S}_{MV}} \sum_{s_{o,MV} \in \mathcal{S}_{MV}} \mathbf{S}_{MV}\left(s_{t,MV} \mid taxpayer\right) \mathbf{S}_{MV}\left(s_{o,MV} \mid corrupt\right)$$
$$\mathbb{I}_{s_{MV}+s_{t,MV}+s_{o,MV}>1}.$$

Let $\hat{\pi}\left(s;t\right)$ be the expected payoff of a player of type t who uses strategy s. I assume that the utility that i gets from his or her own monetary payoff m_i as well as the monetary payoffs m_j and m_k of his or her group mates is $\pi\left(s_i;t_i\right) = m_i + \alpha\left(m_j + m_k\right)$. I assume that i maximizes

$$\hat{\pi}\left(s_i;t_i\right) = E\left(m_i + \alpha\left(m_j + m_k\right)\right) + \epsilon\left(s_i,t_i\right) = \pi\left(s_i;t_i\right) + \epsilon\left(s_i,t_i\right). \tag{5}$$

The logit equilibrium model generalizes the Bayes-Nash model by including the error term $\epsilon\left(s_i,t_i\right)$ in the payoffs. The experimental literature interprets $\epsilon\left(s_i,t_i\right)$ as i's optimization error. The optimization error $\epsilon\left(s_i,t_i\right)$ is assumed to be i.i.d. Under the logit equilibrium model, the decision-making can be thought of as follows: each player first learns t_i and $\epsilon\left(s_i,t_i\right)$ for each s_i, then chooses a strategy s_i from each game that maximizes $\hat{\pi}\left(s_i;t_i\right)$, his or her Bayes-Nash payoff, plus $\epsilon\left(s_i,t_i\right)$. Assume that $\epsilon\left(s_i,t_i\right)$ has a cdf $F(\epsilon) = \exp\left[-\exp(-\lambda\epsilon)\right]$. This distribution has a mean of $\frac{\lambda}{\gamma}$, where γ is Euler's constant (0.577) and variance $\frac{\pi^2}{6\lambda^2}$. The precision (the inverse of the variance) is increasing in λ. Let $\rho_g\left(s_i;t_i,\mathbf{S}\right)$ be the probability that agent i bids s_i conditional on a type draw t_i assuming the other agents are using the strategy $\mathbf{S}$. Since the error terms have an extreme value distribution,

$$\rho_g\left(s_i;t_i,\mathbf{S}\right) = \frac{\exp\left[\lambda\pi\left(s_i;t_i,\mathbf{S}\right)\right]}{\sum_{s' \in \mathcal{S}} \exp\left[\lambda\pi\left(s';t_i,\mathbf{S}\right)\right]}. \tag{6}$$

An equilibrium is a strategy function $\mathbf{S}$ that is a fixed point of (6), that is, $\mathbf{S}_g(s_i \mid t_i) = \rho(s_i; t_i, \mathbf{S}_g)$. As $\lambda \to 0$, the variance of the error term approaches infinity so voter behavior converges to uniformly distributed random choices. As $\lambda \to \infty$, bidder behavior converges towards Bayes-Nash equilibrium behavior. Mckelvey and Palfrey (1995) prove that Quantal Response Equilibria exist.

7.6.2 QRE Estimation

For each game g, I produce estimates $\hat{Q}_{o,g}$, $\hat{Q}_{t,corruptible,g}$ and $\hat{Q}_{t,incorruptible,g}$ of $Q_{o,g}$, $Q_{t,corruptible,g}$ and $Q_{t,incorruptible,g}$ by using the empirical distribution of observed strategies. I then estimate α and λ using maximum likelihood. I pool data from the majority voting and Quadratic Voting games. Given $\hat{Q}_{o,g}$, $\hat{Q}_{t,corruptible,g}$ and $\hat{Q}_{t,incorruptible,g}$, the probability that a taxpayer chooses strategy s_i in game g is

$$p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{t,corruptible,g}, \hat{Q}_{t,incorruptible,g}\right) = \rho(s_{i,g}; t) \tag{7}$$

Given $\hat{Q}_{o,g}$, the probability that an official with corruption opportunities chooses strategy $s_{i,g}$ is

$$p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{o,g}\right) = \rho(s_{i,g}; corruptible). \tag{8}$$

Given $\hat{Q}_{o,g}$, the probability that an official without corruption opportunities chooses strategy $s_{i,g}$ is

$$p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{o,g}\right) = \rho(s_{i,g}; clean). \tag{9}$$

The likelihood function is

$$\begin{aligned} L(\alpha, \lambda) = &\Pi_g \Pi_t p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{t,corruptible,g}, \hat{Q}_{t,incorruptible,g}\right) \Pi_{corruptible} p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{o,g}\right) \\ &\Pi_{incorruptible} p\left(s_{i,g} \mid \alpha, \lambda; \hat{Q}_{o,g}\right) \end{aligned}$$

I use KNitro to maximize the likelihood function.

7.6.3 QRE Results

I fit both a restricted model with $\alpha = 0$ and an unrestricted model with α estimated to best fit the data.

	Restricted Model	Unrestricted Model
λ	0.6663	0.6672
	(0.1167)	(0.3145)
α	...	0.0012
		(141.8595)
Log-likelihood	−1103.53317	−1103.53314

Standard errors, reported in parentheses, were computed by estimating the model on resamples 10 groups with replacement 5000 times.

Table 3: Estimation Results for the QRE Model

The positive estimate for α is not surprising since players used strategies that harmed their own payoffs but helped their groups. The estimated α does not differ significantly from zero ($p = 0.9966$).

Altruism is a plausible explanation for the QV results since QV efficiency would be 100% in a group that maximized group payoffs. Optimization errors are another plausible explanation for the QV results. If players chose strategies at uniformly at random so an audit always had a 50% chance of passing, expected group payoffs would be $0.5 \times (-6) + 0.25 \times (-10) = -5.5$. Because observed behavior is between equilibrium and random uniform behavior, it is not surprising that observed payoffs are between the payoffs of random uniform behavior and equilibrium behavior.

7.7 Attrition

Attrition is hard to avoid in online experimentation due to issues such as connection problems. Four participants (10%) who started the interaction phase dropped out during the experiment. 69% of groups finished with all three members. Attrition is a potential threat to the validity of these results. If participants are more likely to abandon a group that is doing poorly, groups that finish will tend to have above-average payoffs. To investigate whether selective attrition threatens the validity of these results, I estimate a logit model that predicts the probability of dropout from the round number, an indicator for whether the participant had to wait in a lobby for the experiment to begin, a participant's past earnings relative to mean equilibrium earnings by that period, and a participant's future expected future earnings (in equilibrium conditional on the participant's current type and the group's mechanism choice) relative to mean equilibrium expected earnings at that period. I use the Regression Modeling Strategies package (Harrell Jr 2020) for this estimation.

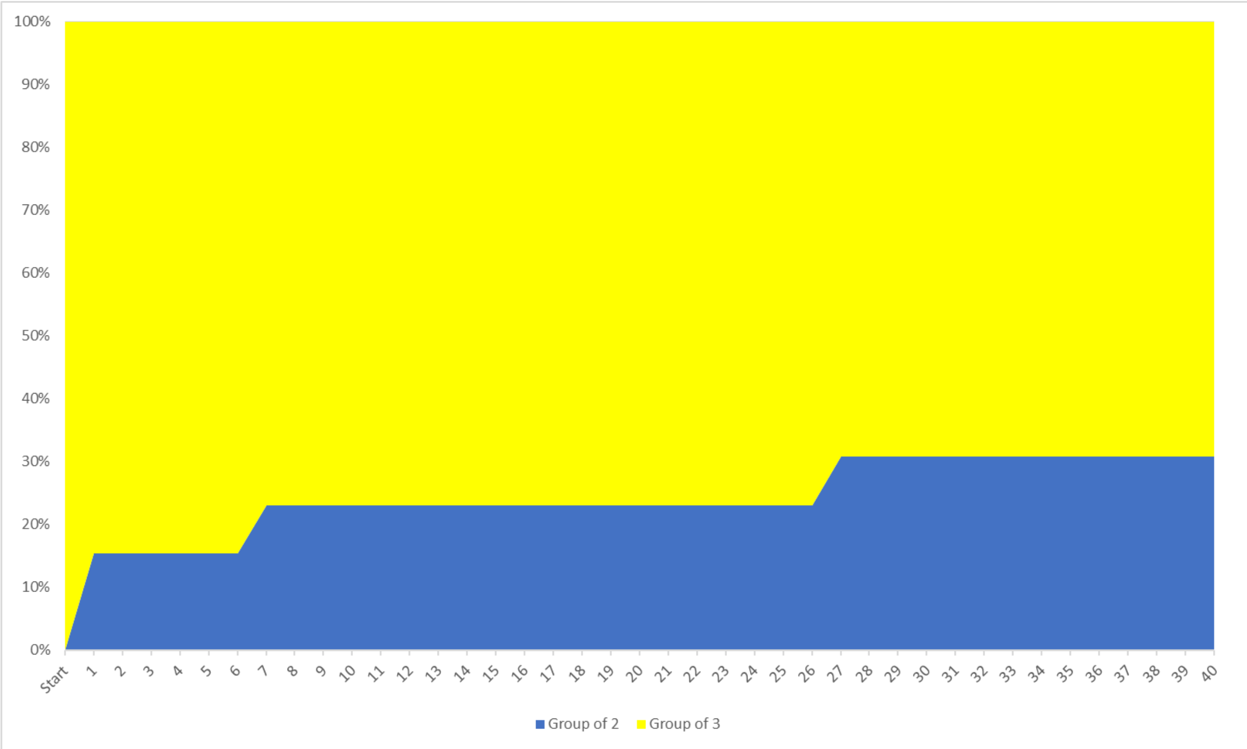

Figure 1: Attrition Throughout the Experiment

Colors depict the group size. I always started with groups of four but let participants continue if a member dropped out.

Participant drops out in period t (0 = no, 1 = yes)		
	(1)	(2)
	Without Game Results	With Game Results
Round	-0.0848	-0.1524
	(0.0820)	(0.0961)
Waited in lobby	1.5315	1.6499
	(1.4452)	(1.3884)
Relative past earnings	. . .	0.0389
		(0.0106)
Relative expected future earnings	. . .	0.2991
		(0.1624)
Constant	-4.6656***	-4.0397***
	(1.1062)	(1.2424)
Observations	1182	1182

Values reflect estimates from a logit model fitted to binary events of participants staying (0) or dropping out (1) in a given round of a session, conditional on the session still having all three participants. 'Round' is the round number, 'Waited in lobby' is a dummy for whether the participant had to wait in a lobby before the start of the round, 'Relative past earnings' is the participant's past earnings relative to average equilibrium earnings at that point in the experiment, 'Relative expected future earnings' is the participant's the participant's expected future earnings in equilibrium conditional on the mechanism choice and current type, relative to average equilibrium future earnings for that round. Standard errors are heteroskedasticity-robust and clustered at the group level.

Table 4: Determinants of Attrition

To check whether relative past earnings and relative expected future earnings are jointly significant, I estimate specification (1) and specification (2) on a training subset of data that includes all but 1 group. Then, for both models, I compute the log-likelihoods of the test subset that includes the group not included in the training subset. A Wilcoxon signed-rank test finds no evidence that specification (2) outperforms specification (1) ($p = 1$). I therefore conclude there is no evidence that selective attrition threatens the validity of my results.

7.8 Learning

It is possible that participants may have learned to play equilibrium strategies over time. To investigate this possibility, I run a linear regression using the round number to predict the gain from switching to the equilibrium strategy. I do not find statistically significant evidence that learning occurred over the course of the experiment. The analysis was performed using R packages plm (Croissant and Millo 2008), lmtest (Zeileis and Hothorn 2002), and multiwayvcov (Graham et al. 2016). The table was generated using stargazer (Hlavac 2018).

	Dependent variable: Gain from switching to the equilibrium strategy
Round	0.033^{*}
	(0.018)
Constant	0.840^{***}
	(0.182)
Note:	$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Standard errors, reported in parentheses, were computed by estimating the model on resamples 10 groups with replacement 5000 times.

Table 5: Learning in the Experiment

8 Further Thoughts

8.1 The Bayesian Underdog Effect in the Corruption Context

Weyl (2017) finds that when private value are affiliated rather than independent, some inefficiency results because supporters of unlikely winners believe a tie is more likely than supporters of likely winners. He terms this phenomenon a Bayesian Underdog Effect. Because individuals know their own values, the efficiency loss is small. The efficiency loss can happen only rarely because it is caused by one alternative being more likely to win. Similarly, in equilibria where taxpayers vote for more audits, officials believe the chance their votes are important is relatively high when corruption opportunities exist, taxpayers believe the chance their votes are important is moderate, and officials believe the change their votes are important is relatively low when corruption opportunities do not exist. These differing beliefs increase the vote expenditures of officials when corruption opportunities exist and decrease the vote expenditures of officials when corruption opportunities do not exist. As a result, QV over-weights the preferences of officials when corruption opportunities exist and under-weights the preferences of officials when corruption opportunities do not exist. Therefore, officials are usually not audited when corruption opportunities exist and officials are almost always audited when corruption opportunities do not exist.

8.2 Incentives to Reveal Expertise Under QV

This example shows that QV does not provide experts who are not trusted by the rest of the population to reveal expertise when they are indeed trustworthy. Government officials are experts at determining whether corruption opportunities exist. Furthermore, the government officials and taxpayers have a common interest: neither group wants to waste money auditing the government when corruption opportunities do not exist. The result that QV may perform worse than majority voting in a partially-shared-interest setting is surprising given that prior work suggests that QV will perform well in such settings. For example, Posner and Weyl (2017) suggest that QV will outperform majority voting in a setting with partially shared interests and asymmetric information.

8.3 Elections for Abusable Positions

QV may pose a problem for the elections of officials to positions where corrupt officials can profit. Corrupt officials would steal from the public for personal gain if elected and therefore have a strong monetary incentive to get themselves elected. Under QV, they may attempt to win the election either by buying votes for themselves or colluding with other corrupt individuals that they are working with. To get a sense for the potential magnitude of this problem, consider a real-world example of corruption. From 2002 to 2008, Kwame Kilpatrick stole $4.5 million ($5.3 million in 2019 dollars) from Detroit (Cohn 2016). Credit constraints might not be an issue for corrupt individuals trying to buy elections because banks sometimes participate in corruption (Gradel and Simpson 2015). The number of corruption convictions among Detroit mayors suggests corruption is rare: only 2 of the 77 mayors of Detroit have been convicted of corruption. An adverse selection problem may occur because the mayoral candidates who are willing to pay the most to become mayor are likely the ones who intend to steal money.

Intuitively, it seems impossible for a society to choose honest candidates over corrupt candidates when only the candidates themselves know whether they are corrupt. When a mechanism designer lacks information, he is subject to the constraint that he must induce agents to provide truthful information. Such mechanisms are the best an uninformed mechanism designer can do (Myerson 1979). Consider the following model: A social planner has must choose a candidate for office and has two candidates available. Each of the candidates is corrupt with probability p determined independently. Each candidate's type is private information. An honest benefit gets a benefit of w for holding office, representing the benefits legally available to the office-holder. A corrupt candidate gets a benefit of $w + s$, where s represents the benefits a corrupt candidate can illegally obtain from office. The social planner seeks to minimize the probability a corrupt candidate is chosen. By the Revelation Principle (Myerson 1979), it suffices to consider direct mechanisms. Each candidate type maximizes the probability it attains office, so to induce truthful reporting, the mechanism designer must give clean and corrupt candidates the same probability of attaining office. When multiple people engage in corruption and the social planner knows which people are aware whether the government is corrupt, the planner can create a direct mechanism that has an efficient equilibrium. The planner can punish anyone reporting the government is clean if one informed person has reported the government is corrupt. However, this mechanism has inefficient equilibria as well, including one where all corrupt individuals report the government is clean and thus prevent the planner from discovering corruption and one where informed individuals randomize. When the informed individuals randomize, the planner fails to gain accurate information about corruption and is sometimes even forced to punish some individuals. Moreover, it could be difficult in practice for a planner to know which individuals are informed.

9 Conclusion

The corruption examples show that QV can be inefficient when a poorly informed, unsuspecting majority can sometimes be overwhelmed by an opposition minority that catches it off guard. These examples are similar to the adverse selection problem in markets for private goods studied by Akerlof (1970). In both models, efficiency is low because the poorly informed agents benefit most from changing the allocation when the well-informed agents lose the most from changing the allocation. It is like the right to an honest government being sold by the government officials. This right is worthless when the government is already honest. When the government is corrupt, this right is costly for the officials to give up but even more valuable for the taxpayers. When the informational advantage of the corrupt officials is high relative to the gains from trade, taxpayers cannot pass the legislation with high probability when it is valuable.

Because QV is only approximately efficient in private-value and pure-common-interest settings, those are the only settings where a strong theoretical justification for using QV exists. It is plausible, however, that QV would be approximately efficient whenever voters had common rather than conflicting interests. If information that causes one voter to like a policy more also causes other voters to like that policy more, the problem in the above example does not arise. Although QV might be better than majority voting in cases involving asymmetric information about policy effects, because there are cases where majority voting is efficient and QV is not approximately efficient, it is an empirical matter whether QV or majority voting is better in applications. The structure of this example suggests that we should be especially wary about using QV in a setting where a minority with superior information has interests that are opposed to that of society as a whole. Gun rights and corruption control are two such issues: in both, potential criminals have the best information on whether the proposed law would deter antisocial activity. A tax reform aimed at closing tax loopholes to extract more tax revenue from a minority of wealthy people is another example where QV might do poorly. The wealthy are likely better informed about how a tax reform targeting them will affect them than the general population and their interest in keeping their own wealth conflicts with the majority's interest in raising public revenue. The wealthy would put up more opposition to reforms that are surprisingly effective at collecting taxes from them.

The variant of QV used also determines the risk of an inefficient minority victory due to an information asymmetry. QV with money carries the highest risk of an inefficient minority victory because a minority's influence is limited only by that minority's willingness and ability to spend money. The variant of QV recommended for short- and medium-term use by Posner and Weyl (2018) using voice credits that are evenly distributed among individuals is less prone to inefficient minority victories because a minority's influence is limited by the amount of voice credits its members have received. Determining whether QV is efficient in practice in real-world settings that involve both conflicting interests and uncertainty about policy effects is an important area for future research. Another interesting area for future research is the effectiveness of information-providing institutions for reducing the amount of inefficiency in QV caused by poor information. It is possible that efficiency losses from poor information can be mitigated if credible information is readily accessible to voters.

My experiment finds no support for the theoretical prediction that QV can perform worse than majority voting in a corruption game. This experimental evidence is a reason to hope that asymmetric information may not cause problems in real-world implementations of QV.

10 Appendix 1: Computation of Equilibrium for QV on a Costless Anti-Corruption Policy

It is optimal for government officials to spend zero when corruption opportunities do not exist because in that case, they do not care about which alternative is selected. When corruption opportunities exist, official i's first-order condition is

$$0 = -s\frac{\left(1 + e^{\phi \sum_{j=1}^{N} a_j}\right) \phi e^{\phi \sum_{j=1}^{N} a_j} - e^{\phi \sum_{j=1}^{N} a_j} \phi e^{\phi \sum_{j=1}^{N} a_j}}{\left(1 + e^{\phi \sum_{j=1}^{N} a_j}\right)^2} - 2a_i \tag{10}$$

$$= -s\phi\frac{e^{\phi \sum_{j=1}^{N} a_j}}{\left(1 + e^{\phi \sum_{j=1}^{N} a_j}\right)^2} - 2a_i. \tag{11}$$

Therefore,

$$-s\phi\frac{e^{\phi \sum_{j=1}^{N} a_j}}{\left(1 + e^{\phi \sum_{j=1}^{N} a_j}\right)^2} = 2a_i. \tag{12}$$

Hence,

$$a_i = -s\phi\frac{e^{\phi \sum_{j=1}^{N} a_j}}{2\left(1 + e^{\phi \sum_{j=1}^{N} a_j}\right)^2}. \tag{13}$$

Let $a_g(1)$ denote the equilibrium action of a government official when corruption opportunities exist and let a_t denote the equilibrium action of a taxpayer. Then,

$$a_g(1) = -s\phi \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2}. \tag{14}$$

Taxpayer i's first-order condition is

$$\begin{aligned} 0 &= \frac{p\theta s}{k} \frac{\left(1+e^{\phi \sum_{j=1}^N a_j}\right)\phi e^{\phi \sum_{j=1}^N a_j} - e^{\phi \sum_{j=1}^N a_j}\phi e^{\phi \sum_{i=1}^N a_i}}{\left(1+e^{\phi \sum_{i=1}^N a_i}\right)^2} - 2a_i & (15) \\ &= \frac{p\theta s\phi}{k} \frac{e^{\phi \sum_{j=1}^N a_i}}{\left(1+e^{\phi \sum_{j=1}^N a_i}\right)^2} - 2a_i. & (16) \end{aligned}$$

Therefore,

$$\frac{p\theta s\phi}{k} \frac{e^{\phi \sum_{i=1}^N a_i}}{\left(1+e^{\phi \sum_{i=1}^N a_i}\right)^2} = 2a_i. \tag{17}$$

Thus,

$$a_i = \frac{p\theta s\phi}{k} \frac{e^{\phi \sum_{i=1}^N a_i}}{2\left(1+e^{\phi \sum_{i=1}^N a_i}\right)^2}. \tag{18}$$

Therefore,

$$a_t = \frac{p\theta s\phi}{k} \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2}. \tag{19}$$

Therefore, when corruption opportunities exist, the vote total for the proposal is

$$\begin{aligned} & N_g\left(-s\phi \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2}\right) + N_t \frac{p\theta s\phi}{k}\phi \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2} & (20) \\ &= \left(-N_g + \frac{p\theta}{k} k N_g\right) s\phi \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2} & (21) \\ &= (p\theta - 1) N_g s\phi \frac{e^{\phi(N_g a_g(1)+N_t a_t)}}{2\left(1+e^{\phi(N_g a_g(1)+N_t a_t)}\right)^2} & (22) \end{aligned}$$

11 Appendix 2: Equilibrium Conditions For QV on a Costly Anti-Corruption Policy

When corruption opportunities exist, government official i's first-order condition is

$$0 = -\left(s + \frac{c}{N}\right)\phi\frac{e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}}{\left(1+e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}\right)^2} - 2a_i.$$

Therefore,

$$-\left(s + \frac{c}{N}\right)\phi\frac{e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}}{\left(1+e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}\right)^2} = 2a_i. \tag{23}$$

Hence,

$$a_i = -\left(s + \frac{c}{N}\right)\phi\frac{e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}}{2\left(1+e^{\phi(a_i+(N_g-1)a_g(1)+N_ta_t)}\right)^2}. \tag{24}$$

Hence, an equilibrium condition is

$$a_g(1) = -\left(s + \frac{c}{N}\right)\phi\frac{e^{\phi(N_ga_g(1)+N_ta_t)}}{2\left(1+e^{\phi(N_ga_g(1)+N_ta_t)}\right)^2}. \tag{25}$$

Taxpayer i's first-order condition is

$$\begin{aligned}0 =& \frac{p\theta s}{k}\frac{\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}}{\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}\right)^2} - p\frac{\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}}{\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}\right)^2}\frac{c}{N}\\ &-(1-p)\frac{c}{N}\frac{\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(0))}}{\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(0))}\right)^2} - 2a_i.\end{aligned}$$

Therefore,

$$\begin{aligned}&-\frac{pc\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}}{N\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}\right)^2} + \frac{p\theta s\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}}{k\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(1))}\right)^2}\\ &-\frac{(1-p)c\phi e^{\phi(a_i+(N_t-1)a_t+N_ga_g(0))}}{N\left(1+e^{\phi(a_i+(N_t-1)a_t+N_ga_g(0))}\right)^2} = 2a_i.\end{aligned}$$

Thus,

$$a_i = \left(\frac{\theta s}{k} - \frac{c}{N}\right) \frac{p\phi e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}}{2\left(1+e^{\phi(a_i+(N_t-1)a_t+N_g a_g(1))}\right)^2} - \frac{\phi(1-p)ce^{\phi(a_i+(N_t-1)a_t+N_g a_g(0))}}{2N\left(1+e^{\phi(a_i+(N_t-1)a_t+N_g a_g(0))}\right)^2}. \quad (26)$$

Therefore, an equilibrium condition is

$$a_t = \left(\frac{\theta s}{k} - \frac{c}{N}\right) \frac{p\phi e^{\phi(N_t a_t+N_g a_g(1))}}{2\left(1+e^{\phi(N_t a_t+N_g a_g(1))}\right)^2} - \frac{\phi(1-p)ce^{\phi(N_t a_t+N_g a_g(0))}}{2N\left(1+e^{\phi(N_t a_t+N_g a_g(0))}\right)^2}. \quad (27)$$

When corruption opportunities do not exist, the first-order condition of government official i is

$$0 = -\frac{c}{N}\phi \frac{e^{\phi(a_i+(N_g-1)a_g(0)+N_t a_t)}}{\left(1+e^{\phi(a_i+(N_g-1)a_g(0)+N_t a_t)}\right)^2} - 2a_i. \quad (28)$$

Therefore, an equilibrium condition is $a_g(0) = -\frac{c\phi e^{\phi(N_g a_g(0)+N_t a_t)}}{2N\left(1+e^{\phi(N_g a_g(0)+N_t a_t)}\right)^2}$.

12 Appendix 3: Setting Values for the First Costly Audit Example

I base my values off the anti-corruption experiment of Olken (2007). This experiment increased the probability of an audit from 0.04 to 1 and measured the change in the amount of money stolen from road projects. I consider the proposal that would increase the probability that a government official was audited. Olken (2007) measures the amount of materials used in a road and compares it to the amount of materials used in an road that was built honestly. A corrupt official might steal money that was supposed to be spent on materials and then reduce the quality of the road by building it with fewer materials. Around 25% of officials used more materials than Olken (2007) estimates are required. I assume that due to measurement error and road-specific heterogeneity, another 25% of officials needed fewer materials than Olken (2007) estimates were needed to build the road properly. Therefore, I assume that there is a 50% chance officials building a road had no opportunity to commit corruption and a 50% chance that officials had an opportunity to commit corruption. Hence, I set $p = 0.5$. Olken (2007) estimates that audits cost \$500, reduced average theft by \$468, and increased the benefits of the average road by \$1,213. Based on Olken (2007), I set $N = 2500$, $N_g = 7$, and $c = \$500$, and $\theta = 2.58$. Olken (2005) finds that audits reduce theft by 8% of the value of the road on average but only 6.5% of the value of the road when the village head does not face an upcoming election within 2 years. I analyze the case where the village head does not face an upcoming election within the next two years. To model the case where the village head does not face an upcoming election within the next two years, I set $s = \$109$.

13 Appendix 4: Sensitivity to Parameter Values

I now present figures that illustrate the effect of altering one parameter while leaving the others at their original value.

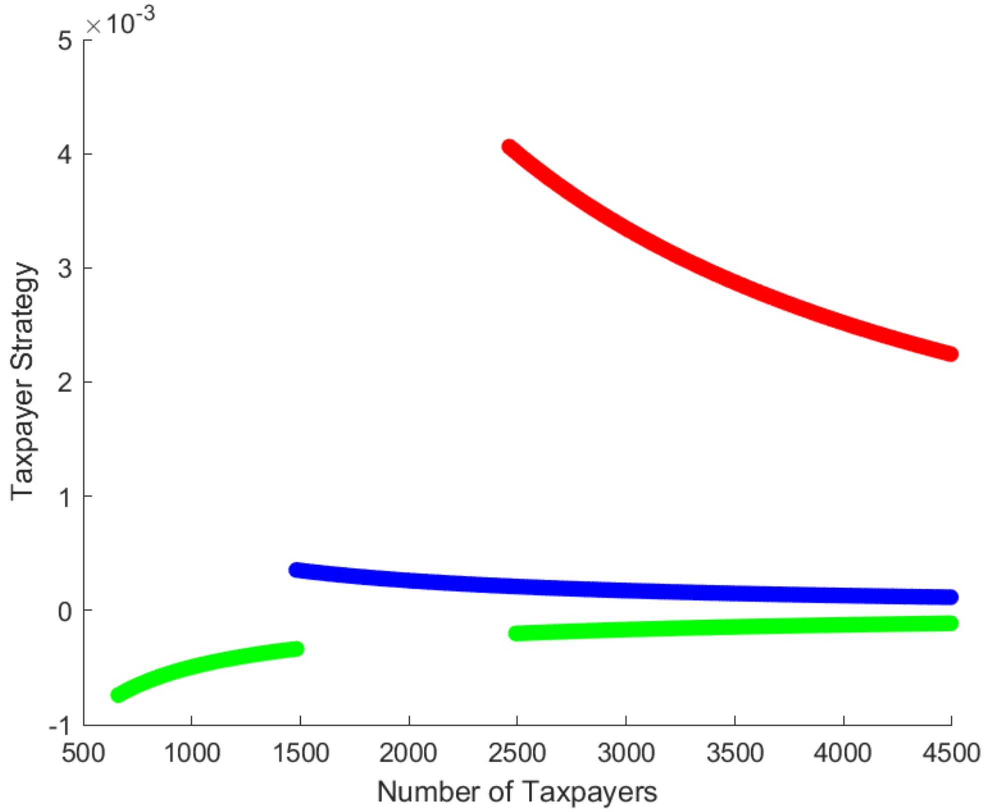

Figure 2: Taxpayer Strategies as a Function of the Number of Taxpayers

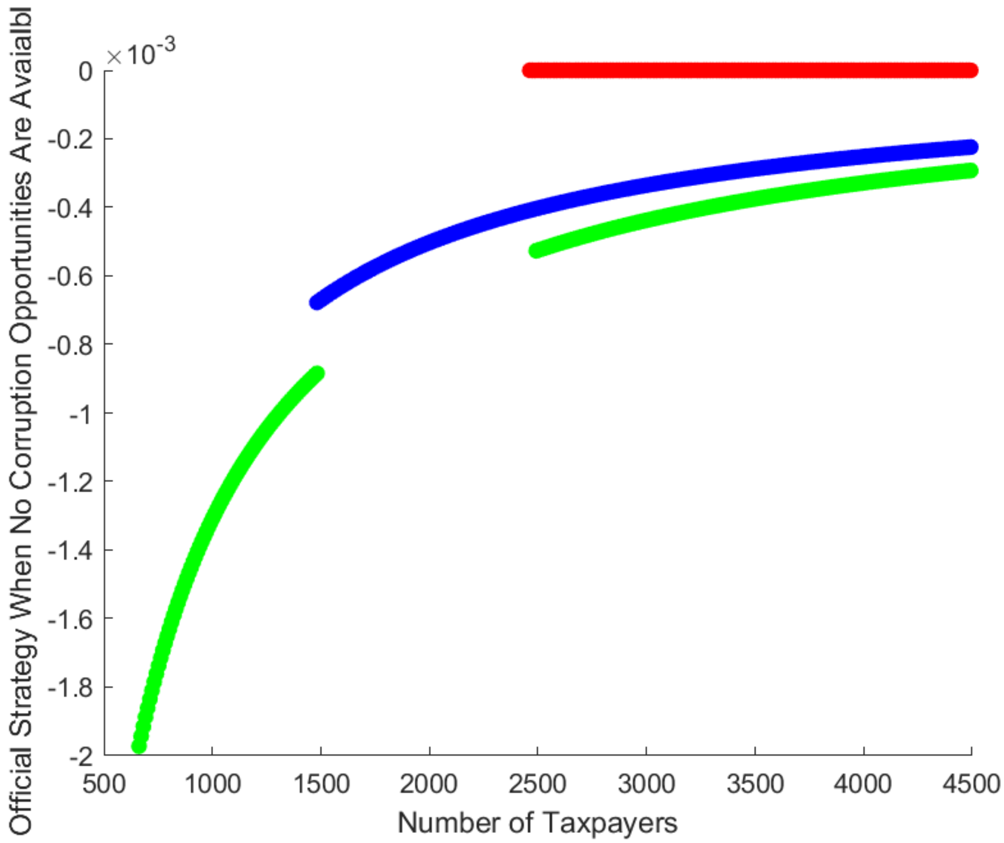

Figure 3: Official Strategies When No Corruption Opportunities Exist as a Function of the Number of Taxpayers

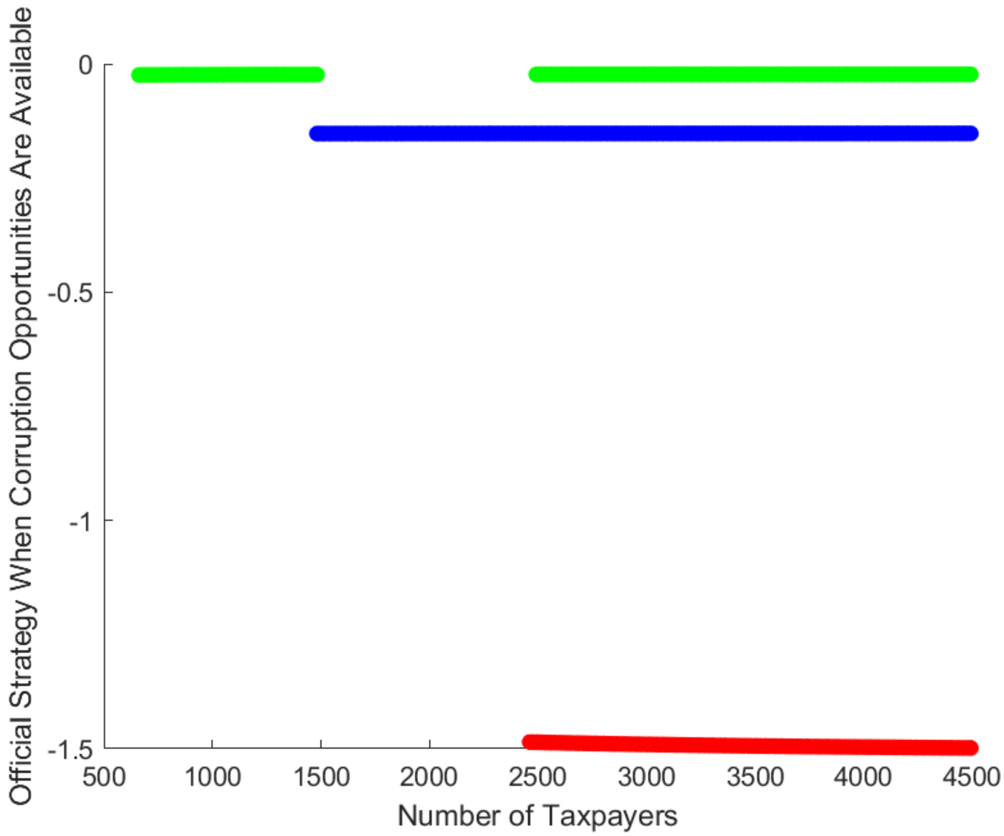

Figure 4: Official Strategies When Corruption Opportunities Exist as a Function of the Number of Taxpayers

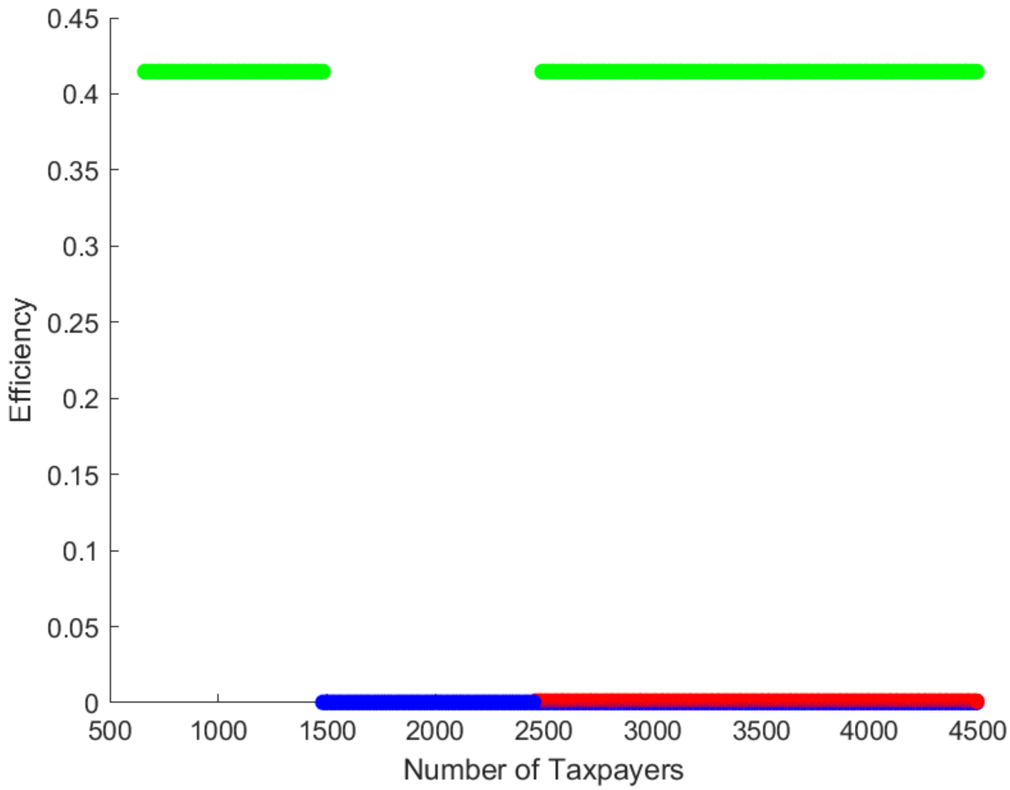

Figure 5: Efficiency as a Function of the Number of Taxpayers

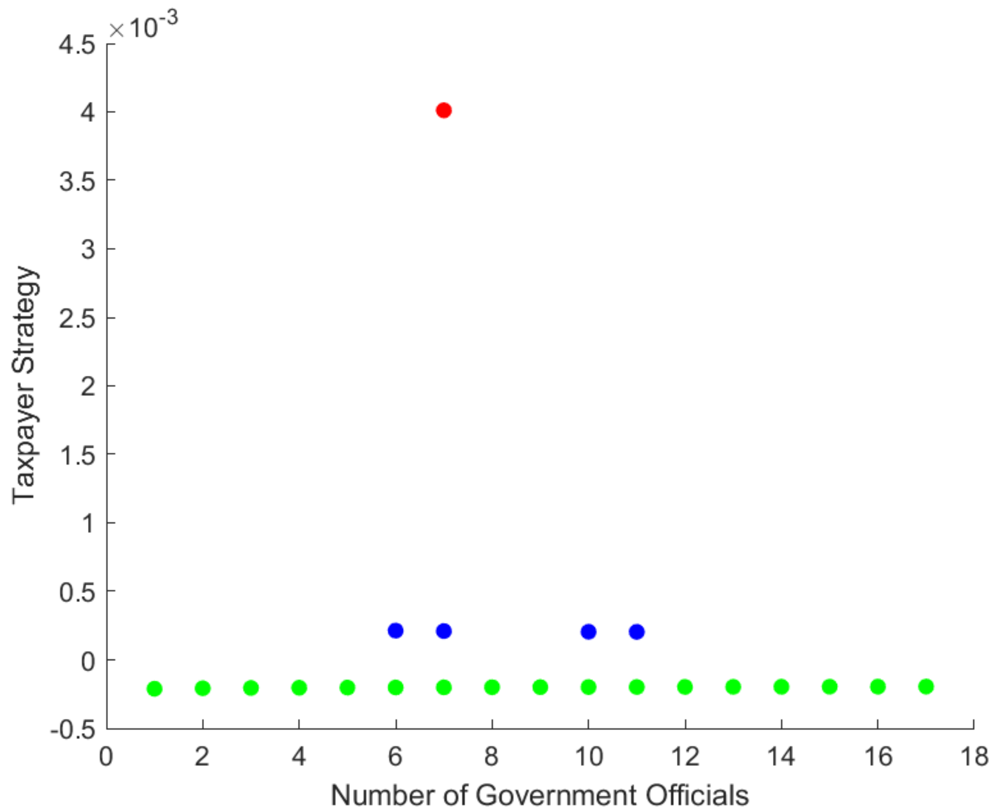

Figure 6: Taxpayer Strategies as a Function of the Number of Government Officials

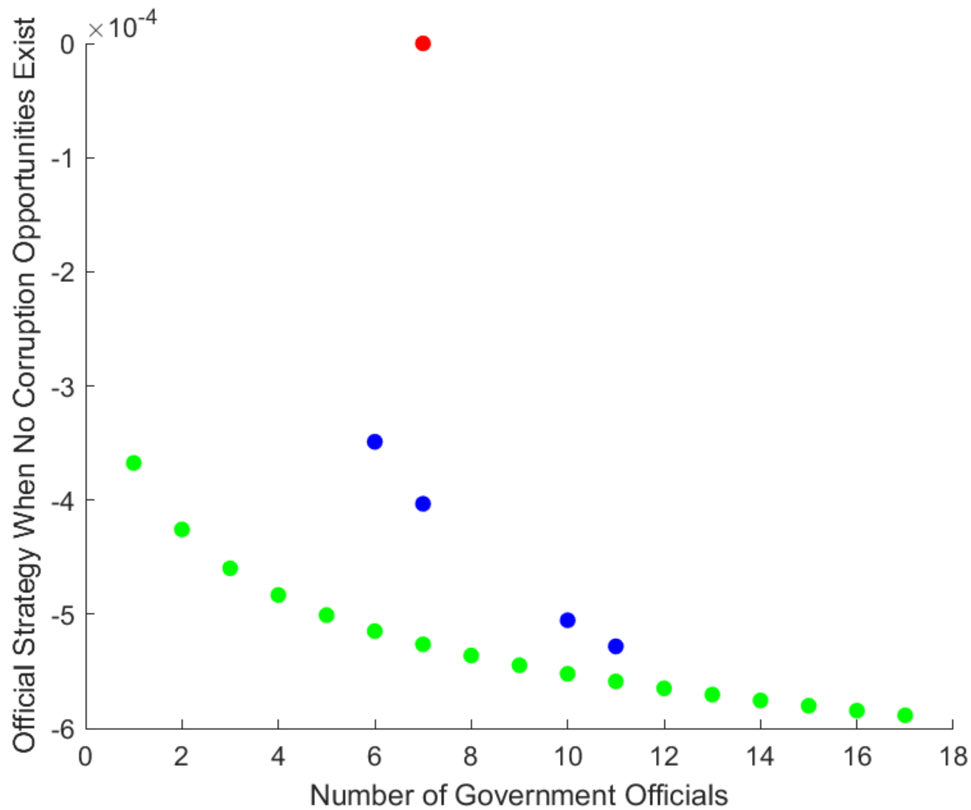

Figure 7: Official Strategies When No Corruption Opportunities Exist as a Function of the Number of Government Officials

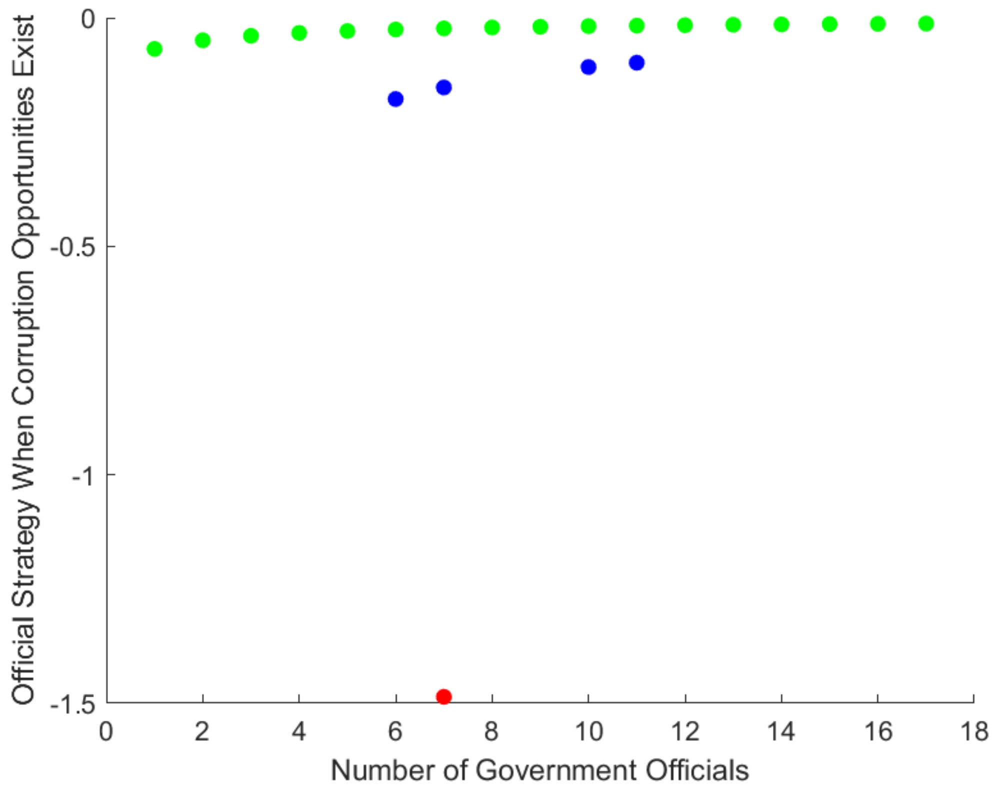

Figure 8: Official Strategies When Corruption Opportunities Exist as a Function of the Number of Government Officials

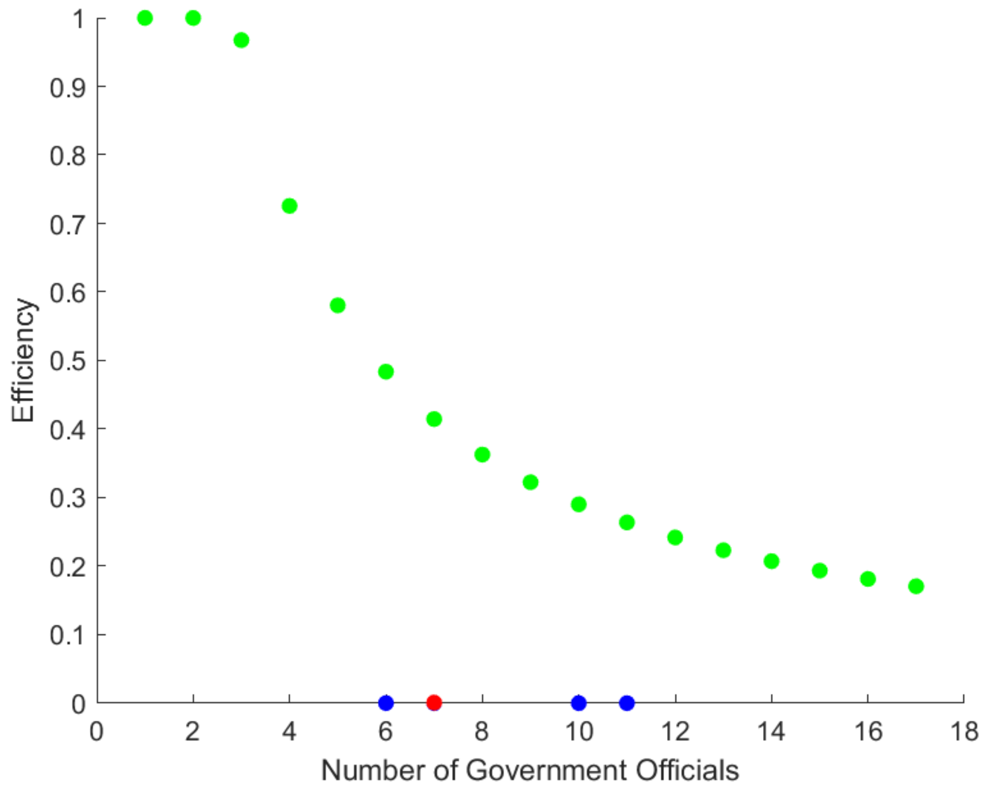

Figure 9: Efficiency as a Function of the Number of Government Officials

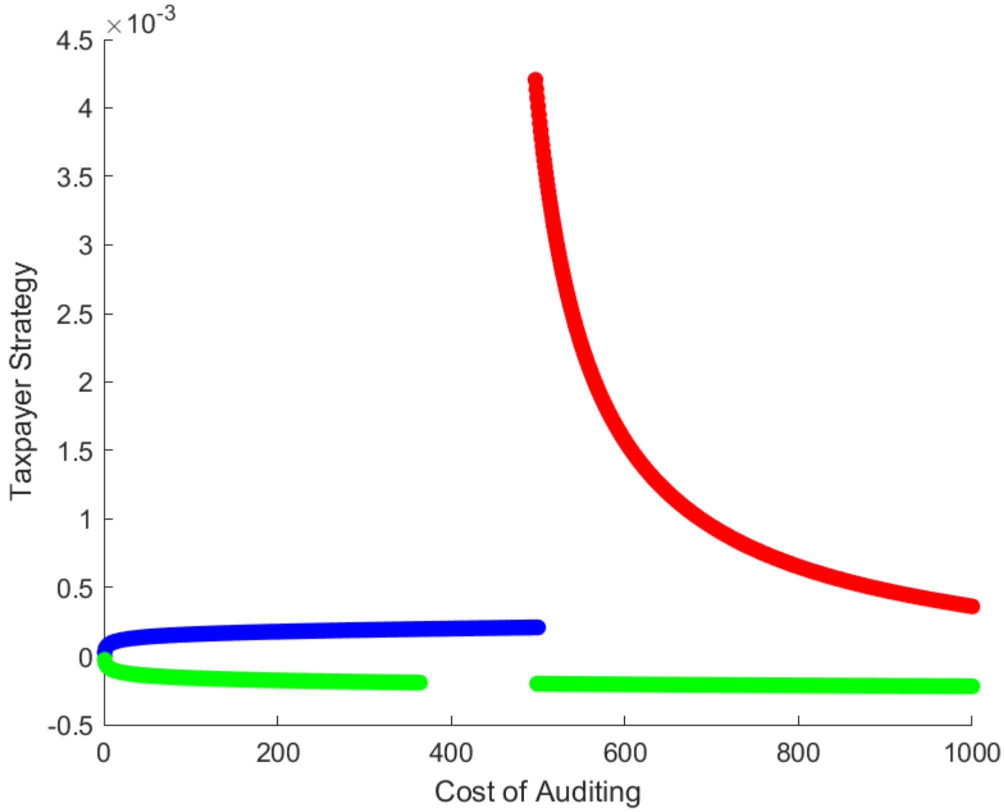

Figure 10: Taxpayer Strategies as a Function of the Cost of Auditing

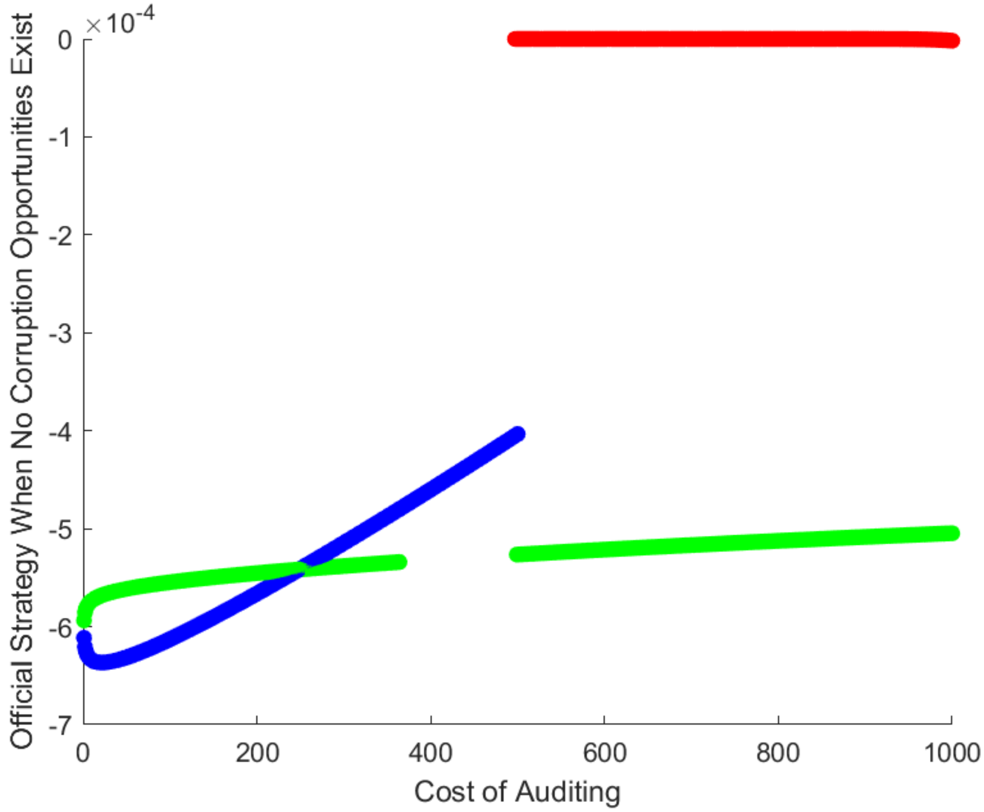

Figure 11: Official Strategies When No Corruption Opportunities Exist as a Function of the Cost of Auditing

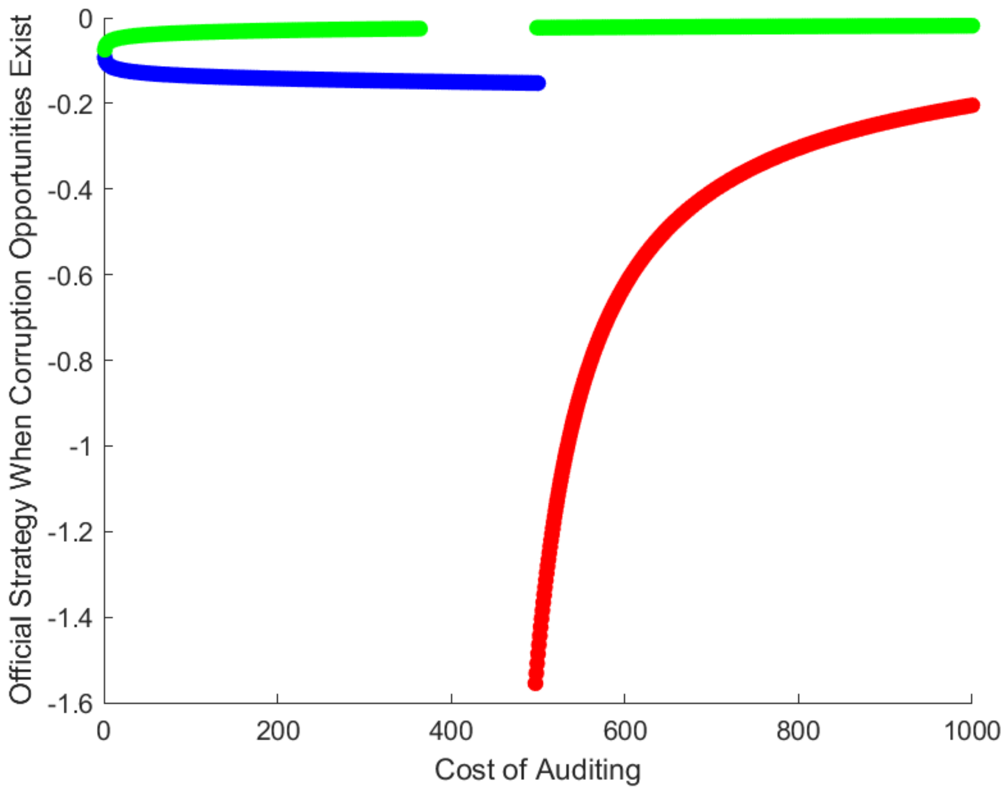

Figure 12: Official Strategies When Corruption Opportunities Exist as a Function of the Cost of Auditing

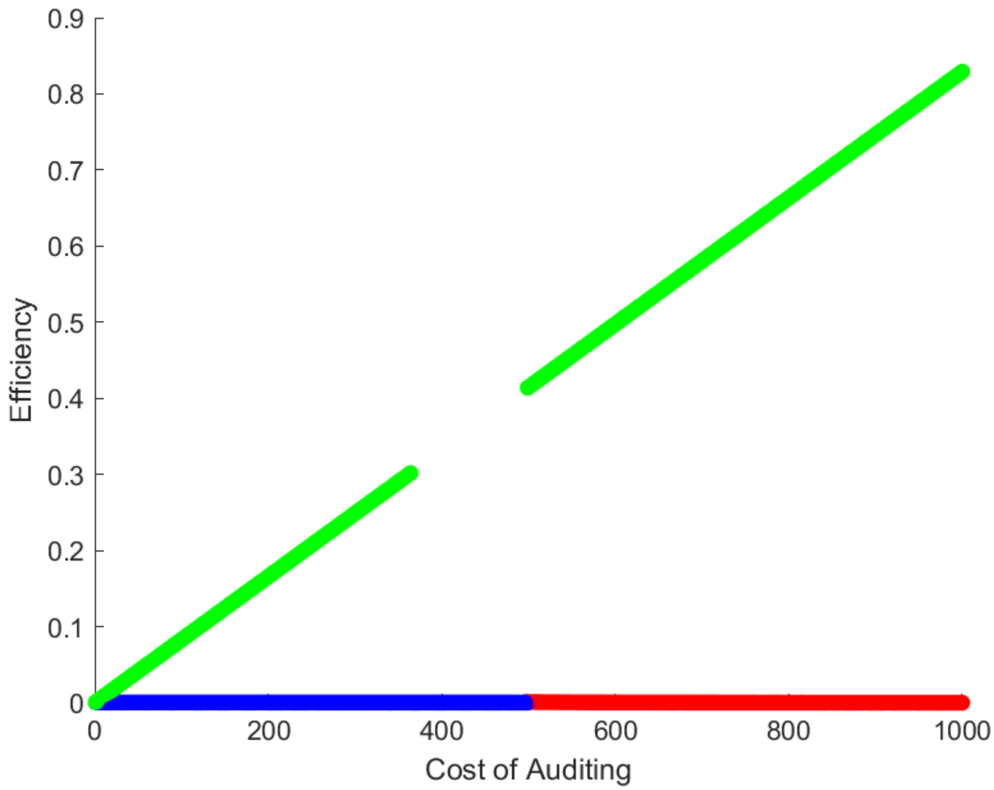

Figure 13: Efficiency as a Function of the Cost of Auditing

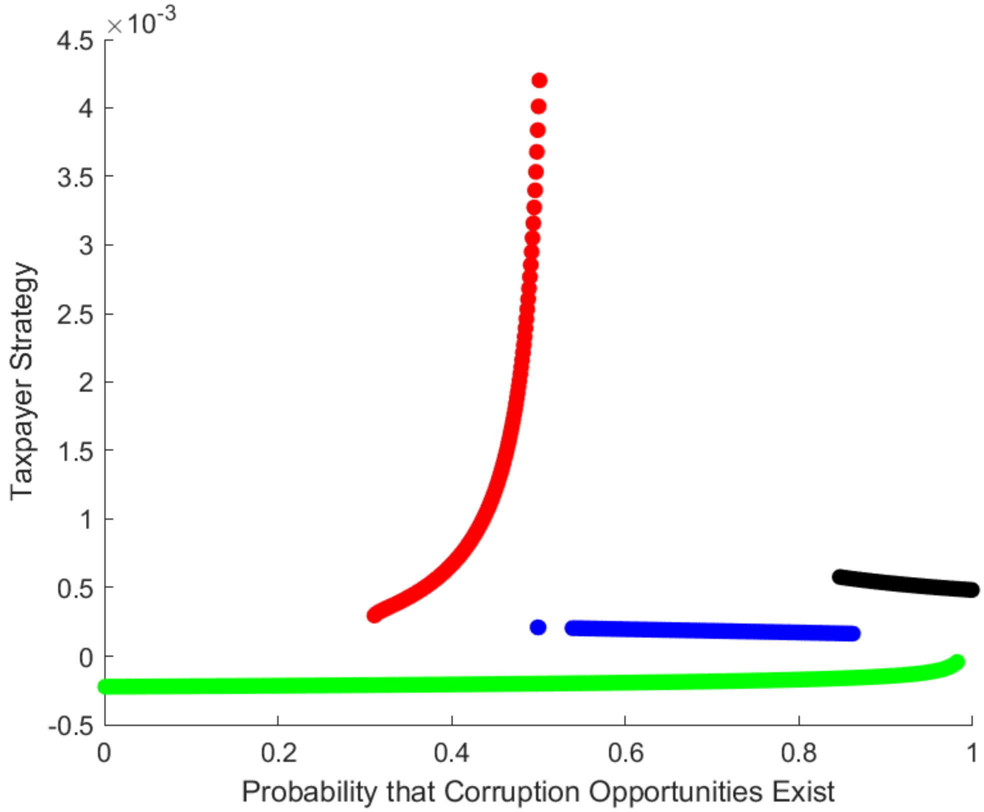

Figure 14: Taxpayer Strategies as a Function of the Probability That Corruption Opportunities Exist

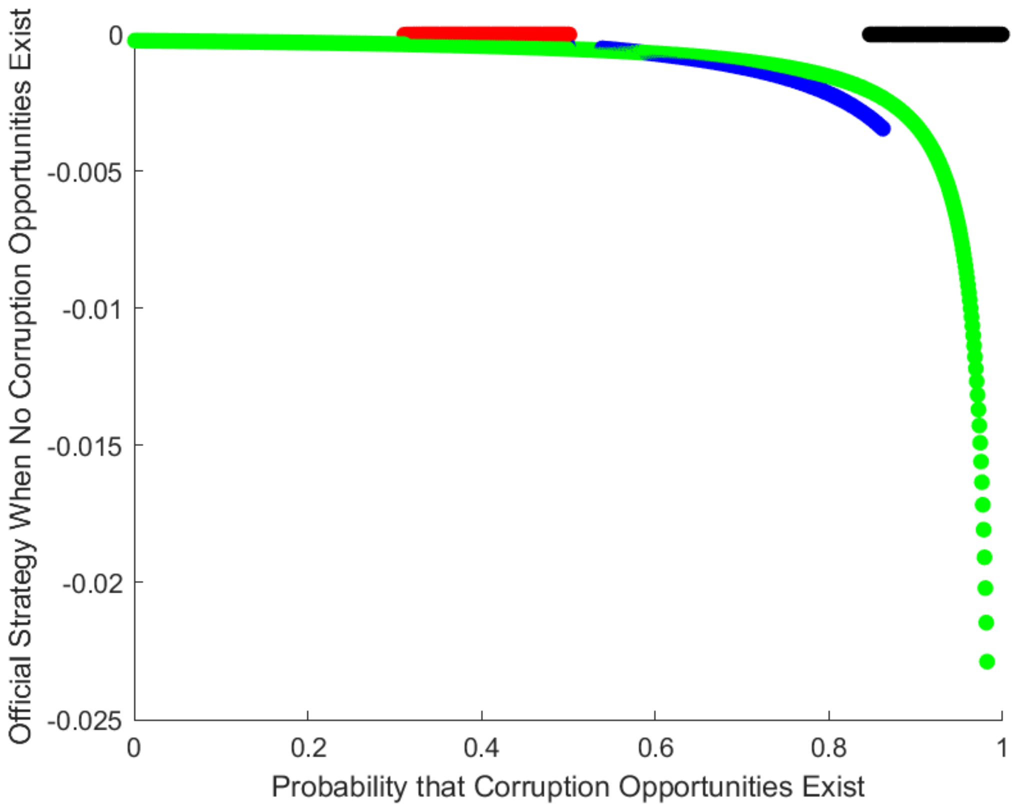

Figure 15: Official Strategies When No Corruption Opportunities Exist as a Function of the Probability That Corruption Opportunities Exist

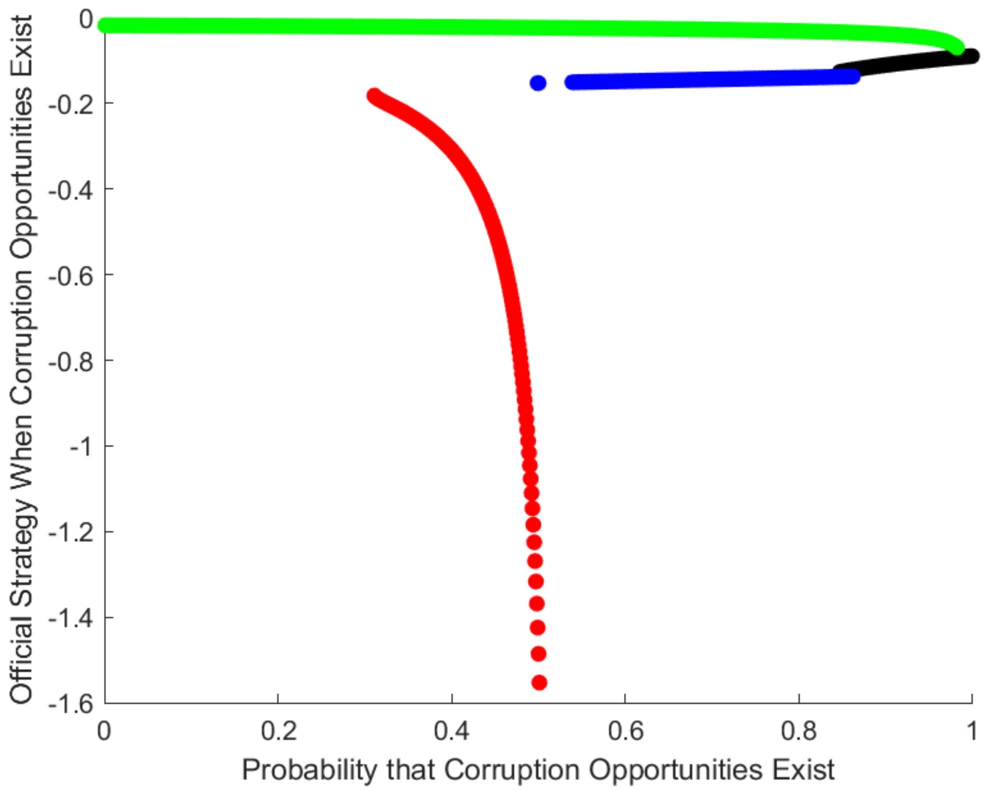

Figure 16: Official Strategies When Corruption Opportunities Exist as a Function of the Probability That Corruption Opportunities Exist

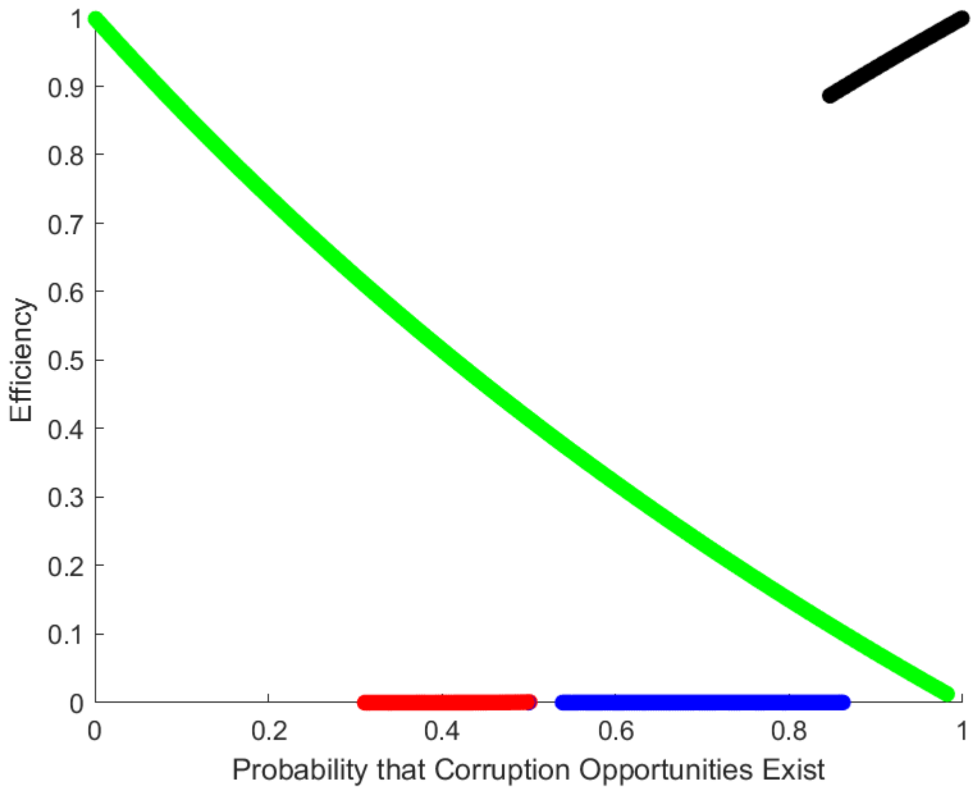

Figure 17: Efficiency as a Function of the Probability That Corruption Opportunities Exist

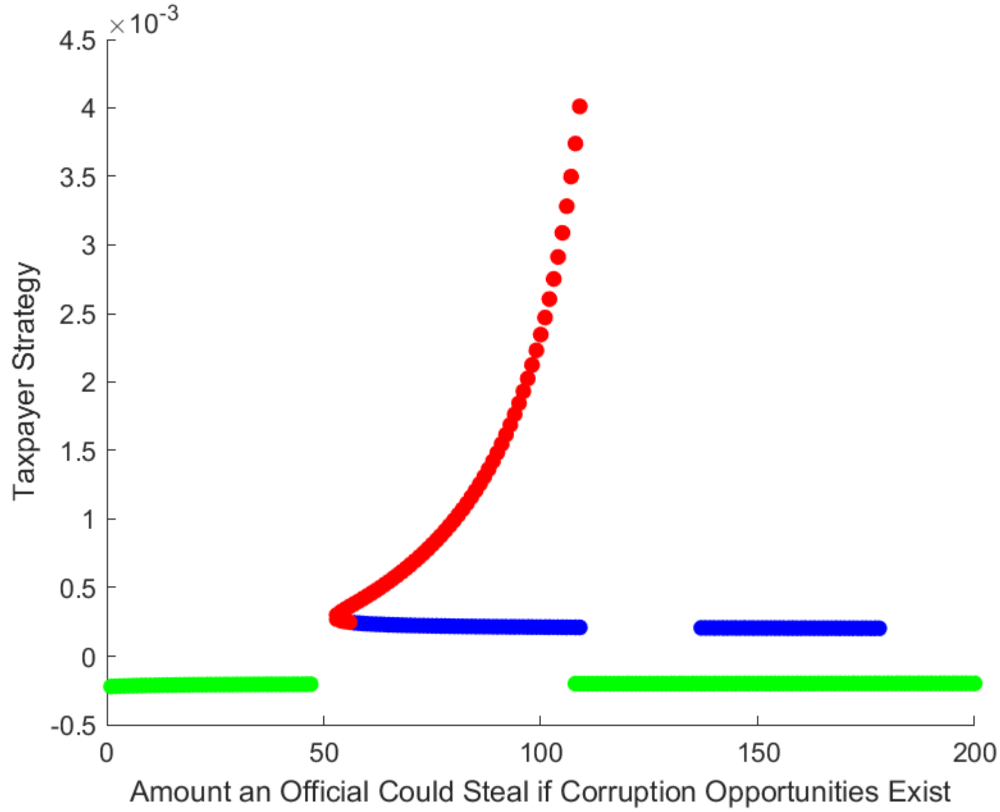

Figure 18: Taxpayer Strategies as a Function of the Amount an Official Could Steal When Corruption Opportunities Exist

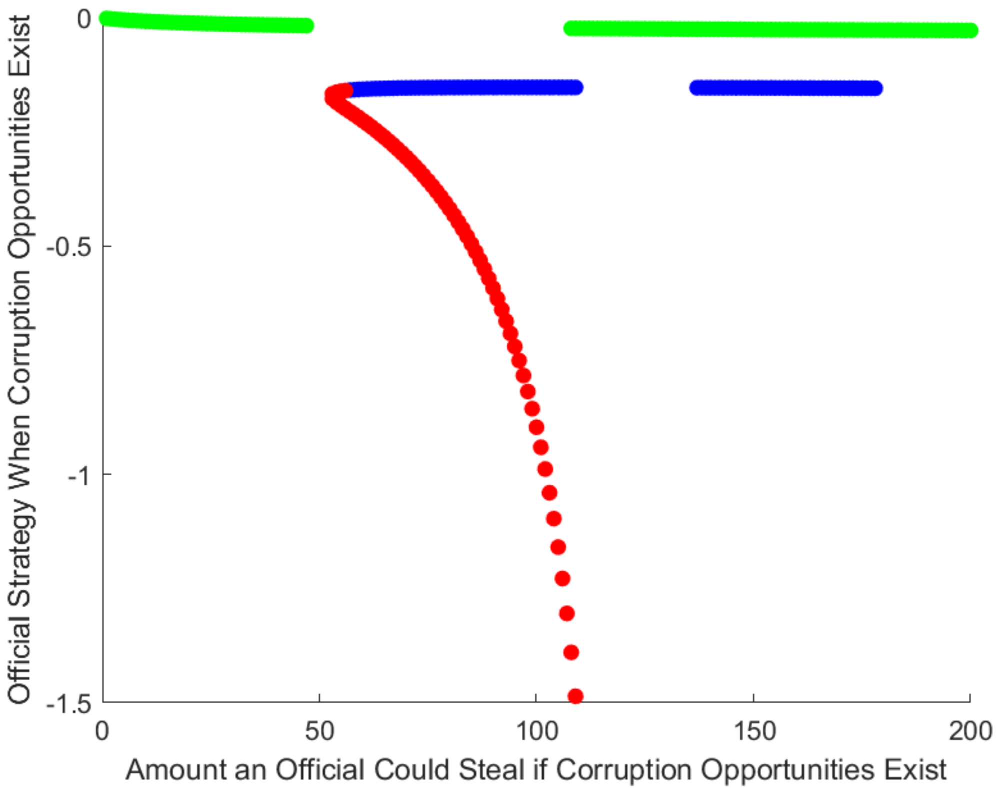

Figure 19: Official Strategies When No Corruption Opportunities Exist as a Function of the Amount an Official Could Steal When Corruption Opportunities Exist

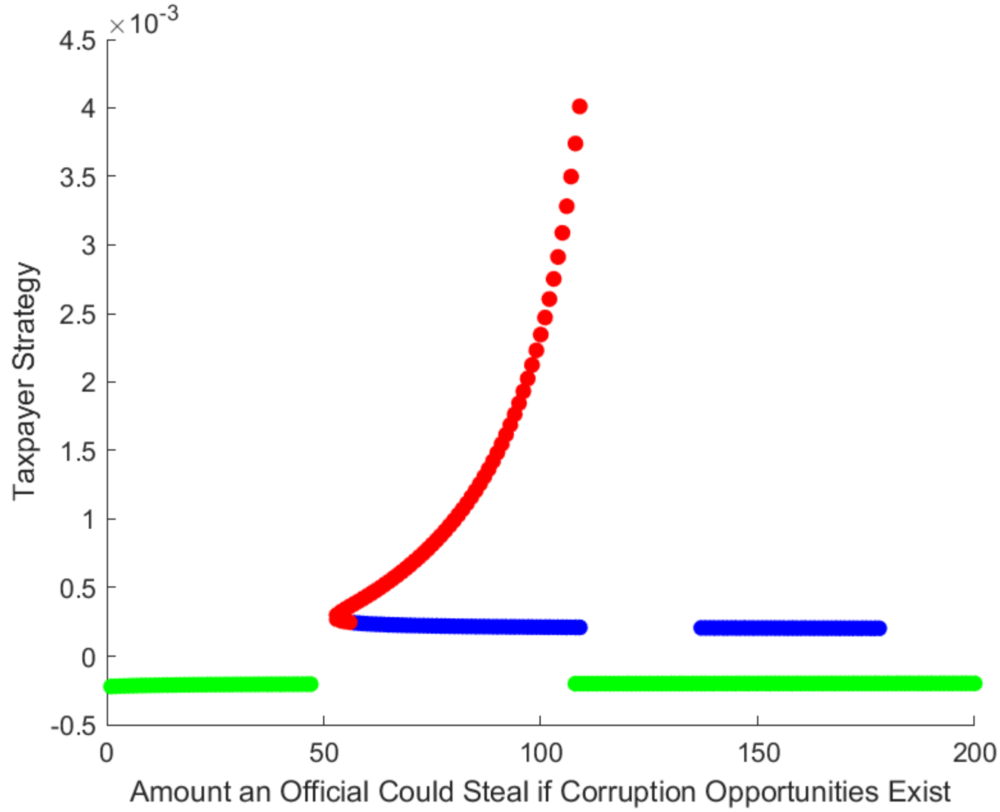

Figure 20: Official Strategies When Corruption Opportunities Exist as a Function of the Amount an Official Could Steal When Corruption Opportunities Exist

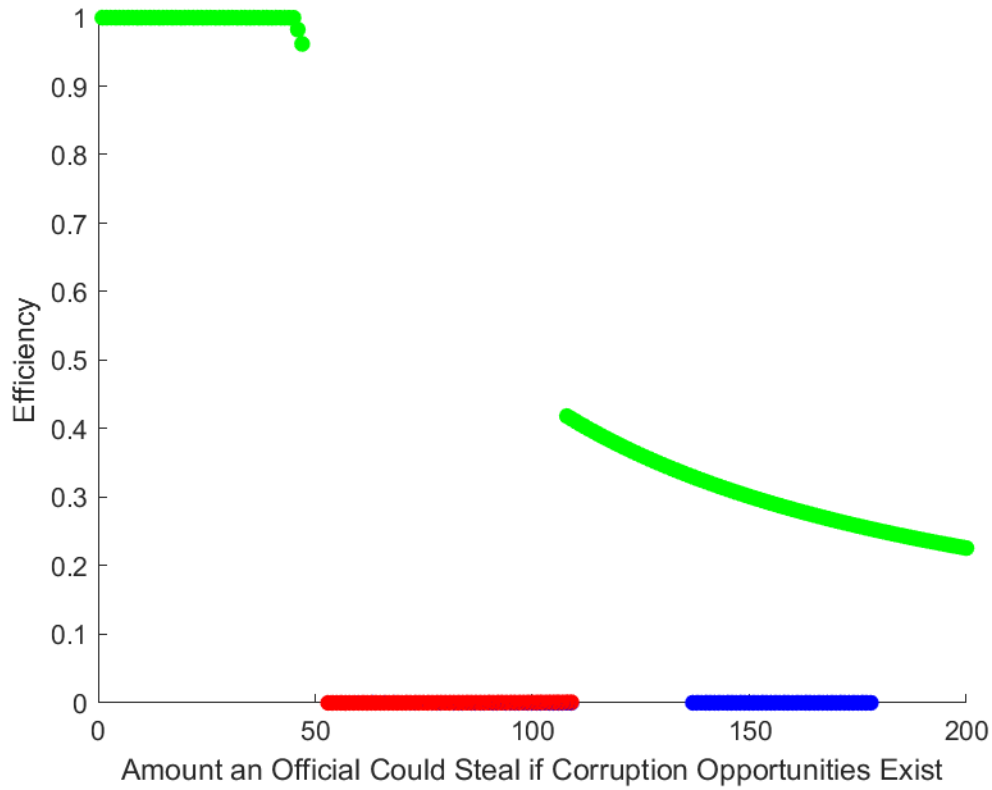

Figure 21: Efficiency as a Function of the Amount an Official Could Steal When Corruption Opportunities Exist

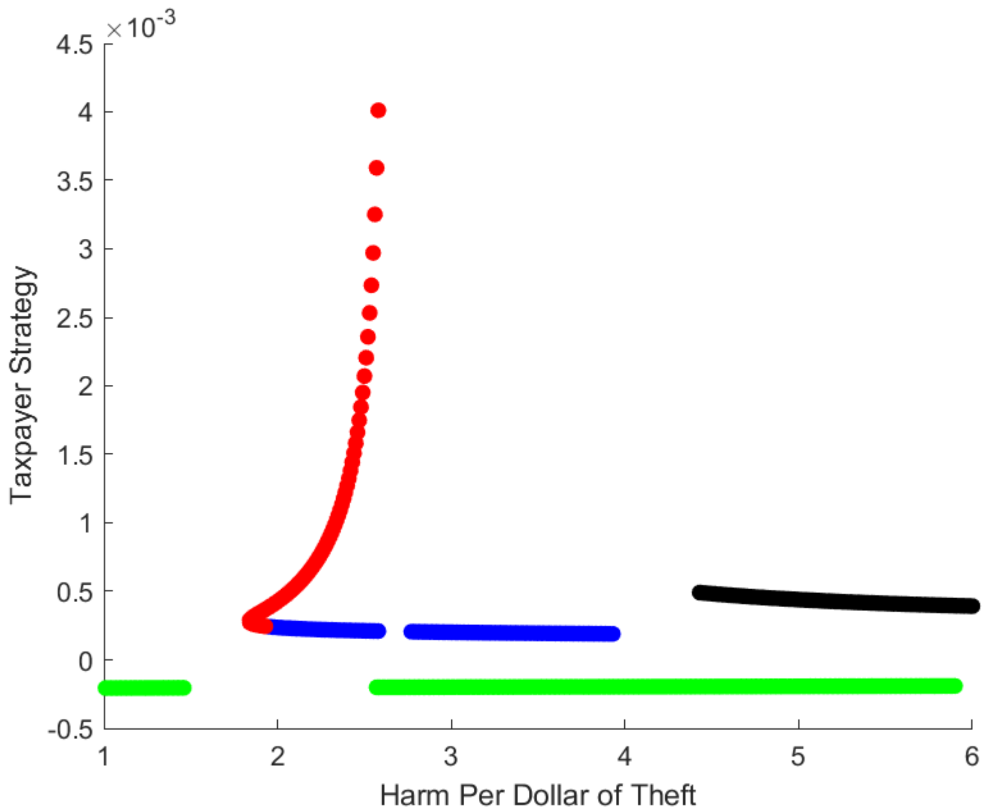

Figure 22: Taxpayer Strategies as a Function of the Harm Per Dollar of Corruption

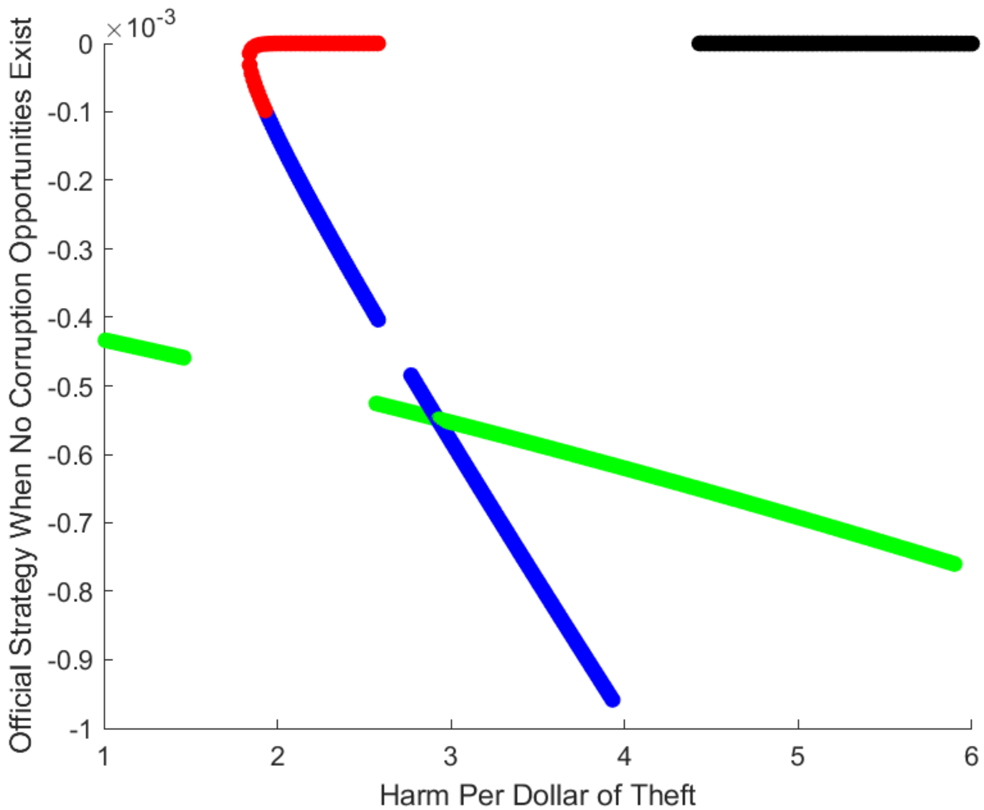

Figure 23: Official Strategies When No Corruption Opportunities Exist as a Function of the Harm Per Dollar of Corruption

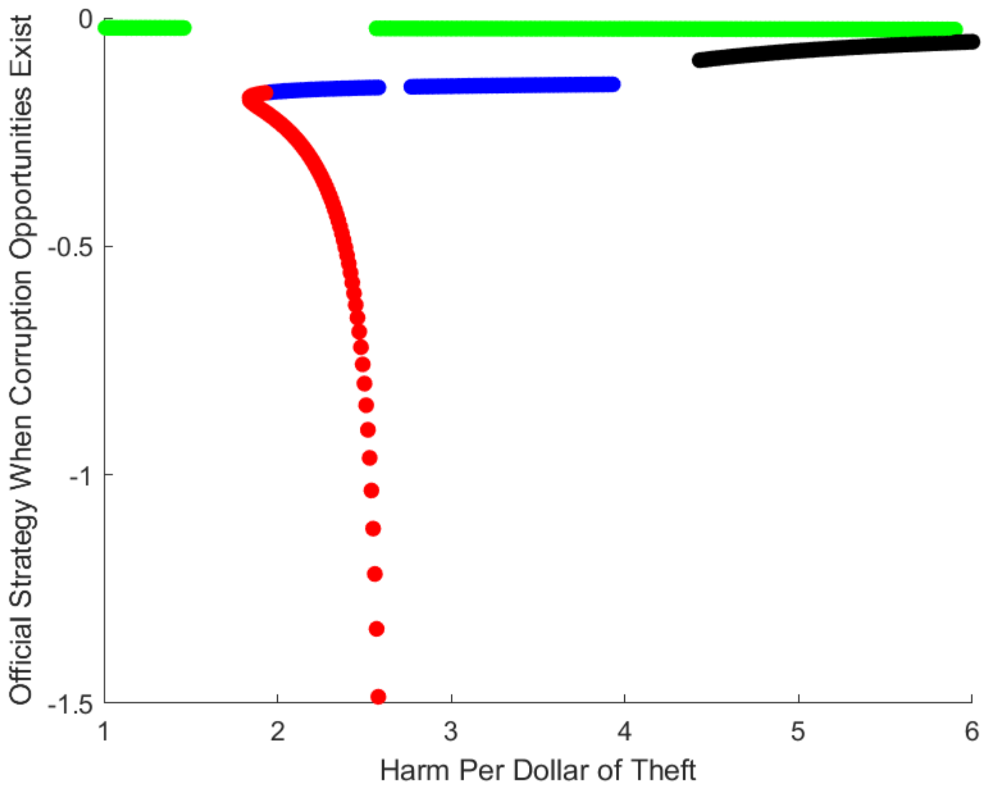

Figure 24: Official Strategies When Corruption Opportunities Exist as a Function of the Harm Per Dollar of Corruption

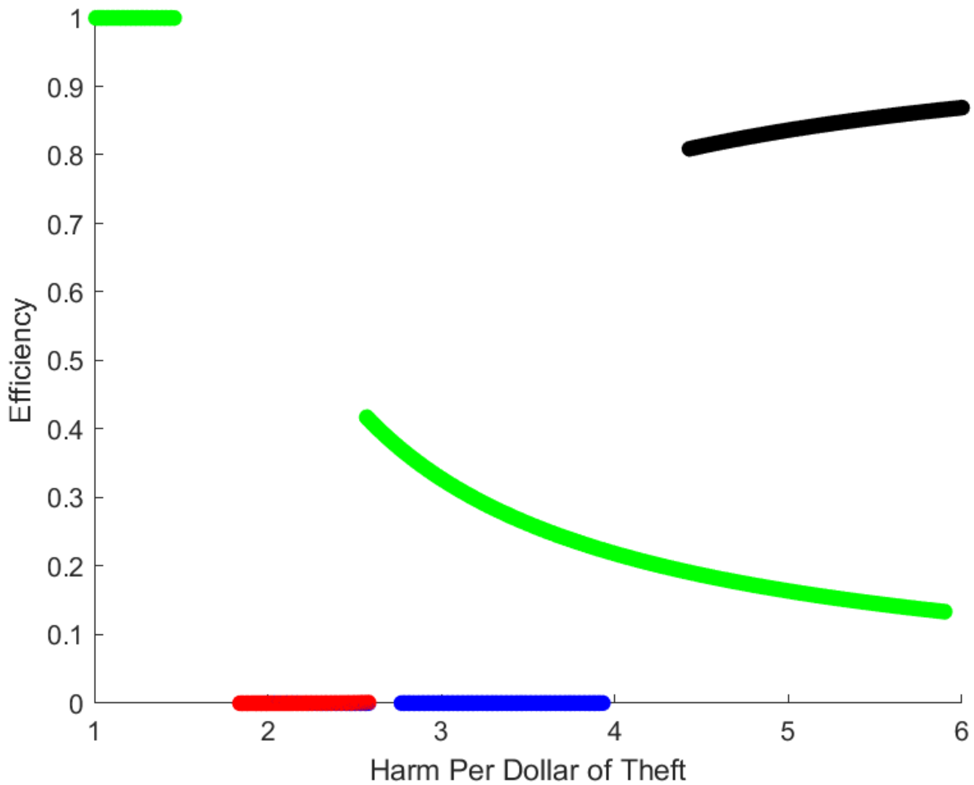

Figure 25: Efficiency as a Function of the Harm Per Dollar of Corruption

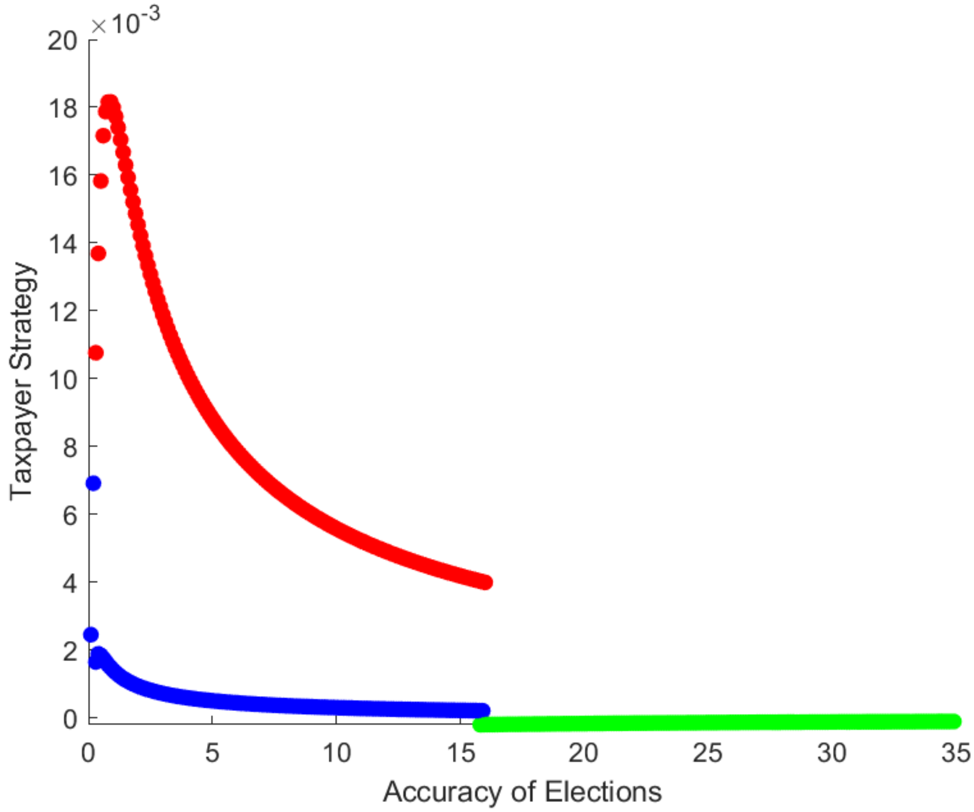

Figure 26: Taxpayer Strategies as a Function of the Accuracy of Elections

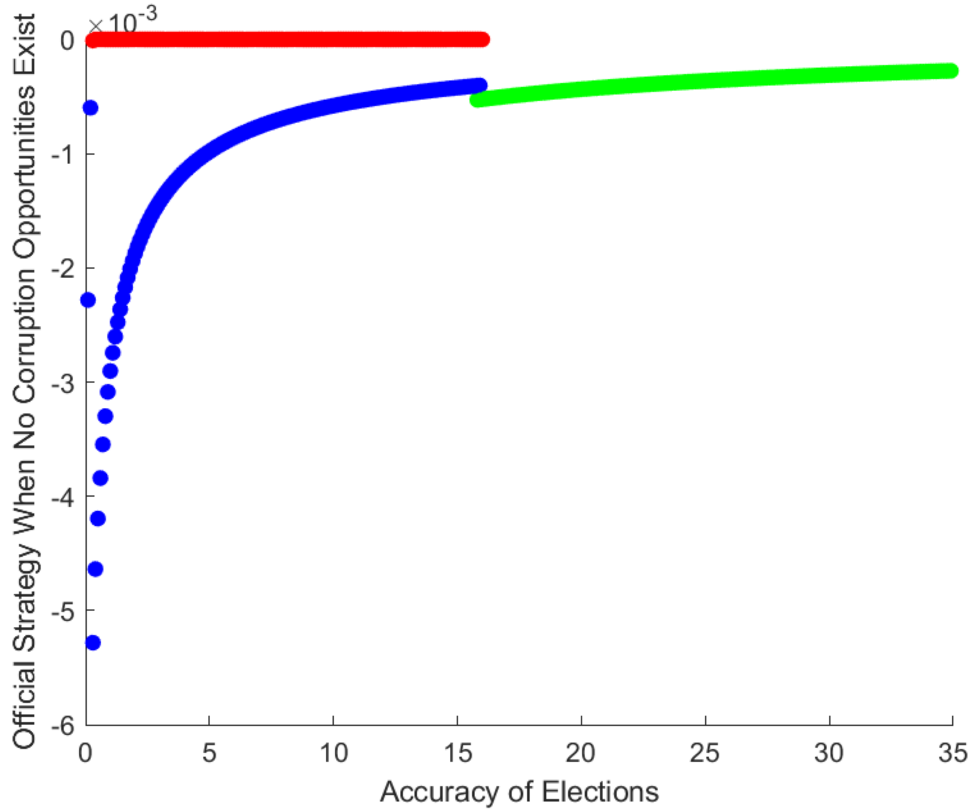

Figure 27: Official Strategies When No Corruption Opportunities Exist as a Function of the Accuracy of Elections

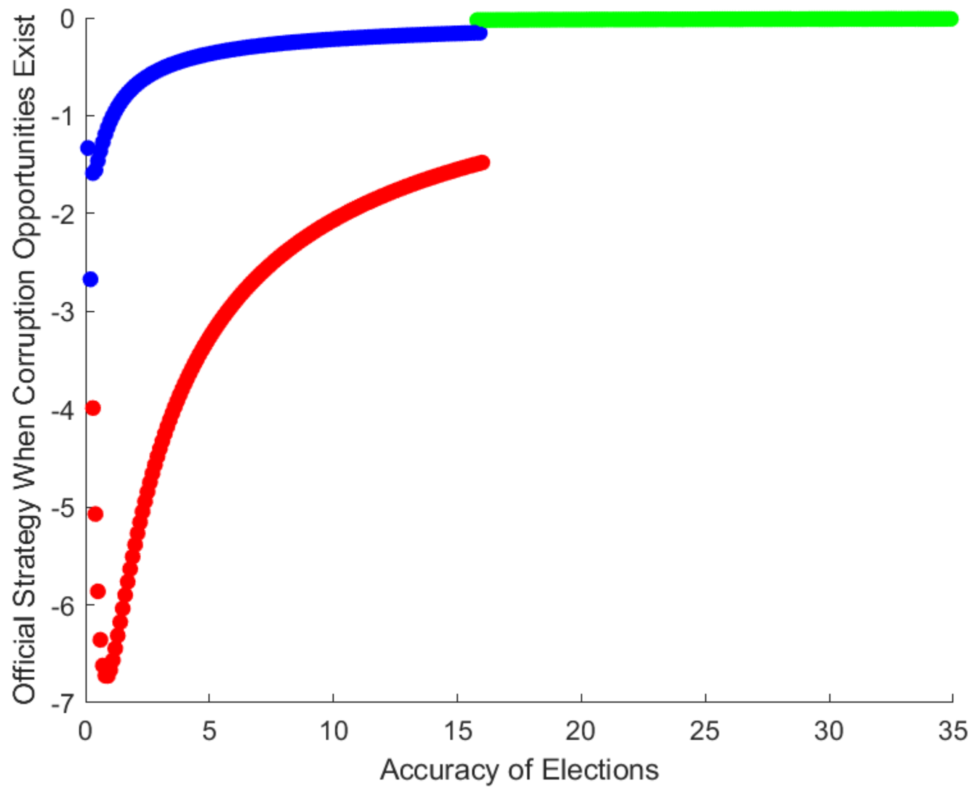

Figure 28: Official Strategies When Corruption Opportunities Exist as a Function of the Accuracy of Elections

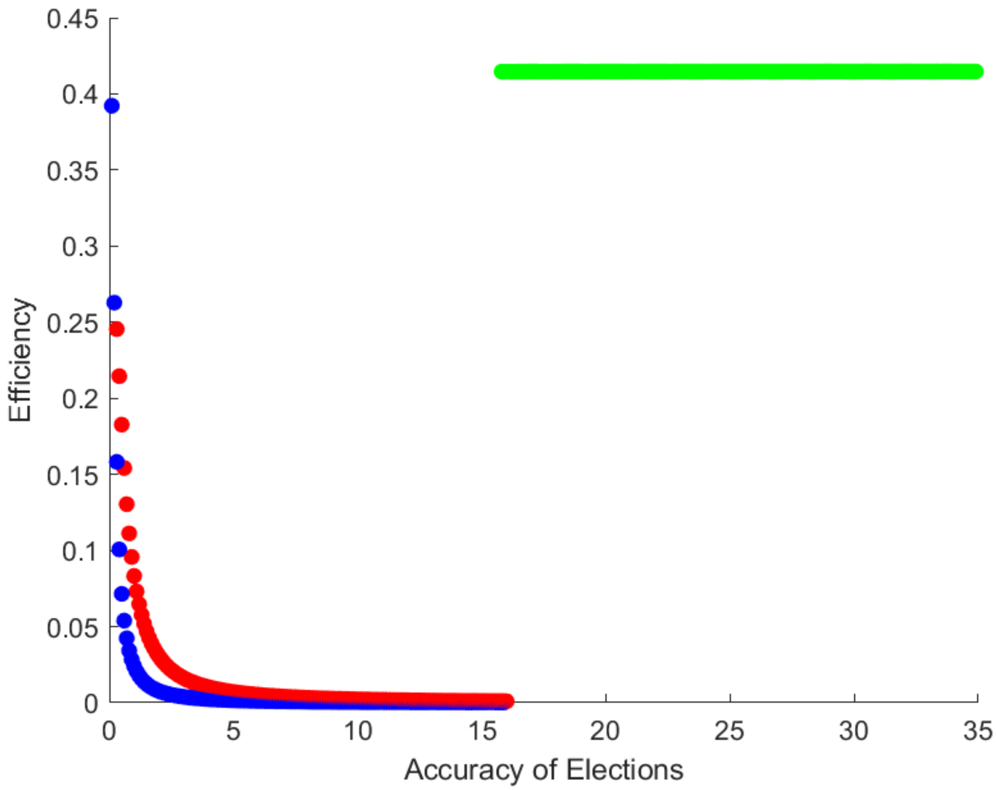

Figure 29: Efficiency as a Function of the Accuracy of Elections

I now examine the effect of increasing the number of government officials while holding the total amount that could be stolen constant. Formally, N_g is changed and s is simultaneously changed to $s = \frac{763}{N_g}$.

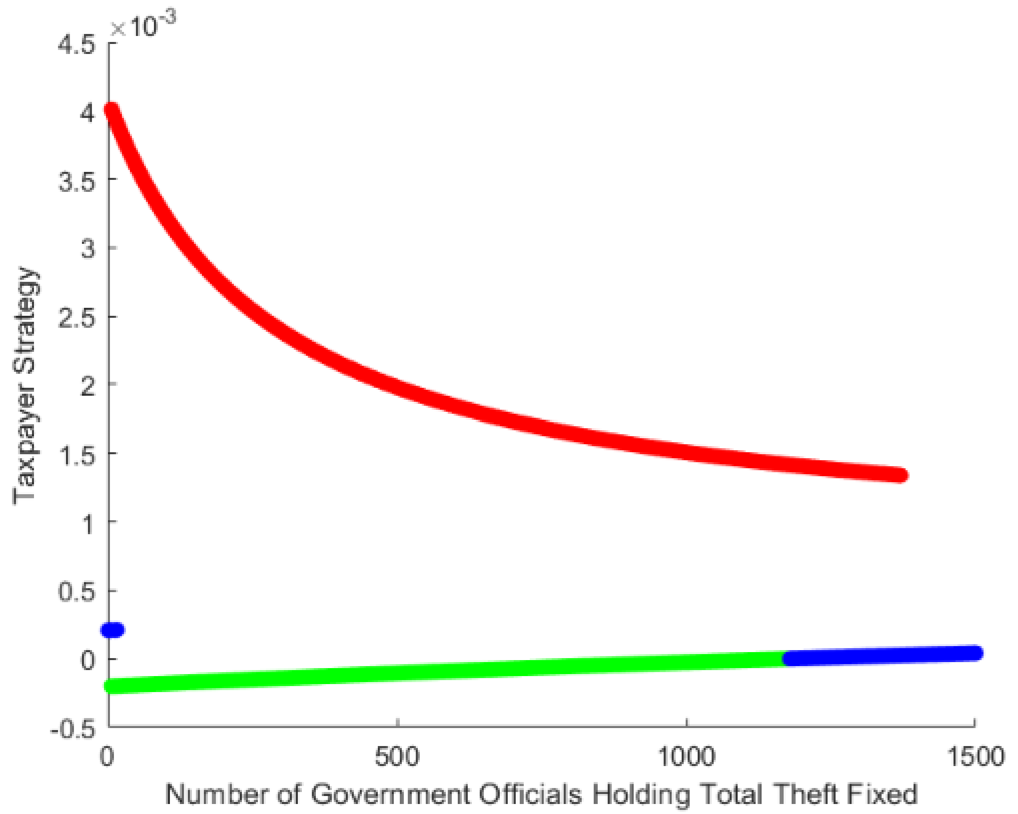

Figure 30: Taxpayer Strategies as a Function of the Number of Government Officials Holding Maximum Total Theft Constant

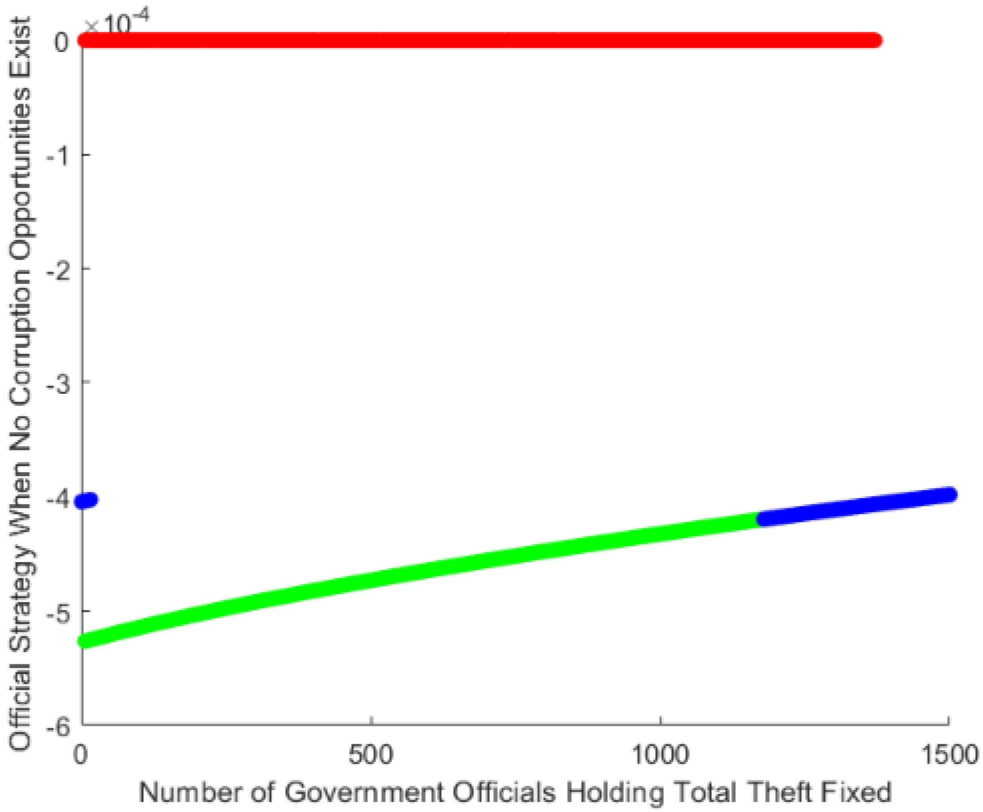

Figure 31: Official Strategies When No Corruption Opportunities Exist as a Function of the Number of Government Officials Holding Maximum Total Theft Constant

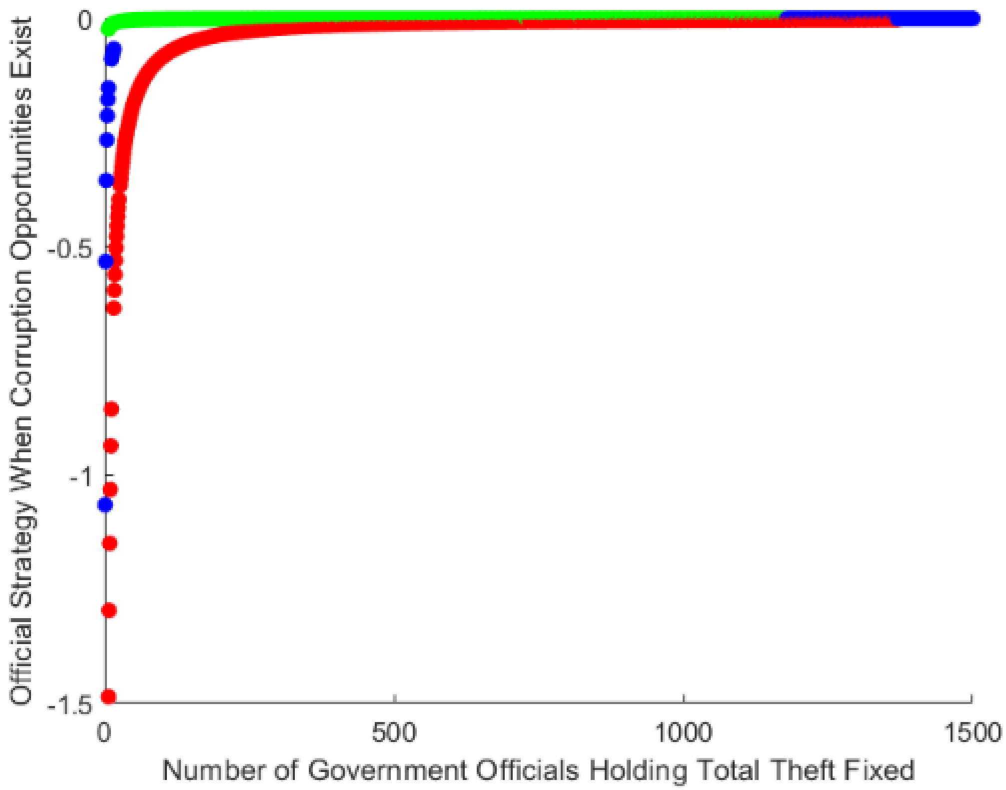

Figure 32: Official Strategies When Corruption Opportunities Exist as a Function of the Number of Government Officials Holding Maximum Total Theft Constant

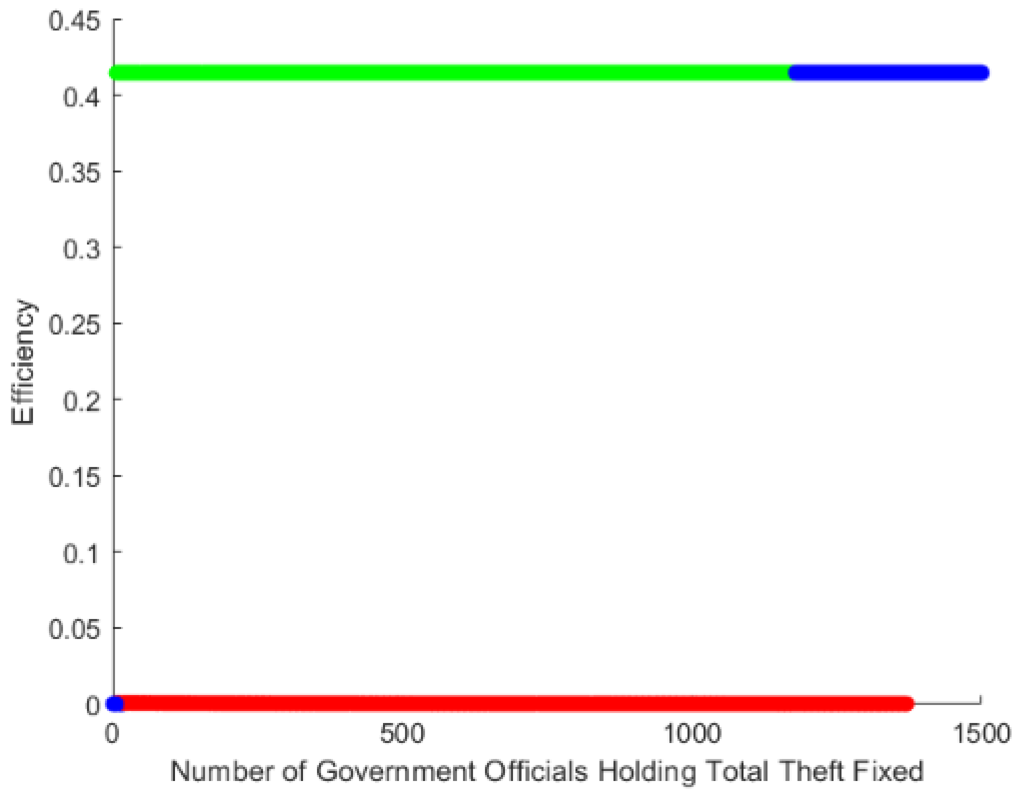

Figure 33: Efficiency as a Function of the Number of Government Officials Holding Maximum Total Theft Constant

14 Appendix 5: Instructions for Part 1

Note: the language used in the instructions differs from the language used in the paper. The the corruptible state in the paper corresponds to the state with a corrupt government in the instructions and the incorruptible state in the paper corresponds to the state with a clean government in the instructions.

This setup of this HIT is different from HITs that you might be used to completing via MTurk. You will be playing in a group together with two real people who also accepted this HIT, who are completing it at the same time. It is therefore important that you complete this HIT without interruptions. Including the time for reading these instructions, the HIT will take about 20 minutes to complete.

During the HIT, please do not close this window or leave the HIT's web pages in any other way. If you do close your browser or leave the task, you will not be able to re-enter.

In this HIT you will play a game with the same people for multiple rounds. In these rounds, you can earn Points. At the end of the HIT these Points will be converted into real money (50 Points = $1.00). You will receive a code to collect your payment via MTurk upon completion.

This game is played by three people. For each of the next 20 rounds, one participant is randomly selected to be a government official and the other two participants will be taxpayers. It is possible for different people to be selected as government officials in different rounds. There is a 50% chance the government official is clean and a 50% chance the government official is corrupt. Only the government official knows whether he or she is corrupt. Your group will decide whether to perform one audit using majority voting and whether to perform one audit using Quadratic Voting. Each audit of the government will cost each participant 2 Points. If the official is corrupt, for each time the government is not audited, the official gains 6 Points and each taxpayer loses 8 Points. If the official is not corrupt, the only change that audits cause to the number of Points players receive is due to the cost of auditing.

1. Your group will use majority voting to decide whether to perform the first audit. Each participant will vote for or against auditing the government and the majority voting will cause the government to be audited if a majority of the group votes for an audit.

2. Your group will use Quadratic Voting to determine whether to perform the second audit. Each participant can spend up to 8 Points voting for or against auditing. Each participant can only spend whole Points and may not spend fractions of Points. The number of votes each person purchases equals the square root of the number of Points that person spent. For instance, a person who spent 4 Points receives purchases the 2 votes because 2 is

the square root of 4. Quadratic Voting will cause the government to be audited if more votes were purchased for auditing than against auditing. If the vote totals are tied, Quadratic Voting will cause an audit with 50% probability. Points spent on Quadratic Voting are evenly distributed among the other participants. Each Point a player spends on Quadratic Voting results in each other player gaining half a Point.

Participants will submit decisions for majority voting and Quadratic Voting at the same time. For the first 20 rounds, at the beginning of each round, each participant receives 24 Points.

15 Appendix 6: Instructions for Part 2

The first experiment of this section is now over. A second and final experiment will follow.

Your group will now use majority voting to decide whether to have majority voting or Quadratic Voting determine the rewards it will get from the next 20 rounds. For each of the next 20 rounds, each member of your group will be given 16 Points and the chosen mechanism will determine whether one audit occurs.

16 Appendix 7: Participant Self-Reported Mechanism Choice Reasons

Self-reported reasons for choosing majority voting:

I figured majority voting would be simpler, however, I realized afterwards that the possible points would have been higher (24 vs. 16) so I now wish I would have voted for quadratic.

The calculation aspect gets removed in majority voting.

It was easier to understand.

I thought that majority voting was the most straight-forward, so went with that.

It seemed like it could get more complicated in terms of the amount of points people used to vote and perhaps decrease the overall score for everyone if people are willing to spend more.

i thought that the majority would be faster and pay out better, but it seems i was incorrect

Self-reported reasons for choosing Quadratic Voting:

I wasn't strongly leaning in either direction, but I felt that I had a little more control with quadratic voting. With majority voting, an audit was almost always picked so I couldn't use as much strategy.

I prefer the option of Quadratic Voting so I can control the points spent particularly if the official is corrupt versus clean.

Majority voting is simpler but Quadratic may offer interesting opportunities depending on how points are spent.

I chose quadratic because it makes the game more interesting and because, if only the other players had realized that if we use more votes we get more points. Alas, they did not.

17 Appendix 8: Additional QRE Calculations

$$
\begin{aligned}
&\hat{\pi}\left(s_{i,QV}; taxpayer\right)\\
=&\frac{1}{2}\left(\left(1-Q_{t,corruptible,QV}\left(s_i\right)\right)\left(-8+\alpha(-8+6)\right)+Q_{t,corruptible,QV}\left(s_i\right)\left(-2-4\alpha\right)\right)\\
&+\frac{1}{2}Q_{t,incorruptible,QV}\left(s_i\right)\left(-2-4\alpha\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|+E\left((1-\alpha)\frac{|s_o|+|s_t|}{2}\right)+\epsilon\left(s_{i,QV}\right)\\
=&\frac{1}{2}\left(\left(1-Q_{t,corruptible,QV}\left(s_{i,QV}\right)\right)\left(-8-2\alpha\right)+Q_{t,corruptible,QV}\left(s_i\right)\left(-2-4\alpha\right)\right)\\
&+\frac{1}{2}\left(Q_{t,incorruptible,QV}(s_{i,QV})(-2-4\alpha)\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|+E\left((1-\alpha)\frac{|s_{o,QV}|+|s_{t,QV}|}{2}\right)\\
&+\epsilon\left(s_{i,QV}\right)\\
=&\left(1-Q_{t,corruptible,QV}\left(s_{i,QV}\right)\right)\left(-4-\alpha\right)+Q_{t,corruptible,QV}\left(s_{i,QV}\right)\left(-1-2\alpha\right)\\
&+\left(Q_{t,incorruptible,QV}(s_{i,QV})(-1-2\alpha)\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|+E\left((1-\alpha)\frac{|s_{o,QV}|+|s_{t,QV}|}{2}\right)\\
&+\epsilon\left(s_{i,QV}\right)\\
=&-4-\alpha+3Q_{t,corruptible,QV}\left(s_{i,QV}\right)-\alpha Q_{t,corruptible,QV}\left(s_{i,QV}\right)\\
&+\left(Q_{t,incorruptible,QV}\left(s_{i,QV}\right)\left(-1-2\alpha\right)\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|+E\left((1-\alpha)\frac{|s_{o,QV}|+|s_{t,QV}|}{2}\right)\\
&+\epsilon\left(s_{i,QV}\right).
\end{aligned}
$$

$$
\begin{aligned}
&\hat{\pi}\left(s_{i,QV}; corruptible\right)\\
=&\left(1-Q_{o,QV}\left(s_{i,QV}\right)\right)\left(6-16\alpha\right)+Q_{o,QV}\left(s_{i,QV}\right)\left(-2-4\alpha\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|\\
&+E\left(\left(1-\alpha\right)\left|s_{t,QV}\right|\right)+\epsilon\left(s_{i,QV}\right)\\
=&6-16\alpha+\left(-8+12\alpha\right)Q_{o,QV}\left(s_{i,QV}\right)+\left(\alpha-1\right)\left|s_{i,QV}\right|+E\left(\left(1-\alpha\right)\left|s_{t,QV}\right|\right)+\epsilon\left(s_{i,QV}\right).
\end{aligned}
$$

$$\hat{\pi}(s_{i,QV}; incorruptible) = Q_{o,QV}\left(s_{i,QV}\right)\left(-2-4\alpha\right) + \left(\alpha-1\right)\left|s_{i,QV}\right| + E\left(\left(1-\alpha\right)\left|s_{t,QV}\right|\right) + \epsilon\left(s_{i,QV}\right).$$

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19 Description of Supplementary Material

These files contain the data and code that can be used to reproduce results. These files are available online and not part of the pdf.