Detection and Deterrence in the Economics of Corruption: a Game Theoretic Analysis and some Experimental Evidence

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Abstract

This thesis contributes to our understanding of corruption deterrence for a specific class of game-theoretic corruption models, in which we assume that inspection of corrupt behaviour happens through randomisation. Three models are explored theoretically and one experimentally. All models are three-player variations of the inspection game, and their typically unusual insights result from mixed-strategy equilibrium solutions. The first model examines an inspection game between an inspector and two potentially collaborating offenders (a corrupt client and an official). Strikingly, its comparative statics suggest that higher penalties on corrupt clients increase the probability of corruption in the mixed equilibrium. The second model compares two states of the world, one where corrupt officials merely reject bribes (if they do not accept them), and one where corrupt officials report bribes (the latter leading to definite punishment of clients). The surprising result here is that, when officials prefer to report bribes (instead of merely rejecting them), the probability of corruption is again higher in equilibrium. The third model takes into account three different types of officials, a reporting type, a rejecting type, and a corruptible type. Its results show that e.g. an increase in the proportion of the reporting type increases the probability of corruption. To compare our theoretical results with data, we test a simple version of this game in the laboratory. Results of this pilot experiment were mixed, suggesting that three-player mixed-equilibrium behaviour is only in part and only qualitatively true on the aggregate, but not quantitatively or for individual play. An epilogue describes developments of a new, much improved experimental design and software, intended for future experiments.

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This thesis represents not only my work of typing all these words, the endless research, the many hours and days of staring at a screen, the drawing of graphs, and the working out of equations. It has fundamentally changed my life. I owe to everybody involved where I am now, all the opportunities and adventures, all the doors that have opened. I owe to this endeavour an immense amount of learning and the faint hope that I am a better and happier person because of it.

First and foremost I wish to thank John Bone, my supervisor, for his patience, understanding, support, and friendship (all of these by far outstripped his occasional reluctance to put up with my relentless efforts of illustrating my thickness). In many ways he is one of the wisest people I have come across. I am also greatly indebted (both metaphorically and literally) to my parents, without whom none of this would have been possible. Equal thanks go to Linda and Christopher. I'll be thankful until the end. I am especially thankful to Naomi for her love and support. The last year, particularly the months before submission, would have been so much less fun without you (and probably a bit shorter too). I am deeply grateful to Daniel Molto, Richard McManus, Colin von Negenborn, Elisabeth Does, Caroline Schimanski, Vangelis Chiotis, and Beth Kahn for the many helpful discussions over the years. I want to thank Alistair Clark, Daniel Gustafsson, Gabriel Williams, Steven Hirschler, Sophie Dentzer, Magnus Niklasson, Juliana Bidadanure, Elisabeth Thorson, all of the previous lot, and all of those I did not yet mention for their friendship and support. I am especially grateful to John Hey for his generous help, encouragement, and friendship, as well as for the great experience of teaching Microeconomics for him - he certainly is the most charming professor I know. I am very grateful to Matt Matravers for helping out whenever things got tricky. I thank Andrew Pickering, Manfred Holler, Tim Stanton, Mark Koyama, Mozaffar Quizilbash, Neil Carter, Paul Schweinzer, Nicole Lindstrom, Johann Lambsdorff, several anonymous referees, as well as many other academics I have met at conferences and summer schools over the years. All of them have helped me greatly in their own ways. Special thanks go to the Ronald Coase Institute and its founders, as well as to Jason Shachat. I am grateful to Ajit Mishra and Giacomo De Luca for their thoughtful comments and for the effort of reading this document. I thank the School of Politics, Economics and Philosophy and related departments for their help and support. Finally, I wish to thank Sam Schmitt and Mark Bailey for their understanding and generosity in letting me take time off from teaching at St Paul's School, when, days before my deadline, my extension was pulled away from under my feet.

Declaration

Some of the motivational arguments in the introduction of this thesis have been researched and developed in my Master's dissertation.

My supervisor, John Bone, has been both very patient and supportive in guiding my way as I developed the model for chapter 2 during many very helpful discussions, but all of the written work is mine only. The paper has been published in Review of Law and Economics in 2014. An earlier version of this paper has previously appeared as a DERS departmental working/discussion paper at the University of York. The version as it appears in this thesis has been amended to be consistent with the notation and terminology of the rest of the thesis.

In addition to further guidance, John Bone has also helped me solve the comparative aspect between the two variants in chapter 3. My analysis contained a mathematical error, which we tracked down in a joint discussion session. This aspect of the chapter is rather crucial, for which reason we declare joint authorship. Apart from changes to some introductory paragraphs at the proofreading stage of journal submission, which were made jointly with John Bone, the rest of the work was written by myself only. The paper, in its original form, has been accepted for publication in a special issue on corruption of the Journal of Interdisciplinary Economics (JIE), forthcoming in 2014. The paper, as it appears in this thesis, is a development of the JIE paper. Apart from the adaptation of notation and terminology for conformity with the rest of the thesis, some substance has been added. The paper now includes a more detailed discussion of other types of equilibria as well as a simulation of these with some (in relative terms) plausible data.

Chapter 4 is joint work with John Bone. While all written work, all the algebra and the simulations are my own work, John Bone has had some considerable input as regards the structure of the paper, the direction of its argument, and its model's visual representations.

The experimental work in chapter 5 was oft-discussed with John Bone and always planned to be joint work. While we both had developed potential models to be experimentally tested, we settled for a model I had developed. The experimental design was always discussed jointly, but experimental programming was my work only. John Bone wrote the final draft of the instructions in paper form, as it was handed out to participants of the experiment. When running the experiment, I took the part of controlling the server computer, while John assumed the role of experimental instructor. Evaluation of the data as well as writing up has all been my own work only.

Chapter 6 has been my own work only. Its content attempts to summarise the programming efforts that went towards an experiment, which was to follow the work in chapter 5. It was at first planned to appear in this thesis, but when another author joined it had grown in size and direction and is now planned to be run in the Autumn term 2014. All of the programming work has been my own, but some of the design decisions of its latest version where the result of discussions with John Bone and Jason Shachat. Some of the theoretical underpinnings that are only outlined in this chapter resulted from those same discussions.

Chapters 2, 3, 4 and 5 have been presented at various conferences throughout 2012-2014 and (ESA, PCS, EPCS, EALE, RES, PolEcon etc.). I am very thankful for numerous comments from those, who attended my presentations.

Further to the above, I, Dominic E. Spengler, declare that this thesis titled, "Detection and Deterrence in the Economics of Corruption: a Game Theoretic Analysis and some Experimental Evidence" and the work presented in it are my own. I confirm that:

- This work was done wholly while in candidature for a research degree at the University of York.
- Neither the thesis nor the original work contained therein has been submitted to this or any other institution for a degree.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, and the attributions listed above, this thesis is entirely my own work.
- I have acknowledged all main sources of help.

Chapter 1

Introduction

Today, most anti-corruption efforts (on the part of anti-corruption agencies, multinational corporations, supranational institutions and nation states) are informed by or the result of corruption studies in political economy, the vast majority of which attest to negative effects of corruption. Over the past few decades, a global anti-corruption consensus has emerged (Krastev, 2004), which portrays corruption as one of the most devastating obstacles to economic development. Accepting economic development as desirable, there is thus some serious motivation to minimise corruption, especially in some badly effected developing countries. The arguments brought forward are made on the basis different methodologies, ranging from historical arguments, to arguments about political power relations and about systems of government, to econometric analyses of causes and consequences of corruption, to microeconomic/game-theoretic models of corruption. Much of the point of this literature is to understand corruption in order to defeat it (at least where it is understood as a public bad)[1], and so its theories are used to derive anti-corruption strategies and policies. Nearly all of these theories of corruption are based on a fairly narrow set of assumptions. Ranging from loosely defined assumptions (in historical and political arguments), to formal models in economics, the standard in the corruption literature continues to be based on either the Homo Œconomicus/Rational Choice set of assumptions, as far as behaviour is concerned, and an even narrower set of assumptions, predominantly based on Gary Becker's (1968) seminal work on the economics of crime, as far as incentives are concerned.

To give an example of loosely defined assumptions, consider the following quote from (Jain, 2001, p.72):

[1] Méon & Weill (2010) and Dreher & Gassebner (2011) are some recent examples of arguments, which suggest that corruption may "grease the wheels".

> The level of corruption in a country with an ineffective legal system may begin to rise in response to, say, an external shock. The political elite may find the increased income from corruption irresistible. Once corrupted, the elite will attempt to reduce the effectiveness of the legal and judicial systems through manipulation of resource allocation and appointments to key positions. Reduced resources will make it difficult for the legal system to combat corruption, thus allowing corruption to spread even more.

The argument follows a vague, but comprehensible economic logic. Although other authors writing this type of literature may go into further detail about the relations between, for example, shock and corruption incentives, this sort of argument lacks the definition and likely the understanding of the underlying assumptions (behavioural or otherwise). So, if such theories and corresponding arguments lack precision with regards to their underlying assumptions, anti-corruption strategies and policy implications that follow from this type of theory must lack the same precision.

The assumptions made on the other side of the spectrum are much more rigorous. More formal microeconomic/game-theoretic models of corruption adhere to the principle of methodological individualism and because of their strictly logical nature they become testable. The agents in such models have defined sets of actions available to them, their incentives are structured by payoff parameters whose relative sizes are unambiguously defined, and the number and types of agents that feature in those models as well as their behaviour are defined. Given such models, predictions can be made about exogenous changes in the parameters in those models. Programming experimental computer software, which captures the exact structure of such games, allows experimenters to observe when human beings conform and when they deviate from the theoretical predictions. Indeed various (anti-) corruption models have been tested in economic experiments. Looking more closely at both the theoretical and the experimental literature of corruption in economics, it appears, however, that the vast majority of it makes the same assumptions about the incentives and the behaviour of the modelled agents. Much of this literature is reviewed in the work presented in this thesis (in particular chapter 5). So, while in this literature the assumptions about incentives and behaviour are clearly defined, they are fairly homogenous, as will be discussed shortly.

This (deliberately brief and by no means exhaustive) assessment of the current state of affairs of global anti-corruption efforts reveals a pressing question, which became the motivation for this research project. If the combined anti-corruption efforts are based on more or less the same set of assumptions about the economic incentives and the behaviour of corrupt agents, whether these are strictly defined, or worse, if they are ambiguous, those assumptions had better be right, but are they? With perhaps a little too much ambition, the early beginnings of the research for this thesis explored several theories of (bounded) rationality and a range of psychological theories such as cognitive-dissonance theory, social identity theory and others. Several ideas were explored and later abandoned. One example was a project in which we modelled corruption based on herding and group conformity by using information cascades. Others included several ideas for experimental work based on the nudging principles by Thaler & Sunstein (2008). Several other attempted and abandoned projects could be added to this list. In the end it became necessary to set the focus on a very narrow set of assumptions that would be questioned and the results of changes thereof analysed in this thesis. Part of this implied that all the work presented in this thesis does now not deviate from the traditional rationality axioms, although this was precisely what motivated the research project in the first place. Instead, a much more humble observation became the foundation for every chapter in this thesis.

As mentioned above, Becker's work on the economics of crime and the assumptions he made in it has been very influential in the study of corruption. Without providing more detail, one could argue that the contribution of this thesis is to change one of Becker's crucial but radical assumptions and to study the effects of this in the context of some corruption games. It follows an explanation of this.

In a decision theoretic context Becker suggested that the occurrence of crime depend on two factors, the correct combination of which would lead to optimal crime deterrence. He found that, if regulators could control both the probability of detection and the size of the penalty for a given crime, then the optimal policy would be to minimise the probability of detection and to maximise the size of the penalty. He argued that, if penalties were expressed as fines, then these would bring money to the government, while in contrast detection would be costly, because an increase in its probability could only be achieved through the employment of more inspecting officers. The model seems intuitive, but it is not unproblematic. An obvious problem is that from a moral point of view it seems disproportionate to punish petty crimes with a maximum penalty in order to keep deterrence optimal. Another problem lies with the meaning of maximal punishment. People have different amounts of wealth and their wealth is limited. This suggests that a) people can only be penalised to the limit of their wealth and b) either that different people must be punished differently for the same crime or that to some people the *same* punishment is much more meaningful than to others. Both of these problems suggest that the penalty must be limited and therefore the probability of detection higher and more costly. The cost-optimum of deterrence might therefore be at a rate of offence that is greater than zero.

Despite these problems Becker's model has been widely accepted and utilised for many other models in the economics of crime literature. As will be discussed in more detail in the following chapters, most theoretical work on corruption is based on this model. There is, however, another, potentially more grave problem with Becker's crime model. It presupposes that the probability of detection is exogenous, meaning that it is externally fixed and does not depend on the decision of an inspector. Tsebelis (1989) showed that Becker's results are only true in the decision-theoretic context, in which he obtained them. In a game-theoretic environment, where the probability of detection depends on the decision of an inspector, the relation between size of penalty and probability of detection remains the same, but it leads to an undesired side-effect. For maximising the fine on offence does not only mean that there is a minimal need for detection; it also tells inspectors, who are employed to provide this low level of inspection that their inspection effort, so long as it is exerted, is fruitless. Only as long as the probability of inspection is above a certain threshold will offenders be deterred. But if crime is deterred, inspectors will not find crime. If we assumed this to be the case, a criminal inspector's job specification is thus not to find crime, but to try to find it where there is not any, *because* she is trying to find it. Tsebelis was not the first to see this problem. This insight was borrowed from the so-called inspection game, which has been around since the early 1960s. Some of this literature will be reviewed below and much of it is reviewed in the papers presented in this thesis. Tsebelis contribution was to apply this insight to the economics of crime. He constructed a simple game-theoretic model of crime, where the probability of detection, i.e. the decision of an inspector to inspect or not, is endogenous.

Here is how Tsebelis' inspection game works. Consider a game with one inspector and one offender. If at a given size of penalty the inspector's inspection effort exceeds a certain threshold there will be no crime, and so long as the inspector's incentives are such that success and rewards are based on finding and prosecuting crime, she will then be inclined not to inspect. If one expects there to be no crime, there is no point in trying to find some. The inspector will thus only inspect so long as she can reasonably expect to find crime with some probability. This effect goes both ways. If the inspection effort drops below a certain threshold, the offender will offend, because at a given (high) size of penalty, crime has just become profitable. In game-theoretic terms there is thus no equilibrium in pure strategies. If the probability of inspection is below a certain threshold, crime will soar, causing inspectors to want to inspect, causing in turn offenders not to want to offend and so on and so forth. The equilibrium is, instead, in mixed strategies in this game. Only if the inspector inspects with the critical probability at the threshold, where the offender is indifferent between offending and not offending, can there be an equilibrium; and that is, at the critical probability of offence, at which the inspector is indifferent between inspecting and not inspecting. As will be shown later is typical for inspection games, this game has a unique mixed-strategy Nash equilibrium. This implies the following logic. Increasing the penalty on the offender will cause her to no longer be indifferent (i.e. to prefer not to offend). Thus, to move back into equilibrium, the inspector has to follow suit by reducing the probability of inspecting. Contrarily, the offender's probability mix does not have to change, as nothing in the payoff function of the inspector changes after a penalty increase. So, accepting the assumption that the probability of inspection depends on the decision of an inspector, we must grant that Becker's normative thought of maximising the size of penalty will not only reduce the *need* for a lower probability of detection, but it will necessarily reduce the probability of detection itself, while the amount of crime remains unaffected in equilibrium. A range of literature has emerged around Tsebelis' application of the inspection game. Common to all of it is the way in which offence is modelled. All models assume either a single offender or multiple offenders that, each committing separate and independent offences, are met with an inspector. This suggests that crime is taken to be a non-collaborative act.

The thought that the probability with which crime gets detected depends on someone's doing, i.e. on the inspection effort of an inspector, is not unusual. It is very intuitive. Somehow, however, this insight had not previously been applied to the corruption literature. Our insight was that corruption, like any other form of crime that is typically countered with penalties in case of detection, should be modelled like an inspection game, too. This has in some sense become the decisive feature of this thesis. So, unlike previous work in the inspection game literature, we wanted to model corruption as a crime that must involve the collaboration of at least two people. A bribe alone might be punishable, but it ought to be accepted and met with some form of quid pro quo in order to fit the definition of corruption with which we work.[2] The nature and the direction of bribe and reciprocation may differ[3], but the fundamental feature of the offence being a collaborative one is shared by all forms of corruption.

To provide a foundation for the rest of the thesis, the following describes such a model of corruption as a collaborative offence with endogenous detection, i.e. where the likelihood

[2]Defining corruption is a notoriously controversial issue, which we will not discuss here. Heidenheimer & Johnston (2002) considers various definitions and their limitations. Corruption is most commonly described as the abuse of public power for private benefit. Concretely, we define corruption as a collaborative crime between a corrupt client and an official, whereby a bribe alone does not complete the act of corruption, but only the compound act of reciprocated bribery does. We maintain this definition for the rest of this thesis.

[3]Both bribes and quid pro quos may be offered or demanded. A bribe can be a monetary payoff or some other favour and a quid pro quo might be a public good given in return for a bribe or given as some form of obligation to clients or relatives. Many examples are plausible; one would be a firm who bribe in order to obtain a license; another would be a foreign national aiming to obtain a working permit etc.

of detection depends on the actions of an inspector. A fleshed out and slightly altered version of this is the substance of chapter 2 and several, more eventful variations of this model form the basis of chapters 3-5. Some more details about the contents of each chapter are mentioned below.

Our basic model is a three-player game with imperfect information, in which a client can offer or not offer a bribe to a public official – who in turn can either accept or reject the bribe – and an inspector, who can either inspect or not inspect whether there has been an offence. The two possible offences are either an attempted but rejected bribe or an accepted and thus reciprocated bribe. So, unlike other work around the inspection game, in this model there are two offenders between which the corrupt transaction might take place, and unlike other work in the theoretical literature on corruption there is a separate agent, the inspector, whose decision represents the probability with which the two offenders might be found out about, if ever they offend.[4]

Apart from some less interesting pure-strategy equilibria where corruption takes place despite inspection (simply because penalties are set in such a way that bribing and accepting/reciprocating pays off despite being captured and penalised), we can configure parameters such that we obtain either a partially mixed equilibrium or a completely mixed equilibrium in each of the games presented in this thesis.[5] The partially mixed equilibrium comes about when parameters are set such that the client mixes between her respective strategies to keep the inspector indifferent, while the inspector mixes between her respective strategies to keep the client indifferent, all while the official accepts/reciprocates for sure, because she strictly prefers to do so at the probability of inspection which makes the client "only" indifferent. One way of thinking about this equilibrium is that, where the probability of accepting/reciprocating is equal to one, this effectively means that the official becomes a null-agent, and so the game reduces to Tsebelis' inspection game. For the same reason we observe the same comparative statics as Tsebelis. The completely mixed equilibrium comes about when setting parameters such that all three players mix with their respective strategies as to make each other indifferent. This implies that the probability of inspection at which the client is indifferent is in fact equal to the probability of inspection which makes the official indifferent. All this will be discussed and analysed in detail in each of the papers presented in this thesis.

Given what we have discussed so far, it is now important to be clear about the kinds of assumptions we are making about the behaviour and the incentives of the agents in

[4]Other papers that model detection endogenously are discussed in the related literature sections of the papers presented in this thesis, but they do so differently. As far as I know there are no other papers that follow this procedure.

[5]The exception here is chapter 4, which contains a section in which we make the bribe itself endogenous. In this version of the game there is only one equilibrium.

our model. It is all well and good to stipulate that there are some dominant models in the literature whose assumptions we change for allegedly more intuitive ones. The real issue is, however, to provide some justification for why we believe that our assumptions are the "right" kinds of assumptions. Given that we have already decided to remain, at least in our theoretical work, within the realm of rational, self-interested, utility maximising behaviour, it is fairly straightforward to make plausible assumptions about the incentives of the offenders in our game. In line with Becker's story, we assume that offering bribes and accepting/reciprocating has a positive payoff, while penalties that are incurred if inspected effect the expected payoff negatively, such that, if the combination of the probability of detection and the size of the penalty outweighs the benefit from committing the respective offences, no offence will be committed and vice versa.

Deciding about the incentives of the inspector is not so straightforward, however. Before considering the merits of different assumptions about the nature of the inspector in our game, we state the assumptions that we do make, including a rationale that makes them at least *prima facie* plausible. So, apart from anything else, for all the models in this thesis we make the following assumptions:

1. Inspecting has a strictly higher payoff than not inspecting if there has been a bribe than if there hasn't been one.
2. Inspecting has a strictly higher payoff if there has been an accepted/reciprocated bribe, than it does if there has been a rejected/unreciprocated bribe.
3. Not inspecting has a strictly better payoff than inspecting, if there has not been a bribe.
4. The inspector has perfect technology, so an inspection will reveal any committed crime for sure.
5. Being inspected whenever a crime was committed always leads to penalisation.

In our model these are the exact opposites to the offenders' payoffs, who both prefer to offend if there is no inspection, and prefer not to offend if there is inspection. These incentives are typical for the inspection game, and we adopt them specifically in relation to the literature that followed on from Tsebelis' (1989) introduction of the inspection game to the economics of crime literature.[6] The reasoning behind them is intuitive. The inspector, employed by some government agency, is paid a salary for performing her

[6]Bianco et al. (1990), for example, provide some early responses to Tsebelis' work, in which the one-shot nature and the two-person restriction of Tsebelis' game is criticised – and as a result Tsebelis' work is strengthened – but the inspector's incentives are not scrutinised.

duty, which in this case consists of inspecting transactions between clients and public officials. Perusing transactions for corrupt activity requires effort, but capturing offenders *in flagranti* is rewarded/honourable/increases the likelihood of a future promotion. So, if there is no offence, the inspector prefers to shirk and if there is an offence, she prefers to inspect.

John Bone, whom I am indebted to for this and many other helpful discussions, points out that this setup is not as straightforward as it might look at first glance. Suppose the client bribes and the official accepts/reciprocates, but the inspector does not inspect. In this case, the client and official supposedly got away with their corrupt activity, and since it has not been inspected, nobody knows that it has occurred (apart from the perpetrators – though they have good reason to keep the corrupt act private information). Then, who is to make this inspector better off for shirking (which he will do in the false belief that no corruption has taken place), if not only the game theorist? In response to Bone's qualms one might say that the answer lies presumably in defending the concept of a (mixed-strategy) Nash equilibrium. Only if we philosophically accept the mixed-strategy Nash equilibrium as a solution, can we solve such types of the inspection game. And if we do, then the situation where the offenders offend, while the inspector does not inspect, are not Nash equilibrium outcomes. The fact that there can only be "pure" outcomes following mixed equilibrium play, so that the inspector would be worse off for shirking if there was an offence (because, trivially, a mixed-strategy equilibrium can only exist in form of probabilities), is then not an issue. In a game with a unique mixed-strategy equilibrium any outcome must by definition be undesirable for someone.

There are of course other ways of how the inspector could be interpreted. Here is an alternative. There are three players in this game, a client, an official and society. Within this framework, there is no government agency that sets the penalties or the incentives for the inspector, but rather society *is* both the inspector and those government agencies. Its task is then to inspect whether some of its members – here the client and the official – have committed a crime and it sets the penalties for crimes committed. If this were the case, we return at least in part to Becker's framework. So, society would set maximal penalties such that costly inspection efforts can be minimal. At this point we would re-enter the debate that was initiated by Tsebelis: game-theoretic problems should not be solved in a decision theoretic framework. This has been discussed at some length in Tsebelis (1989), Bianco et al. (1990), Tullock (1995), Tsebelis (1995) and other papers.

In awareness of these points, we have settled for the set of assumptions about the nature and the incentives of the inspector that were outlined above. There is, however, another implicit assumption which we adopt from the inspection game literature. It is assumed that the inspector's payoffs are independent of the other players' payoffs. So, for example an increase in the penalty of an offender does nothing to the absolute payoffs of the inspector. Of course, an increase in such a penalty might indirectly effect the probability with which the inspector has to mix between her pure strategies in order to keep the offender or offenders indifferent (in the event that we are considering a mixed-strategy equilibrium). But the point here is a different one. To illustrate it, consider a version of Tsebelis' inspection game, in which an increase in the penalty on the offender simultaneously increases the inspector's reward for successful inspection in proportional terms. Note that the game remains the same in principle; opposing payoffs imply a unique mixed-strategy Nash equilibrium, the crucial feature of which is that both players are indifferent between their respective actions, given the mixture each player plays. We will not prove existence of this equilibrium here, but instead reason through it without mathematical illustration, supposing that everybody is indifferent. So, assuming a marginal increase in the offender's penalty, the offender would now strictly prefer not to offend, causing the inspector to strictly prefer not to inspect. Simultaneously, the increase in the inspector's reward for successful inspection means that the inspector would want to inspect for sure, causing the offender to prefer not to offend. What brings both players back to equilibrium is thus not only a decrease in the probability of inspection (to the point where the offender is indifferent again), but also a decrease in the probability of an offence (to the point where the inspector is indifferent again). So, a small and by no means unreasonable change in the implicit assumptions of the inspection game might have quite radical implications. The important point of Tsebelis' contribution (and that of much subsequent literature that added to the same canon) relied in large part on the result that increased penalties *do not* decrease crime rates. Yet we find that they do if only we make a small and plausible change in the assumptions about incentives. Nevertheless, to remain in keeping with this literature, we maintain the independence of the inspector's and offenders' payoffs in all of the models presented in this thesis. The only exception is here chapter 5 (an experimental paper), in which we do assume that payoffs are interdependent. So, for simplicity of the theoretical model, the inspector confiscates the penalties from the client and official respectively, if ever she finds that they have offended. But in order to obtain the same comparative statics effects as in the previous theoretical papers (and to stay in line with the inspection game literature), we treat an exogenous change in the penalty parameters as an externality on the respective offender, and not as a change in the size of the transfer between agents. So, for example, an increase in the penalty on the client (for offering a bribe) has no effect on the amount that could be confiscated by the inspector in our setup. Since this is so, there is some value in addressing the implications of the case where a change in the penalty of the client does imply a change in the reward of the inspector at least briefly (and without mathematical illustration) in this introductory text. We do this here only for the completely mixed equilibrium and will show these and other effects extensively in a more formal fashion in the substantive chapters of this thesis.

Consider first the case where an increase in the penalty on the client (for offering a bribe) has no effect on the amount that could be confiscated by the inspector (as in our setup). Given the completely mixed equilibrium within which we consider exogenous parameter changes when every player is indifferent between her actions, the comparative statics effects are the following. A marginal increase in the penalty on the client, ceteris paribus, decreases the relative expected payoff from offering a bribe and thus leaves the client in a position where she strictly prefers not to offer a bribe. To return her to the point of indifference, it would be required that either the probability with which the official accepts/reciprocates increases or that the the probability of inspection decreases. It is obvious, when looking at the structure of the model, that the probability of inspection cannot change, because this has an effect on the official's payoffs, such that otherwise she would no longer be indifferent. Therefore, the probability of accepting/reciprocating the bribe needs to increase, while the probability of inspection remains unchanged. Given the increase in the probability of accepting/reciprocating, the inspector is no longer indifferent herself, and thus the probability of offering a bribe needs to decrease to balance out this effect. If the change in the probability of offering a bribe was, however, equal to the change in the probability of accepting/reciprocating, this would have the following implications for this inspector. If an accepted/reciprocated bribe remains as likely as before, the probability of a rejected/unreciprocated bribe must go down, while the probability of no bribe increases. Since this would imply an increase in the relative expected payoff for not inspecting, we know that the probability of accepting/reciprocating has to change at a faster rate than the probability of offering a bribe in order to keep the inspector indifferent. This, in turn, shows that the probability of an accepted/reciprocated bribe, i.e. corruption, must increase, if we increase the penalty on the client exogenously. We confirm all of this algebraically in the various models in this thesis.

Now suppose that an increase in the penalty on the client would simultaneously increase the reward paid to the inspector as in the previous example. If the increases in the two variables were equivalent, then this would have the following implications. Like before, the probability of offering a bribe would have to increase to balance out the decrease in the probability of accepting/reciprocating a bribe, which was required following a penalty increase. Like before, this implies a shift in probability from an unreciprocated bribe to no bribe, while the probability of an accepted/reciprocated bribe remains unchanged. But unlike before, this would not increase the relative expected payoff of not inspecting, because inspecting has simultaneously become more lucrative due to the increased reward.

So, changing the independent payoff assumption in our versions of the inspection game replaces the surprising result that a higher penalty on corrupt clients should increase corruption by the following: increasing the penalty on corrupt clients does not change the incidence of corruption in equilibrium.

We recognise that these are important results that follow from small changes in our assumptions about the incentives of agents in our models. But as mentioned earlier, it is at the same time important to remain in keeping with crucial features of models found in a given literature, if one wanted to contribute to that literature. Indeed two of the papers in this thesis have been accepted for publication and fulfil at least in part the role of additions to the inspection game literature.

There are yet other ways one could model the incentives of the inspector. Suppose, for example, that inspection is not only costly, but that there is a limit to the amount of offenders the inspector could inspect. Such a model is discussed in some other literatures. Graetz et al. (1986) develops such a model in the tax compliance literature. Dionne et al. (2009) have a similar type of model on insurance fraud. Avenhaus & Kilgour (2004) (one inspection and 2 inspectees) and Hohzaki (2007) (multiple inspectees) provide models in the naval research literature, modelling the inspection game as taking place between patrol boats and smugglers. Yet another way of modelling the inspector's incentives would be to reward the amount of inspections, regardless of their success. While this could not be captured by the way we have modelled corruption in the papers presented in this thesis, such a payoff structure for the inspector could be analysed in a version with multiple offenders as in the examples provided above. A more simplistic way of introducing this feature would be to model the probability of detection exogenously, which has been done for example by Lambsdorff & Nell (2007), which again returns us to the point of departure, where we argue that the inspection ought to be done by *someone*.

We have discussed the decisions about the incentive assumptions we have made in the papers presented in this thesis and stressed that this is important. It was, however, only indirectly mentioned that the reliance on mixed-strategy Nash equilibrium as a solution to our game (and other inspection games) is an odd assumption to make about the behaviour of people in real life. Although mixed equilibria require no change of behavioural assumptions in theory, laboratory experiments show that even two-player mixed-strategy equilibrium play is not at all as easily observed as pure-strategy equilibrium play.[7] So, with our attempt to add a crucial feature to the way corruption was previously modelled in the literature by introducing an inspector to the game, we have created a new problem. If it is difficult to show that subjects behave according to mixed-strategy Nash equilibrium predictions in two-player games, what behaviour should we expect from subjects when faced with a game whose solution is a mixed equilibrium between three players? This question gave rise to the experimental work in chapter 5, in which we test a simultaneous version of our basic game outlined above in order to shed some light on the validity of the theoretical work developed in this thesis. Since the title of this thesis suggests that 'some experimental evidence' would accompany our theories, it should be stressed here that our experimental contribution is as of yet based on pilot results. We hope to gather more substantial data from experiments that are planned to run after the submission of this thesis (i.e. after September 2014).

The following short synopsis serves as a plan for the rest of this thesis. Chapter 2, "Endogenous Detection of Collaborative Crime: the Case of Corruption", is similar to the basic game that was outlined earlier. So, just as in the above, this paper solves a version of the inspection game, in which there might be a collaborative offence between a bribe-offering client and a corrupt official, which might be inspected by an opportunistic inspector. In contrast to the above game, we assume here that officials have the option to either keep the bribe (if one is offered) without reciprocating or to accept it with reciprocating – they cannot reject it. This is so, because this paper does not only make a contribution to the inspection game literature, but because our basic underlying corruption model is deliberately similar to that in Lambsdorff & Nell (2007), and like their paper, we address the question of optimal deterrence when penalties can be distributed asymmetrically between the two offenders. We are critical of Lambsdorff & Nell (2007), who argue that asymmetric penalties (and/or rewards for reporting corrupt behaviour) should be set as to undermine the social norm of reciprocity and thus destroy an equilibrium in which there is corruption. We argue that an equilibrium where there is corruption (given self-interested, rational, utility-maximising agents) can only exist so long as the social norm of reciprocity is represented by a variable in the model, which is not the case in Lambsdorff & Nell (2007). Our results from comparative statics analyses are surprising, but typically so, because the game belongs to the inspection-game family and has, depending on parameter configuration, different types of mixed-strategy equilibria. As mentioned earlier, we find two interesting mixed equilibria, a partially mixed one where the official always reciprocates while the other players randomise and a completely mixed one, where all three players randomise to keep each

[7]Some examples of this literature are O'Neill (1987), Goeree & Holt (2012), and Okano (2013); Rauhut (2009) runs a laboratory experiment on the inspection game. Many other papers are discussed in chapter 5.

other indifferent. In the partially mixed equilibrium we find that a marginal increase in the penalty on the client, ceteris paribus, decreases the probability of inspection, while the probability of corruption (i.e. an accepted/reciprocated bribe) remains unchanged. This is like in Tsebelis' original inspection game. In the completely mixed equilibrium, we find that, ceteris paribus, a marginal increase in the penalty on corrupt officials decreases the probability of corruption, while a marginal increase in the penalty on the client increases the probability of corruption. Those results are clearly different from previous arguments (Lambsdorff & Nell, 2007; Rose-Ackerman, 1999), which suggest that harsher penalties on bribers would be optimal from a deterrence point of view.

Chapter 3, "Does Reporting Decrease Corruption?", is an extension of the work in the previous chapter. In this paper we compare two cases of our three-player inspection game. In the first, the official can either accept and reciprocate or reject an offered bribe, just like in the basic model outlined earlier. In the second case, the official can either accept and reciprocate or report an offered bribe. As the title suggests, we compare the two cases to see whether regulation, which rewards reported bribery decreases the probability of corruption, as basic intuition would suggest. Apart from finding the same comparative statics with regards to marginal penalty changes as in the previous chapter, we find that in the context of this model, rewarding reporting to a greater extent than rewarding rejected bribes increases the probability of an accepted/reciprocated bribe, i.e. corruption. This is so at least within plausible ranges of changes in the reward for reporting. This chapter is a development of a paper accepted for publication in the Journal of Interdisciplinary Economics (see declaration of authorship) and can be seen as a predecessor to chapter 4, which is explained shortly.

Chapter 4, "Corruption and Corruptiblity: (Further) Perverse Results from a Mixed-Strategy Inspection Game", introduces different types of officials into the game, and the second part of this paper introduces the idea of an endogenous bribe. Specifically, nature determines the probability distribution over three different types of officials: the reporting type 1 official always reports an offered bribe and never accepts/reciprocates; the corruptible type 2 official is opportunistic and so rejects or accepts/reciprocates depending on the relative parameter values; the rejecting type 3 official always rejects and never accepts/reciprocates an offered bribe. So, while chapter 3 considered exogenous changes in the reward for reporting for a single type of official, chapter 4 assumes that there is a reporting type of official, for whom reporting is always a dominant strategy. Given this addition, we observe the comparative statics effects as we change the probability distribution over the different types of officials and simulate this with some plausible numerical parameter values. For the exogenous bribe case we find the following. In the partially mixed equilibrium of this game, we find that increasing the probability of the reporting type 1 by 5% (while decreasing the probability of the rejecting type 3 and keeping that of the corruptible type 2 constant), increases the probability of corruption by about 0.5%. Similarly, we find that increasing the probability of the corruptible type 2 by 5% (while decreasing type 3 and keeping type 1 constant) increases corruption by about 2%. In the completely mixed equilibrium of the exogenous bribe variant, we find that increasing the probability of the reporting type 1 by 5% (while decreasing type 3 and keeping type 2 constant), increases the probability of corruption by about 3%. Moreover, we find that increasing the probability of the corruptible type 2 (while decreasing type 3 and keeping type 1 constant), does not change the probability of corruption. For the endogenous bribe case we find the following. Increasing the probability of the reporting type 1 by 50% (while decreasing the probability of the rejecting type and keeping that of the corruptible type constant) increases the probability of corruption by less than 1%. However, increasing the probability of the corruptible type 2 by 5% (while decreasing type 3 and keeping type 1 constant), increases the rate of corruption by 2%. In addition we report that an increase in the probability of type 1 (versus type 3) increases both the probability of inspection and the size of the bribe, while an increase of type 2 (versus type 3) does the opposite. Marginal penalty changes have the same effect in this chapter as they do in the previous chapters.

Chapter 5, "Lab-testing mixed-strategy play in a corruption game with endogenous detection", reports the result of a pilot study, in which we test hypotheses that were generated from the predictions of a simultaneous version of our three-player inspection game with collaborative offence. The theory is similar to the basic model that was introduced earlier on and predictions of marginal penalty changes are identical to those in the previous chapters. Since, for simplicity, this game is not sequential, there is an additional Nash equilibrium where there is no offering of a bribe, no accepting/reciprocating and no inspecting, as well as either the partial or the completely mixed equilibrium (depending on the parameter configuration). Testing this game in the laboratory has raised many design questions, which will be discussed in some detail in chapter 5 and which have been carefully reconsidered since. After settling for some good and (in hindsight) some less useful design choices, we ran two sessions with the same three treatments each. We ran two sessions in order to be able to make changes to the experimental procedure. In session 1, subjects were given pen and paper and, as a consequence, the session overran its time limit. In session 2 pen and paper were not given out. The treatment variables were the penalty on the official and the penalty on the client, respectively. The former was increased in treatment 2 and as per the completely mixed equilibrium prediction it was hypothesised that it should decrease the probability of an accepted/reciprocated bribe, while the latter was increased in treatment 3, for which it was hypothesised that it should increase the probability of corruption in the completely mixed equilibrium. We found, however, that both a penalty increase on the official as well as a penalty increase on the client decreased the probability of corruption. Looking at our data more closely revealed the following. Very little could be inferred from inspecting individual level data. However, across subjects and periods of play the treatments did have their predicted effects with respect to qualitative changes in the probabilities of offering a bribe and accepting/reciprocating a bribe. The size of changes in each of these probabilities was far from our predictions, which resulted in said deviation from our prediction for the probability of corruption. The aid of pen and paper as well as more time to deliberate on choices seemed to improve subjects' ability to play according to our predictions for the completely mixed equilibrium.

Many lessons were learned from the initial design choices and the software was completely re-programmed several times over. A second version of the software was developed to run a larger scale experiment together with John Bone. Unexpectedly, Professor Jason Shachat joined our team before we were going to run the experiment. Shachat proposed some significant additions to the game, including solving the game for correlated equilibria. With this in mind, a third version of the experimental software was programmed and with many changes and extensions this project is still underway. As mentioned earlier, a more substantial experiment is planned to be run after Autumn 2014.

Chapter 2

Endogenous Detection of Collaborative Crime: the Case of Corruption

Abstract

We construct a one-shot corruption game with three players, a client who can decide to bribe or not, an official who can reciprocate or not and an inspector who can decide to inspect or not. We employ four penalties that can be distributed asymmetrically, making it possible to punish bribing and bribe-taking as well as reciprocating and receiving reciprocation to different degrees. Penalties apply if corruption is detected. The probability of detection is endogenised, as it depends on inspection. The model differs from other inspection games in that the offence (corruption) can only be completed through a joint effort of the two offending players. This leads to surprising results, especially in conjunction with asymmetric penalties. First, in contrast to Tsebelis' results, we find that, with endogenous detection, higher penalties do reduce the overall rate of offence. Second, this result holds only if the penalty for reciprocating on the official is raised. Surprisingly, and unlike other asymmetric penalty prescriptions in the corruption literature, higher penalties on the client have the opposite effect. They may reduce the probability of bribery, but they also increase the probability of reciprocation to the extent that the overall probability of reciprocated bribery is increased.

Keywords: Inspection game · Corruption · Asymmetric penalties · Endogenising detection

JEL Classification: K42 · H00 · C72 · O17

Introduction

By application of basic demand theory, Becker (1968) famously showed that when looking at the determinants of criminal behaviour, crime levels depend on the probability of detection and the size of penalty. More specifically he demonstrated that, when detection is costly and penalties in form of fines are free, the combination of a maximum penalty and minimum detection efforts results in socially optimal deterrence. Tsebelis (1989; 1990a; 1990a; 1995)[1] found that Becker's conclusions are only valid in a decision-theoretic context, where the probability of detection is defined as an exogenous variable. He extended Becker's model with the introduction of a second player, an inspector, to represent the probability of detection as an endogenous variable. The results were surprising: in this game-theoretic context, the effect of raising the penalty is no longer that of a reduction in crime, but instead a reduction of the rate of inspection. This is due to the unique mixed-strategy Nash equilibrium of this game, where the rate of inspection depends on the rate of offence and vice versa.

Some literature has emerged in response to these results. Several scholars have pointed out that Tsebelis' findings only hold under certain conditions.[2] We do the same. The innovation of our game lies in its specific setup. We adapt the model to fit the collaborative crime of corruption. Where all other models of said literature assume either single offenders/inspectors or populations of offenders, our model features two offenders who can collaborate in an offence (corruption) as well as a single non-corrupt[3] inspector.

In formal terms, our game is constructed as follows. We define an action for each of our offenders; a client can bribe or not and an official can reciprocate or not. We define reciprocation as the act of returning the favour of a bribe, that is the return of some sort of quid pro quo (e.g. a government contract) to the client. The hard crime of corruption as reciprocated bribery can thus only happen in a joint effort between the two players. The game involves four penalties, one for bribing and one for receiving the reciprocation (both of those on the client), as well as one for accepting a bribe and one for reciprocating (both of those on the official). This allows us to use asymmetric penalty distributions, and thus to offer more insightful policy recommendations. Penalties apply

[1] Graetz et al. (1986) developed a similar model already before Tsebelis. This will be discussed later.

[2] Bianco et al. (1990) argued that if the game was iterated or had more players, it might lead to different results. Graetz et al. (1986), Cox (1994), Friehe (2008), and Pradiptyo (2007) all offered different results in slight variations of Tsebelis' model.

[3] The inspector is assumed to be a rational self-interested utility maximiser with regards to inspection effort, but does not engage in accepting bribery herself.

with the probability of inspection, which is represented by the actions of a third player, the inspector; she can inspect or not inspect and her payoffs depend on whether there is an offence or not.

We obtain the following results. First, we are able to reproduce Tsebelis' inspection game in our model (Tsebelis type). We achieve this by setting the parameters such that the official always reciprocates, for instance because penalties for reciprocating are very low. We then obtain a mixed-strategy equilibrium in which the probability of reciprocation is always equal to one, while an increase in a penalty for the client results in a reduction of the probability of inspection. Second, and chiefly, we obtain a mixed-strategy equilibrium in which all three players randomise with probabilities strictly between zero and one (completely mixed type). In this case, asymmetric penalties have very significant effects. We find that raising the penalty of reciprocation on the official increases the probability of bribery, but decreases the probability of reciprocation and inspection. Contrarily, raising any penalty on the client (bribing and receiving the reciprocation) reduces the probability of bribery, but increases the probability of reciprocation, while the probability of inspection remains unchanged. Moreover, we find that the probability of reciprocation changes at a faster rate than the probability of bribery. In other words, the change in the probability of reciprocation determines the sign of reciprocated (successful) bribery, i.e. corruption. Policy implications thus deviate both from Becker's and Tsebelis' recommendations. We find that, in order to achieve optimal corruption deterrence the penalty for reciprocating ought to be maximised, while the penalties for bribing and for receiving the reciprocation ought to be minimised.

The rest of the paper is organised as follows. Section 2.2 explains the relation to both the literature on corruption and the inspection game literature. Section 2.3 explains the model and its assumptions. In section 2.4 we provide an informal analysis of the effects of marginal penalty changes on the two types of equilibria we obtain. Section 2.5 provides a formal analysis of our results. Section 2.6 discusses optimal deterrence recommendations that follow from our completely mixed type equilibrium. Section 2.7 concludes.

2.2 Related research

This paper seeks to contribute to two literatures. First, in its treatment of the asymmetric penalties proposition, it ties in with research in political economy and economic theory of corruption. Jain (2001) offers a general overview of corruption within said disciplines.[4] Aidt (2003) offers a review of microeconomic theory of corruption. A range of analyses in the corruption and optimal deterrence literature follow the orthodox approach of Gary Becker, in assuming that detection be an exogenous variable.

The idea of asymmetric penalties was first developed by Rose-Ackerman (1999). She noted that, since it takes two people to commit the specific crime of corruption, it might in fact suffice to deter one of the two parties. To enforce this, she suggested asymmetric penalties to undermine the bond between corruptor and corruptee. This idea has been refined by Lambsdorff & Nell (2007), who developed the corresponding formal model and policy implications for the anti-corruption legislation in Germany and Turkey. Like Rose-Ackerman, the authors assume Becker's optimal deterrence formula and suggest asymmetric penalties to destroy the force of social norms/reciprocity in order to undermine corrupt behaviour.[5] They find that under exogenous detection, giving severe punishment for bribing and for reciprocating (but low punishment for accepting bribery and for receiving the reciprocation) is the most efficient penalty distribution.

Engel et al. (2012) compare symmetric and asymmetric punishment in an experiment, and find that more lenient punishment of bribers (the asymmetric case) increases the frequency of corrupt deals. This is because, asymmetric punishment also increases the frequency of self-reports by bribers and thus increases reciprocity, which in some sense complements the leniency for reporting argument introduced by Lambsdorff & Nell (2007). In conceding that policy implications hinge on the size of the probability of detection, which here, too, is exogenously fixed, Engel et al. (2012) conclude that policy makers ultimately have to weigh up the merits of deterrence versus law enforcement. As mentioned earlier, our results contrast with this literature.

It is worth noting that legislation differs widely between countries with respect to penalty symmetry, which stresses the importance of this research. Under German law, for instance, a briber is considered as guilty as a bribe-taker, which allegedly gives moral justification to equal punishment.[6] Our results show, however, that punishing officials more gravely is the more effective deterrent, suggesting that an asymmetric penalty distribution leads to the greater social good despite the putatively unjust nature of the punishment for the individuals involved in the crime.

[4]See also Rose-Ackerman (2006) for a more extensive handbook on the economics of corruption.

[5]Lambsdorff (2007) elaborated on this idea and developed what he refers to as the invisible foot principle. Basu et al. (1992) also use asymmetric penalties. However, they do so only for bribing and accepting bribery, but not for reciprocating.

[6]The upper bound of prison sentences and fines is equal for bribing and accepting bribes under §§331-335 of the German criminal code (Strafgesetzbuch). This is argued to be justified, since the misappropriation of public funds or goods happens in a mutual act. Thus, as people are deemed equal before the law as per the constitution, they deserve equal punishment.

More importantly, however, this paper offers an interesting addition to the literature around Tsebelis' inspection game. Like other contributions within this literature, our results depend on mixed-strategy Nash equilibria. A number of studies such as Graetz et al. (1986) and Dionne et al. (2009) show that mixed-strategies as expressions of population proportions or frequencies of activities are not at all meaningless. This is corroborated by empirical evidence (Levitt & Miles (2007)). Interestingly, while based on the same fundamental mechanism as the inspection game, Graetz et al. (1986) and Dionne et al. (2009) have emerged in separate literatures, the former as part of the tax evasion literature and the latter as part of the insurance fraud literature. Recent contributions to the inspection game literature are Andreozzi (2004), Friehe (2008) and Pradiptyo (2007).

Basu et al. (1992), Besley & Mclaren (1993), Mookherjee & Png (1995) and Marjit & Shi (1998) develop corruption models, in which detection is endogenised, although not in the same way as in the inspection game. Common to all four is the basic model structure. It is assumed that a briber has to enter a Nash bargaining game with an official, whose trade-off lies between accepting/demanding a bribe or reporting the bribe/receiving a reward for doing so/etc. Even if bribery can ascend in an hierarchy, as is the case in Basu et al. (1992) and Besley & Mclaren (1993), there is always a connection between the briber and the official (inspector) in the higher tier, in so far as the former may choose to bribe the latter. In contrast to this family of models, we assume in our model that the corrupt collaborators and the inspector cannot strike any deals between each other.[7] Given rational agents, we assume that client and official vis-à-vis the inspector can only anticipate each others' strategy choices, but they cannot collude.

2.3 Setup and assumptions

We begin with the original two-player one-shot game by Lambsdorff & Nell (2007), in which a client (C) can decide to bribe or not to bribe and an official (O) can then decide to reciprocate or not to reciprocate. Penalties are given for bribing/accepting the bribe[8] (p_L and q_L) on the one hand, and for reciprocating and receiving the reciprocation (q_H and p_H) on the other. Penalties apply with probability α, an exogenous parameter. If there is bribery and the official decides to reciprocate, she will gain the bribe (b) and a

[7]If we were to convert our game into a cooperative one, this would require a bargaining game between all three parties, where client, official and inspector have to negotiate on the payoff to the inspector. This might however lead to issues of crime control as shown in Marjit & Shi (1998).

[8]Note that in this game the official automatically accepts, if she is offered a bribe. She cannot reject. This is plausible if the size of the bribe is always high enough to achieve acceptance, but not necessarily reciprocation. Alternatively, one might think that an official would first decide whether to accept a bribe or not, and then reciprocate in case of acceptance. However, since we are focussed on detection there is no need to make alterations of this kind.

reciprocity bonus (r), but she also faces penalties for accepting the bribe (q_L) and for reciprocating (q_H), if detected with α. In this case, the client gains the benefits of the reciprocation (v), but loses the bribe and faces the penalties for bribery (p_L) and for receiving the reciprocation (p_H) if detected. If the official decides not to reciprocate after bribery, she gains the bribe, but she has to pay penalty q_L if detected, and does not gain the social benefit r. The client loses the bribe in this case and has to pay penalty p_L if detected. If there is no bribery, the payoff for both the client and the official is zero. We adopt this structure in our model.[9]

The reciprocity bonus (r) requires explanation. Lambsdorff and Nell assume that there is a social norm of reciprocity, which makes bribery possible in the first place. Corruption requires reciprocal trust, because it is amoral and illegal[10]. In real life it would always be better for a corrupt official to just accept bribes, but then not to reciprocate, if it was not for either the fear of losing reputation, or the threat of punishment or some other form of social pressure. This is reflected in the game. Backward induction shows that, if r is not sufficiently large, the official will never reciprocate and thus the client will never bribe.[11]

In our model we want to endogenise the detection parameter. First of all, in order to allow for mixed-strategy equilibria, we need to replace the actions of the client and official with probability distributions. Let thus the probability of bribery be γ and the probability of not bribing $1 - \gamma$. Likewise, let β be the probability for reciprocating and $1 - \beta$ the probability for not reciprocating. Further, we introduce an inspector (I). The probability of detection α is replaced by the inspector, who can decide to inspect with probability α or not to inspect with probability $1 - \alpha$. We construct her payoffs in Tsebelis' format, as is shown in Table 1. Similar to Tsebelis' inspection game, we assume that inspecting is better in case of (reciprocated) bribery, than it is in case of no bribery and vice versa: $0 < \Delta x, \Delta y, \Delta z$.

[9] Lambsdorff and Nell's original model also included additional nodes, where players could defect and report on each other. We exclude these for simplicity.

[10] The bonus (r) can then either be seen as an investment in the future (for instance as a positive discount factor) or one could replace it with a threat in form of a cost of punishment for not reciprocating.

[11] As shown later, r needs to outbalance αq_H. The official gains r by reciprocating, but she also risks an additional penalty (q_H) with probability α.

Table 1: Tsebelis type inspector payoffs

Decision	Inspect α	Not inspect $1-\alpha$
Bribe, accepted and reciprocated: $\gamma\beta$	$x+\Delta x$	x
Bribe, accepted but not reciprocated: $\gamma(1-\beta)$	$y+\Delta y$	y
Not bribe: $1-\gamma$	z	$z+\Delta z$

As our model features two offenders and their respective actions, we need to make an additional assumption about the inspector's preferences over inspection of reciprocated bribery versus inspection of unreciprocated bribery. Following our intuition we assume that inspecting a case of reciprocated bribery is more rewarding than mere bribery ($y < x$ and $\Delta y < \Delta x$).[12] We call this the 'bigger catch' assumption. To remain in line with Tsebelis' inspection game, we assume that every inspection is successful. The intuition for the inspector's payoffs is as follows. The inspector has no incentive to inspect whenever she believes that no offence has taken place, because inspection is cumbersome, and so she prefers to shirk (i.e. not inspect). If she believes that there is an offence, however, she does prefer to inspect, as this entails a bonus or a promotion by her employer. The 'bigger catch' assumption elaborates on this interpretation, suggesting that inspecting a reciprocated bribe leads to a better bonus/promotion than an unreciprocated bribe.[13]

[12]For completeness, note that $y < x$ represents the intuition that it is worse not to inspect, if there is reciprocated bribery, i.e. full-blown corruption, than if there is a mere unreciprocated bribe.

[13]It is, of course, possible to change these assumptions, and indeed this could have profound consequences for the results we obtain with our model. For example, it is here assumed that the inspector's payoffs are independent of the penalties levied on the offenders, so that, say, an increase in the penalty on the client does not change the payoff, which the inspector receives for inspecting a bribe. If this were different, such that an increase in the penalty were to increase the payoff for an inspected bribe, the results would differ with the effect that such a penalty increase does not alter the probability of corruption, instead of increasing it, as will be argued in this paper. This and other changes of assumptions were discussed during the introduction. However, to remain in keeping with the assumptions in the literature around the inspection game, we do not deviate from those assumptions in this paper.

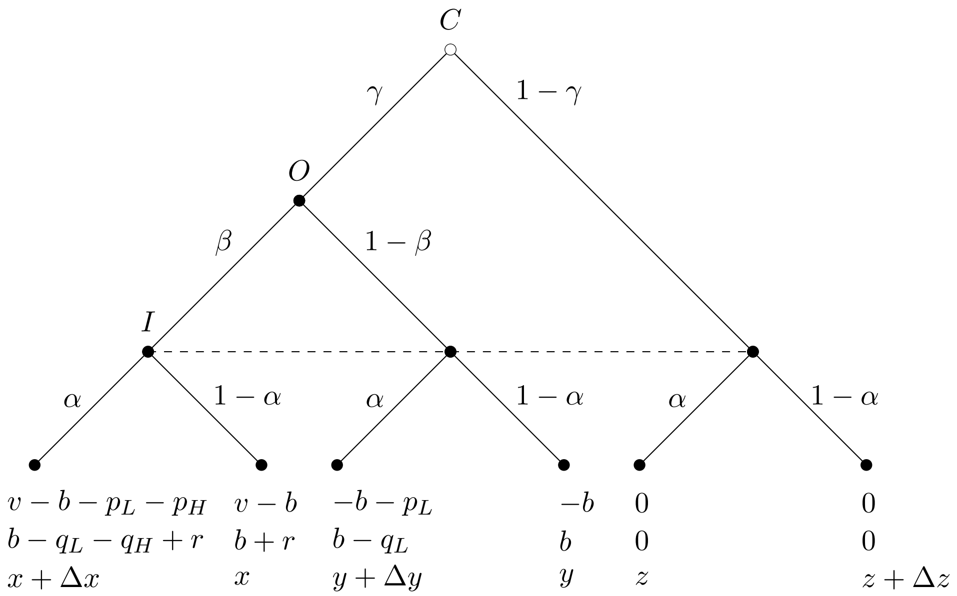


FIGURE 1: Extensive form game

For reasonable and intelligible outcomes we make the following additional assumptions about the remaining variables in the game. For the standard game, we assume that $b > 0$, i.e. that a bribe cannot be zero or negative.[14] Further, we assume that $v > 0$, i.e. the client's benefit from receiving the reciprocation must be positive (otherwise the client would not be interested in the reciprocation, even if she could get it without bribery). The default assumption about the penalties is $p, q > 0$.[15] We further assume that $r \geq 0$. The necessary condition for reciprocation is then $r \geq \alpha q_H$.

2.4 An informal analysis of the model

This section identifies Nash equilibria in our model and classifies them into different types. We are informally analysing these equilibria as we marginally change the penalties on the client (p_L, p_H), and later in this section, as we marginally change the penalty

[14] A negative bribe could be seen as a bribe from official to client, but this case shall not concern us here.

[15] This assumption can be changed to $p, q \geq 0$, depending on what we believe to be more realistic or more suitable with a view to determining the most effective way of deterring corruption. We might for example believe that not all four penalties are distinguished by some legislations. Moreover, in Lambsdorff and Nell's original game players could not only report on each other, but reporting was rewarded. They called this leniency. An investigation of this case might be worthwhile in a variation of our game. In yet another variation it might also be useful to think of the penalty for bribing as a positive incentive that cancels out the cost of the bribe. This makes sense, if bribing occurred in order to gain access to a public good, to which one was entitled anyway (cf. Basu (2011)).

on the official (q_H).[16] One type of equilibrium occurs where the penalties on both offenders are sufficiently low, such that relative to their benefit from v, b and r, both offenders strictly prefer to offend, even if inspection is certain (i.e. the inspector strictly prefers to inspect). It is here the case that $\alpha = 1$, $\gamma = 1$ and $\beta = 1$.[17] Similarly, another type of equilibrium occurs where the penalties on at least the client are so high that even without inspection no bribe is initiated. It is then the case that $\alpha = 0$, $\gamma = 0$ and $\beta = 0$.[18]

More interesting are the two following types: one where the official reciprocates for sure, such that $\beta = 1$, while the client and the inspector play completely-mixed strategies, such that $\alpha, \gamma \in (0, 1)$, which we call the Tsebelis type; and one where all three players play completely-mixed strategies, such that $\alpha, \gamma, \beta \in (0, 1)$, which we call the completely mixed type.

To obtain the Tsebelis type, we assume that the official's expected payoff for reciprocating (essentially determined by b and r) is sufficiently high so that she strictly prefers to reciprocate before and after a marginal manipulation of penalties, i.e. even if inspection were certain, while the other players' strategies are completely mixed. Here the probability of inspection in equilibrium is determined by the requirement to keep the client indifferent, and so we are able to reproduce Tsebelis' result. To obtain the completely mixed type, the offenders' penalties are set relative to their benefits such that the probability of inspection is now determined by the requirement to keep the official indifferent. In this case we obtain a result that deviates from Tsebelis' result.

Tsebelis type: If we marginally increase either p_L or p_H, ceteris paribus, the client ceases to be indifferent (her expected payoff for bribing is reduced). To keep her indifferent, either the probability of reciprocation (β) must increase or the probability of inspection (α) must decrease. Given that $\beta = 1$, α must decrease. Also, to keep the inspector indifferent, the probability of bribery (γ) must not change. This configuration reproduces Tsebelis' result: increasing the penalty does not decrease the probability of bribery, but instead decreases the probability of detection.

Proposition 1. *Given that $\beta = 1$ and $\alpha, \gamma \in (0, 1)$, an increase of p_L or p_H does not decrease the probability of bribery (it remains constant), but instead decreases the probability of detection.*

[16] We will see later that changing either penalty on the client has the same qualitative effect on the equilibrium and that changing penalty q_H on the official has the opposite effect on the equilibrium. Penalty q_L has no effect, because it features both in the payoff for inspected reciprocation and inspected non-reciprocation.

[17] At this point and from now onwards α, γ and β denote equilibrium values of these variables.

[18] Strictly speaking, i.e. following game-theoretic reasoning, the official is then indifferent between her respective actions, because no bribe has been offered. This implies that in this case infinite equilibria occur where $\alpha = 0$, $\gamma = 0$ and $\beta \in [0, 1]$.

Completely mixed type: As before, if we marginally increase either penalty on the client (p_L or p_H), ceteris paribus, the client ceases to be indifferent (her expected payoff for bribing is reduced). To keep her indifferent, either the probability of reciprocation (β) must increase or the probability of inspection (α) must decrease. However, α cannot decrease, for otherwise the official would cease to be indifferent, because we have not changed her expected payoffs. It follows that therefore β must increase. Unlike before, γ cannot remain constant, but must decrease, to keep the inspector indifferent.

To see this, recall that the inspector's deliberation depends on these events: the probability of a reciprocated bribe ($\gamma\beta$); the probability of an unreciprocated bribe ($\gamma(1-\beta)$); and the probability of no bribe ($1-\gamma$). If the probability of reciprocation (β) increases, while the probability of bribery (γ) does not change, this would imply a shift in probability from unreciprocated bribe to reciprocated bribe. Our assumed payoffs for the inspector then imply an increase in the relative expected payoff from inspection. So, to offset this, γ must decrease. Suppose γ decreases sufficiently to keep $\gamma\beta$ constant. This would imply a shift in probability from unreciprocated bribe to no bribe, with the overall probability of a reciprocated bribe remaining unchanged. Our assumed payoffs for the inspector then imply a decrease in the relative expected payoff from inspection. So, to keep the inspector indifferent, the increase in β must be accompanied by a decrease in γ, but in a smaller proportion, so that the probability of a reciprocated bribe increases.

Proposition 2. *Given that $\alpha, \gamma, \beta \in (0,1)$, increasing any penalty on bribery does decrease the probability of bribery, but it also increases the probability of reciprocation (while the probability of detection remains constant).*

Analogously, if we marginally increase the penalty on the official (q_H), ceteris paribus, the official ceases to be indifferent (her expected payoff for reciprocation is reduced). To keep her indifferent, the probability of inspection (α) has to decrease. If α decreases, the client ceases to be indifferent (her payoff for bribing is raised). So, to keep her indifferent, β has to decrease.

Proposition 3. *Given that $\alpha, \gamma, \beta \in (0,1)$, increasing the penalty on reciprocation (q_H) increases the probability of bribery, but it decreases the probability of reciprocation and the probability of detection.*[19]

The above discussion about the relationship between changes in the probability of bribery (γ) and reciprocation (β) must hold for changes of any parameters other than the payoffs of the inspector:

[19] As noted in footnote 15, changing q_L has no effect on any of the probabilities.

Proposition 4. *Given that $\alpha, \gamma, \beta \in (0,1)$, an increase (respective decrease) in γ must be accompanied by a proportionally greater decrease (respective increase) in β, such that the probability of reciprocated bribery ($\gamma\beta$) changes in the same direction as the probability of reciprocation and in the opposite direction to the probability of bribery.*

These results differ from Tsebelis' finding: increasing any penalty for bribing does have the effect of decreasing the probability of bribery, while increasing the penalty for reciprocation does decrease reciprocation. However, any change in the probability of bribery is accompanied by a higher change of the probability of reciprocation, which means that the probability of reciprocated bribery, i.e. corruption, increases if we punish the client more severely, whereas it decreases if we punish reciprocation more severely.

2.5 Formal analysis

Having informally analysed marginal changes in the equilibria of the Tsebelis type and of the completely mixed type, we provide an algebraic proof of these results in this section. We will be able to consider what happens to each type of equilibrium if we marginally change the penalties on the client (in the Tsebelis type and in the completely mixed type, and the penalties on the official in the completely mixed type only). To differentiate between the two types, it is helpful to consider what determines the probability of detection in each type. Given that α is bounded ($0 \leq \alpha \leq 1$), we will see that $\alpha = min\{\frac{r}{q_H}, \frac{\beta v - b}{\beta p_H + p_L}\}$ determines whether we are in a Tsebelis type or in a completely mixed type equilibrium.

The key notion in this analysis is that, whenever players are playing completely mixed strategies, they are indifferent between their respective actions. So, to express indifference, for each player we equate the payoffs for each strategy. Using the payoffs in Figure 1, we can construct equations (2.1), (2.2) and (2.3).[20] The first describes when the client is indifferent, the second describes when the official is indifferent and the third describes when the inspector is indifferent.

$$\beta(v - b - \alpha p_L - \alpha p_H) + (1-\beta)(-b - \alpha p_L) = 0 \tag{2.1}$$

$$\alpha(b - q_L - q_H + r) + (1-\alpha)(b + r) - \alpha(b - q_L) - (1-\alpha)b = 0 \tag{2.2}$$

$$\gamma\beta\Delta x + \gamma(1-\beta)\Delta y + (1-\gamma)(-\Delta z) = 0 \tag{2.3}$$

In the Tsebelis type it was assumed that $\beta = 1$ and $\alpha, \gamma \in (0,1)$, i.e. this type is characterised by the assumption that the official strictly prefers to reciprocate, while the

[20]Equation (2.1) is simplified.

other players' strategies are completely mixed in equilibrium. Recall that the condition for $\beta = 1$ is that $\alpha < \min\{1, \frac{r}{q_H}\}$. This implies that the value of α is instead determined by the requirement to keep the client indifferent, which is the case if $\alpha = \frac{\beta v - b}{\beta p_H + p_L}$. Figure 2 illustrates the Tsebelis type graphically. It displays the reaction functions of the Tsebelis type equilibrium.

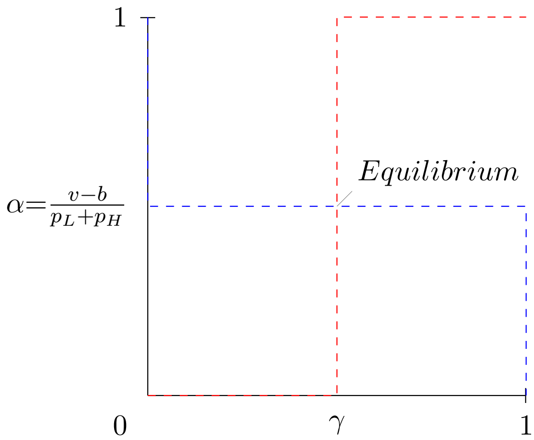


FIGURE 2: Tsebelis type

Rearranging equations (2.1) and (2.3) and substituting β with one gives us the following equilibrium probabilities. Recall that (2.4) keeps the client indifferent and (2.5) keeps the inspector indifferent.

$$\alpha = \frac{v - b}{p_L + p_H} \tag{2.4}$$

$$\gamma = \frac{\Delta z}{\Delta x + \Delta z} \tag{2.5}$$

And, of course, by assumption the equilibrium probability for the official is the following:

$$\beta = 1 \tag{2.6}$$

It is easy to see that marginally changing either p_L or p_H will have a decreasing effect on α (since α is a function of the payoffs of the client), while γ does not change (since γ is a function of the payoffs of the inspector). We can thus confirm Proposition 1 and have reproduced Tsebelis' result.

In the completely mixed type it was assumed that $\alpha, \gamma, \beta \in (0, 1)$. This type is characterised by the fact that the value of α is now determined by the requirement to keep the official indifferent. This is the case if and only if $\frac{r}{q_H} < \min\{\frac{\beta v - b}{\beta p_H + p_L}, 1\}$, and where $\beta = 1$ reciprocity is at its upper bound, such that $\alpha = \frac{r}{q_H}$. Figure 3 illustrates this graphically by displaying the reaction functions of the completely mixed type equilibrium.

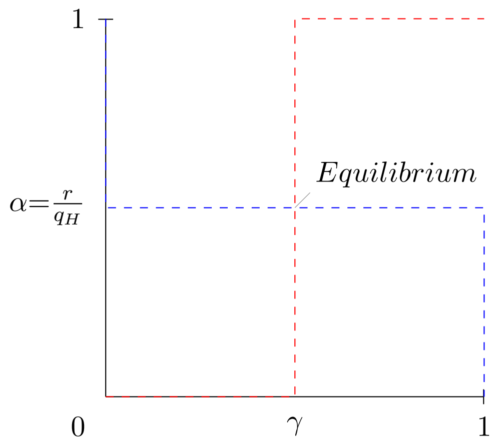


FIGURE 3: Completely mixed type

We can solve for the equilibrium probabilities α, γ, and β respectively by rearranging (2.1), (2.2), and (2.3). Recall that under the requirement to keep each player indifferent between their respective strategies, (2.7) was derived from the client's payoffs, (2.8) from the official's payoffs, and (2.9) from the inspector's payoffs.

$$\alpha = \frac{r}{q_H} \tag{2.7}$$

$$\gamma = \frac{\Delta z}{\beta(\Delta x - \Delta y) + \Delta y + \Delta z} \tag{2.8}$$

$$\beta = \frac{b + \alpha p_L}{v - \alpha p_H} \tag{2.9}$$

For procedural completeness we derive and report the explicit equilibrium solutions for equations 2.8 and 2.9, expressing the behavioural variables as functions of payoffs only.

$$\gamma = \frac{(vq_H + rp_L)\Delta z}{(bq_H + rp_H)(\Delta x - \Delta y) + (vq_H + rp_L)(\Delta y + \Delta z)} \tag{2.10}$$

$$\beta = \frac{bq_H + rp_L}{vq_H - rp_H} \tag{2.11}$$

We can see from equation (2.9) that a marginal increase in either p_L or p_H, ceteris paribus, leads to an increase in β, as α remains unchanged. Knowing from our 'bigger catch' assumption that $0 < \Delta x - \Delta y$, and following (2.9), we can infer through (2.8) that increasing either p_L or p_H must be accompanied by a decrease in γ. As neither p_L nor p_H feature in (2.7), we know that α must remain unchanged.

Further, we can infer from (2.7) that a marginal increase in q_H, ceteris paribus, must decrease α. Given the latter, (2.9) shows that increasing q_H must also decrease β. Again, since $0 < \Delta x - \Delta y$, and following (2.9), we can infer through (2.8) that decreasing q_H must by accompanied by an increase in γ.

We can confirm the negative relationship between γ and β by totally differentiating (2.3), that is the equation which keeps the inspector indifferent, and we obtain:

$$\frac{\mathrm{d}\beta}{\mathrm{d}\gamma} = -\frac{\beta\Delta x + (1-\beta)\Delta y - \Delta z}{\gamma(\Delta x - \Delta y)} \tag{2.12}$$

Given our assumptions about the payoffs of the inspector that $-\Delta z < 0 < \Delta y < \Delta x$ and given that (2.12) is negative, we can infer that a change in γ must be accompanied by a change in β in the opposite direction, thereby confirming Propositions 2 and 3.

It remains the question of what happens to the overall probability of a reciprocated bribe ($\gamma\beta$), if, for example, γ changes. Using (2.3) we can observe the change in $\gamma\beta$ if γ changes and obtain:

$$\frac{\mathrm{d}\gamma\beta}{\mathrm{d}\gamma} = -\frac{\Delta y + \Delta z}{\Delta x - \Delta y} \tag{2.13}$$

The sign is negative, which signifies that the probability of a reciprocated bribe ($\gamma\beta$) changes in the opposite direction to γ (and thus in the same direction as β), which confirms Proposition 4.

2.6 Optimal Deterrence

In search of the penalty structure for optimal crime deterrence in a completely mixed type equilibrium, we find the following. As established earlier, the penalty for accepting bribery (q_L) features in both reciprocated and unreciprocated bribery. Changing it has therefore no influence on the probability distributions over α, γ and β. As argued in the previous sections, increasing q_H reduces α and β, as well as $\gamma\beta$, but it increases γ. Further, we showed that increasing p_L has the same effect as increasing p_H does. It leads to an increase in β and to an increase in the overall probability of reciprocated bribery at equilibrium (but a reduction of γ). Table 2 illustrates those findings.

There are various combinations of penalty raises, all of which reduce to the same effects as the singular penalty raises. Obviously, increasing a penalty has the opposite effect of decreasing a penalty. The optimal deterrence mechanism is thus an asymmetric distribution of penalties, where p_L and p_H are minimised and q_H is maximised. Our model prescribes that this will have the optimal effect of reducing both reciprocation and the overall probability of reciprocated bribery. With regards to the asymmetric penalties debate within the corruption literature, we are able to confirm Lambsdorff and Nell's finding that reciprocating should be punished severely. Their suggestion to also punish

TABLE 2: Change over α, γ and β when increasing penalties asymmetrically. *Note that decreasing the exogenous parameters gives the exact opposite results*

	Exogenous parameter to be increased		
Endogenous variable	Penalty for bribing (p_L)	Penalty for reciprocating (q_H)	Penalty for receiving the reciprocation (p_H)
Probability of bribery (γ)	−	+	−
Probability of reciprocation (β)	+	−	+
Probability of reciprocated bribery ($\gamma\beta$)	+	−	+
Probability of detection (α)	No effect	−	No effect

bribing severely is according to our results, however, not at all advisable. Regarding the inspection game literature, we offer yet another model in which Tsebelis' results do not hold. We can conclude that given two collaborating offenders and an asymmetric penalty distribution, an increase in the penalty for reciprocating does reduce the overall rate of offence in the case of corruption.

Finally, we recognise that our assumptions about the payoffs of the inspector are not the only possible setup. The question of an optimal incentive structure for inspectors from the perspective of a social planner goes beyond the scope of this paper, but might make for interesting future research.

2.7 Conclusion

We have constructed a corruption game with two novel aspects, each catering to a specific literature. On the one hand, we built in asymmetric penalties as we found them in the political economy of corruption literature. This makes it possible to punish bribing and bribe-taking as well as reciprocating and receiving reciprocation to different degrees and allows us to make policy suggestions. On the other hand, we endogenise the probability of detection as is done in Tsebelis' inspection game. In contrast to other versions of the inspection game, our model incorporates three agents, a client, an official and an inspector. The fact that the offence (corruption) can only be completed in a joint effort between two of the players leads to surprising results, especially in conjunction with asymmetric penalties. Lambsdorff and Nell showed that, under exogenous detection, optimal deterrence could be achieved if bribing and reciprocating are punished severely, while bribe-taking and receiving the reciprocation are punished only mildly.

With detection as an endogenous variable, we find confirmed that higher penalties do reduce the overall rate of offence, if the offence is reciprocated bribery as a joint effort between client and official. This stands in contrast to Tsebelis' results. However, this result holds only if the penalty for reciprocating on the official is raised (maximised). For it increases the probability of bribery, but reduces the probability of both reciprocation and overall reciprocated bribery. Surprisingly, and unlike Lambsdorff and Nell's asymmetric penalty prescription, higher penalties on the client have the opposite effect. They may reduce the probability of bribery, but they also increase the probability of reciprocation to the extent that the overall probability of reciprocated bribery increases. So, in contrast to some existing anti-corruption regulation (e.g. Germany) our research does not only recommend an asymmetric distribution of penalties, but it puts forward the argument that penalties should be minimal for corrupt clients and maximal for corrupt officials. Several interesting extensions of our model are possible and should be addressed in future research.

Chapter 3

Does Reporting Decrease Corruption?

Abstract

We construct two cases of a three player one-shot corruption game, one in which reporting on corrupt clients is cumbersome and one in which it is rewarded (profitable). Both cases feature a client who can bribe or not, an official who can reciprocate or not, and an inspector who can inspect or not. In the first case, the official accepts the bribe by reciprocating or simply rejects the bribe by choosing not to reciprocate. In the second case the official either accepts and reciprocates or rejects and reports the bribe. Under successful inspection, offending players receive separate penalties, which can be varied asymmetrically. Under plausible assumptions about the values of payoff parameters, we obtain a mixed-strategy Nash equilibrium in both cases, akin to Tsebelis' inspection game. We obtain two interesting results. First, marginally changing the penalties moves the equilibrium probabilities in both games in the same directions, suggesting robustness of the model. We find that larger penalties on the client increase the overall probability of reciprocated bribery, i.e. corruption, while larger penalties on the official decrease corruption. Second, when comparing the two models, we obtain the surprising result that the probability of reciprocated bribery (corruption) is higher in the case, where the official is rewarded for reporting on the client.

Keywords: Reporting · Whistle blowing · Leniency · Inspection game · Corruption · Asymmetric penalties · Endogenising detection

JEL Classification: K42 · H00 · C72 · O17

Introduction

Corruption is a collaborative crime. It is not bribery alone that causes potential harm to society, but it is the abuse of public resources induced by bribery. Intuitively, the threat of punishment should act as a deterrent to corrupt individuals. Similarly, one would assume that giving officials the incentive to report on clients through rewards should reduce corruption. However, constructing plausible models of corruption shows that intuition can be misleading. We provide a theoretical account, showing that, in some plausible circumstances, both of those intuitions can be wrong.

Becker (1968) and Becker & Stigler (1974) were the first to model crime (and optimal deterrence) from an economic point of view. Taking the probability of detection and the size of penalty as the exogenous determinants of crime, their decision-theoretic analysis suggested that (when detection is costly and penalties in form of fines are free to the social planner) the combination of a maximum penalty and minimum detection efforts results in socially optimal deterrence. This model is still predominant in much of the theoretical economic work of corruption.[1]

Tsebelis (1989) extends Becker's analysis by endogenising the probability of detection. In his model, an inspector deliberately chooses some probability of inspection (for simplicity inspection is here equivalent to detection, in the event of an offence being committed). But a choice of probability strictly between zero and one can be rational for the inspector only if she is indifferent between inspecting and not inspecting. And that in turn, by assumption, depends on the probability of the criminal offending. If this were zero then the inspector would strictly prefer not to inspect, while if it were one then she would strictly prefer to inspect. So there is some critical probability of offending, between zero and one, the value of which depends on the inspector's payoff function, at which the inspector is indifferent between inspecting and not inspecting, and thus willing to randomise between them. But conversely for the criminal there is some critical probability of inspection, the value of which depends on the criminal's payoff function, at which the criminal is indifferent between offending and not offending, and thus willing to randomise. So, in this game between criminal and inspector, the equilibrium probability of inspection is determined by the criminal's payoffs, while the equilibrium probability of offending is determined by the inspector's. Now consider an exogenous increase in the penalty. Given that this changes only the criminal's payoffs, the equilibrium probability of offending must remain unchanged, while the equilibrium probability of inspecting must fall, to keep the criminal indifferent between offending

[1] Aidt (2003) reviews some of this literature.

and not. This is contrary to the first intuition described above that an increase in the penalty reduces the incidence of offending.

Concerning the second intuition – that rewarding officials for reporting on bribery should make corruption less likely – the literature is thin. Related fields are "whistle-blowing", which is generally understood as "raising a concern about malpractice within an organisation or through an independent structure associated with it" (UK Standing Committee on Standards in Public Life in Drew, 2003), and the idea of "self-reporting" in fraud contexts. In contrast, we are focussing on the specific case of rewarding officials for reporting on corrupt clients, when a bribe has been offered to them.

In dealing with both concerns – optimal deterrence and rewarding reporting – we consider two (very similar) cases of a simple model of corruption. Defining corruption as a collaborative crime, our model is an inspection game with two offenders. The two cases reflect two states of affairs: a world in which reporting is cumbersome and a world in which reporting on clients is rewarded (profitable).

Formally, our model has the following features.

We define actions for each player. A client can offer a bribe or not to an official. The official can either accept/reciprocate, reject, or report an offered bribe. Here is where we distinguish between the two cases of policy in our model. In case 1, mere rejecting always has a greater payoff than rejecting and reporting. In case 2 we assume the opposite. We will analyse both cases separately.

We define reciprocation as the act of returning the favour of a bribe, that is the return of some sort of quid pro quo (e.g. a government contract) to the client. The hard crime of corruption as reciprocated bribery can thus only happen in a joint effort between the two players. The game involves three penalties, one for bribing and one for receiving the reciprocation (both of those to the client), as well as one for accepting and reciprocating on the official. Distributing penalties asymmetrically allows for more insightful policy recommendations. Penalties apply with the probability of inspection, which is represented by the actions of a third player, the inspector; she can inspect or not inspect and her payoffs depend on whether there is an offence or not.

Our model has two main types of equilibrium, depending on the payoff structure. First, if the reward/penalty levels are such that officials would reciprocate for sure, even given the certainty of inspection, then the game in effect reduces to a Tsebelis-type inspection game between client and inspector. So, as in Tsebelis' game outlined above, increasing penalties on the client will have no effect on bribery but will reduce the probability of inspection, in equilibrium.

The second type of equilibrium, and the main focus of our analysis, occurs at reward/penalty levels such that officials would reciprocate for sure given a zero probability of inspection, but reject/report for sure given the certainty of inspection. This equilibrium is completely mixed, with randomisation not only by the client and the inspector, but also by the official. Here, as one of us has discussed elsewhere (Spengler, 2014), increasing the penalties on clients actually increases the equilibrium probability of reciprocated bribery (corruption). But also, as we find by comparing two cases of the model, a regime in which officials report (when rejecting) has a greater equilibrium level of reciprocated bribery than one in which they do not report. It is this result, which is central to this paper.

The rest of the paper is organised as follows. Section 3.2 considers related literature on corruption, reporting, and on the inspection game. Section 3.3 acts as a preamble to the analysis of both cases. Section 3.4 provides both an informal analysis and a formal analysis of case 1 and presents its results with a view to optimal corruption deterrence. Section 3.5 does the same for case 2. Section 3.6 formally compares both cases in equilibrium and shows that in case 2 (with reporting), for plausible ranges, there is a higher probability of reciprocated bribery than in case 1 (without reporting). Section 3.7 concludes.

3.2 Related work

This paper makes two contributions to the literature. On the one hand, it can be regarded as an extension of Tsebelis' (1989; 1990a; 1990a; 1995) inspection game, and therefore contributes to the literature that followed on from Tsebelis' initial work. On the other, it offers interesting insights into optimal deterrence of corruption and the rewarding of officials for reporting on clients, thereby contributing to the economics literature on corruption.

First, as an addition to the 'inspection game' literature, our findings, too, result from Nash mixed-strategy equilibria. The concept of a probability in a mixed-strategy equilibrium is based on the idea that players randomise between their respective pure strategies when indifferent. Probabilities can be interpreted as fractions of populations or as the probability with which actions take place. A number of studies have emerged, as for instance Andreozzi (2004), Friehe (2008) and Pradiptyo (2007). The same fundamental concept has also been used outside of the inspection game context, as the work of Graetz et al. (1986) in the tax evasion literature and of Dionne et al. (2009) in the insurance fraud literature shows. Some other works, namely Basu et al. (1992), Besley & Mclaren (1993), Mookherjee & Png (1995) and Marjit & Shi (1998), also model corruption with endogenous detection. In contrast to the players in these cooperative games, our players collaborate merely as selfish profit maximisers, but do not negotiate and our inspector is not corruptible. We thus avoid an ascending hierarchy of bribery.

Second, our work ties in with the political economy and economic theory of corruption literature.[2] The idea of asymmetric penalties had at least implicitly existed for a very long time. For example, Noonan (1984) describes how, in an ecclesiastical context, up until at least the thirteenth century, punishment was reserved for *bribees* (i.e. officials), and not clients. Rose-Ackerman (1999) was the first to contribute theory on asymmetric punishment of clients and bribe-takers. She argued that deterring one of the two collaborators necessary in a corrupt act required less resources and should therefore be preferred. On the basis of Becker's optimal deterrence argument, this idea was formalised by Lambsdorff & Nell (2007).[3] It proposes that, for optimal deterrence, penalties for bribing and reciprocating should be high, while they should be low for accepting bribery and receiving reciprocation. Conversely, Basu et al. (1992) argue that penalties should be low for reciprocation, but high for bribing and accepting bribery. In contrast, our results suggest maximal punishment on officials and minimal punishment on clients. Finally, Engel et al. (2012) offer experimental evidence, which suggests that asymmetric penalties generally provide more effective deterrence than symmetric penalties.

Surprisingly, there is not much literature on the idea of rewarding officials for reporting on bribery. Lambsdorff & Nell (2007) consider the effects of leniency in their model, by giving clients and officials the option to report on each other. In line with their findings for optimal deterrence, leniency is proposed to act as a wedge between client and bribee, suggesting that leniency might further deter corruption. Although informally, Brunetti & Weder (2003) argue that in the reverse case, where clients are asked to pay a bribe, there be no incentive to report on officials due to the reciprocal benefit. Empirical work by Zipparo (1999) finds that *a)* a lack of sufficient evidence against clients, *b)* the unavailability of legal protection, *c)* personal unaffectedness, *d)* fear of negative repercussions and other issues are reasons why officials refrain from reporting bribery. In our paper we stipulate that unrewarded reporting is cumbersome, but it can easily be exchanged for any of the above reasons. A range of work has been done on self-reporting and leniency – an aspect we do not explore in this paper. One important example is, however, Buccirossi & Spagnolo (2006), who find that leniency in case of self-reporting may, if ill-designed, lead to more corruption. Yet more research on leniency

[2] Jain (2001) provides a succinct summary of this literature. Rose-Ackerman (2006) provides an extensive account of the economics of corruption. As mentioned earlier, Aidt (2003) reviews literature on the microeconomic theory of corruption.

[3] Asymmetric penalties to undermine the force of reciprocal relationships like corruption are the building blocks of the invisible foot principle in Lambsdorff (2007).

and whistle-blowing is based on other multi-agent contexts such as cartel formation, but it is still (to some extent) relevant to the study of corruption. In the context of cartel deterrence, experimental evidence (based on a repeated Bertrand price game) suggests that reporting can be effective (Bigoni et al., 2008). In contrast, Apesteguia et al. (2007) found their predictions of successful cartel repression through rewarded whistle-blowing (in a one-shot Bertrand model) not confirmed by experimental data. Spagnolo (2008) offers an extensive summary of this literature.

3.3 Preamble to the analysis

We construct two cases of a three player one-shot game. In the first, we have a client who can bribe or not, an official who can accept and reciprocate or reject the bribe, and an inspector who can inspect or not. In the second, we have a client who can bribe or not, an official who can accept and reciprocate or reject and report the bribe, and an inspector who can inspect or not.

First, consider the similarities between the two cases. Both cases feature the same penalties, allowing us to distribute punishment asymmetrically. The client can be penalised for bribing (p_L) and for receiving reciprocation (p_H). By reciprocation we mean that the official "returns the favour" in form of some quid pro quo. We will show later that both of those penalties have the same effect. The official can be penalised for accepting the bribe and for reciprocating. In our model, we assume that the official always reciprocates, when she accepts. We thus conflate the penalties for accepting and reciprocating into q.

Second, for what follows, we make a crucial and plausible assumption (call this assumption "P") about the preferences and payoffs of the three players. The client prefers to offer a bribe if and only if the inspector's probability choice of inspection is below a certain threshold and further that this threshold is less than certain inspection (i.e. probability one). This should hold even if the official were to accept and reciprocate for sure. Likewise, the official prefers to accept and reciprocate if and only if the probability of inspection is below a certain threshold and further that this threshold is less than inspection with certainty. The inspector, on the other hand, prefers to inspect if and only if the probability of offering a bribe is greater than a certain threshold and that this threshold is greater than zero. This suggests that the game has opposing payoffs. Given this assumption regarding preferences and payoffs, it is easy to see that there is no equilibrium in this game, whereby any of the three players is best off by choosing one action with certainty. So, we can exclude both pure-strategy equilibria and mixed-strategy equilibria, in which any of the players plays a degenerate mixed-strategy. The unique equilibrium of this game must therefore be in completely mixed strategies.

Now, we are interested in comparing both cases. To do this, consider how the two cases differ and what motivates these differences. In case 1, "P" requires for the official that bribery pays more than it does to reject, if and only if there is no inspection, but less than to reject if there is inspection and thus a penalty. In case 2, "P" still holds, however, the official now prefers to reject and report the bribe, rather than just to reject it. Here is what we consider a move from case 1 into case 2: suppose that there was no reward for reporting on clients, but instead that reporting was, at the very least, cumbersome.[4] In case of certain inspection, the official would then clearly prefer to merely reject the bribe, rather than also report it. This circumstance reflects case 1. Suppose now that the social planner was to slowly raise a reward to officials for reporting on corrupt clients. This could be interpreted as monetary, moral or other rewards to the official from reporting. If this is done sufficiently, such that the payoff for reporting surpasses the payoff for merely rejecting bribery, we move into case 2. Just as we pass the threshold, all payoff parameters are virtually the same between the two cases. To be precise, all parameters are the same, apart from the payoff for rejecting and the payoff for reporting, which differ marginally. We can then compare the probabilities with which players mix between their strategies and thus observe what happens to the probability of reciprocated bribery as we move from case 1 (without reporting) into case 2 (with reporting). This last step of the analysis will allow us to conclude that rewarding reporting, within plausible ranges, is not an advisable policy.

Before comparing the two cases, however, we provide a detailed analysis of each case in itself. Focusing on the completely mixed equilibrium, we study how the probabilities, with which players mix between their strategies, change. We do so, as we marginally change the penalties on each offender and as we marginally change the (reward) payoff to the official for rejecting and, respectively, reporting.

3.4 Corruption in a world without reporting – case 1

Consider Figure 4, the extensive form game of case 1, where $\gamma \in (0,1)$ is the probability of bribery, $\beta \in (0,1)$ is the probability of acceptance and reciprocation and $\alpha \in (0,1)$

[4] One might as well imagine that reporting has a psychological effect, such as fear of retaliation from a reported client.

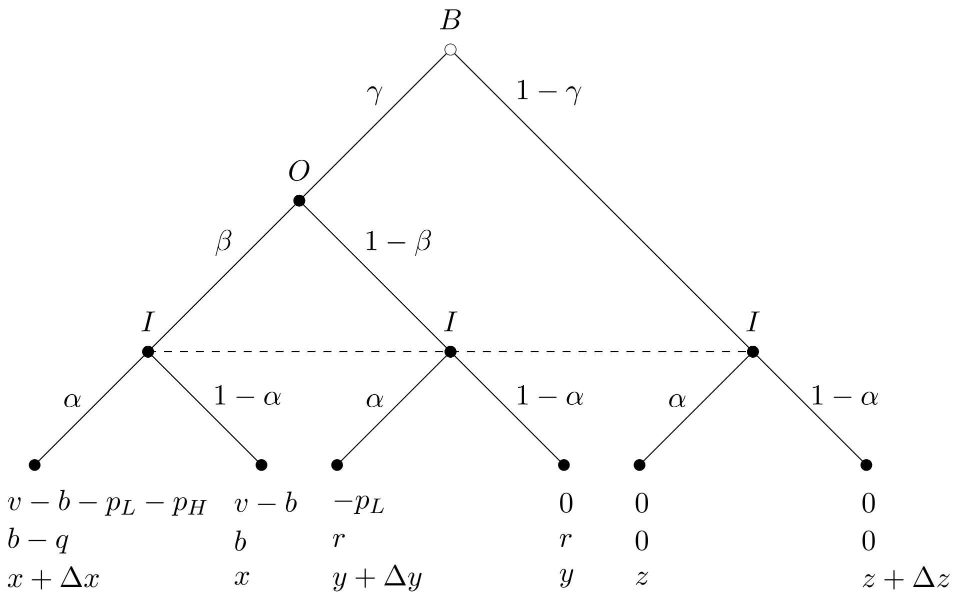


FIGURE 4: Extensive form game without reporting

the probability of detection.[5] In case 1, the probability $1-\beta$ in Figure 4 reflects the notion of rejecting an offered bribe (and not that of reporting).

For the client we assume that bribery is profitable, if it is met with reciprocation, but not with inspection, where b is a bribe and v is the benefit from reciprocation to the client. This implies that $0 < b < v$ and $0 < p_L, p_H$, such that $v - b - p_L - p_H < 0$.

For the inspector we derive our initial assumptions from Tsebelis' inspection game, assuming that inspection is profitable, as long as at least one offender offends, but costly, if there is no offence. This implies that $x < 0 < x + \Delta x$, that $y < 0 < y + \Delta y$, but that $z < 0 < z + \Delta z$. This setup reflects the intuition that successful inspection is worthwhile, as it leads to promotion or similar benefits, while unsuccessful inspection merely costs effort. The complexity of the model requires that we make some further assumptions about the inspector's payoffs. We assume that inspecting reciprocated bribery is more lucrative than inspecting mere bribery and, analogously, that not inspecting reciprocated bribery incurs a greater loss than not inspecting mere bribery due to the higher opportunity cost of non-inspection. This implies that $0 < y + \Delta y < x + \Delta x$ and that $x < y < 0$.

For the official we assume that receiving a bribe is profitable so long as there is no inspection, implying that $0 < r < b < q$. The parameter r can be interpreted in several

[5] We define these probabilities here as strictly between zero and one, since the previous assumption "P" suggested that we are looking at a completely mixed equilibrium. We will relax this condition in the formal analysis.

ways. One way to describe it would be as a neutral payoff, reflecting the preferred option available to the official, when reciprocating (and accepting bribery) appears not profitable. It could also be interpreted as some form of moral relief when rejecting the bribe or as some minor reward for rejecting that does not exceed the value of an uninspected bribe.

Given our previous assumption "P", the unique equilibrium of this game is in mixed strategies. The following analysis continues based on the same assumption. Other types of equilibria are possible, if we relax assumption "P". For completeness, we will discuss these equilibria briefly at the end of this section.

3.4.1 An informal analysis of case 1

We assume that the penalties on both offenders relative to the benefits from v, b and r are such that $\alpha, \gamma, \beta \in (0, 1)$, meaning that strategies are completely mixed in equilibrium.[6] The crucial feature of a mixed-strategy equilibrium is that each player who mixes her pure strategies ought to be indifferent between her respective pure strategies *vis-à-vis* the probability distributions with which the other players mix between their respective pure strategies. Before expressing indifference and the implied equilibrium probabilities algebraically, we provide an informal analysis of the effects of marginal penalty changes on the equilibrium probabilities.

Consider a marginal increase of either of the penalties on the client (p_L, p_H) in equilibrium. If all else remains equal, the client's expected payoff for bribing has now decreased, such that she ceases to be indifferent. To keep her indifferent, either the probability of reciprocation (β) has to increase or the probability of inspection (α) has to decrease. We know that α cannot change, because otherwise the official would cease to be indifferent. Therefore, β must increase. If, however, β increases, the inspector will no longer be indifferent. Thus, to keep her indifferent, γ must decrease. This establishes the movement of all three equilibrium probabilities, when marginally increasing penalties on the client.

Now, consider a marginal increase in the penalty on the official (q) in equilibrium. If all else remains equal, the official's expected payoff for accepting and reciprocating has now decreased, such that she ceases to be indifferent. To keep her indifferent, the probability of inspection (α) has to decrease. If α decreases, the client is no longer indifferent; she would now prefer to bribe for sure. Thus, to keep the client indifferent, following the

[6] We assume that $\alpha, \gamma, \beta \in (0, 1)$ holds before and after a marginal upwards or downwards change in any of the penalties.

earlier reasoning, β must decrease. It follows that, if β decreases, the inspector can only be kept indifferent, if γ increases. It thus holds:

Proposition 5. *Given that $\alpha, \gamma, \beta \in (0, 1)$, increasing any penalty on bribery decreases the probability of bribery, but it also increases the probability of reciprocation (while the probability of detection remains constant). Analogously, increasing the penalty on accepting bribery and reciprocation (q) increases the probability of bribery, but it decreases the probability of reciprocation and the probability of detection.*

However, Proposition 1 is a necessary, but insufficient condition for keeping the inspector indifferent. It matters to what extent the two probabilities change, which we can ascertain as follows. The inspector's information set compels her to consider the event *(i)* of a reciprocated bribe which occurs with probability $\gamma\beta$, the event *(ii)* of an unreciprocated bribe, which occurs with probability $\gamma(1-\beta)$, and the event *(iii)* of no bribe, which occurs with probability $1-\gamma$.

Suppose that γ decreases, while β remains constant. This would imply a shift in probability from (reciprocated) bribery to no bribe – events *(i)* & *(ii)* become less likely and event *(iii)* becomes more likely. Our assumed payoffs then indicate a decrease in the expected payoff from inspecting; the inspector ceases to be indifferent. We know from before that, to offset this, β must increase. Suppose β changes to the same extent as (and in the opposite direction of) γ, such that the probabilities of reciprocated and unreciprocated bribery (events *(i)* & *(ii)*) remain constant. Our assumed payoffs of the inspector then still imply that event *(iii)* becomes more likely, while the probabilities of events *(i)* and *(ii)* do not change, such that she would prefer not to inspect. So, to keep the inspector indifferent between inspecting and not inspecting, the increase of β ought to be larger in proportion than the decrease of γ, such that the overall probability of reciprocated bribery increases. It thus holds (for changes of any parameters other than the payoffs of the inspector):

Proposition 6. *Given that $\alpha, \gamma, \beta \in (0, 1)$, a decrease of γ must be accompanied by a proportionally greater increase of β, and vice versa, such that the probability of reciprocated bribery ($\gamma\beta$) moves in the same direction as the probability of reciprocation (β).*

Finally, it is easy to see what would happen, were we to increase the reward for rejecting bribery, r, to the official.[7] In fact, it follows the same reasoning as for increasing q: as rejecting becomes more attractive, the official is no longer indifferent between her respective pure strategies. To keep her indifferent, the probability of inspection must

[7] We explore this here for completion. For our analysis it suffices to assume that r represents the neutral payoff of rejecting in a sense of opting out of engaging in corrupt behaviour.

decrease. As this will cause the client to no longer be indifferent, the probability of reciprocation has to increase. This leads us to once more claim Propositions 1 and 2.

We are able to confirm these Propositions mathematically, which we do in the next subsection.

3.4.2 Formal analysis of case 1

To express indifference algebraically, for each player we equate the payoffs for each strategy. Using the payoffs in Figure 4, we obtain equations (3.1), (3.2), and (3.3). The first keeps the client indifferent; the second keeps the official indifferent; and the third keeps the inspector indifferent:

$$\beta[v - b - \alpha(p_L + p_H)] + (1 - \beta)(-\alpha p_L) = 0 \tag{3.1}$$

$$\alpha(b - q) + (1 - \alpha)b = \alpha r + (1 - \alpha)r \tag{3.2}$$

$$\gamma\beta(x + \Delta x) + \gamma(1 - \beta)(y + \Delta y) + (1 - \gamma)z = \gamma\beta x + \gamma(1 - \beta)y + (1 - \gamma)(z + \Delta z) \tag{3.3}$$

Supposing the completely mixed equilibrium under assumption "P", we obtain the following equilibrium probabilities for γ, β and α from the previous equations:

$$\beta = \frac{\alpha p_L}{v - b - \alpha p_H} \tag{3.4}$$

$$\alpha = \frac{b - r}{q} \tag{3.5}$$

$$\gamma = \frac{\Delta z}{\beta(\Delta x - \Delta y) + \Delta y + \Delta z} \tag{3.6}$$

For procedural completeness we derive and report the explicit equilibrium solutions for equations 3.4 and 3.6, expressing the behavioural variables as functions of payoffs only.

$$\beta = \frac{(b - r)p_L}{(v - b)q - (b - r)p_H} \tag{3.7}$$

$$\gamma = \frac{[(v - b)q - (b - r)p_H]\Delta z}{(b - r)p_L(\Delta x - \Delta y) + [(v - b)q - (b - r)p_H](\Delta y + \Delta z)} \tag{3.8}$$

Formally, taken together, the probabilities in equations (3.4), (3.5), and (3.6) are a completely mixed Nash equilibrium under the following conditions. For the strategy space $\gamma, \beta, \alpha \in [0, 1]$ and given our previous assumptions about the relative size of payoff parameters, sequential rationality requires that: for the client the probability of offering a bribe must be equal to zero, if the probability of accepting/reciprocating is less than the probability of accepting/reciprocating in equation (3.4) and equal to one in the reverse case; for the official the probability of accepting/reciprocating must be equal to zero, if the probability of inspection is greater than the probability of inspection in equation (3.5) and equal to one in the reverse case; and for the inspector the probability of inspection must be equal to zero, if the probability of offering a bribe is less than the probability of offering a bribe in equation (3.6) and equal to one in the reverse case. Further, we define $\tilde{\alpha}$ as the probability of inspection at which the client is indifferent given that the official accepts/reciprocates for sure:

$$\tilde{\alpha} = \frac{v - b}{p_L + p_H} \tag{3.9}$$

We then obtain the completely mixed equilibrium if $0 < \alpha < min\{\tilde{\alpha}, 1\}$. To see the existence of this equilibrium, consider the following rationale. If the probability of inspection was greater than the critical probability that keeps the official indifferent, she would not reciprocate for sure and so the client would not offer a bribe for sure. But if there is no offering of a bribe, the inspector would not inspect for sure, thus contradicting the premise that the probability of inspection was greater than that, which keeps the official indifferent. Further, suppose that the probability of inspection was lower than the critical probability that keeps the official indifferent, in which case the official would accept/reciprocate for sure. Since then the probability of accepting/reciprocating is greater than that, which keeps the client indifferent in equation (3.4), the client would offer a bribe for sure. If an offered bribe is certain, however, the inspector would inspect for sure, which contradicts the premise that the inspector would inspect with a probability less than that, which keeps the official indifferent. So, the unique equilibrium probability of inspection must be that indicated by α in equation (3.5).

Further, and given the previous reasoning, suppose that the probability of accepting/reciprocating is greater than the supposed equilibrium value in equation (3.4), in which (as just established) the probability of inspection is that, which keeps the official indifferent. Since then the client would offer a bribe for sure, the probability of an offered bribe is greater than that which keeps the inspector indifferent, as indicated by (3.6). In that case, however, the inspector would inspect for sure, which contradicts our previous conclusion that the probability of inspection must be that indicated by α in equation (3.5). Suppose instead that the probability of accepting/reciprocating is less than the supposed equilibrium value in equation (3.4), in which the probability of inspection is that, which keeps the official indifferent. Since then the client would for sure not offer a bribe, the probability of an offered bribe is less than that, which keeps the inspector indifferent. So, the inspector would for sure not inspect, which contradicts the previous conclusion again. So, the unique equilibrium must occur where the probability of accepting/reciprocating is equal to that indicated by β in (3.4) and given α in (3.5).

Finally, given the previous two paragraphs' conclusions, suppose that the probability of offering a bribe is either less or greater than (but not equal to) the probability of an offered bribe indicated by equation (3.6), which is directly based on the probability of accepting/reciprocating in (3.4) and indirectly on the probability of inspection in (3.5). Since then the client would then either offer a bribe for sure or not offer a bribe for sure, the probability of an offered bribe is not equal to that, which keeps the inspector indifferent. Then the inspector would either inspect for sure, or respectively, for sure not inspect, both of which contradict the first conclusion that the equilibrium probability of inspection must be equal to that indicated by α in (3.5). So, the unique equilibrium must occur at the probability values indicated by equations (3.4), (3.5), and (3.6).

This equilibrium can be illustrated graphically, which we do in Figure 5. In the right-hand quadrant, equation (3.4) is displayed, showing the probability of accepting/reciprocating as a function of the probability of inspection. In the left-hand quadrant, equation (3.6) is displayed, showing the probability of offering a bribe as a function of the probability of accepting/reciprocating. For illustration purposes we define a set of (in relative terms) plausible numerical values, with which we obtain the completely mixed equilibrium. The set of values can be found in Table 3 and they give the probability values γ^A, β^A, and α^A. (For better comparison we use the same numerical values here, as we do when comparing the completely mixed equilibrium to other types of equilibria later.) Looking at Figure 5, we can retrace the reasoning of the previous paragraphs: if any player was to mix with a probability greater or less than the probability values γ^A, β^A, and α^A, this would result in a contradiction instead of an equilibrium.

Table 3: Parameter values for the completely mixed equilibrium

Parameter	v	b	p_L	p_H	q	r	$x+\Delta x$	x	$y+\Delta y$	y	z	$z+\Delta z$
Numerical values	12	3	8	8	4	2	10	1	8	7	5	8

We now turn to a comparative statics analysis of this equilibrium. Looking at (3.5), we derive that an increase in either q or r will decrease the probability of inspection, α. Equation (3.4) shows that a decrease in α leads to a decrease in β. Equation (3.6) shows that a decrease in β will lead to an increase of γ.[8]

Analogously, looking at (3.4), we derive that an increase in p_L or p_H will cause β to increase. Equation (3.6) shows that an increase in β will lead to a decrease of γ. In fact, we can confirm that γ and β must always move in opposite directions by totally

[8]To confirm this, recall that $0 < \Delta x, \Delta y, \Delta z$ and that $\Delta y < \Delta x$.

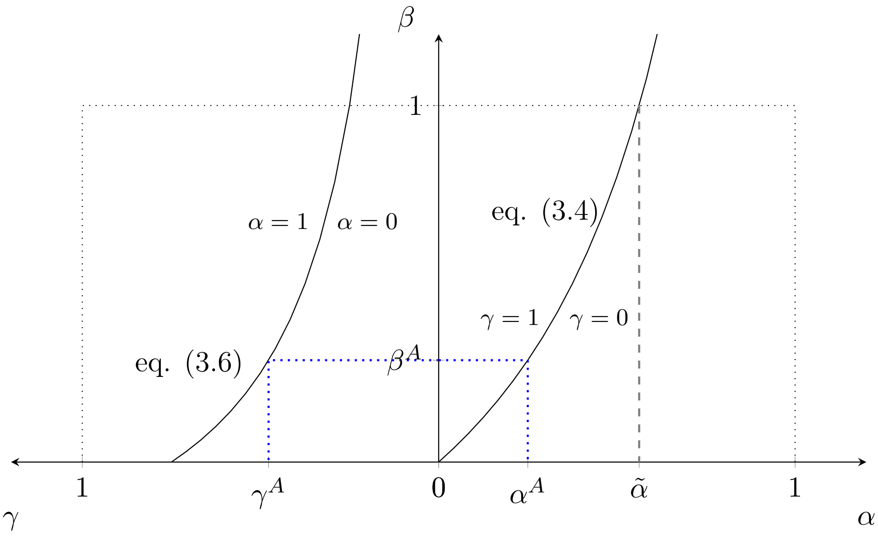


FIGURE 5: Completely mixed equilibrium (obtaining γ^A, β^A, and α^A through values in Table 3).

differentiating (3.3):

$$\frac{\mathrm{d}\gamma}{\mathrm{d}\beta} = -\frac{\gamma(\Delta x - \Delta y)}{\beta(\Delta x - \Delta y) + \Delta y + \Delta z} \tag{3.10}$$

The sign of (3.10) is negative. We thus infer two effects. First, increasing the penalty on the official will decrease the probability of detection and the probability of acceptance and reciprocation, but it will lead to an increase of the probability of bribery. Second, increasing any penalty on the client will decrease the probability of bribery, but it will increase the probability of acceptance and reciprocation, while the probability of inspection remains unchanged. This confirms Proposition 1.

It remains to be seen what happens to the overall probability of accepted and reciprocated bribery, if we increase any of the penalties. It suffices to see the change in $\gamma\beta$ if γ changes; we can totally differentiate (3.3) and obtain:

$$\frac{\mathrm{d}\gamma\beta}{\mathrm{d}\gamma} = -\frac{\Delta y + \Delta z}{\Delta x - \Delta y} \tag{3.11}$$

Its sign is negative, which suggests that $\gamma\beta$ must move in the opposite direction to γ, and thus in the same direction as β. We conclude that increasing penalties on clients increases corruption (accepted and reciprocated bribery), whereas increasing penalties on officials decreases corruption. This confirms Proposition 2.

We collate the above results in Table 4.

TABLE 4: Change in α, γ and β when increasing penalties asymmetrically in case 1. *Note that decreasing the exogenous parameters gives the exact opposite results*

	Exogenous parameter to be increased		
Endogenous variable	Penalty for bribing (p_L)	Penalty for receiving the reciprocation (p_H)	Penalty or reward on/for official (q or r)
Probability of bribery (γ)	−	−	+
Probability of reciprocation (β)	+	+	−
Probability of reciprocated bribery ($\gamma\beta$)	+	+	−
Probability of detection (α)	No effect	No effect	−

The comparative statics effects just discussed can also be represented graphically, which we do in Figure 6 for an increase in r. To see this, consider the set of numerical values in Table 5. In addition to the previous set of values, which gave us γ^A, β^A, and α^A, we obtain γ^{A+}, β^{A+}, and α^{A+} through equations (3.4)-(3.6). In Figure 6 the arrows indicate the movement along equations (3.4) and (3.6) and the shift in equilibrium probabilities.

TABLE 5: Parameter values for the completely mixed equilibrium

Parameter	v	b	p_L	p_H	q	r	$x+\Delta x$	x	$y+\Delta y$	y	z	$z+\Delta z$
Numerical values (A)	12	3	8	8	4	2	10	1	8	7	5	8
Numerical values (A+)	12	3	8	8	4	2.6	10	1	8	7	5	8

3.4.3 Other equilibria

It is possible to obtain other types of equilibria. Essentially, this depends on the value of α that makes the client indifferent in comparison to the value of α that makes the official indifferent (see equations (3.5) and (3.9), which gave $\alpha = \frac{v-b}{p_H+p_L}$ and $\alpha = \frac{b-r}{q}$).

As discussed, the completely mixed equilibrium is obtained if $0 < \alpha < min\{\alpha_C, 1\}$, so no further analysis is needed here. We obtain another equilibrium if we suppose that either penalty q is sufficiently low and/or the payoff (reward) for rejecting r is sufficiently low,

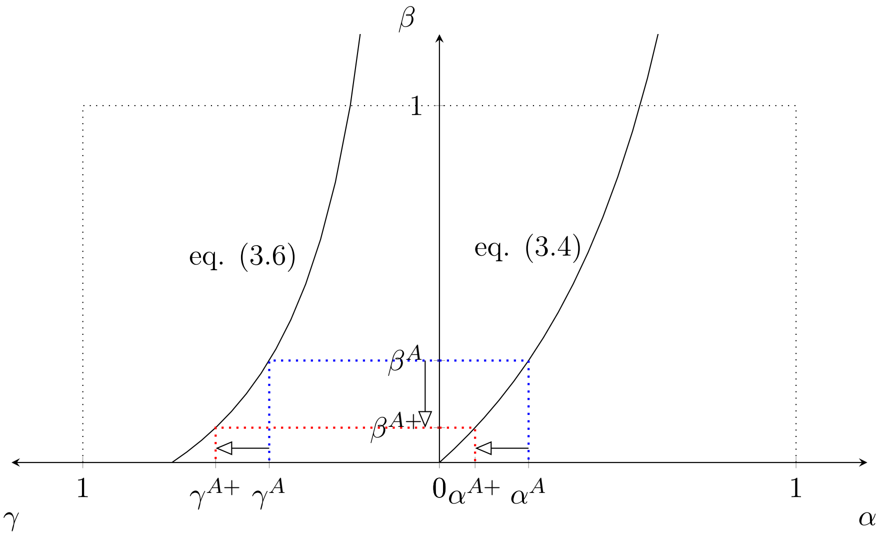


FIGURE 6: A marginal increase in r, causing a shift of the equilibrium probabilities γ^A, β^A, and α^A to γ^{A+}, β^{A+}, and α^{A+}.

such that the official prefers to accept and reciprocate even if inspection is certain, i.e. $1 \leq \frac{b-r}{q}$. Note that this implies $\beta = 1$, so that, if the penalties p_L and p_H are sufficiently low, and thus $1 \leq \frac{v-b}{p_H+p_L}$, the client prefers to offer a bribe even if inspection is certain. In this case we obtain an equilibrium where a bribe is offered, accepted and reciprocated despite definite inspection (so $\gamma, \beta, \alpha = 1$).

Similarly, if $\alpha \leq 0$ (the probability of inspection that keeps the official indifferent in equation (3.5)), i.e. such that the official always prefers to reject, this suffices to induce an equilibrium where there is no bribe offered, no accepting and reciprocating and hence no inspection (where $\alpha, \gamma, \beta = 0$).

Now suppose that we configure parameters in such a way that $\frac{(v-b)}{p_H+p_L} < \frac{b-r}{q}$. The probability of inspection is then determined by the requirement that the client be indifferent, so $\alpha_C < min\{\frac{b-r}{q}, 1\}$. In this case the official accepts and reciprocates for sure ($\beta = 1$), while the client and the inspector mix with the respective probabilities of offering a bribe and inspecting that make each other indifferent. We do not analyse this partially mixed type of equilibrium here, but we have done so elsewhere (Spengler, 2014). The following simulation shall suffice.

Figure 7 illustrates the completely mixed equilibrium, the partially mixed equilibrium and their mutual boundary as we increase the (reward) payoff r stepwise. Table 6 provides a set of plausible numerical parameter values which we use as a basis for Figure 7.[9] Consider first the completely mixed equilibrium, which we denote in blue and with the superscript A. As before, in the right quadrant, the curve, labelled accordingly

[9]Note that the values for the completely mixed equilibrium are the same as the ones used earlier to illustrate the equilibrium and its comparative statics effects.

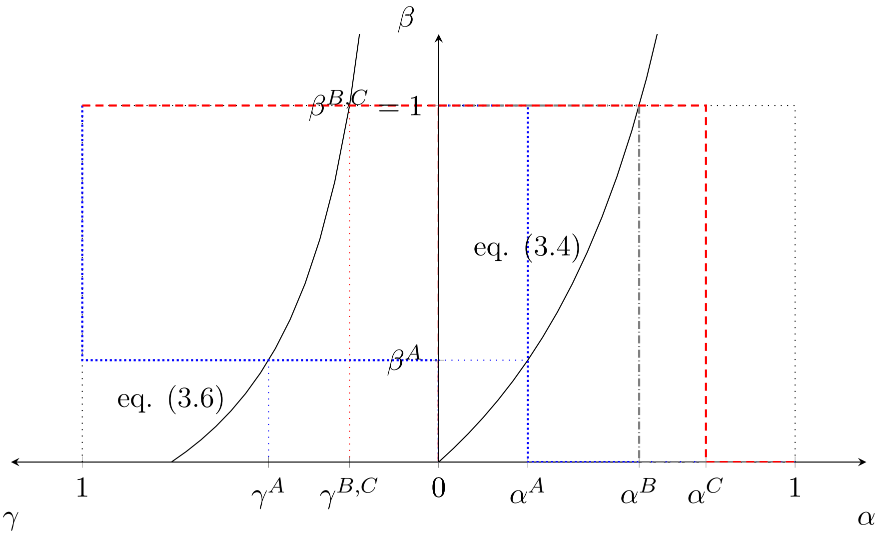


FIGURE 7: Displaying the completely mixed equilibrium (A, blue dotted line, $r = 2$), the partially mixed equilibrium (C, red dashed line, $r = 0$), and their mutual boundary (B, black dash-dotted line, $r = 0.75$)

with equation (3.4), describes the probability of reciprocation (β) as a function of the probability of inspection (α). Setting $r = 2$, we obtain $\alpha^A = 0.25$, where equation (3.4) provides the equilibrium value for β^A on the vertical axis. The curve in the left quadrant describes the probability of bribery (γ) as a function of β, denoted as equation (3.6). Given β^A, through equation (3.6), we obtain the equilibrium value γ^A on the reversed horizontal axis.

Now consider the partially mixed equilibrium, which we denote in red and with the superscript C. Setting $r = 0$, we obtain $\alpha^C = 0.75$, where equation (3.4) provides the equilibrium value for $\beta^{B,C} = 1$ on the vertical axis. Given $\beta^{B,C}$, through equation (3.6) we obtain the equilibrium value $\gamma^{B,C}$ on the reversed horizontal axis. Note that the only difference between the boundary and the partially mixed equilibrium type is the following. On the boundary (denoted in gray and with the superscript B, and obtained by setting $r = 0.75$), the official is indifferent between accepting and rejecting the bribe, and randomises with the degenerate mixed-strategy probability 1, while in the partially mixed equilibrium, the official strictly prefers to accept and reciprocate.

To illustrate the transition from the partial equilibrium into the completely mixed equilibrium, we use the same set of numerical parameter values from Table 6. Figure 8 shows the transition between the two equilibria as we increase r, the partial equilibrium being in the shaded area.

TABLE 6: Parameter values

Equilibrium type	v	b	p_L	p_H	q	r	$x+\Delta x$	x	$y+\Delta y$	y	z	$z+\Delta z$
Completely mixed equilibrium (A)	12	3	8	8	4	2	10	1	8	7	5	8
Boundary (B)	12	3	8	8	4	0.75	10	1	8	7	5	8
Partially mixed equilibrium (C)	12	3	8	8	4	0	10	1	8	7	5	8

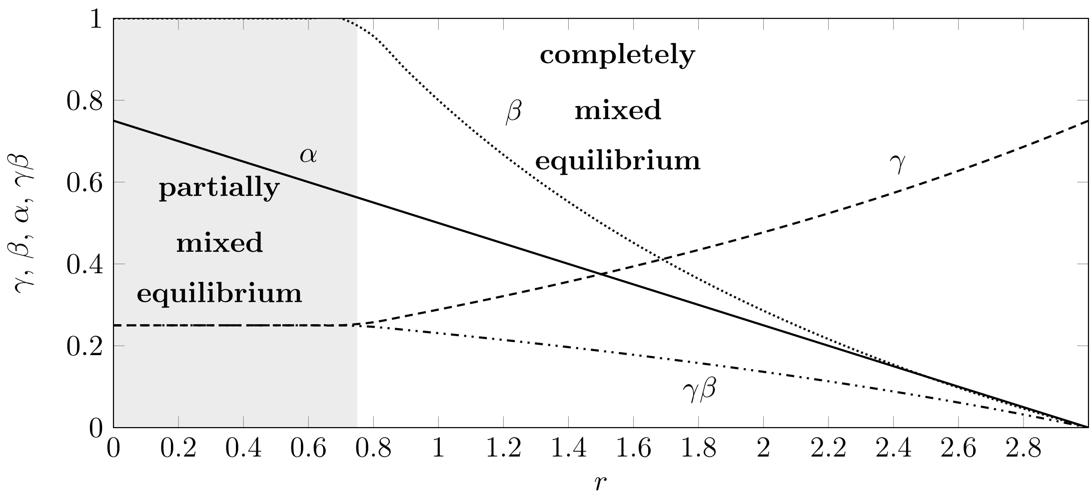


FIGURE 8: Transitioning from the partially mixed equilibrium into the completely mixed equilibrium as we increase r from 0 to 3 for the set of numerical values chosen. *We use values for intelligible ranges of* γ, β, α

3.5 Corruption in a world with reporting – case 2

Consider now Figure 9, the extensive form game of case 2, where γ' is the probability of bribery, β' is the probability of acceptance and reciprocation and α' the probability of detection. In this case the probability $1-\beta'$ reflects the notion of rejecting and reporting a bribe. Note that, for better representation, the histories β' and $1-\beta'$ are mirror inverted in Figure 9.

We carry over all previous assumptions from case 1, in addition to the following. Most importantly, given the possibility of reporting on bribery, the official prefers to reject and report if she expects to be inspected, which is denoted by s. Note again that, between the two games, the payoff for reporting in case 2 is marginally but strictly greater than the payoff for mere rejection in case 1, such that $r < s$. Figure 9 further shows that, in contrast to case 1, the client now faces penalty p_L for sure, if the bribe is rejected and reported (instead of $\alpha'(-p_L)$ if only rejected) and that the inspector's payoff is here w, as the inspector does not have an action in this instance. As a result, the inspector

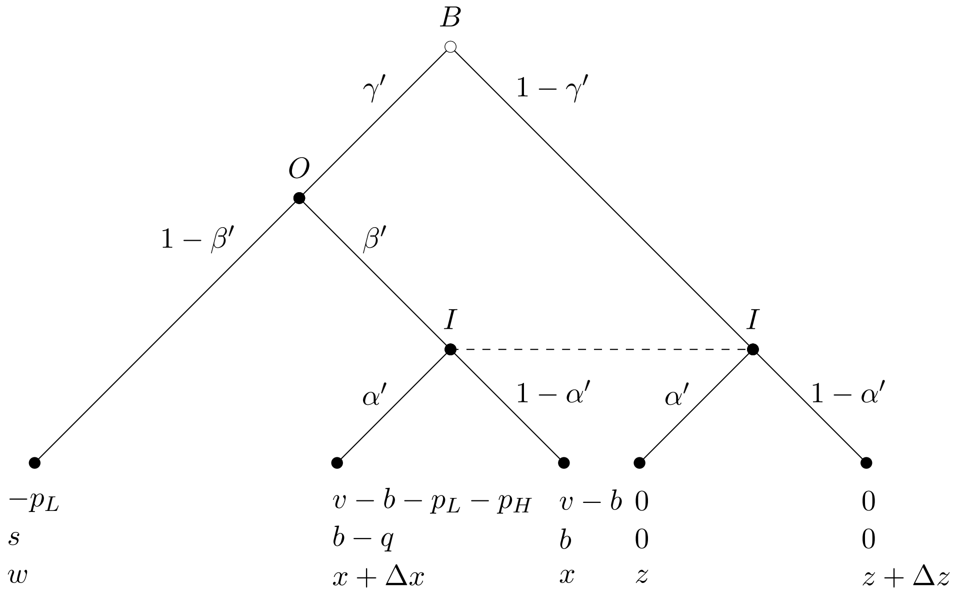


FIGURE 9: Extensive form game with reporting

only randomises over two histories in her information set: either a reciprocated bribe or no bribe. It suffices to adapt the conventional inspection game assumptions about the inspector's payoffs, where $0 < \Delta x, \Delta z$.

3.5.1 Informal analysis of case 2

Based on assumption "P" and on case 1, we assume that, given $\alpha', \gamma', \beta' \in (0,1)$, we are in a unique mixed-strategy Nash equilibrium. Recall the crucial notion that, to play a mixed-strategy, each player ought to randomise between her respective pure strategies with the probability distribution that keeps the other players indifferent between their respective pure strategies.

As before, we provide a brief informal analysis of the effects of marginal penalty changes on the equilibrium. In fact, not all that much changes from case 1 to case 2. Marginally increasing any penalty on the client (p_L, p_H) in equilibrium, ceteris paribus, reduces her expected payoff for bribing. To keep her indifferent, β' must increase, because α' cannot decrease, as this would render the official to no longer be indifferent. If β' increases, γ' must decrease to keep the inspector indifferent.

Analogously, a marginal increase of either the penalty on the official (q) or the reward for reporting (s) reduces the expected payoff for reciprocating of the official, thus α' ought to decrease to offset this effect. However, if α' decreases, the client's expected payoff for bribing increases. Thus to offset this, β' must also decrease. Finally, if β'

decreases, γ' must increase to keep the inspector indifferent. These effects are identical to Proposition 1.

The inspector's deliberation now only depends on only two events, that of a reciprocated bribe *(i)* and that of no bribe *(iii)*, which simplifies the analysis. Suppose that, in equilibrium, γ decreases. This would imply a shift in probability from bribe to no bribe, or from event *(i)* to event *(iii)*. Consequently, the inspector would no longer be indifferent, but prefer not to inspect. To offset this, β' must increase. Suppose γ' decreased and β' increased in proportion, such that $\gamma'\beta'$ remained constant. This would imply that the probability of event *(i)* remained constant, while the probability of event *(iii)* increased. In this case the inspector would again prefer not to inspect, because her expected payoff for non-inspection would have increased. As a result, we find Proposition 2 confirmed. Any change in γ' must be accompanied by a disproportionately larger change in β' in the opposite direction, such that the probability of a reciprocated bribe ($\gamma'\beta'$) always changes in the same direction as the probability of reciprocation (β'). Again, we can confirm these results mathematically, which we do in the next subsection.

3.5.2 Formal analysis of case 2

We follow the previous procedure. To express indifference algebraically, for each player we equate the payoffs for each strategy. Using the payoffs in Figure 9, we obtain equations (3.12), (3.13), and (3.14). The first keeps the client indifferent; the second keeps the official indifferent; and the third keeps the inspector indifferent:

$$\beta'[v - b - \alpha'(p_L + p_H)] + (1 - \beta')(-p_L) = 0 \tag{3.12}$$

$$\alpha'(b - q) + (1 - \alpha')b = \alpha' s + (1 - \alpha')s \tag{3.13}$$

$$\gamma'\beta'(x + \Delta x) + (1 - \gamma')z = \gamma'\beta' x + (1 - \gamma')(z + \Delta z) \tag{3.14}$$

From these, we obtain the following equilibrium probabilities for γ', β' and α':

$$\beta' = \frac{p_L}{v - b - \alpha'(p_L + p_H) + p_L} \tag{3.15}$$

$$\alpha' = \frac{b - s}{q} \tag{3.16}$$

$$\gamma' = \frac{\Delta z}{\beta' \Delta x + \Delta z} \tag{3.17}$$

Again, we derive and report the explicit equilibrium solutions for equations 3.15 and 3.17 for completeness, expressing the behavioural variables as functions of payoffs only.

$$\beta = \frac{qp_L}{(v-b+p_L)q-(b-s)(p_L+p_H)} \tag{3.18}$$

$$\gamma = \frac{[(v-b+p_L)q-(b-s)(p_L+p_H)]\Delta z}{qp_L\Delta x+[(v-b+p_L)q-(b-s)(p_L+p_H)]\Delta z} \tag{3.19}$$

Since the reasoning that shows the existence of the completely mixed equilibrium is parallel to that in case 1, we omit a lengthy derivation and continue with a comparative statics analysis. Looking at (3.16), we know that an increase of either q or s will result in a decrease of α'. Subsequently, a decrease in α' leads to a decrease in β' through (3.15) and to an increase in γ' through (3.17). In other words, increasing the penalties on the official will decrease the probability of inspection and of accepting and reciprocating bribery, but it will increase the probability of bribery.

Looking at (3.15), we know that if we increase p_H, β' will increase also. As before, (3.17) shows that if β' increases, γ' will decrease and vice versa. It is more difficult to see what happens to β' if p_L changes. We differentiate (3.15) accordingly:

$$\frac{\mathrm{d}\beta'}{\mathrm{d}p_L} = \frac{1-\beta'(1-\alpha')}{v-b-\alpha'(p_L+p_H)+p_L} \tag{3.20}$$

Given that $\alpha', \beta' \in (0,1)$, we know that both the numerator and the denominator must be positive. We thus infer that p_L ought to move in the same direction as β', suggesting that the effect of p_L is qualitatively the same as that of p_H. We can totally differentiate (3.14) to see that γ' must, in fact, always move in the opposite direction to β':

$$\frac{\mathrm{d}\gamma'}{\mathrm{d}\beta'} = -\frac{\gamma'\Delta x}{\beta'\Delta x-\Delta z} \tag{3.21}$$

Its sign is negative. We can thus confirm that increasing either penalty for bribing will decrease the probability of bribery, but increase the probability of acceptance and reciprocation. It remains the question of what happens to the overall probability of $\gamma'\beta'$ if, for example, β' changes. We totally differentiate (3.14) and obtain:

$$\frac{\mathrm{d}\gamma'\beta}{\mathrm{d}\beta'} = \frac{\Delta z}{\Delta x} \tag{3.22}$$

Its sign is positive, showing that $\gamma'\beta'$ must move in the same direction as β'. We conclude that, if either p_L or p_H increases, this will foster corruption ($\gamma'\beta'$), whereas increasing q will deter corruption. These results are the same as those from case 1. We collate the results from the this section in Table 7.

TABLE 7: Change in α', γ' and β' when increasing penalties asymmetrically in case 2. *Note that decreasing the exogenous parameters gives the exact opposite results*

	Exogenous parameter to be increased		
Endogenous variable	Penalty for bribing (p_L)	Penalty for receiving the reciprocation (p_H)	Penalty or reward on/for official (q or s)
Probability of bribery (γ')	$-$	$-$	$+$
Probability of reciprocation (β')	$+$	$+$	$-$
Probability of reciprocated bribery ($\gamma'\beta'$)	$+$	$+$	$-$
Probability of detection (α')	No effect	No effect	$-$

3.5.3 Other equilibria

As in case 1, it is possible to obtain other types equilibria. In fact, following the analogous procedure will derive the conditions for the same set of equilibrium types. Since this is so, we do not replicate the previous procedure here.

3.6 Does reporting decrease corruption?

As we said in the preamble, we are now interested in comparing the two cases. Recall what can be considered a move from case 1 to case 2: we assumed that, as long as there is no (or an insufficiently large) reward for reporting on bribers, the official prefers to merely reject the bribe, because reporting is cumbersome; this describes case 1. However, if the reward for reporting was greater than (for want of a better term) the gratification of rejection, this circumstance would reflect case 2.

In the analyses of the previous two sections we have considered the effects of marginally changing the penalties on each of the offenders, as well as the effects of marginally changing the reward for rejecting and, respectively, for reporting. We did all of this within the plausible range $b - q < r < b$, and, respectively, $b - q < s < b$. So, we have analysed both cases in the completely mixed equilibrium. As we move from case 1 to case 2 within this equilibrium, that is as s increases and surpasses r, and while all other exogenous parameters remain unchanged, we can analyse what happens to the probabilities with which players mix between their respective pure strategies in equilibrium. Recall that, in the completely mixed equilibrium, the probability of inspection was determined by the requirement to keep the official indifferent. A brief look at equations 3.23 and 3.24 confirms that α decreases as a function of r, so as s surpasses r, we know that $\alpha' < \alpha$. However, for the following analysis, let us, at first, suppose that all exogenous parameter values are the same in both cases, including $r = s$. As equations 3.23 and 3.24 show, this implies that $\alpha = \alpha'$.

$$\alpha = \frac{b - r}{q} \tag{3.23}$$

$$\alpha' = \frac{b - s}{q} \tag{3.24}$$

We then know that between the two cases only the payoffs for the client and the payoffs for the inspector have changed. For the client, a bribe rejected in case 1 is a bribe reported in case 2. For the inspector, a rejected bribe would have been a node in her information set in case 1, while a reported bribe is not a node in her information set in case 2. Supposing a reported bribe, the client now faces penalty p_L for sure, whereas, given a rejected bribe, she would only have incurred p_L with probability α. Since $\alpha \in [0, 1]$, we know that $\alpha p_L \leq p_L$. This implies a decrease in the expected payoff for bribing as long as we are in the completely mixed equilibrium, where $\alpha \in (0, 1)$. Given this change, the client is temporarily out of equilibrium. To bring her back to the point of indifference, the probability of accepting and reciprocating needs to increase (since the probability of inspection does not change), so we can infer that, if $r = s$, $\beta < \beta'$. Consider the equations that keep the client indifferent in case 1 (see 3.25) and in case 2 (see 3.26).

$$\beta = \frac{\alpha p_L}{v - b - \alpha p_H} \tag{3.25}$$

$$\beta' = \frac{p_L}{v - b - \alpha(p_L + p_H) + p_L} \tag{3.26}$$

Comparing both equations, we can see that, if we add $(1 - \alpha)p_L$ to both the numerator and the denominator of (3.25), we obtain (3.26). Given that $\beta \in (0, 1)$, we know that, in either case, the numerator must be larger than the denominator. We can thus infer that adding $(1 - \alpha)p_L$ to both the numerator and the denominator of (3.25) leads to an increase of β.[10] So we can confirm that $\beta < \beta'$.

The previous sections have shown that, in each separate case, an increase in β must be accompanied by a decrease of γ and an increase of $\gamma\beta$. It is now the question whether this holds as we compare both cases. From the inspector's perspective, there are two crucial elements to the transition from case 1 to case 2. One is that the node of a rejected and unreciprocated bribe drops out of her information set. This in itself implies

[10] Given $x < y$, it follows that $\frac{x}{y} < \frac{x+z}{y+z}$.

a decrease in the inspector's expected payoff from inspecting. This is intuitive, because a formerly rejected and unreciprocated bribe could have benefited the inspector, had she inspected it, whereas a reported bribe is irrelevant to her.

The other crucial element to understanding the implications of transitioning from case 1 to case 2 is to consider the effects of an increase in the probability of accepting and reciprocating on the two nodes that remain in the inspector's information set. Suppose that, following an increase in the probability of accepting and reciprocating, the probability of bribing does not change. In this case, the probability of reciprocated bribery increases, while the probability of no bribe remains unchanged. Given that after the transition the probability of a rejected bribe reduces to zero, this may or may not keep the inspector indifferent. So, depending on the parameter configuration a potentially large decrease in γ is required to keep the inspector indifferent after the transition into case 2.

To see this mathematically, consider the equations that keep the inspector indifferent in each case, where (3.27) refers to case 1 and (3.28) refers to case 2:

$$\gamma\beta\Delta x + \gamma(1-\beta)\Delta y + (1-\gamma)(-\Delta z) = 0 \tag{3.27}$$

$$\gamma'\beta'\Delta x + (1-\gamma')(-\Delta z) = 0 \tag{3.28}$$

We equate (3.27) and (3.28), rearrange and obtain:[11]

$$\gamma\beta\left[\Delta x + \frac{(1-\beta)\Delta y}{\beta} + \frac{\Delta z}{\beta}\right] = \gamma'\beta'\left[\Delta x + \frac{\Delta z}{\beta'}\right] \tag{3.29}$$

Looking at (3.29), it is now easy to see that the inequality $\beta < \beta'$ implies that $\gamma\beta < \gamma'\beta'$. Figure 10 illustrates these findings.[12] It is shown that, given $r = s$, the probability of accepting/reciprocating is greater in case 2 than in case 1. It is also shown that the probability of an offered bribe is greater in case 2 than in case 1, but this holds true only if the difference between the curves denoted by equations (3.6) and (3.17) is sufficiently large. At any rate, we know from the reasoning in the previous paragraphs that the equilibrium probability of reciprocated bribery (corruption) is greater in case 2 than in case 1, given $r = s$. For this analysis we have so far assumed that $r = s$. We only move into case 2, if and only if s is marginally, but strictly greater than r. As a result, $\alpha' < \alpha$. However, it is possible to find an $\epsilon = \alpha - \alpha'$, which is sufficiently small, such that $\beta < \beta'$. Consider Figure 11, which illustrates this point. Looking at the superimposed equations (3.4) and (3.14) in the right-hand quadrant, we observe a case where $r < s$ ($r = 1.3$, $s = 1.5$). To understand Figure 11, consider the value of α if $\beta = 1$ and, respectively, the

[11] Equating (3.27) and (3.28) first gives: $\gamma\beta\Delta x + \gamma(1-\beta)\Delta y + (1-\gamma)(-\Delta z) = \gamma'\beta'\Delta x + (1-\gamma')(-\Delta z)$.
[12] We continue to use the same set of numerical values as in case 1.

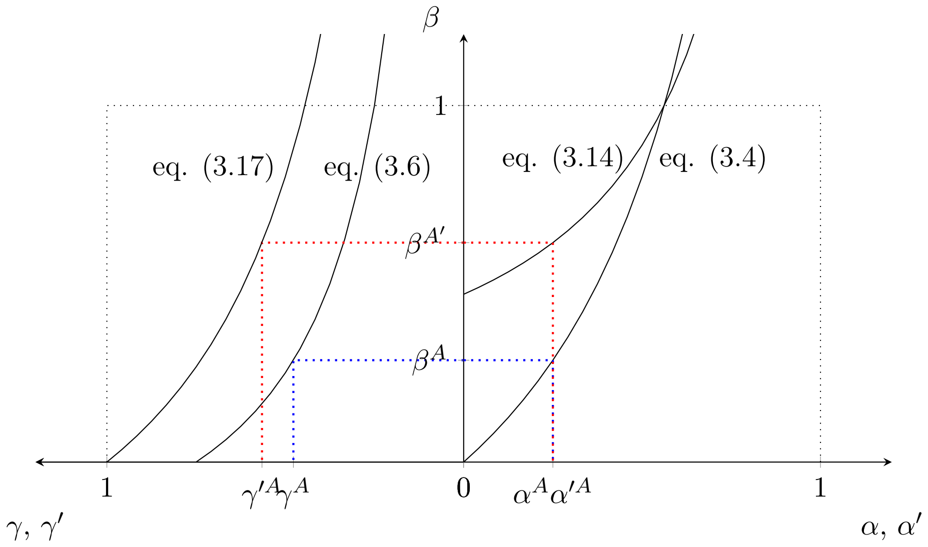


FIGURE 10: Comparing cases 1 and 2 in the completely mixed equilibrium, given $r = s$. *Values used are same as above, i.e.* $r, s = 2$, *resulting in* $\alpha, \alpha' = 0.25$, $\beta = 0.29$, $\beta' = 0.62$, $\gamma = 0.48$, *and* $\gamma' = 0.57$

value of α' if $\beta' = 1$, here again denoted by $\tilde{\alpha}$. Recall from our previous discussion about transitioning between equilibria that this was the equilibrium point on the boundary between the completely mixed equilibrium and the partially mixed equilibrium, where the official is indifferent between her actions but mixes with probability 1. Looking at equations (3.4) and (3.14), it is easy to see that then both reduce to $\tilde{\alpha} = \frac{v-b}{p_L+p_H}$. Figure 11 shows that, as we move towards the origin, there is a potentially large range for which case 2 is accompanied by a higher probability of reciprocation. Looking at equations (3.4) and (3.14), it can be inferred that this range would increase through an increase in p_H, as this would shift the curves in the right quadrant vertically apart. As a result, only a very substantial increase of s over r would be able to offset the sudden increase of reciprocation in case 2. Figure 11 illustrates the maximal difference between r and s (i.e. the payoff for rejecting and reporting, respectively), within which the equilibrium corruption rate is greater in case 2 than in case 1. More generally, so long as $s \in (r, r + \epsilon]$, the probability of accepting/reciprocating remains greater in case 2 than in case 1, and in consequence, so does the equilibrium probability of corruption. So, under the assumption that all parameter values stay the same between cases 1 and 2 (for plausible ranges of these values, as defined above), we obtain the important and counterintuitive result that in a world where officials are encouraged to report on bribery, corruption is more likely. To see that these ranges are indeed plausible, consider Figure 12. It shows the probabilities with which each player mixes and the probability of corruption for the completely mixed equilibrium, using the parameter values set in the previous section for a parallel increase in r and s. Note the ratio of the change in the probabilities of bribery and of accepting and reciprocating for any vertical

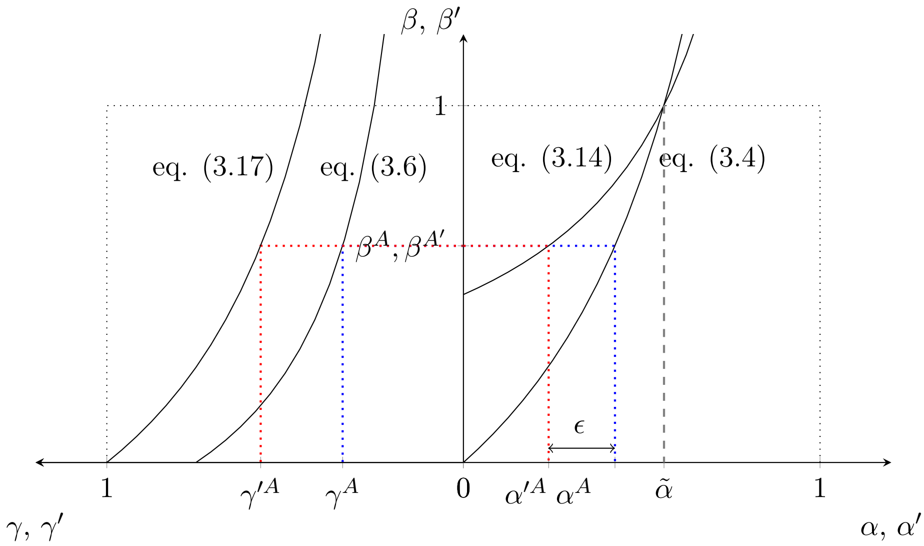


Figure 11: Transition from case 1 to case 2. *Values used are same as above except* $r = 1.3$ *and* $s \approx 2.$, *resulting in* $\alpha = 0.43$, $\alpha' = 0.38$, $\beta = 0.61$, $\beta' = 0.73$, $\gamma = 0.34$, *and* $\gamma' = 0.52$

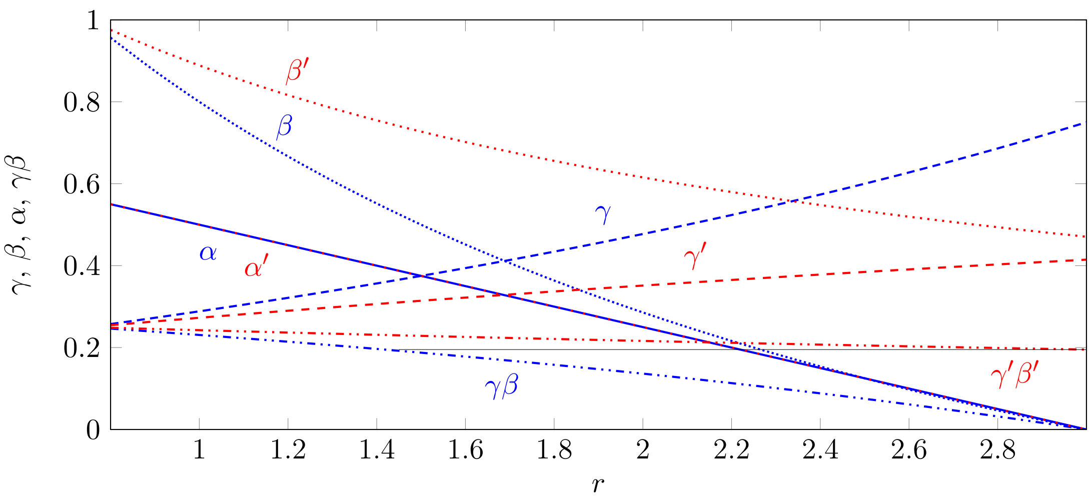


Figure 12: Comparing the the probabilities of bribery, reciprocation, inspection, and reciprocated bribery between cases 1 and 2 as we increase r and s from 0 to 3 for the set of numerical values chosen. *We use values for intelligible ranges of* γ, β, α

slice. It shows that a transition from case 1 to case 2 has the predicted consequences: the probability of a bribe decreases, but the probability of accepting and reciprocating increases substantially, such that the increase in the probability of corruption is large (up to 20% as we approach $r = 3$ for our set of parameter values). These effects increase, as we increase the values of r and/or s. The more unlikely corruption is, the larger is the range for which in case 2 there is more corruption than in case 1. (Of course, as either s or r continue to increase beyond the size of the bribe (b), the probability of corruption in equilibrium will reduce to zero.) A careful look at Figure 12 shows that, with this data, the reward for reporting can be substantially larger than that for rejecting and yet the probability of corruption is larger in the reporting case 2. The thin black line helps to visualise this.

3.7 Conclusion

We construct two separate extensive form corruption games with three players, in which a client and an official can bribe and reciprocate respectively and an inspector can inspect or not inspect. They differ as follows. Case 1 assumes that the official, if she decides not to reciprocate, simply rejects the bribe. The inspector does not know this, in which case both, the history of reciprocated bribery and the history of rejected bribery are relevant for the computation of expected utility for the inspector. Case 2 assumes that a reward makes it profitable for the official to report, rather than merely reject. In this case, the rejection/reporting history node becomes irrelevant to the inspector. Despite this difference between the cases, our results with regards to optimal deterrence remain robust. Maximum penalties on the official (for accepting and reciprocating bribery) deter corruption maximally (i.e. the overall probability of reciprocated bribery is reduced maximally), while maximum penalties on the client do the opposite. These results deviate both from Becker-type corruption deterrence prescriptions (such as Lambsdorff & Nell (2007)) as well as from other inspection game predictions. Comparing both cases as we marginally raise a reward for reporting over the default payoff for rejection reveals that, as soon as reporting becomes more profitable, the probability of reciprocated bribery (corruption) undergoes a discontinuous increase. This remains true as long as clients are punished for bribing. At least within a plausible range and with some leeway, corruption is more likely if we reward officials for reporting on clients. Only minimising penalties on clients reduces this range. The policy implications of these findings are significant. Not only do we confirm that asymmetric penalties have a higher deterrent effect on the probability of reciprocated bribery in our model, but we recommend that, under ceteris paribus condition, legislation that encourages reporting of bribery by officials can significantly increase the incidence of corruption and should therefore be altered.

Chapter 4

Corruption and Corruptibility: (Further) Perverse Results from a Mixed-Strategy Inspection Game

Abstract

In a society with many corruptible officials, do we get more or less corruption than in a society with fewer corruptible officials? Similarly, in a society with many whistleblowers – officials that report bribes that they have been offered – do we expect more or less corruption than in a society with fewer whistleblowers? We model corruption in a three-player inspection game, in which a client can offer or not offer a bribe, an official can accept, reject, or report the bribe, and an inspector can inspect or not inspect to reveal whether there has been a (accepted/reciprocated) bribe. Changing the probability distribution over types of officials that either always report, always reject or opportunistically accept or reject bribes, provides some interesting comparative statics. In a variant of the model where the bribe size is exogenous, we find that an increase in the probability of the reporting type increases the probability of corruption, while an increase in the probability of the corruptible type might either increase the probability of corruption or leave it unchanged, depending on the parameter configuration. In a second variant of the model where the bribe size is endogenous, we find that an increase in the probability of either the reporting type or the corruptible type increase the probability of corruption.

Keywords: Reporting · Whistle blowing · Leniency · Inspection game · Corruptibility · Corruption · Endogenous detection

JEL Classification: K42 · H00 · C72 · O17

Introduction

In a society with many corruptible officials, do we get more or less corruption than in a society with fewer corruptible officials? Similarly, in a society with many whistleblowers – officials that report bribes that they have been offered – do we expect more or less corruption than in a society with fewer whistleblowers? We develop a game-theoretic model to answer these questions and obtain some predictably surprising results. The results are predictably surprising, because our model is based on the inspection game, which typically solves for mixed strategy equilibria. We construct a scenario where clients (firms, private persons) are seeking to gain an advantage from bribing officials in order to receive some form of reciprocation. Bribing entails a risk of punishment given the probability of detection. In our model, clients do not know what kind of behaviour to expect from officials. We assume that there are three types of officials, some that take bribes if it pays off, some that always reject bribes and some that always reject and report bribes. Moreover, the probability of inspection and thus punishment depends on the action of an inspector.

This feature (endogenous inspection) links the paper to the literature on the inspection game, a model with which Tsebelis (1989, 1990b) presented a challenge to the policy implications of Becker's and Stigler's seminal works on the economics of crime (Becker, 1968; Becker & Stigler, 1974). In contrast to much previous and contemporary work, the inspection game has a structure of strictly opposing payoffs, resulting in a game with a unique mixed-strategy equilibrium (offenders only have incentive to offend, if there is no inspection, while inspectors only have incentive to inspect if there is an offence). In Tsebelis work, it lies in the nature of the mixed equilibrium that an increase in the size of the penalty on the offender will decrease the offender's expected utility of offending and thus requires a decrease in the incidence of inspection in equilibrium, while the incidence of an offence remains unchanged.

Our model shares these features with the original inspection game, and provides yet another set of interesting results. We analyse two variants of this game, one in which the size of the bribe is exogenous and one in which it is endogenous. We solve both variants using perfect Bayesian equilibrium and document the results from comparative statics exercises.

In the exogenous bribe variant we obtain two interesting equilibria (unique given the respective parameter setup), a partially mixed equilibrium and a completely mixed equilibrium. In the former, client and inspector randomise between their strategies to keep each other indifferent, while the corruptible type of official accepts/reciprocates with certainty. In the completely mixed equilibrium all three players randomise to keep each other indifferent. In the endogenous variant, the unique equilibrium is in partially mixed strategies. Here, client and inspector randomise between their strategies to keep each other indifferent, while the size of the bribe makes the corruptible official indifferent between accepting and not accepting, such that the the latter nevertheless accepts/reciprocates with certainty in equilibrium (and thus plays a degenerate mixed strategy).

We observe the following comparative statics effects. While the results of marginal, asymmetric penalty changes on clients and corruptible officials are equivalent to those in some of our previous work (Spengler, 2014; Bone & Spengler, 2014), the focus of this paper lies on varying the proportions of corruptible vis-à-vis rejecting and reporting types of officials.[1] In both variants of the game we find that an increase in the proportion of reporting type officials increases the probability of corruption. The effects of a marginal increase in the incidence of corruptible officials are more subtle and less surprising. Both, in the completely mixed equilibrium of the exogenous bribe variant, as well as in the endogenous bribe variant, an increase in the incidence of corruptible officials increases the probability of corruption. In the partially mixed equilibrium of the exogenous bribe variant, the incidence of corruption remains unchanged, if the proportion of corrupt officials rises.

To illustrate the comparative statics of our model, we define a set of (in ordinal terms) plausible parameters and visualise the movement from one equilibrium into the other, when increasing the probability distribution over types of officials. From our simulation data we observe the following. In the partially mixed equilibrium of the exogenous bribe variant, a 5% shift in probability from a rejecting type official to a reporting type official increases the probability of corruption by about 0.5% and a 5% shift in probability to the corruptible type official increases the probability of corruption by over 2%. In the completely mixed equilibrium of the exogenous bribe size, a shift in probability from a rejecting type official to a reporting type official increases the probability of corruption by about 3%, while an increase in the incidence of a corruptible type does not change the probability of corruption. Increasing the incidence of the reporting type, while simultaneously decreasing the incidence of the corruptible type

[1] In the partially mixed equilibrium results are similar to those in the original inspection game. Increased penalties do not change the probability of corruption, but will reduce the probability of inspection. In the completely mixed equilibrium, higher penalties on officials reduce the probability of corruption, but higher penalties on clients increase the probability of corruption.

(while keeping the probability of the rejecting type constant), shows that the probability of corruption peaks on the threshold between the partially mixed and the completely mixed equilibrium. In the endogenous bribe variant, we observe that an increase in the incidence of the reporting type (vis-à-vis the rejecting type) increases the probability of corruption minimally (a 50% increase in the reporting type increases corruption by less than 1%), while a 5% increase in the incidence of the corruptible type (vis-à-vis the rejecting type) increases the rate of corruption by 2%.

The rest of this paper is organised as follows. Section 4.1 gives an overview of the related literature. Section 4.2 describes and analyses the exogenous-bribe version of the game, including the simulation of comparative statics effects. Section 4.3 does the same with the endogenous-bribe version of the game and section 4.4 concludes.

4.1 Related Literature

This paper contributes to two strands of literature. One is the theory around the inspection game. The other is about the notions of corruptibility and whistle-blowing in the corruption literature.

Much work has been done on the inspection game. It's basic structure has been applied to arms control as well as various strands of economics, such as taxation, operations, accounting, auditing, environmental regulation and crime.[2] Fandel & Trockel (2013) develop a note-worthy three-player inspection game in which a manager's faulty decision is inspected by a controller, whereby the top-management decide upon the validity of the controller's report. Our paper differs from this, not only in structure but also in its application; ours contributes to the economics of crime. Recent work in this area includes Andreozzi (2004), Friehe (2008) and Pradiptyo (2007). The crucial common feature between Tsebelis' original game as well as other pieces in the inspection game literature and our model is the assumption that detection is endogenous. What differentiated some of our previous work (Spengler, 2014; Bone & Spengler, 2014) from that of others was the introduction of a second offender (the official in our model) and thereby linking the inspection game literature to the corruption literature. In addition to this, we now introduce different types of officials and the aspect of an endogenous bribe.

Corruptibility has mostly been researched in theoretical and experimental economics. Some informative work in other disciplines exists, such as in criminology (Withrow & Dailey, 2004). There is also some non-experimental empirical work on corruptibility

[2] Avenhaus et al. (2002) and Avenhaus & Canty (2009) provide an overview of the inspection game literature.

(Miller, 2006). The aspect of corruptibility in the theoretical corruption literature has so far been addressed in form of either of two interpretations. The first and more significant interpretation of corruptibility enquires how and whether corruption causes corruption. The second, more general interpretation of corruptibility takes it to mean simply the likelihood that an official reciprocates (and thus is corruptible) or that an agent performs a corrupt action, a notion which in our paper is distinct from corruptibility. The first interpretation is related to persistence and pervasiveness of corrupt behaviour. The corruptibility of individual agents (e.g. public officials) depends either on existing social norms (and thus on the past) or on a given agent's actual or perceived exposure to corrupt behaviour (and thus on present context). Early but oft-cited works in this field include Andvig & Moene (1990), Lui (1986), whose models' multiple equilibria include such where an increase in corruption makes inspection of corrupt behaviour less effective and thus leads to pervasive levels of corruption. Mishra (2006) provides two separate approaches to the question of persistence. The first, which differentiates itself from the literature by taking into account not only the cost-benefit analysis of non-compliance but also that of compliance, shows how pervasiveness results in persistence when corrupt behaviour becomes optimal despite corruption controls. The second makes use of evolutionary game-theory. It models how "mutant" corrupt (or collusive) behaviour can outperform honest behaviour and result in a corrupt equilibrium. Ryvkin & Serra (2012) develop an interesting model in which the uncertainty of potentially corrupt partners determines the amount of corruption in society. Other work in this area includes Palifka (2002), Sah (1991), Apesteguia et al. (2007), Buccirossi & Spagnolo (2006). A dated survey of the earlier literature is offered by Bardhan (1997).

There have been a number of experimental contributions, usefully reviewed in Ortmann (2005), which largely conform with the more general interpretation of corruptibility as a measure of the probability of corrupt reciprocity. The exception is here Falk & Fischbacher (2002), who hypothesise and confirm in their points-stealing experiment that the level of theft in the subject pool could influence the likelihood of theft of a given subject. Further experimental work enquires about corruptibility in relation to wages for public officials, such as Abbink (2002) and Barr et al. (2009, 2010). Schulze & Frank (2003) tease apart the intrinsic motivation for honest behaviour from deterrent effects of the presence of inspection, and consider both gender and opportunity costs of salaries as determinants of corruptibility. In contrast to this literature, we distinguish between the probability that a corrupt official reciprocates and the probability that an official is corruptible in the first place. Therein also lies the novelty of our approach. We define corruptibility as an exogenous probability, the comparative static effects of which we then investigate under different equilibrium conditions. So, in contrast to models such as Andvig & Moene (1990), in our model the probability of an official being of a corrupt type is an input rather than an equilibrium output.

The literature on reporting and whistle-blowing in the context of economics of corruption is indeed very sparse. Lambsdorff & Nell (2007) model a basic sequential game between a briber and a corrupt official. Looking at the effects of increasing rewards for reporting corrupt behaviour, they find that doing so will undermine reciprocity and thus act as a deterrent. Our model differs from this setup, not only because we assume endogenous detection, but because we vary the probability that the official is of the reporting type in our analysis.[3] Buccirossi & Spagnolo (2006) develop a model where corrupt agents can self-report, and show that this may increase corruption, depending on the design of rewards. We do not consider the option of self-reporting.

A range of relevant work related to whistle-blowing exists in other areas of economics. Berentsen et al. (2008) develop a model on doping in sports and report positive welfare effects when giving players the option to report on their fellow sportsmen. The game is surprisingly similar to ours in that it models the doping controller endogenously (i.e. like our inspector), which results in a unique perfect Bayesian Nash equilibrium in mixed strategies. In contrast to this model, our offending agents do not compete, but they collaborate. Similarly, we do not assume that inspection is conducted for each agent separately, but that there is one joint inspection. Finally, Berentsen et al. (2008) model the whistle-blowing aspect as a signalling game, whereby we model it in form of a reporting type official. A range of theoretical work exists in the context of cartel formation, which in part is applied to corruption. Some of the recent work in this area includes Aubert et al. (2006), Bigoni et al. (2008), Bigoni & Fridolfsson (2012), and Apesteguia et al. (2007). Spagnolo (2008) provides a useful summary of this literature. In the tax literature, Cerqueti & Coppier (2013) report that rewards paid to tax inspectors might improve their relative bargaining position, if false reports are rewarded, which leads to undesired effects. Arce (2010) provide a general economic approach to whistle-blowing. By using an evolutionary game-theoretic model to examine ethical aspects of whistle-blowing, they investigate the conflicting moral interpretations of a whistle-blower as either a "hero" or a "rat". Heyes & Kapur (2007) theoretically examine the effect of policy on whistle-blowing activities. In considering the aspects of whistle-blower protection after reporting, the responsiveness of regulatory authorities to reporting, and the severity of punishment of the perpetrators, it is found that depending on the motivations behind whistle-blowing behaviour, neither strict pursuit of reports nor maximal penalties on perpetrators are optimal in the battle against organisational fraud. Schmidt (2005) discusses the economic aspects of whistle-blowing with regards

[3]Bone & Spengler (2014) show that, under endogenous detection, reporting may increase corruption.

to accounting standards from a neo-institutional perspective. They find that, depending on the whistle-blower's incentives, whistle-blowing to an outside organisation (e.g. a regulator) might worsen the negative effects of the reported misconduct. In contrast, reporting internally, i.e. within the organisation, is shown to have positive efficiency effects.

Some useful research on whistle-blowing outside of economics includes the following. Reckers-Sauciuc & Lowe (2010) conduct a behavioural study, examining dispositional effects on the inclination to whistle blow. Macey (2007) provides an interesting legal analysis of whistle-blowing as a form of insider trading, namely that where the valuable (traded) information is about corporate corruption, fraud or misconduct. Keil et al. (2010) analyse data from failed IT-projects, where employees either report bad news or withhold information about the true project status. The authors find that a holistic cost-benefit differential helps whistle-blowers when weighing the factors that influence the intention to whistle-blow.

4.2 A model with exogenous bribery

We present a simple model of corruption between a client, an official and an inspector. In this game the client can choose to offer or not offer a bribe to an official; the official, depending on her type $\theta = \{1, 2, 3\}$, can either choose to accept or reject the bribe, or report it; and the inspector can choose to inspect or not whether there has been a (reciprocated) bribe. Figure 13 is a partial representation of this extensive form game with imperfect and incomplete information. Information is incomplete because the official's type is only known to herself, while the probability distribution over types is common knowledge. Information is imperfect because the inspector does not know the history of play when entering her information set. Our partial representation in Figure 13 omits the initial chance node at which the official's type is determined. Since we assume three types of officials, the complete representation of the game would therefore contain three nodes in the client's information set, and nine nodes in the inspector's.

The official's types are defined as follows. Type 1 always rejects and reports $(r_1, b < s_1)$ and is drawn with probability $\rho \in [0, 1]$. Type 2 never reports and accepts if and only if the combination of the penalty and the probability of inspection are sufficiently low $(s_2 < r_2 < b)$; this type is drawn with probability $\lambda \in [0, 1 - \rho]$. Type 3 always rejects but never reports $(s_3, b < r_3)$ and is drawn with probability $(1 - \rho - \lambda)$.[4]

[4]We chose this probability distribution between the three types, because we thought it preferable to consider the comparative statics of increasing or decreasing the proportion of corrupt officials and because it allows for an analysis of the case where there are no reporting officials (for instance if regulation does not recognise or reward reporting).

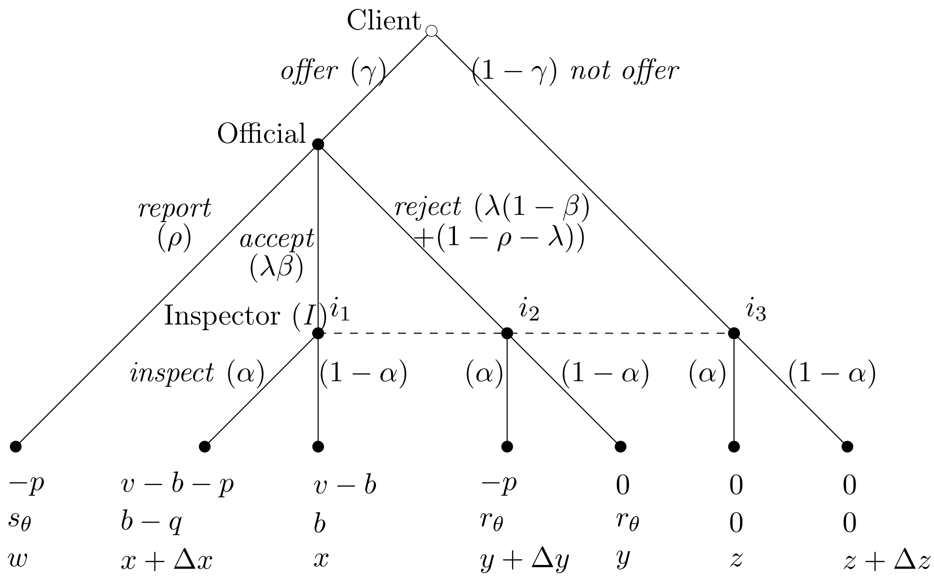


FIGURE 13: Extensive form game

We make the following additional assumptions about payoffs. All parameters are strictly positive ($v, b, p, q, r_\theta, s_\theta, x, y, z > 0$). The payoff for a bribe is only positive if it is reciprocated, but not inspected, such that $v - b - p < 0 < v - b$. Similarly, the payoff for accepting/reciprocating is only positive if and only if there is no inspection, such that $b - q < 0 < b$. The inspector prefers inspecting reciprocated bribery over unreciprocated (i.e. rejected) bribery ($y + \Delta y < x + \Delta x$) and prefers to inspect, if and only if an offence has taken place.

The inspector's information set includes the histories *accept*, *reject*, and *not offer* and consequently has to decide to inspect or not. If the official reports (i.e. is of type 1), the inspector does not play. Both the client and the type 2 official can be punished with penalties p (client) and q (official), respectively, if inspected.

Given the Bayesian nature of the game we express players' strategy choices in probabilities, where the client offers a bribe with $\gamma \in [0, 1]$, the type 2 official accepts and reciprocates with $\beta \in [0, 1]$, and the inspector inspects with $\alpha \in [0, 1]$.

The solution concept for this game is Perfect Bayesian Equilibrium (PBE). It requires that at each given information set the respective player's chosen strategy is sequentially rational, given the other players' strategies and the Bayesian-updated probability distribution over nodes in a given information set. Before considering potential equilibria, we define the conditions under which each of the three players is indifferent between her respective actions, and following from this the conditions under which the respective pure strategies of each player become sequentially rational, best responses. The client's expected utilities of offering and, respectively, not offering are:

$$Eu(\gamma = 1|\beta, \alpha) = \rho(-p) + \beta\lambda\alpha(v - b - p) + \lambda \tag{4.1}$$

$$Eu(\gamma = 0|\beta, \alpha) = 0 \tag{4.2}$$

We equate equations (4.1) and (4.2) and obtain the condition under which the client is indifferent between offering and not offering a bribe:

$$\lambda\beta(v - b) - [\rho + (1 - \rho)\alpha]p = 0 \tag{4.3}$$

We can solve equation (4.3) for β and α respectively and obtain the probabilities with which the other players reciprocate and inspect respectively to make the client indifferent:

$$\beta_C = \frac{[\rho + (1 - \rho)\alpha]p}{\lambda(v - b)} \tag{4.4}$$

$$\alpha_C = \frac{\lambda\beta(v - b) - \rho p}{(1 - \rho)p} \tag{4.5}$$

Given equation (4.4), the optimal (sequentially rational) strategy for the client is, ceteris paribus, $\gamma = 0$ if $\beta < \beta_C$ and $\gamma = 1$ if $\beta > \beta_C$. Given equation (4.5), the optimal strategy for the client is $\gamma = 0$ if $\alpha > \alpha_C$ and $\gamma = 1$ if $\alpha < \alpha_C$.
We follow the same procedure for the corruptible type 2 official. Equating her expected payoffs gives:

$$b - \alpha q - r_2 = 0 \tag{4.6}$$

Solving for α gives the probability of inspection (α_O) that keeps the official indifferent:

$$\alpha_O = \frac{b - r_2}{q}. \tag{4.7}$$

The optimal (sequentially rational) strategy for the official is then $\beta = 0$ if $\alpha > \alpha_O$ and $\beta = 1$ if $\alpha < \alpha_O$.

The inspector's information set I includes nodes i_{1-3} and thus excludes the case of a reported bribe. The inspector's beliefs that information set I is reached from the respective histories '*accept*' (i_1), '*reject*' (i_2) and '*not offer*' (i_3) are expressed by the following posterior probabilities:

$$P(i_1|I) = \frac{\lambda\beta}{\gamma(\lambda\beta) + \gamma[\lambda(1 - \beta) + (1 - \rho - \lambda)] + (1 - \gamma)} = \frac{\lambda\beta}{1 - \rho\gamma} \tag{4.8}$$

$$P(i_2|I) = \frac{\gamma[(1 - \rho) - \lambda\beta]}{1 - \gamma\rho} \tag{4.9}$$

$$P(i_3|I) = \frac{1-\lambda}{1-\rho\gamma} \tag{4.10}$$

Equating the expected payoffs for inspecting and not inspecting we obtain the inspector's indifference condition in equation (4.11), and solving this for γ gives us the probability of a bribe offered which keeps the inspector indifferent in equation (4.12).

$$\frac{\gamma\lambda\beta(\Delta x - \Delta y)}{1-\gamma\rho} + \frac{\gamma(1-\rho)\Delta y}{1-\gamma\rho} - \frac{(1-\gamma)\Delta z}{1-\gamma\rho} = 0 \tag{4.11}$$

$$\gamma_I = \frac{\Delta z}{\lambda\beta(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z} \tag{4.12}$$

The optimal strategy for the inspector is thus, ceteris paribus, $\alpha = 0$ if $\gamma < \gamma_I$ and $\alpha = 1$ if $\gamma > \gamma_I$. We derive and report the explicit equilibrium solutions for equations 4.4 and 4.12 for completeness, expressing the behavioural variables as functions of payoffs only.

$$\beta = \frac{pq[\rho + (1-\rho)r_2]}{\lambda q(v-b)} \tag{4.13}$$

$$\gamma = \frac{pq[\rho + (1-\rho)r_2]\Delta z}{\lambda^2 q(v-b)(\Delta x - \Delta y) + pq[\rho + (1-\rho)r_2][(1-\rho)\Delta y + \Delta z]} \tag{4.14}$$

Naturally, depending on the assumptions about the probability distribution over types of officials and about payoff parameters, the model has different equilibria. Our particular interest is to analyse the comparative statics in equilibrium, and as such the change in the probability of corruption, when changing the proportions of the different types of officials against one another. We define the probability of bribery, reciprocated by a corruptibly type 2 official $\gamma\lambda\beta \equiv \chi$ as the probability of corruption. So, one useful way of classifying equilibria is to structure the analysis according to the way we set the probability distribution over types. Consider the following six cases.

1. Suppose that $\rho = 1$. Since here the official is always of type 1, a bribe could not be reciprocated. So, unless we change previous payoff assumptions to $p < 0$, the unique Nash equilibrium is in pure strategies where it is sequentially rational for both client and inspector to neither offer nor inspect (i.e. $\gamma, \alpha = 0$) while the type 1 official always reports.

2. Suppose $\lambda, \rho = 0$. Since here the official is always of type 3, a bribe could not be reciprocated. So, similar to the above, the unique equilibrium is where $\gamma, \alpha = 0$ and where the type 3 official always rejects.

3. Suppose $\lambda = 0$ and $\rho \in (0, 1)$. Since here the official is always of either type 1 or type 3, a bribe could not be reciprocated. So, again similar to the above, the

unique equilibrium is where $\gamma, \alpha = 0$, whereby the type 1 would always report and the type 3 official would always reject.

4. Suppose $\lambda = 1$. Since here the official is always of type 2, no comparative statics effects are possible with regards to the probability distribution over types. The game becomes very similar to that in Spengler (2014).[5] Its comparative statics analysis shows that, in its context, the probability of corruption decreases if, ceteris paribus, greater punishment is levied on the official, and the probability of corruption increases when, ceteris paribus, greater punishment is levied on the client. The probability of corruption is minimised where penalties on bribers are minimised and penalties on officials are maximised and vice versa.

5.-6. Suppose $\lambda \in (0, 1)$ and $\rho \in [0, 1)$. If $\rho = 0$, the official is either of type 2 or of type 3, both with positive probability, but never of type 1. If $\rho \in (0, 1)$, the official is going to be of any of the three types with positive probability. An analysis of existing equilibria and of comparative statics effects for both cases follows in the next section.

So, supposing that $\lambda \in (0, 1)$ and $\rho \in [0, 1)$, we classify equilibria according to parametric regions and their mutual boundaries, given the aforementioned assumptions about the relative size of parameters. One useful way of doing this is to suppose some given probability of inspection (α) and to compare this to the specific level of α which makes the client indifferent (α_C) and respectively to that which makes the official indifferent (α_O). In order to be able to define boundaries, consider the upper bound of α_C where $\beta = 1$:

$$\alpha_{C|\beta=1} = \frac{\lambda(v-b) - \rho p}{(1-\rho)p} \tag{4.15}$$

Region A: If $\alpha_{C|\beta=1} < 0$, the unique equilibrium is at $\gamma, \alpha = 0$, $\beta = 1$.
The client should not offer, because the expected payoff for not offering is non-negative (whereas the payoff for offering if $\alpha = 0$ is $\lambda\gamma(v-b) - \rho p < 0$). If $\gamma = 0$, it is sequentially rational for the inspector not to inspect, thus $\alpha = 0$. Since $\alpha q = 0$ and $r2 < b$, we know that $\beta = 1$. So, it would then be sequentially rational to accept/reciprocate, should the client ever offer. Thus, $\gamma, \alpha = 0$ and $\beta = 1$ is a PBE.

Boundary A/B: If $\alpha_{C|\beta=1} = 0$, a range of equilibria exists at $\gamma \in [0, \gamma_{I|\beta=1}]$, $\beta = 1$, $\alpha = 0$.
If $\alpha_{C|\beta=1} = 0$ the client is indifferent between offering and not offering, while the inspector does not inspect. If $\alpha_{C|\beta=1} \gtrless 0$, we are either in Region A or B. Marginal

[5] The difference is in the penalties. Where the previous paper worked with two penalties per offender, this paper works with a single penalty per offender. The comparative statics effects of marginal penalty changes are, however, the same.

changes in the probability distribution over types (or in the size of penalties) will affect α (since $\beta = 1$), which shows that this equilibrium is a single point, i.e. the boundary between Regions A and B.

Region B: If $0 < \alpha_{C|\beta=1} < min\{\alpha_O, 1\}$, the unique partially mixed equilibrium is at $\gamma_{I|\beta=1}$, $\beta = 1$, $\alpha_{C|\beta=1}$.
Suppose that $\alpha < \alpha_{C|\beta=1}$. Then both client and official should offer and accept/reciprocate, respectively, for sure. Thus the inspector should inspect for sure or $\alpha = 1$, which is a contradiction. Suppose that $\alpha_{C|\beta=1} < min\{\alpha_O, \alpha\}$. Then either the client only or both the client and the corruptible type 2 official should for sure not offer and accept/reciprocate respectively. Thus, the inspector should not inspect, which is a contradiction. So, the strategies $\gamma_{I|\beta=1}$, $\beta = 1$, $\alpha_{C|\beta=1}$ and the inspector's beliefs $P(i_1|I) = \frac{\lambda}{1-\rho\gamma}$, $P(i_2|I) = \frac{\gamma[(1-\rho)-\lambda]}{1-\rho\gamma}$, $P(i_1|I) = \frac{1-\lambda}{1-\rho\gamma}$ are a PBE.

Boundary B/C: If $\alpha_{C|\beta=1} = \alpha_O$, the unique equilibrium is at $\gamma_{I|\beta=1}$, $\beta = 1$, α_O. (Here, all three players are indifferent between their respective actions, while the official plays the degenerate mixed strategy $\beta = 1$ in equilibrium. Marginal changes in α directly or indirectly (through marginal changes in penalties or the distribution over types of officials) imply a move into either Region B or C.)

Region C: If $0 < \alpha_O < min\{\alpha_{C|\beta=1}, 1\}$, the unique completely mixed equilibrium is at $\gamma_{I|\beta_C}$, $\beta_{C|\alpha_O}$, α_O.
Suppose that $\alpha < \alpha_O$. Then the expected payoffs of the client and the official require that both offer and accept/reciprocate, respectively. In this case the inspector should inspect for sure, thus $\alpha = 1$. This is a contradiction. Suppose that $\alpha_O < \alpha \leq min\{\alpha_{C|\beta=1}, 1\}$. Then the corruptible type 2 official should not accept/reciprocate for sure, in which case the client should not offer. Thus, the inspector should not inspect, so $\alpha = 0$. This is also a contradiction. So, the unique equilibrium must be at α_O, $\beta_{C|\alpha_O}$, $\gamma_{I|\beta_C}$. So, it follows that the inspector's beliefs $P(i_1|I) = \frac{\lambda\beta}{1-\rho\gamma}$, $P(i_2|I) = \frac{\gamma[(1-\rho)-\lambda\beta]}{1-\gamma\rho}$, $P(i_3|I) = \frac{1-\lambda}{1-\rho\gamma}$, and the set of strategies $\gamma_{I|\beta_C}$, $\beta_{C|\alpha_O}$, α_O are a PBE.

Boundary B/C': If $\alpha_{C|\beta=1} = 1$, the unique equilibrium is at $\gamma_{I|\beta=1}$, $\beta = 1$, α_O.
Here the client is indifferent, if inspection is certain. Suppose the client randomises with $\gamma < 1$. Then the inspector should not inspect for sure, such that $\alpha = 0$, in which case the client would offer for sure. Then the inspector should inspect for sure, thus $\alpha = 1$, in which case the client would be indifferent. The client must therefore play a

degenerate mixed strategy with $\gamma = 1$ in equilibrium.

Region C': If $1 < min\{\alpha_C, \alpha_O\}$, the unique equilibrium is at $\gamma, \beta, \alpha = 1$.
We assume that q in the type 2 official's case (eq. 4.7) and the relative sizes of ρ, λ and p in the client's case (eq. 4.5) are such that $1 < min\{\alpha_C, \alpha_O\}$. It is thus sequentially rational for both the client and the official to offer a bribe and accept/reciprocate for sure, while payoff sizes remain such that the inspector has incentive to inspect for sure. It is thus easy to see that, while the inspector's payoff parameters remain unchanged, we obtain a unique PBE at $\gamma, \beta, \alpha = 1$.)

Consider moving from region to region as we change the probability distribution over types. Equation 4.15 shows that, if $\alpha_{C|\beta=1} < 1$, a decrease in ρ (reporting type 1 official) and/or an increase in λ (corruptible type 2 official) must increase α, and thus moves us from Region A, through Region B, into Region C. Similarly, if $1 < \alpha_{C|\beta=1}$, a decrease in ρ (reporting type 1 official) and/or an increase in λ moves us from Region A, through Region B, into Region C'.[6]

Figure 14 illustrates the transition from Region B (in blue) into C (in red) and their mutual boundary B/C as we decrease ρ while holding λ constant for the case where $\alpha_O, \alpha_{C|\beta=1} < 1$. While it is not depicted in Figure 14, it is easy to imagine the scenario where $1 < \alpha_O$, in which case an increase in $\alpha_{C|\beta=1}$ would show a movement from Region B into Region C'. Table 8 provides a set of plausible numerical parameter values which we use as a basis for Figure 14. First, consider the partially mixed equilibrium which

TABLE 8: Parameter values set for both regions

Equilibrium type	ρ	λ	v	b	p	q	r_2	x	Δx	y	Δy	z	Δz
Partially mixed equilibrium (B)	0.25	0.6	8	1	12	4	0	10	5	8	3	8	3
Boundary (B/C)	0.13	0.6	8	1	12	4	0	10	5	8	3	8	3
Completely mixed equilibrium (C)	0.05	0.6	8	1	12	4	0	10	5	8	3	8	3

we obtain in Region B. We denote this in red and with the superscript B. In the right quadrant, the red dotted line describes the probability of reciprocation (β) as a function of the probability of inspection (α), denoted as $f(\alpha^B)$, which we obtain by setting $\rho = 0.25$ and $\lambda = 0.6$, and given the remaining parameter values in Table 8. We now obtain $\alpha^B = 0.13$, which is the probability of inspection in equilibrium. The solid red

[6]Note that any equilibrium in this game is subgame perfect, since the game has no proper subgames.

line is the reaction function, which shows the condition for the client's and the official's indifference. Further, $f(\alpha^B)$ provides the equilibrium value for accepting/reciprocating, which is denoted by $\beta^B = 1$ on the vertical axis. So, we have established the values for the probabilities of inspecting and accepting/reciprocating a bribe in the partially mixed equilibrium. In the left quadrant, the red dotted curve describes the probability of offering a bribe (γ) as a function of β, denoted as $g(\beta^B)$. Given β^B, through $g(\beta^B)$, we obtain the equilibrium value γ^B on the reversed horizontal axis. The solid red line, which is vertical where $\beta^B = 1$, is the reaction function, which shows the condition for the inspector's indifference. Now, we have also established the probability of offering a bribe in the partially mixed equilibrium.

On the boundary (denoted in gray and with the superscript B/C, and obtained by setting $\rho = 0.13$), the official is indifferent between accepting and rejecting the bribe, and randomises with the degenerate mixed-strategy probability 1. In contrast, in the partially mixed equilibrium, the official strictly prefers to accept and reciprocate. As shown in Figure 14, as we decrease ρ, the probability of inspection increases in equilibrium until we cross the boundary B/C.

Now consider the completely mixed equilibrium, which we obtain in Region C. We denote this in blue and with the superscript C. In the right quadrant, the blue dotted line describes the probability of reciprocation (β) as a function of the probability of inspection (α), denoted as $f(\alpha^C)$, which we obtain by setting $\rho = 0.05$, ceteris paribus. The latter determines that $\alpha^C = 0.25$, which is the probability of inspection in equilibrium. Shown as the black line in the right quadrant is the reaction function, which shows the condition for the client's and the official's indifference at α^C. Further, $f(\alpha^C)$ provides the equilibrium value for accepting/reciprocating, which is denoted by β^C on the vertical axis. So, we have established the values for the probabilities of inspecting and accepting/reciprocating a bribe in equilibrium. In the left quadrant, the blue dotted curve describes the probability of offering a bribe (γ) as a function of β, denoted as $g(\beta^C)$. Given β^C, through $g(\beta^C)$ we obtain the equilibrium value γ^C on the reversed horizontal axis. The solid blue line that is vertical where $\beta = \beta^C$ is the reaction function, which shows the condition for the inspector's indifference. Now, we have also established the probability of offering a bribe in the completely mixed equilibrium in the example in Figure 14.

Finally, note that under reasonable payoff assumptions there is no pure strategy equilibrium where there is no offered bribe, no acceptance and no inspection. An equilibrium where $\gamma, \beta, \alpha = 0$ is only possible if we assume that $v < b$ and/or $b < 0$. Those assumptions are not reasonable in the context of this game. If $b < v$ and $0 < b$, and the set of strategies $\gamma, \beta, \alpha = 0$ is not a PBE. Suppose the client does not offer a bribe. Then the

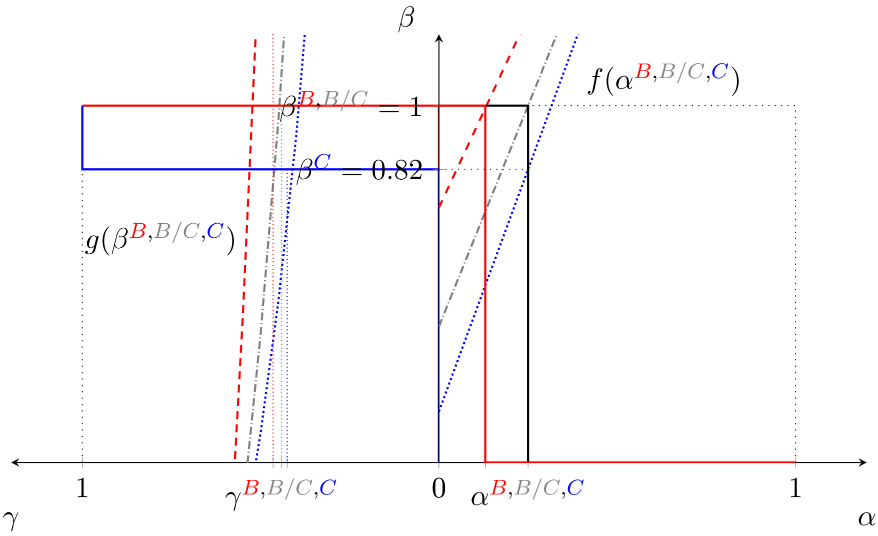


FIGURE 14: Displaying the partially mixed equilibrium (Region B, red dashed line, $\rho = 0.25$, $\lambda = 0.6$, $\gamma^B = 0.47$, $\beta^B = 1$, $\alpha^B = 0.13$), the completely mixed equilibrium (Region C, blue dotted line, $\rho = 0.05$, $\lambda = 0.6$, $\gamma^C = 0.43$, $\beta^C = 0.82$, $\alpha^C = 0.25$), and their mutual boundary (gray dash-dotted line, $\rho = 0.13$, $\lambda = 0.6$, $\gamma^{B/C} = 0.44$, $\beta^{B/C} = 1$, $\alpha^{B/C} = 0.25$)

official is indifferent between accepting/reciprocating and rejecting and so might reject. Given rejection, offering is a strictly dominated strategy. Consequently, the inspector will then not inspect. However, looking at the continuation game at the official's decision node (at history '*offer*'), which is off the equilibrium path, it is only optimal for the type 2 official to respond with $\beta = 0$ if and only if $\alpha > \frac{b-r_2}{q}$ (and otherwise with $\beta_C = \frac{[\rho(1-\alpha)+\alpha]p}{\lambda(v-b)}$). But since the inspector's belief for being at any history other than '*not offer*' must be equal to zero so long as $\gamma = 0$, this belief is not consistent with type 2 official's best response, which if $\alpha = 0$, would be $\beta = 1$. This equilibrium is thus not a PBE, because it is not reasonable for the inspector to believe that, off the equilibrium path, the type 2 official would reject.

The rest of this section contains a comparative statics analysis for Regions B and C, as well as simulations for changes in the probability distribution over types of officials, which illustrates a transition between the two regions.

Region B: partially mixed equilibrium ($\gamma_{I|\beta=1}$, $\beta = 1$, α_C)

We are now interested in the comparative statics effects when marginally changing the probabilities with which the official is of either of the three types. The cases we are considering are increases in the probability of a type 1 (reporting) or type 2 (corruptible) official, which implies decreasing the incidence of a type 3 (rejecting) type official.

Suppose a marginal increase in the probability of a reporting type 1 official. Looking at the client's expected payoffs, this implies a shift in the probability of receiving a penalty with the probability of inspection (α) to receiving penalty p for sure due to reporting. So, the client is inclined, ceteris paribus, not to offer a bribe, which is outside of equilibrium. To bring her back to the point of indifference, either the probability of accepting/reciprocating needs to increase or the probability of inspection needs to decrease. Since in the partial equilibrium the type 2 official already accepts/reciprocates with certainty ($\beta = 1$), the probability of inspection needs to decrease. Looking at the inspectors payoffs, it is now more likely that an offered bribe goes reported and less likely that an offered bribe is rejected, so the inspector is inclined not to inspect, which again is outside of equilibrium. To bring her back to the point of indifference, either the probability of accepting/reciprocating (β) needs to increase or the probability of offering a bribe (γ) needs to increase. Since $\beta = 1$, we know that γ needs to increase. Finally, since $\beta = 1$, and since we are not changing the probability of a type 2 (corruptible) official, we also know that an increase in γ implies an increase in the probability of corruption (accepted/reciprocated bribe by a corruptible official), χ.

Proposition 7. *Given that $\gamma_{I|\beta=1}$, $\beta = 1$, and $\alpha_{C|\beta=1}$, an increase in the probability of a reporting type 1 official (ρ), while the probability of a rejecting type 3 official decreases accordingly, implies a decrease in the probability of inspection (α), an increase in the probability of offering a bribe (γ) and an increase in the probability of corruption (χ).*

Suppose now a marginal increase in the probability of a corruptible type 2 official (λ), while the probability of a rejecting type 3 official decreases accordingly. Looking at the client's expected payoffs, an increase in λ implies that the client is inclined to offer a bribe, since it is now more likely that she encounters a corruptible official than a rejecting type. To bring her back to equilibrium, i.e. to the point of indifference, either the probability of accepting/reciprocating (β) must decrease or the probability of inspection (α) must increase. Since $\beta = 1$ in equilibrium, α must increase. Looking at the inspector's expected payoffs, an increase in λ implies that she is now inclined to inspect, since it is more likely that an offered bribe will be accepted/reciprocated. To return her to the point of indifference, we know that the probability of offering a bribe (γ) needs to decrease, because $\beta = 1$ in equilibrium. Knowing that, following an increase in λ, β remains constant and γ must decrease, we can also infer what should happen to the probability of corruption ($\chi = \gamma\lambda\beta$). Given that $\beta = 1$, suppose an increase in λ, while γ remains unchanged. This means a shift in probability from an rejected/unreciprocated bribe to an accepted/reciprocated bribe, while the probability of no bribe does not change. In this case the inspector would prefer to inspect for sure and, as reasoned above, we are outside of equilibrium. Suppose instead that, as λ increases, γ decreases proportionally, such that $\gamma\lambda$ remains constant. This would imply a shift in probability from rejected/unreciprocated bribe to no bribe, while the probability of an accepted/reciprocated bribe would remain unchanged. In this case, the inspector would strictly prefer not to inspect and we are again outside of equilibrium. To keep the inspector indifferent, an increase in λ therefore requires a decrease in smaller proportion of the probability of offering a bribe, γ. So, the probability of corruption (χ) must increase.

Proposition 8. *Given that $\gamma_{I|\beta=1}$, $\beta = 1$, and $\alpha_{C|\beta=1}$, an increase in the probability of a corruptible type 2 official (λ), while the probability of a rejecting type 3 official decreases accordingly, implies an increase in the probability of inspection (α), a decrease in the probability of offering a bribe (γ) and an increase in the probability of corruption (χ).*

The rest of this subsection shows these results more formally. Since $\beta = 1$, equation (4.3) and (4.11) become:

$$\lambda(v - b) - [\rho + (1 - \rho)\alpha]p = 0 \tag{4.16}$$

$$\gamma\lambda(\Delta x - \Delta y) + \gamma(1 - \rho)\Delta y - (1 - \gamma)\Delta z = 0 \tag{4.17}$$

Informally, the following inferences with regards to the probability distribution over types of officials are possible.[7] If ρ increases, to keep the left-hand side of equation (4.16) equal to zero, α must decrease. To see this, we rearrange equation (4.16) and take its derivative with respect to ρ:

$$\alpha_C = \frac{\lambda(v - b) - \rho p}{(1 - \rho)p} \tag{4.18}$$

$$\frac{\partial\alpha}{\partial\rho} = \frac{p\lambda(v - b) - p^2}{[(1 - \rho)p]^2} < 0 \tag{4.19}$$

If ρ increases, to keep the left-hand side of equation (4.17) equal to zero, γ and thus χ, the probability of corruption, must increase. To see this, we rearrange equation (4.17).

$$\gamma = \frac{\Delta z}{\lambda(\Delta x - \Delta y) + (1 - \rho)\Delta y + \Delta z} \tag{4.20}$$

Multiplying this by λ gives:

$$\chi = \frac{\lambda\Delta z}{\lambda(\Delta x - \Delta y) + (1 - \rho)\Delta y + \Delta z} \tag{4.21}$$

[7] We observe the following effects of penalty changes. If p increases, to keep the left-hand side of equation (4.6) equal to zero, α must decrease. To see this, note that $\frac{\partial\alpha}{\partial p} = \frac{\lambda(v-b)p-p^2}{[\lambda(v-b)-\rho p]^2}$ is negative.

Partial derivatives of these confirm the informal inferences:

$$\frac{\partial \gamma}{\partial \rho} = \frac{\Delta y \Delta z}{[\lambda(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z]^2} > 0 \tag{4.22}$$

$$\frac{\partial \chi}{\partial \rho} = \frac{\lambda \Delta y \Delta z}{[\lambda(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z]^2} > 0 \tag{4.23}$$

These confirm Proposition 1. If λ increases, to keep the left-hand side of equation (4.16) equal to zero, α must increase.

$$\frac{\partial \alpha}{\partial \lambda} = \frac{(v-b)(1-\rho)p}{[(1-\rho)p]^2} > 0 \tag{4.24}$$

If λ increases, to keep the left-hand side of equation (4.17) equal to zero, γ must decrease, and thus χ must increase. We confirm this as follows:

$$\frac{\partial \gamma}{\partial \lambda} = -\frac{(\Delta x - \Delta y)\Delta z}{[\lambda(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z]^2} < 0 \tag{4.25}$$

$$\frac{\partial \chi}{\partial \lambda} = \frac{\Delta z[(1-\rho)\Delta y + \Delta z]}{[\lambda(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z]^2} > 0 \tag{4.26}$$

These confirm Proposition 2.

Region C: completely mixed equilibrium ($\gamma_{I|\beta_C}$, $\beta_{C|\alpha_O}$, α_O)

As in the previous subsection, we consider the effects of marginal changes in the probability distribution over the different types of officials. Suppose a marginal increase in the probability of a reporting type 1 official, while the probability of a rejecting type 3 official decreases proportionally. Looking at the expected payoffs of the client, an increase in the probability of a reporting type 1 official (ρ) implies an increase in the expected payoff for not offering a bribe, since reporting, and thus penalty p with certainty, becomes more likely. To keep her indifferent, either the probability of inspection (α) must decrease or the probability of accepting/reciprocating (β) must increase. We know that, to keep the corruptible official indifferent, α must not change, so β must increase. Suppose that the increase in ρ was proportional to the increase in β. This would imply a shift in probability from the outcome that an offered bribe is rejected to both the outcome that a bribe is accepted/reciprocated and that it is reported. If the bribe is accepted/reciprocated, the benefit from bribing, $v - b$ becomes more likely and the penalty p is incurred with the probability of inspection, while, if the bribe is reported, the penalty is incurred with certainty. So, depending on the size of the benefit from bribing $v - b$ and the probability of inspection α, β could increase with either faster, equal, or slower velocity compared to ρ.

Looking at the expected payoffs of the inspector, an increase in ρ and β would imply a decrease in the incidence of a rejected bribe and an increase in the incidence of an accepted/reciprocated bribe. Depending on the relative rate of increase of ρ and β, the inspector might thus be inclined to either remain indifferent, to prefer to inspect or to prefer not to inspect. We know that inspecting an accepted/reciprocated bribe has a higher payoff than inspecting a rejected bribe, but we cannot infer the relative rates of change in ρ and β. So, depending on the these relative rates of change, to keep the inspector indifferent either of three events have to occur. If γ remains unchanged, the probability of corruption (χ) must increase, since β increases while λ remains unchanged. If γ increases, χ must increase at a faster rate. A decrease in γ can only occur if β increases at so much faster a rate than ρ that a decrease in γ is required to keep the inspector indifferent. If the decrease in γ was proportional to β, such that $\gamma\beta$ remains constant, this would imply a shift in probability of from a rejected/unreciprocated bribe to no bribe, with the incidence of an accepted/reciprocated bribe remaining unchanged. So, β must increase at a faster rate than γ decreases, such that if γ ever increases, the probability of corruption, χ, must still increase.

Proposition 9. *Given that $\gamma_{I|\beta_C}$, $\beta_{C|\alpha_O}$, α_O, an increase in the probability of a reporting type 1 official (ρ), while the probability of a rejecting type 3 official decreases accordingly, implies an increase in the probability of accepting/reciprocating (β), and an increase in the probability of corruption (χ), while the probability of inspection (α) remains unchanged and the probability of offering a bribe (γ) might either increase, decrease or remain constant, depending on parameter configuration.*

Suppose a marginal increase in the probability of a corruptible type 2 official, while the probability of a rejecting type 3 official decreases accordingly. Looking at the expected payoffs of the client, an increase in the incidence of a corruptible official implies that offering a bribe is now strictly preferred. So, to keep her indifferent, either the probability of inspection (α) has to increase or the probability accepting/reciprocating (β) has to decrease. Since α must remain unchanged to keep the official indifferent, β must decrease. Looking at the inspector's expected payoffs, an increase in the probability of a corruptible type 2 official (ρ) would increase her expected payoff from inspecting, so to keep her indifferent either γ or β must decrease. We know that β must decrease to keep the client indifferent. Note that γ must not change. To see this, suppose a marginal increase (decrease) in γ, i.e. a shift in probability from the probability of the event of no offered bribe to the event of an offered bribe (or vice versa) from the inspector's point of view. In either case the inspector would not remain indifferent. So, given that in equilibrium γ must remain constant, while λ and β move in opposite direction with equal velocity, the probability of corruption, χ, must also remain unchanged.

Proposition 10. *Given that $\gamma_{I|\beta_C}$, $\beta_{C|\alpha_O}$, α_O, an increase in the probability of a corruptible type 2 official (λ), while the probability of a rejecting type 3 official decreases accordingly, implies a decrease in the probability of accepting/reciprocating (β), while the probability of inspection (α), the probability of offering a bribe (γ), and the probability of corruption (χ) all remain unchanged.*

The rest of this subsection shows these results more formally. Recall equations (4.3) - (4.7) and the following simplification of equation (4.11):

$$\gamma\beta\lambda(\Delta x - \Delta y) + \gamma(1-\rho)\Delta y - (1-\gamma)\Delta z = 0 \tag{4.27}$$

Informally, the following inferences with regards to the probability distribution over types of officials are possible.[8] If ρ increases, to keep the left-hand side of equation (4.3) equal to zero, either α must decrease or β must increase. Equation (4.6) shows that α must not change ($\frac{\partial\alpha}{\partial\rho} = 0$), so β must increase:

$$\frac{\partial\beta_C}{\partial\rho} = \frac{(1-\alpha)p}{\lambda(v-b)} > 0. \tag{4.28}$$

Looking for the effect of ρ on γ (through β), we observe:

$$\frac{\mathrm{d}\gamma}{\mathrm{d}\rho} = \frac{\gamma[\Delta y - \frac{\mathrm{d}\beta}{\mathrm{d}\rho}\lambda(\Delta x - \Delta y)]}{\lambda\beta(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z}, \tag{4.29}$$

which sign depends on whether $\frac{\Delta y}{\Delta x - \Delta y} - \frac{(1-\alpha)p}{v-b} \lesseqgtr 0$. Thus, equation (4.29) is positive, if $\alpha \in (1 - \frac{\Delta y(v-b)}{(\Delta x - \Delta y)p}, 1]$. To see this graphically, consider Figure 15. It shows the range of α, given which $\frac{\mathrm{d}\gamma}{\mathrm{d}\rho}$ is positive.

Looking for the effect of ρ on χ (through β), we observe that an increase in λ increases χ:

$$\frac{\mathrm{d}\chi}{\mathrm{d}\rho} = \frac{\gamma\lambda(\frac{\mathrm{d}\beta}{\mathrm{d}\rho}[(1-\rho)\Delta y + \Delta z] + \beta\Delta y)}{\lambda\beta(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z}. \tag{4.30}$$

These confirm Proposition 3.

If λ increases, to keep the left-hand side of equation (4.3) equal to zero, either α must increase or β must decrease. Equation (4.6) shows that α must not change ($\frac{\partial\alpha}{\partial\lambda} = 0$),

[8] We observe the following effects of penalty changes. Since $\frac{\partial\alpha}{\partial p} = 0$, alpha must not change, following an increase in p. Therefore, if p increases, to keep the left-hand side of equation (4.3) equal to zero, β must increase, which $\frac{\partial\beta_C}{\partial p} = \frac{\rho+(1-\rho)\alpha}{\lambda(v-b)} > 0$ confirms. Further, we can confirm by $\frac{\mathrm{d}\gamma}{\mathrm{d}\rho} = -\frac{\gamma\lambda(\Delta x - \Delta y)}{\lambda\beta(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z} < 0$ that, following an increase of β, γ must decrease, but to a lesser extent, such that χ increases, as shown by $\frac{\mathrm{d}\chi}{\mathrm{d}\rho} = \frac{(1-\rho)\Delta y + \Delta z}{\Delta x - \Delta y} > 0$. In contrast, if q increases, α must also increase in equation (4.7), as confirmed by $\frac{\partial\alpha}{\partial q} = -\frac{b-r_2}{q^2} < 0$. Consequently, an increase in α must decrease β: $\frac{\mathrm{d}\beta_C}{\mathrm{d}\alpha} = -\frac{(1-\rho)p}{\lambda(v-b)}$. Following the previous logic, a decrease in β must increase γ and decrease χ.

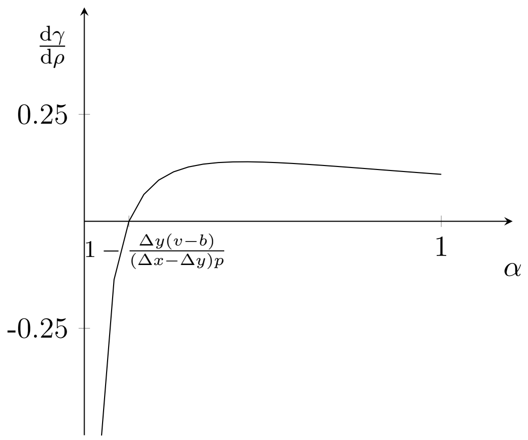


FIGURE 15: Sign of $\frac{d\gamma}{d\rho}$ for ranges of α. *Here shown given our set of of numerical values, where* $1-\frac{\Delta y(v-b)}{(\Delta x-\Delta y)p}=0.125$

so β must decrease to the same extent as λ increases:

$$\frac{\partial \beta_C}{\partial \lambda} = -\frac{[\rho(1-\alpha)+\alpha]p}{\lambda^2(v-b)} = -\frac{\beta}{\lambda} < 0 \tag{4.31}$$

Since a change in λ must be equal to a change in β, to keep the left-hand side of equation (4.3) equal to zero, γ, and thus χ, must not change (for the latter we totally differentiate $\chi = \gamma\lambda\beta$):

$$\frac{d\gamma}{d\lambda} = -\frac{[\beta + \frac{d\beta}{d\rho}\lambda][\gamma(\Delta x - \Delta y)]}{\lambda\beta(\Delta x - \Delta y) + (1-\rho)\Delta y + \Delta z} = 0 \tag{4.32}$$

$$\frac{d\chi}{d\lambda} = \gamma\beta + \lambda[\beta\frac{d\gamma}{d\lambda} + \gamma\frac{d\beta}{d\lambda}] = 0 \tag{4.33}$$

These confirm Proposition 4.

Simulation of equilibria in Regions B and C

Earlier, we set some numerical values in integers for all parameters that are plausible in ordinal terms and simulate changes in the probability distribution over types of officials. Table 9 repeats those parameter values.

TABLE 9: Parameter values set for both regions

v	b	p	q	r_2	x	Δx	y	Δy	z	Δz
8	1	12	4	0	10	5	8	3	8	3

Figures 16, 17 and 18 provide a visual representation of our simulation data. Figure 16 describes a shift in probability from of a reporting type 1 official to a rejecting type 3 official, meaning an increase in ρ while λ does not change (thus keeping the incidence of the corruptible type 2 official constant). We observe a movement from the completely mixed equilibrium in Region C into the partially mixed equilibrium in Region B. Figure 17 describes a shift in probability from a corruptible type 2 official to a rejecting type 3 official, thus increasing λ, while keeping ρ unchanged. Here, we observe a movement from the partially mixed equilibrium in Region B into the completely mixed equilibrium in Region C. In Figure 18 we illustrate a simultaneous change in ρ and λ (thus keeping the probability of a rejecting type 3 official unchanged), again showing a movement from Region C into Region B.

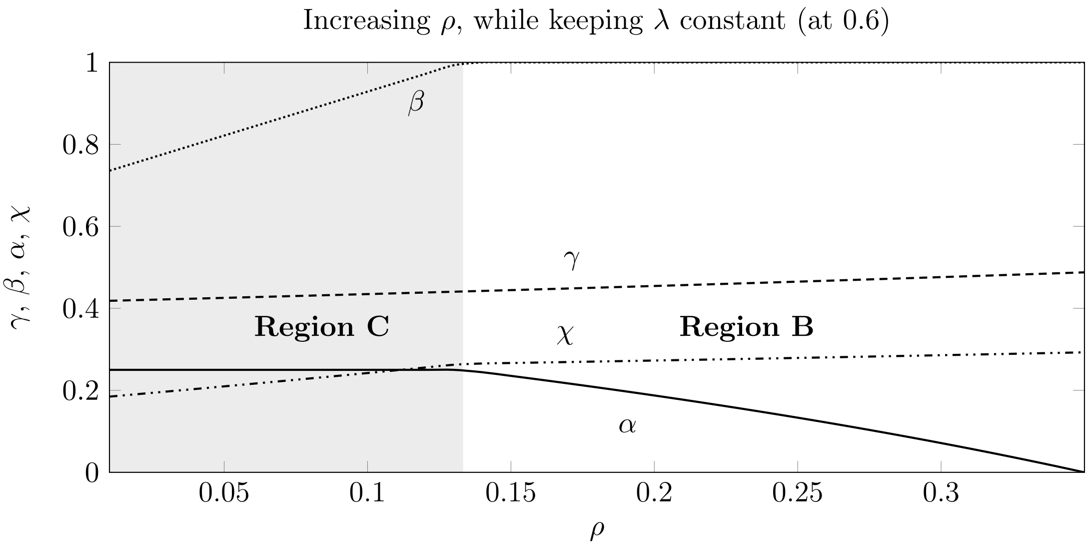


FIGURE 16: Moving from Region C into Region B, i.e. from the completely mixed equilibrium into the partially mixed equilibrium. *We use values for intelligible ranges of* γ, β, α

Tables 10 and 11 present the simulation data itself, the former for the case of changing either ρ or λ while holding the other probability constant, and the latter for the case where we change λ and ρ simultaneously. Table 10 shows that, within the completely mixed equilibrium, with a 5% increase in the probability of a reporting type official, there is an increase in the probability of corruption (reciprocated bribery, given a corruptible type 2 official) of just under 3%. As we move into the partially mixed equilibrium, a 5% increase in the probability of a reporting type official effects an increase in the incidence of corruption of just over 0.5%. Further, it is shown that a 5% increase in the incidence of corruptible type 2 officials (λ) effects an increase of over 2% in the probability of corruption in Region B, while the rate of corruption plateaus as soon as we enter Region C. Table 11 and Figure 18 illustrate a simultaneous change in ρ and λ. As we successively substitute the probability of a (corruptible) type 2 official by the probability of (reporting) a type 1 official, we observe an almost 4% (but slightly diminishing) increase in corruption (χ) for every 5% change in λ versus ρ so long as

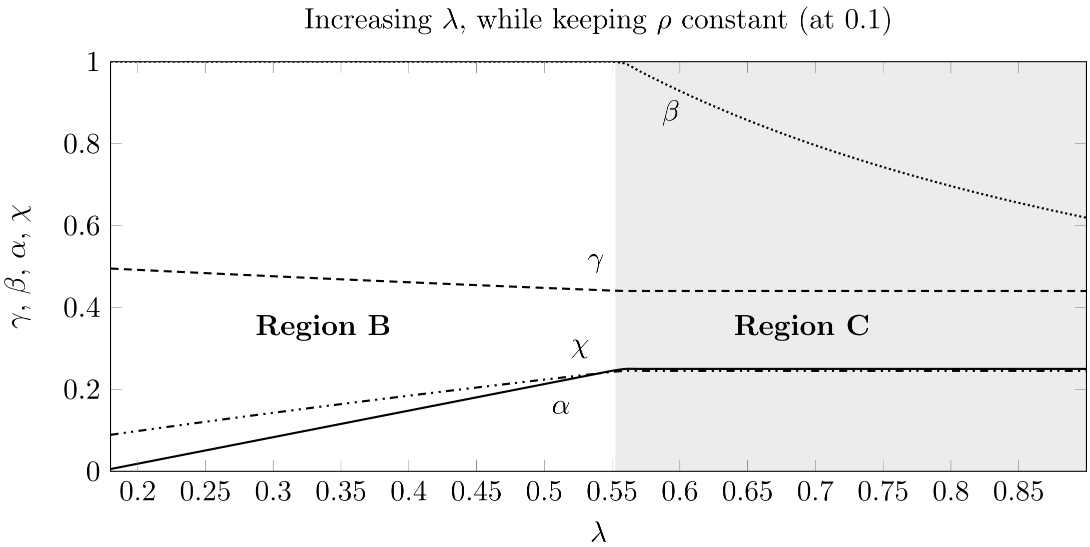


Figure 17: Moving from Region B into Region C, i.e. from the partially mixed equilibrium into the completely mixed equilibrium. *We use values for intelligible ranges of* γ, β, α

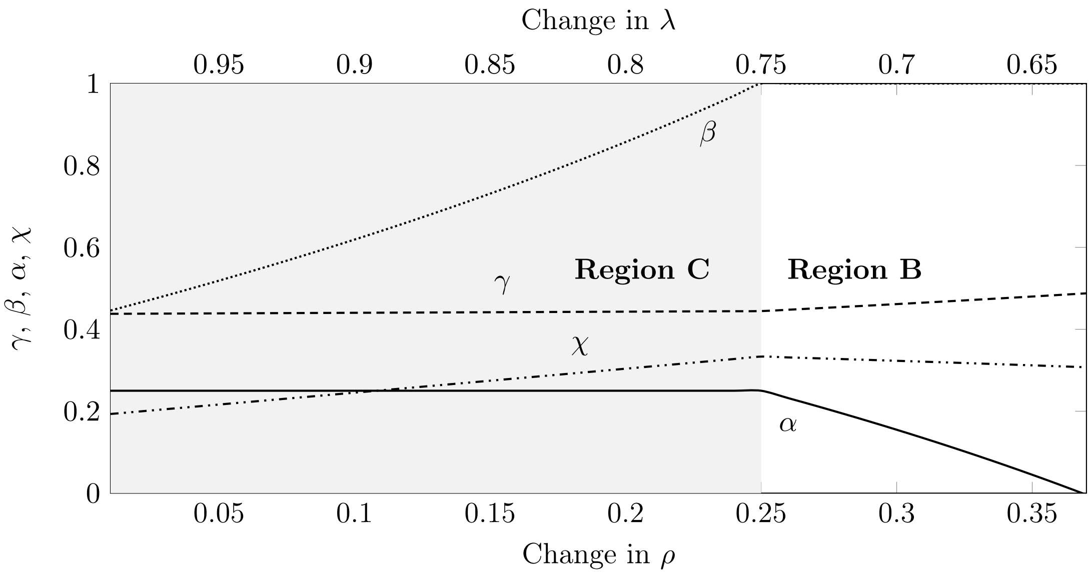


Figure 18: Moving from Region C into Region B, i.e. from the completely mixed equilibrium into the partially mixed equilibrium, while changing both ρ and λ simultaneously. *We use values for intelligible ranges of* γ, β, α

we are in Region B, and a proportionate decrease as soon as we enter Region C. The probability of corruption peaks on the brink of moving from the one region into the other. The intuition for this result is the following. Consider first what happens as we are increasing ρ, while simultaneously decreasing λ in region C. This has an increasing effect on β, but no effect on γ (the increase and respective decrease of ρ and λ cancel each other out). With γ remaining constant, the drastic rise in β (as ρ and λ increase)

TABLE 10: Changing either ρ or λ while, moving from Region B into Region C, i.e. from the partially mixed equilibrium into the completely mixed equilibrium. *Values for intelligible ranges, starting from the base value $\lambda = 0.6$, when varying ρ and from $\rho = 0.1$ when varying λ*

Increase in ρ, while λ remains constant ($1-\rho-\lambda$ decreases)						
χ	γ	β	α	ρ	λ	$1-\rho-\lambda$
0.21	0.43	0.82	0.25	0.05	0.60	0.35
0.24	0.43	0.93	0.25	0.10	0.60	0.30
0.27	0.44	1.00	0.24	0.15	0.60	0.25
0.27	0.45	1.00	0.19	0.20	0.60	0.20
0.28	0.47	1.00	0.13	0.25	0.60	0.15
0.29	0.48	1.00	0.07	0.30	0.60	0.10
0.29	0.49	1.00	0.00	0.35	0.60	0.05
Increase in λ, while ρ remains constant ($1-\rho-\lambda$ decreases)						
χ	γ	β	α	ρ	λ	$1-\rho-\lambda$
0.10	0.49	1.00	0.02	0.10	0.20	0.70
0.12	0.48	1.00	0.05	0.10	0.25	0.65
0.14	0.48	1.00	0.08	0.10	0.30	0.60
0.16	0.47	1.00	0.12	0.10	0.35	0.55
0.18	0.46	1.00	0.15	0.10	0.40	0.50
0.20	0.45	1.00	0.18	0.10	0.45	0.45
0.22	0.45	1.00	0.21	0.10	0.50	0.40
0.24	0.44	1.00	0.25	0.10	0.55	0.35
0.25	0.44	0.93	0.25	0.10	0.60	0.30
0.25	0.44	0.86	0.25	0.10	0.65	0.25
0.25	0.44	0.80	0.25	0.10	0.70	0.20
0.25	0.44	0.74	0.25	0.10	0.75	0.15
0.25	0.44	0.70	0.25	0.10	0.80	0.10
0.25	0.44	0.66	0.25	0.10	0.85	0.05
0.25	0.44	0.62	0.25	0.10	0.90	0.00

increases the total probability of corruption (χ). Since λ, the probability of a corruptible type, features in χ (and ρ does not), the increase in χ is weaker than the increase in β. Now consider what happens as we enter region B. As soon as we reach the threshold, $\beta = 1$ (the corruptible official accepts and reciprocates for sure), so from this point onwards, both β and γ remain constant, while λ decreases. Now, since λ features in χ (but ρ does not), the decrease in λ will decrease χ, the total probability of corruption. This is illustrated in Figure 18.

TABLE 11: Changing ρ and λ while moving from Region B into Region C, i.e. from the partially mixed equilibrium into the completely mixed equilibrium

Increase in ρ, while λ decreases ($1-\rho-\lambda$ remains constant)						
χ	γ	β	α	ρ	λ	$1-\rho-\lambda$
0.22	0.44	0.52	0.25	0.05	0.95	0.00
0.25	0.44	0.62	0.25	0.10	0.90	0.00
0.27	0.44	0.73	0.25	0.15	0.85	0.00
0.30	0.44	0.86	0.25	0.20	0.80	0.00
0.33	0.44	1.00	0.25	0.25	0.75	0.00
0.32	0.46	1.00	0.15	0.30	0.70	0.00
0.31	0.48	1.00	0.04	0.35	0.65	0.00

4.3 A variant with endogenous (variable) bribe size

Finally, lets assume that the bribe size is continuous and variable. There exists then a partially mixed perfect Bayesian equilibrium, where the client offers a bribe of the size $b_{C=O}$, mixing with γ_I, where the type 2 official mixes with $\beta = 1$, and where the inspector mixes with α_C, whereby the inspector beliefs that her information set is reached from the respective histories with probabilities '*accept*'$= \frac{\lambda\beta}{1-\rho}$, '*reject*'$= 1 - \frac{\lambda\beta}{1-\rho}$, and '*not offer*'$= 1-\lambda$.

The client decides whether to bribe or not, and if so, what the size of the bribe should be. Given the chance that the client encounters a corruptible type 2 official (with probability λ), the former will only bribe and the latter will only accept/reciprocate, if and only if the size of the bribe makes this profitable. Thus, the bribe size must fall between these boundaries, which are given by:

$$b_O = r_2 + \alpha q \tag{4.34}$$

$$b_C = \frac{\lambda\beta v - [\rho - (1-\rho)\alpha]p}{\lambda\beta} \tag{4.35}$$

On either side of this spectrum there cannot be an equilibrium in which bribery exists. In fact, provided that the bribe size is continuous, the equilibrium must be in a single point. Figure 19 illustrates this. Since every value ϵ by which the bribe might be larger than necessary is inefficient, the bribe size must lie on the lower boundary, at which the official is indifferent between accepting and rejecting. The equilibrium must thus be at the point where the official is indifferent, but reciprocates for sure (thus playing a degenerate mixed strategy). So, in equilibrium the type 2 official must mix with:

$$\beta_C = 1. \tag{4.36}$$

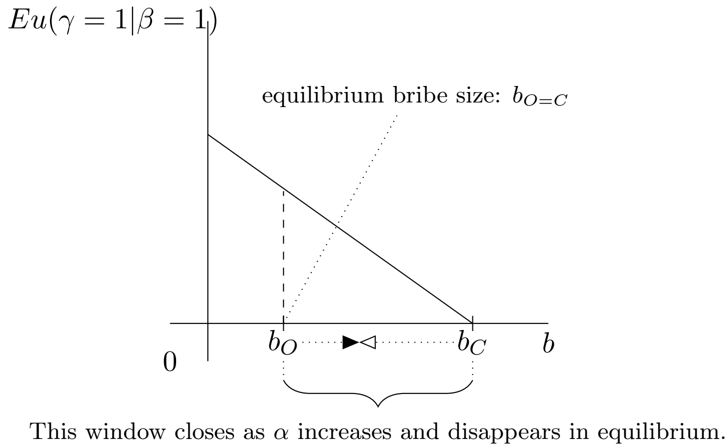


FIGURE 19: Size of a variable bribe (where $Eu(\gamma = 1|\beta = 1)$ is the client's exp. payoff for offering if reciprocated)

If the bribe size is efficient but profitable for the client, such that $b = b_O < b_C$, the client has incentive to bribe for sure. This cannot be an equilibrium, because the inspector would here have incentive to inspect for sure, which is a contradiction. The unique equilibrium must therefore be where α adjusts, such that both the client and the inspector randomise with the respective probabilities that make each other indifferent. Since $\beta = 1$, the equilibrium probabilities and the equilibrium bribe size are given by equations (4.37), (4.38) and (4.39):

$$\gamma_I = \frac{\Delta z}{\lambda(\Delta x - \Delta y) + (1 - \rho)\Delta y + \Delta z}. \tag{4.37}$$

$$\alpha_C = \frac{\lambda(v - r_2) - \rho p}{\lambda q - (1 - \rho)p} \tag{4.38}$$

$$b_{C=O} = \frac{\lambda v - [\rho - (1 - \rho)\alpha]p}{\lambda} \tag{4.39}$$

As before, we are interested in the effects of marginal changes in the probability distribution over types of officials. Suppose a marginal increase in the probability of a reporting type 1 official, while the probability of a rejecting type 3 official decreases accordingly. Looking at the expected payoffs of the client, an increase in ρ implies that she is inclined not to offer a bribe. So, to keep her indifferent, either the probability of accepting/reciprocating (β) has to increase or the probability of inspection (α) has to decrease. Since $\beta = 1$, we know that α must decrease. Looking at the expected payoffs of the official, a decrease in α implies that she is now inclined to accept/reciprocate for sure. To keep her indifferent, the size of the bribe has to decrease accordingly. Looking at the inspector's expected payoffs, an increase in ρ implies that she now prefers not to inspect. So, to keep her indifferent, either γ or β must increase. Since $\beta = 1$ in equilibrium, we know that γ must increase, and since λ remains unchanged, the probability of corruption, χ, must also increase.

Proposition 11. *Given γ_I, $\beta = 1$, α_C and $b_{C=O}$, an increase in the probability of a reporting type 1 official (ρ), while the probability of a rejecting type 3 official decreases accordingly, implies a decrease in both the probability of inspection (α) and the size of the bribe (b), and an increase in both the probability of offering a bribe (γ) and the probability of corruption (χ), all while the probability of accepting/reciprocating (β) remains unchanged.*

Suppose a marginal increase in the probability of a corruptible type 2 official (λ), while the probability of a rejecting type 3 official decreases accordingly. Since it is now more likely that she encounters a corruptible official, the client now strictly prefers to offer a bribe. To return her to the point of indifference, we know that the probability of inspection (α) has to increase, since $\beta = 1$. If α increases, the corruptible type 2 official is no longer indifferent, but prefers not to accept/reciprocate. To keep her at the point of indifference, the size of the bribe (b) has to increase. Looking at the expected payoffs of the inspector, an increase in λ makes the incidence of reciprocated bribery more likely and that of a rejected bribe less likely, such that she now strictly prefers not to inspect. Given that $\beta = 1$, to return her to the point of indifference, the probability of offering a bribe (γ) must increase. Suppose γ increases sufficiently to keep $\gamma\lambda$ unchanged. This would imply a shift in probability from rejected/unreciprocated bribe to no bribe, with the probability of corruption, χ, remaining unchanged, in which case the inspector would strictly prefer not to inspect. So, to keep her indifferent, λ must increase at a faster rate than that with which γ decreases, such that the overall probability of corruption (a reciprocated bribe in the event of a corruptible official) increases.

Proposition 12. *Given γ_I, $\beta = 1$, α_C and $b_{C=O}$, an increase in the probability of a corruptible type 2 official (λ), while the probability of a rejecting type 3 official decreases accordingly, implies an increase in the probability of inspection (α), the size of the bribe (b), and the probability of corruption (χ), as well as a decrease in the probability of offering a bribe (γ), all while the probability of accepting/reciprocating (β) remains unchanged.*

The next part of this section shows these results more formally.[9] Note that the result that a marginal increase in ρ must increase γ, and thus increase the probability of corruption χ, was shown in equations (4.20) and (4.21) in the previous section. If ρ

[9]Marginal penalty changes have the following effects. In equilibrium, the probability of acceptance/reciprocation must be equal to one. It follows that, looking at equation (4.37), the probability of offering a bribe does not change, and thus χ remains constant as far as penalty changes go. Looking at equation (4.38) and (4.39), it is now easy to see that increasing either p or q will reduce the probability of inspection, as well as the size of the bribe, while the probability of corruption (reciprocated bribery) remains unchanged. The results under a variable bribe are thus similar to Tsebelis' (1989) results.

increases, this also effects both α_C and b_C, and given equation (4.34) these relative changes must be equal in direction.

$$\frac{\partial\alpha}{\partial\rho} = -\frac{[\lambda(v - r_2 + q) - p]p}{[\lambda q - (1-\rho)p]^2} \tag{4.40}$$

Since equilibrium requires that $\alpha \in [0,1]$ in equation (4.38), equation (4.40) is positive only if $0 < (1+\rho)p - \lambda q$.

$$\frac{\mathrm{d}b}{\mathrm{d}\rho} = \frac{[\frac{\mathrm{d}\alpha}{\mathrm{d}\rho}(1-\rho) + (1-\alpha)]p}{\lambda} \tag{4.41}$$

$$\frac{\mathrm{d}b}{\mathrm{d}\alpha} = \frac{(1-\rho)p}{\lambda} \tag{4.42}$$

These confirm Proposition 5.

An increase in λ must decrease γ and increase χ. This, too was shown in the previous section in equations equations (4.22) and (4.23). If λ increases, this again effects both α_C and b_C, and given equation (4.34) these relative changes are equal in direction as already shown in equation (4.42).

$$\frac{\partial\alpha}{\partial\lambda} = \frac{-(1-\rho)p(v-r_2) + \rho pq}{[\lambda q - (1-\rho)p]^2} \tag{4.43}$$

This can be either negative or positive, depending on the relative sizes of penalties.

$$\frac{\mathrm{d}b}{\mathrm{d}\lambda} = \frac{[(\frac{\mathrm{d}\alpha}{\mathrm{d}\lambda}\lambda - \alpha)(1-\rho) + \rho]p}{\lambda^2} \tag{4.44}$$

This has the same sign as equation (4.43). These confirm Proposition 6.

Simulation of the endogenous bribe equilibrium

Using the same set of parameter values as in the previous section, we simulate changes in the probability distribution over types of officials in the endogenous bribe equilibrium. Figure 20 illustrates the comparative statics of a shift in probability from a reporting type 1 official to a rejecting type 3 official, while keeping the probability of a type 2 official constant. We observe that, while the probability of corruption goes up moderately, the size of the bribe as well as the probability of inspection increase substantially, as we increase ρ in 5% steps. Table 12 shows that a 50% increase in ρ effects a less than 1% increase in χ. In Figure 21 we illustrate the comparative statics of 5% increments in the probability of corruptible type 2 officials while keeping the incidence of reporting types unchanged. As both the probability of inspection and the size of an offered bribe

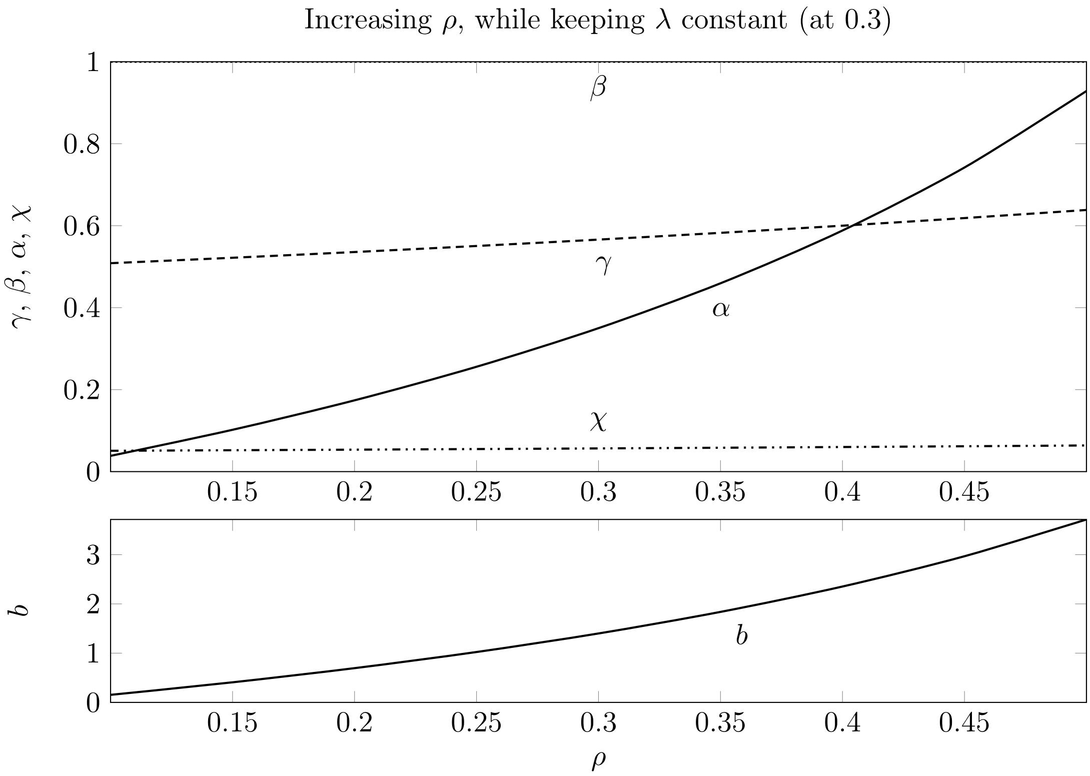


FIGURE 20: Increasing ρ in the endogenous bribe variant. *Using the same parameter values as in the previous section, we display intelligible ranges of* γ, β, α

decrease substantially, we observe a strong increase in the probability of corruption. Table 12 shows that a 5% increase in λ leads to an approximately 2% increase in χ.

4.4 Conclusion

In this paper we have used a game-theoretic model of corruption to analyse the effects of changing the likelihood that corrupt clients encounter corruptible versus honest types of public officials. Based on the setup of an inspection game, our model features three agents, a client who can offer or not offer a bribe, an official who might either accept, reject, or reject and report the bribe, and an inspector who can inspect or not inspect whether there has been a (accepted/reciprocated) bribe. Modelling the probability of detection endogenously is what makes our game a part of the inspection game family: the inspector's incentives are such that inspecting (accepted/reciprocated) bribery and not inspecting in case of no bribe are strictly preferred to inspecting if there is no bribe or not inspecting if there has been a (accepted/reciprocated) bribe. In this setup, the official's behaviour depends on her type. If she is of the reporting type, she will always reject and report if a bribe is offered. If she is of the rejecting type, she will always reject if a bribe is offered. Only if she is of the corruptible type, might she reciprocate

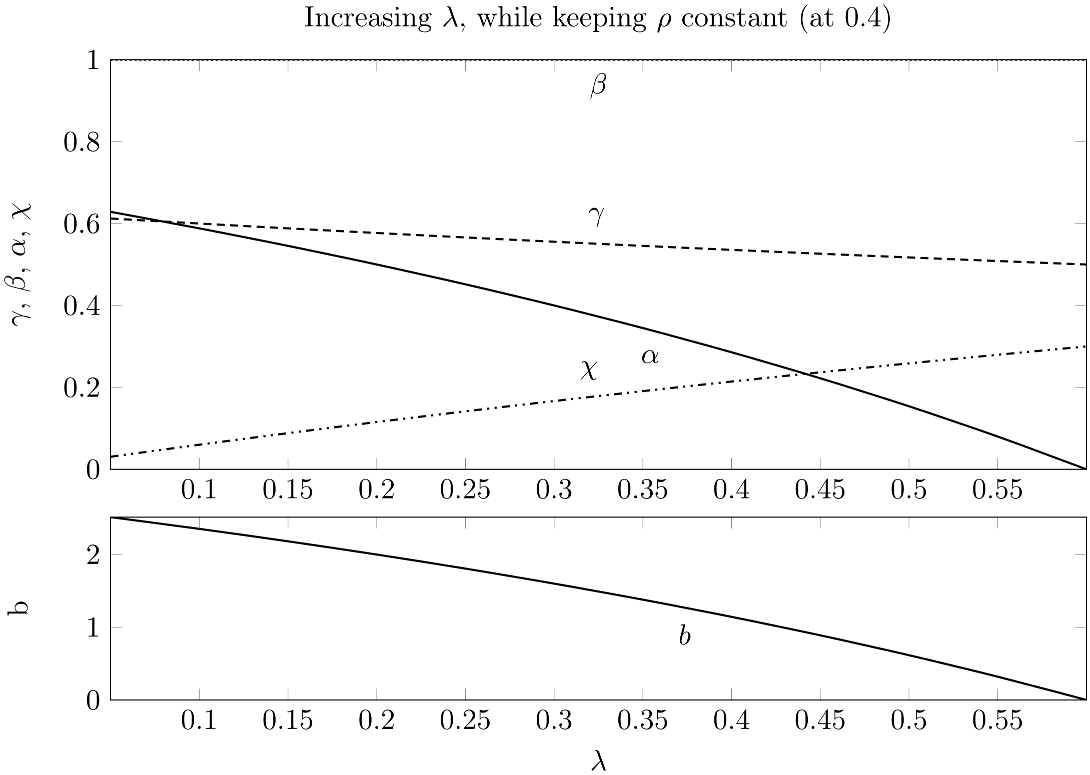


FIGURE 21: Increasing λ in the endogenous bribe variant. *Using the same parameter values as in the previous section, we display intelligible ranges of* γ, β, α

given that a bribe is offered. We model two variants of this game, one in which the size of the bribe offered is exogenous and one in which it is endogenous, meaning that the client can decide the size of the bribe.

We analyse both variants of this model by varying the probability distribution over the different types of officials and simulate our results with some fictional, but in ordinal terms, plausible parameter values. We find the following results. In the exogenous bribe variant, we obtain either a partially mixed perfect Bayesian equilibrium or a completely mixed equilibrium, depending on the relative sizes of parameter values. In the former, the equilibrium inspection rate keeps the client indifferent, but is low enough such that the corruptible official would always accept/reciprocate, while the inspector is kept indifferent by the probability with which the client randomises between offering and not offering a bribe. In the latter, the equilibrium inspection rate keeps both client and corruptible official indifferent, such that all three players randomise with strictly mixed equilibrium probabilities. (Unique equilibria are typical for games of the inspection game class and finding surprising comparative statics effects is part of the nature of mixed-strategy equilibria.) In the partially mixed equilibrium, we observe that an (5%) increase in the probability that the official is of the reporting type 1 (with the incidence of a rejecting type 3 decreasing accordingly) also increases the probability of corruption

Table 12: Increasing ρ and λ respectively in the endogenous bribe variant. *Values for intelligible ranges, starting from the base value $\lambda = 0.1$, when varying ρ and from $\rho = 0.4$ when varying λ. We chose those to remain in keeping with the parameter values chosen for the exogenous bribe variant*

Increase in ρ, while λ remains constant ($1-\rho-\lambda$ decreases)							
χ	γ	β	α	ρ	λ	$1-\rho-\lambda$	b
0.05	0.51	1.00	0.04	0.10	0.10	0.80	0.15
0.05	0.52	1.00	0.10	0.15	0.10	0.75	0.41
0.05	0.54	1.00	0.17	0.20	0.10	0.70	0.70
0.06	0.55	1.00	0.26	0.25	0.10	0.65	1.02
0.06	0.57	1.00	0.35	0.30	0.10	0.60	1.40
0.06	0.58	1.00	0.46	0.35	0.10	0.55	1.84
0.06	0.60	1.00	0.59	0.40	0.10	0.50	2.35
0.06	0.62	1.00	0.74	0.45	0.10	0.45	2.97
0.06	0.64	1.00	0.93	0.50	0.10	0.40	3.71
Increase in λ, while ρ remains constant ($1-\rho-\lambda$ decreases) Note that, in this case, $\frac{\partial\alpha}{\partial\lambda} = -1.66$, so α and b decrease.							
χ	γ	β	α	ρ	λ	$1-\rho-\lambda$	b
0.03	0.61	1.00	0.63	0.40	0.05	0.55	5.18
0.06	0.60	1.00	0.59	0.40	0.10	0.50	5.00
0.09	0.59	1.00	0.55	0.40	0.15	0.45	4.80
0.12	0.58	1.00	0.50	0.40	0.20	0.40	4.57
0.14	0.57	1.00	0.45	0.40	0.25	0.35	4.31
0.17	0.56	1.00	0.40	0.40	0.30	0.30	4.00
0.19	0.55	1.00	0.34	0.40	0.35	0.25	3.64
0.21	0.54	1.00	0.29	0.40	0.40	0.20	3.20
0.24	0.53	1.00	0.22	0.40	0.45	0.15	2.67
0.26	0.52	1.00	0.15	0.40	0.50	0.10	2.00
0.28	0.51	1.00	0.08	0.40	0.55	0.05	1.14
0.30	0.50	1.00	0.00	0.40	0.60	0.00	0.00

(by approx. 0.5%). Increasing the incidence of a corruptible type (while the incidence of a rejecting type decreases), induces an increase (by approx. 3%) in the probability of corruption. In the completely mixed equilibrium, a (5%) shift in probability from rejecting to reporting type official induces a (approx. 2%) rise in the probability of corruption. A shift in probability from rejecting to corruptible type official has no effect on the probability of corruption.

This has important implications for anti-corruption policy. While it is lowers levels of corruption if we discourage the corruptibility of public officials, we recommend that incentives should be set as to encourage rejection of offered bribes. In contrast, corruption is lowest if the proportion of reporting types is minimised in our model, suggesting that the reporting of offered bribes should be discouraged.

In the endogenous bribe variant, the unique perfect Bayesian equilibrium is where the optimal bribe size keeps the corruptible official indifferent between accepting and rejecting, while she accepts/reciprocates for sure, such that again client and inspector each randomise between their strategies as to keep each other indifferent between their respective actions. Our analysis shows that a (50%) shift in probability from reporting to rejecting type of official increases the probability of corruption only marginally (by less than 1%). In contrast, an (5%) increase in the incidence of a corruptible type (while the incidence of a rejecting type decreases accordingly), increases the probability of corruption (by 2%).

In this variant, where the corrupt client chooses the size of the bribe, policy recommendations are less drastic. Since an increase in the proportion of reporting officials only has a very small increasing effect on the probability of corruption, the focus should be set on disincentivising the corruptibility of public officials.

Chapter 5

Lab-Testing Mixed-Strategy Play in a Corruption Game with Endogenous Detection

Abstract

Does higher punishment on bribers really reduce corruption? We model a three-player corruption game with a client, an official and an inspector and test this hypothesis in the laboratory. The client can bribe or not, the official can reciprocate or not and the inspector can inspect or not. Thus, unlike most previous experimental and theoretical research on corruption (cf. Abbink et al. (2002)) we treat the probability of inspection as endogenous. Assuming self-interested and risk-neutral behaviour, the game has two Nash equilibria; one where there is no bribery, no reciprocation and no inspection; and a mixed-strategy equilibrium, in which there is corruption. Anticipating corrupt behaviour in the lab, we focus on analysing the mixed-strategy equilibrium. In the experiment we use neutral language, but subjects know that an 'accepted offer of coins' (reciprocated bribery) bears an efficiency loss, indicating social harm. In contrast to most experiments that seek to measure behaviour in games with unique mixed-strategy equilibria, we allow for genuine strategy mixing by letting subjects choose probabilities. In two additional treatments we vary the penalty on the official and on the client respectively, for which we predict that the former decreases reciprocated bribery (corruption) and the latter increases it. Looking at treatment effects, little can be inferred from individual subjects' behaviour. However, across periods and subjects, central tendencies of single parameters do change according to mixed-strategy predictions. They do so in terms of direction, but not in terms of magnitude. The quantity by which parameters changed suggests that, in contrast to theoretical predictions, both punishing officials as well as punishing clients may reduce corruption. Finally, we find that giving subjects time and pen and paper to deliberate significantly improves results with regards to equilibrium predictions.

Keywords: Inspection game · Corruption · Asymmetric penalties · Endogenising detection · Mixed-strategy

JEL Classification: C72 · C91 · D62 · D73 · K42

Introduction

With increasing globalisation, governments, supranational institutions and multinational corporations have come to a consensus about the detrimental nature of corruption with regards to trade and development (Krastev, 2004). The United States have pioneered this agenda with the 1977 Foreign Corrupt Practices Act and the OECD followed suit when passing the Anti-bribery Convention 20 years later. Yet anti-corruption legislation continues to be heterogeneous among many countries and the question of optimal deterrence remains inconclusive.

Due to its covert nature, corruption measurement proves problematic. The Corruption Perceptions Index issued annually by Transparency International since 1995 as well as other field data allow for the identification of socio-economic causes and consequences of corruption (Lambsdorff, 2007). However, on the one hand, there are growing concerns about the validity of these data sets (Cobham, 2013), and on the other, it is difficult to match this data onto existing models of corruption in the game theoretic literature.

In response to these measurement issues, a range of economic experiments have been conducted to test corrupt behaviour in the laboratory since the late 1990s. Experiments have provided answers to questions about accountability, culture, gender, framing, and various other issues. However, in accordance with most of the theoretical literature on corruption, most corruption related experiments[1] to date adopt one of two lines of thought. They either suppose that bribery takes place between a briber and an inspector, where the bribe has the purpose of averting inspection; or they assume that corruption takes place between a client and a corrupt public official, where both punishment and the probability of detection are assumed to be exogenous variables. None

[1]The exceptions here are Castro (2006), Alatas & Cameron (2009), Alatas et al. (2009), Cameron et al. (2009) and Lowen & Samuel (2011).

of them assume that inspection has to be done by someone, i.e. an inspector, or more specifically that such an inspector's payoffs might be contingent on the incidence of crime. We seek to fill this gap with this paper. Similar to some previous work (Spengler, 2014; Bone & Spengler, 2014), we develop a theoretical model of corruption in which the probability of detection is endogenised; we introduce a third player who takes the role of an inspector.

Previous game-theoretic corruption models (or more generally crime models) are extensions of Becker's crime model, where the probability of inspection is exogenous (Becker, 1968; Becker & Stigler, 1974). In contrast, Tsebelis (1989) and other work that followed on from this argued that the probability of inspection must be seen as an endogenous variable, contingent on the play of an offender. Our model is an extension of this so-called inspection game. In recognition of corruption as a collaborative crime - a bribe is a mere transfer, whereas the quid-pro-quo introduces the externality – we develop the following three player game. A client can bribe or not, an official can accept the bribe (i.e. reciprocate) or reject it and an inspector can inspect or not. In effect, we construct a variation on a trust game, in which both trusting and reciprocation are punishable. Our game differs in two crucial aspects from the standard trust game. First, it is not the loss of the bribe that implies the need for trust (for if it is rejected it will not be lost), but it is the exposure to potential inspection, which implies the need for trust. Second, there is a Nash equilibrium in which there is corruption (i.e. trust). Assuming rational, self-interested, utility-maximising, risk-neutral behaviour, the game has three Nash equilibria: one where there is no bribery, no reciprocation and no inspection; a completely mixed equilibrium, where each player mixes between their respective strategies to keep the other players indifferent; and a partially mixed equilibrium, where the client and the inspector randomise between their actions with the respective probabilities that keep each other indifferent, and where the official reciprocates for sure. The two mixed equilibria suppose a non-zero probability of reciprocated bribery, which we take to be the probability of corruption. The majority of our analysis focuses on the more interesting completely mixed equilibrium. A crucial feature of our model is the use of asymmetric penalties on the client and the official respectively. In line with our previous work, comparative statics exercises provide two crucial results (in the completely mixed equilibrium). First, we find that, in theory, increasing punishment on officials reduces the probability of reciprocated bribery (corruption). This is what first level intuition might confer. Second, we find that increasing punishment on clients, in theory, *increases* the probability of corruption. While we believe that the assumptions we make in our model are plausible, the intuition for this second result might only be prompted when carefully following the logic of the mixed equilibrium analysis.

We test this model in the laboratory by running two preliminary pilot sessions.[2] During the experiment we use neutral language, but subjects know that an 'accepted offer of coins' (reciprocated bribery) bears an efficiency loss. This reflects the negative externality caused by corruption as a public 'bad'. Since our theory predicts that corrupt behaviour only occurs in a mixed-strategy equilibrium, our experiment does not only contribute to the experimental literature on corruption, but also as experimental research on mixed-strategy equilibria. In contrast to most experiments that seek to measure behaviour in games with unique mixed-strategy equilibria, we let subjects mix between their actions. Specifically, we elicit mixtures by letting subjects choose probabilities on sliders.[3] In the experiment, subjects set probabilities for each of the three roles (client, official, inspector) on an input screen via the strategy method, before seeing both the role they have been allocated as well as their payoffs on an output screen. Thus, subjects are both randomly rematched and randomly assigned to one of the three roles each period. To test our theoretical predictions on asymmetric punishment of the two offenders we conduct two additional treatments, in which we vary the penalty on the official and on the client respectively.

Looking at treatment effects, little can be inferred from individual subjects' behaviour. However, across periods and subjects, central tendencies of single parameters do change according to mixed-strategy predictions.[4] This is true in terms of direction, though not in terms of magnitude. Results were closer to equilibrium predictions in the first session, in which subjects had both more time and pen and paper to deliberate on their choices. We find that, with increased deliberation, subjects' behaviour approximates equilibrium probabilities more closely. In both sessions we observe that, when increasing the punishment on the client in the third treatment, the direction of change in probability mixes is correct, but the combined probability of reciprocated bribery does not conform with the prediction. The quantity by which parameters changed suggests that, in contrast to our predictions, both punishing officials as well as punishing clients reduces corruption.

[2] A larger experiment with sufficiently large samples will be run in Autumn 2014. The pilot results do, however, give a flavour of the results.

[3] While we allow for genuine randomisation, other experiments rely on subjects randomising in their minds, for instance by using some sort of external coordination device. But this does not give access to information about the probability with which one action is played versus another. In neuroscience and psychology it is often assumed that people have such randomisation mechanisms as part of their brain functions. For a survey of the relevant literature see Glimcher (2003). Another advantage of this mixture elicitation method is that if subjects display behaviour that shows serial correlation across periods, this cannot be caused by an inability of generating a sequence of random, identical and independently distributed decisions. However, since this experiment relies on a small pilot, we do not explore serial correlations.

[4] There are more deviations in the second session, in which subjects were not allowed rough paper for notes.

The rest of this paper is organised as follows. Section 5.1 will review the literature this paper is related to. Section 5.2 presents the theoretical model and its comparative statics results. Section 5.3 presents the experimental design and defines hypotheses. Section 5.4 presents the experimental results and section 5.5 concludes.

5.1 Related work

This paper's main contribution is to the experimental literature on corruption. However, it also adds to theoretical research on crime deterrence and the inspection game, to existing research of experiments on trust and reciprocity, as well as to the experimental literature that deals with testing for mixed-strategy Nash equilibrium play. We briefly discuss these literatures with a view to highlighting the relevant differences in our work.

To date, a large range of corruption experiments has been conducted.[5] Our paper is specifically related to the following papers in this literature, which like ours, are variations of a trust game.[6]

Alatas & Cameron (2009); Alatas et al. (2009); Cameron et al. (2009) are all based on the same game-theoretic model, featuring a firm, an official and a citizen. In this game, the firm can decide to bribe or not and the official can decide to reject or accept the bribe. The citizen observes previous play and can decide whether to punish or not. As this is a one-shot game, punishing is not payoff-maximising for the citizen. This is anticipated by the official who therefore reciprocates for sure, which in turn induces payment of a maximum bribe (since the payoff of the firm increases in the size of the bribe). In terms of players and actions this game is much like ours, granting that punishment is induced by detection through inspectors rather than by citizens. However, we make the crucial assumption that inspectors do not know whether there has been a crime (bribery or reciprocated bribery) or not. This leads to the mixed-strategy equilibrium as discussed in the next section.

Abbink et al. (2002) conducts a corruption experiment in three treatments. In treatment "pure reciprocity", a briber can bribe an official or not, upon which the official can either reciprocate or not by giving out a favourable contract as opposed to a standard contract. Both bribing and reciprocating is costly to the respective offenders, but there is no punishment in this treatment. Treatment "negative externality" is almost identical to the first with the difference that reciprocation here induces a small cost to all other

[5] For a review of corruption related experiments see Serra & Wantchekon (2012) and for anti-corruption policy implications as a result of experimental studies see Abbink (2012).

[6] It should be said that we do not explicitly test for trust-like behaviour, but we anticipate that it might distort expected mixed-strategy probabilities in equilibrium among subjects. We do ask subjects about other-regarding preferences in a questionnaire after the experiment.

subjects in the lab. Importantly, the social damage exceeds the gain to a corrupt pair. Treatment "sudden death" differed from the first in that subjects would be disqualified from the game and lost all their existing payoffs with a probability of 0.003, if a positive transfer was accepted. It was found that the second treatment had a marginal effect, suggesting that subjects were not overly concerned if their behaviour caused harm to others. The effect of the third treatment was significant in terms of lowering a) the size of transfers, b) the frequencies of transfers and c) the frequency of accepted transfers. It was also found that the overall probably of "sudden death" was underestimated by subjects. Like Abbink et al., we include an efficiency loss and investigate the effect of punishment. In contrast to their setup, our design features endogenous detection and asymmetric penalties.

Castro (2006) develops an extension of the design Abbink et al. (2002) use. In a first treatment (pairs) they replicate the 'negative externality' treatment, in which there is no punishment. In a second treatment (triplets) a third player (an observer) is introduced, who can either consent to the corrupt transaction and partake in its gains or pay to disclose it, in which case both offenders receive zero payoff. Consenting pays a fixed sum plus a bribe (in this treatment the bribe is doubled by the experimenter and paid to both official and observer). Disclosing pays a fixed-sum minus a small fee for disclosure and no bribe. Like in 'pairs', reciprocation by the official causes a negative externality to all other pairs/triplets in the lab. While the optimal solution concept is subgame perfect Nash equilibrium, the authors claim that the game remains unsolvable, because it is incomplete (we do not know the size of the externality before it is revealed at the end of the game). Neglecting the externalities and assuming self-interested, risk-neutral behaviour, predictions are 'no reciprocation', thus 'no bribery' and thus no decision/play for the offender. However, since previous trust game related experiments have shown that the Nash equilibrium concept fails in such contexts, reciprocated bribery might occur and in turn the offender's best response would be to always 'consent' and never 'disclose'. This is self-interestedly rational, since the offender gets both the bribe and a higher fixed sum for consenting. It is found that in the second treatment there is more corruption, suggesting that corruption becomes a reciprocal relation between both the briber and the official as well as between the briber and the offender. The authors hypothesised that there be less corruption in the second treatment, given that there is a chance of getting zero in case of disclosure. However, a reduction in corruption should only be hypothesised, if the observer could actively do something about the externality that he/she is exposed to. In this game disclosure remains an incredible threat: ex-post there is no benefit from disclosing, so the observer should consent, and this should be anticipated by the other two players. Our model differs decisively from this. Whereas in this setup complicity on the part of the offender pays off, not inspecting in case of reciprocated bribery results in a relatively worse payoff for the inspector in our game.

Lowen & Samuel (2011) develop an extension of theoretical work by Mookherjee & Png (1995) and test this in the lab. The game has two players, an owner of a firm who has violated some governmental regulation and who will benefit from this if he/she is not prosecuted, and an inspector. The inspector moves first by deciding between demanding a pre-emptive bribe and choosing a level of effort to find evidence against the firm. If the inspector decides to choose a level of effort and finds no evidence, the game ends with the owner's payoff unchanged while the inspector's effort cost is sunk. If the inspector does find evidence, he/she can decide whether to enforce prosecution (and the game ends with a loss to the owner and a bonus to the inspector) or whether to demand an ex-post bribe. In the latter case, the owner can again decide to accept or reject the bribe, losing the bribe in the former and losing the consequences of prosecution in the latter. If the inspector, back at stage 1, demands a pre-emptive bribe, the owner has to decide whether to accept the offer (and the game ends) or whether to reject it. If he/she rejects it, the game continues like the previous branch: the inspector chooses an effort level, upon which he/she has to decide whether to demand an ex-post bribe or not and the owner has to decide whether to accept the ex-post bribe or not. The experiment had two treatments. The first was taken directly from Mookherjee & Png (1995), the second included the pre-emptive bribe (this was taken from Samuel (2009)). The subgame perfect equilibrium predictions could not be verified by the experimental data. First, inspectors choose significantly lower bribes than the payoff maximising one. This is to some extent in line with previous findings from ultimatum games. The current game is described as a variation on the ultimatum game. Second, neither do inspectors choose the payoff maximising level of effort. Third, corresponding with ultimatum game behaviour of the first finding, owners reject reasonable offers of demanded bribes. Although detection is endogenous in this game as a level of effort, the structure of the game is inherently different; it captures a very specific scenario with the inspector as the corrupt official, whereas we model officials and inspectors as separate players, and therefore inspectors cannot be corrupt.

Bertin (2010) conducts an experiment with four players. In stage 1, two bribers can use some of their endowment to bribe an official in order to compete for a governmental fund. In stage 2, the official decides whether to accept or reject the bribe, and how to split the fund between the bribers. In stage 3, a citizen can decide to punish the official, whereby a 1 token punishment costs him/her $\frac{1}{3}$ tokens. In contrast to our experiment, in this setup the deadweight loss is not borne by the punishing party (i.e. the inspector), so the latter punishes, if so, supposedly only out of altruistic motives. Little evidence is found with regards to high or low levels of punishment, as well as to high or low levels of reciprocation. However, punishment increases significantly where officials have distributed the fund unevenly, whether this be induced by different bribe size or not, which suggests inequity aversion.

Engel et al. (2012) construct a two player game with a proposer/payer and a receiver. The proposer can bribe or not bribe, then the receiver can decide to reject, to accept but *not* reciprocate, or to accept *and* to reciprocate. If the receiver rejects, the game ends. If he accepts but does not reciprocate, the proposer can decide whether to report or not. If the receiver accepts and reciprocates, both players get punished with $\alpha = 0.25$. In treatment 1, the punishment is equal for both players, whereas in treatment 2 punishment is asymmetric. Game theory, assuming risk neutrality and self-interestedness, predicts no corruption in each treatment: the briber's threat of reporting (and thus self-reporting) is not credible, which receivers predict and therefore do not reciprocate. This in turn is predicted by bribers. Lab behaviour differs due to both positive and negative reciprocity preferences. While there is corruption, results show that if bribers are punished more leniently, there is less corruption. Given other-regarding preferences this is rational behaviour, since in the leniency treatment bribers can retaliate by reporting without too high a cost to themselves. Like this paper, we analyse the effect of asymmetric punishment. Unlike ours, this paper treats the probability of detection as exogenous, however.

We contribute to the theoretical literature on corruption by developing a simple corruption game with endogenous detection. We have developed related models elsewhere.[7] Like the previous models, the current model offers surprising results due to the endogenous nature of the probability of detection. Most previous models of corruption are derivatives of Becker (1968)'s crime model.[8] All of these models have in common that the probability of detection is modelled as an exogenous variable. Most notably Tsebelis (1989, 1990a,b), but also Dionne et al. (2009) and Graetz et al. (1986), developed models where the probability of detection is replaced by an inspector. Tsebelis' results suggested that, due to the unique mixed-strategy Nash equlibrium between an offender and an inspector, there would not be the usual effect of an increase in punishment. Instead of reducing the probability of offending, it showed to reduce the probability of inspection. Adding a third player, as we do, results in interesting predictions for optimal corruption deterrence. This will be discussed in the next section.

[7] See Spengler (2014); Bone & Spengler (2014).

[8] For a review of the literature on corruption in general see Jain (2001). For a review of the economics of corruption see Rose-Ackerman (2006). For a review of microeconomic theory of corruption see Aidt (2003).

Finally, we contribute to the literature on testing mixed-strategy equilibrium behaviour in the lab. As mixed-strategy equilibria only predict probabilities, testing them is not straightforward. Most experimenters let subjects choose between pure strategies in repeated, strictly competitive games, where play is observed in frequencies. For simplicity, these games are played in pairs. To gather sufficient data to make meaningful statements about frequencies, games are oft-repeated. Trivial games, where the mixed-strategy equilibrium lies at the 50 percent mark for both players are avoided.

Erev & Roth (1998) reviews 12 such games with a view to comparing equilibrium predictions with theories of short-term and medium-term learning. The authors apply learning theory developed in Roth & Erev (1995) to the data of unique mixed-strategy equilibrium experiments by Suppes & Atkinson (1960), Malcolm & Lieberman (1965), O'Neill (1987), Rapoport & Boebel (1992) and Ochs (1995). Considering phenomena from psychological research, their first model predicts that more successful strategies will be played more frequently and that such learning has a stronger effect in early periods. Their second model predicts additionally that both similar choices and more recently played choices will be employed more frequently. Both (the latter more so than the former) predict behaviour more accurately than the static mixed-strategy equilibrium. We do not test for learning models of this sort for the following reasons. While the mentioned models are based on more than hundred-fold repeated pure-strategy play, we conduct few repetitions and allow for genuine mixed-strategy play. Also, quite apart from testing the validity of static equilibrium predictions, we are interested in policy prescriptions in view of corruption deterrence. For such statements, it suffices to look at central tendencies in the data. We will briefly discuss a selection of important experimental literature on games with unique mixed-strategy equilibria without providing details about their models.

O'Neill (1987) finds that mixed-strategy behaviour is likely more true across groups than for individual subjects. Generally, overall proportions followed the theory, whereas per round play was inventive and "followed hunches". While subjects can observe the gross statistics, they cannot know at a specific point in time what the opponent is playing and will thus not follow theory. We find these results confirmed by our pilot data, though to a lesser extent. This is most likely due to the higher degree of complexity (third player, random rematching, strategy method) and the relatively few repetitions of our treatments.

Ochs (1995) construct an experiment with a feature where subjects were asked to fill in a column of ten boxes and pick an action for each box. Unless subjects chose the same action for all ten boxes, play was executed by a computer at random, but according to the proportion of actions chosen. This is equivalent to a finite set of probability mixtures with 10% increments. It was found that first players generally increased the probability of a strategy whose payoff has been increased by the experimenter, which contradicts equilibrium predictions. This is the typical misinterpretation of a game with a unique mixed-strategy equilibrium. While in our game, on average, subjects reacted to higher own punishment with lower probability of offensive play, the respective other offender (whose punishment was not increased) showed the opposite, and thus the predicted directional behaviour.

In Bloomfield (1994) subjects are also able to choose from a continuum of strategy mixes. Like in our game, subjects are randomly rematched. Play is repeated for 70 rounds over two treatments. In the disclosure treatment, where players' feedback is disclosed publicly, there is greater convergence towards equilibrium, as subjects adapt according to the disclosed information of previous success. In the non-disclosure treatment, convergence is insignificant and subjects do not play according to equilibrium predictions.

Finally, Rauhut (2009) tests the original inspection game and its prediction that higher punishment reduce inspection but have no effect on crime rates. Play is repeated for 30 periods and subjects are randomly rematched. It is found that, while higher punishment does indeed reduce the rate of inspection, it also reduces the rate of stealing.

5.2 Theory

We develop a three player model with a client (C), an official (O) and an inspector (I). The client and the official can be imagined as a firm who bribes a public official in order to be issued an inadequate licence, a governmental contract or any other form of corrupt preferential treatment in the form of a public good, and where this has negative external consequences. The preferences of the inspector in our setup capture two features of the real world - that of an actual inspector and that of society. On the one hand, I bears the cost of reciprocation including the deadweight loss of the corrupt transaction. On the other, I has to exert an effort for inspecting, reflecting the intuition that inspectors do not want to inspect in vain, but only if they expect there to be an offence. We then consider the effect of asymmetric penalties on client and official respectively. We adopt the basic model from previous work (Spengler, 2014; Bone & Spengler, 2014) and adapt it for experimental purposes. Part of this is to transform the extensive form game into a normal form game as well as to add an initial endowment to all payoffs in order to avoid negative payoffs for subjects.

We first describe the game and then analyse its equilibria under a set of assumptions about the relative sizes of payoffs. This basic setup is the baseline treatment. We will then analyse comparative statics. A marginal increase of the penalty on the client provides the predictions for the second treatment (T2), and a marginal increase of the penalty on the official provides predictions for the third treatment (T3).

	Inspect ($\alpha = 1$)		Not inspect ($\alpha = 0$)	
	Accept ($\beta = 1$)	Reject ($\beta = 0$)	Accept ($\beta = 1$)	Reject ($\beta = 0$)
Offer ($\gamma = 1$)	$m - b + v - p_H$ $m + b - q$ $m - c + r_H$	$m - p_L$ m $m - c + r_L$	$m - b + v$ $m + b$ $m - v - d$	m m m
Not offer ($\gamma = 0$)	m m $m - c$	m m $m - c$	m m m	m m m

FIGURE 22: Normal form game with variables

To make the subsequent comparative static analysis more intuitive, the following explanation of the structure of payoffs divides the game into the three scenarios of a ‘reciprocated bribe’, an ‘unreciprocated bribe’, and ‘no bribe’.

Consider the game in Figure 22. Players can take the following actions. C can decide whether to offer a bribe or not, and O can decide whether to accept, in which case the bribe stays with O or to reject, in which case the bribe goes back to C. Accepting the bribe also initiates a transfer from I to C, which entails an efficiency loss. This will be explained shortly. I can decide whether to inspect or not.

All three players receive an initial endowment m. First, consider the case of a reciprocated bribe. Here, in addition to the endowment, C gets the benefit from reciprocation v, loses the bribe C, and, if inspected, loses a high fine p_H. Similarly, O receives the bribe, and, if inspected, loses a fine q. For I, if she does not inspect, she loses both v (as a transfer to player C) and d, which reflects the efficiency loss of the corrupt transaction. If I does inspect, she incurs a cost for inspecting c, but gains reward r_H.[9]

Second, consider the case of an unreciprocated bribe. Here, in addition to m, C has no gain, if not inspected and loses a low fine p_L if inspected. Player O rejected the bribe, and thus remains with m regardless of whether there is inspection or not (i.e. no punishment). I has m if she does not inspect, and gains r_L but loses c if she does inspect. We assume here that $r_L = c$, so that there is no difference between the expected payoffs of inspecting and not inspecting at this history.

[9]The variable r_H reflects a reward to the inspector as well as the recuperation of the losses.

Finally, consider the case of no bribe. Here, both C and O have the same payoff for inspection as they do when there is no inspection. As before, I incurs a cost (c) for inspecting.

Regarding the relative size of payoff parameters we make the following assumptions:

- The inspector receives the fines, when inspecting (reciprocated) bribery: $r_H = p_H + q$ and $r_L = p_L$.
- Cost of inspection and bribery: $0 < c$ and $0 < b$.
- There is an inefficiency loss, which implies that total welfare is reduced in the case of reciprocated bribery, whether inspected or not: $0 < d$.
- Both offenders prefer not to offend when inspected: $-b+v-p_H < 0$ and $b-q < 0$.[10]
- The inspector strictly prefers to inspect reciprocated bribery to not inspecting it: $-c + r_H > m - v - d$
- All players must have some endowment in order to not run into debt, which we maintain only for the purpose of the experiment: $0 < m$.

The solution concept for this game is Nash equilibrium. The game has three Nash equilibria, one in pure strategies, where C does not bribe, O does not reciprocate and I does not inspect; one in mixed strategies, where all three players mix between their respective strategies with the probabilities that make the remaining players indifferent between their respective strategies; and a partially mixed equilibrium, where C and I mix as to keep each other indifferent, while O reciprocates for sure.

To see the first equilibrium, consider Figure 22. It is easy to see that in the bottom-left quadrant of the right matrix no player can obtain a higher payoff by a unilateral deviation, such that each player's payoff is m. This is intuitive. Suppose that C does not bribe for sure ($1 - \gamma = 1$). O is then indifferent between reciprocating or not reciprocating ($\beta = 1 - \beta$), regardless of whether I inspects or not. It is then I's best response not to inspect. Since in this scenario not reciprocating is one of O's best responses, suppose that she does not reciprocate ($1 - \beta = 1$). Then C is indifferent between bribing and not bribing ($\gamma = 1 - \gamma$), and thus not to bribe is one of her best responses. The set of strategies $\gamma, \beta, \alpha = 0$ is thus a Nash equilibrium.

To see the completely mixed equilibrium, assume that $\gamma, \beta, \alpha \in (0, 1)$, such that each player's strategy is in full support, since in a mixed-strategy equilibrium each player

[10] This is in line with Bentham's Rule, which says that the "evil of the punishment must be made to exceed the advantage of the offence" (Bentham, 1887).

must be indifferent between his respective strategies. Using the payoffs in Figure 22, we equate the expected payoffs of the respective actions of each player and get equations (5.1), (5.2) and (5.3). The first expresses indifference for the client, solved for β, the second for the official, solved for α, and the third for the inspector, solved for γ.

$$\beta = \frac{\alpha p_L}{v - b - \alpha(p_H - p_L)} \tag{5.1}$$

$$\alpha = \frac{b}{q} \tag{5.2}$$

$$\gamma = \frac{c}{\beta(v + d + r_H - r_L) + r_L} \tag{5.3}$$

Equation (5.2) provides us with inspector's equilibrium strategy as a function of payoffs. Substituting (5.2) into (5.1), we obtain the official's equilibrium strategy, and substituting the latter into (5.3) gives us the client's equilibrium strategy, both as functions of payoffs.

$$\beta^* = \frac{b p_L}{qv - b(q + p_H - p_L)} \tag{5.4}$$

$$\alpha^* = \frac{b}{q} \tag{5.5}$$

$$\gamma^* = \frac{c[vq - b(p_H - p_L + q)]}{b p_L(v + d + r_H - r_L) + r_L[vq - b(p_H - p_L + q)]} \tag{5.6}$$

So, the set of mixed strategies γ^*, $\beta^*$and α^* is a Nash equilibrium.

In the partially mixed equilibrium, we assume that $\gamma, \alpha \in (0, 1)$ and $\beta = 1$. To see the existence of this equilibrium consider the following. We solve equation (5.1) for α, supposing that $\beta = 1$, and obtain the incidence of inspection at which the client is indifferent:

$$\alpha_C^* = \frac{v - b}{p_H}. \tag{5.7}$$

For completeness, note that equation (5.3) becomes:

$$\gamma_I^* = \frac{c}{v + d + r_H}. \tag{5.8}$$

Now suppose that the probability of inspection is α_C^*, and that $\alpha_C^* < \alpha^*$. It is then the case that O is no longer indifferent, but has an incentive to accept and reciprocate for sure, while C and I keep each other indifferent by mixing with γ_I^* and α_C^* respectively. Again, no player has an incentive to deviate unilaterally, so the set of mixed strategies γ_I^*, α_C^* and $\beta = 1$ is also a Nash equilibrium.

Consider the following comparative statics analysis of the completely mixed equilibrium when marginally changing the size of the penalties p_H, p_L and q. Suppose we increase the penalty p_H on the client. Looking at (5.1), this decreases the size of the denominator and thus increases the probability of reciprocation (β). Considering (5.3), this, in turn, leads to a decrease of the probability of bribery (γ). As p_H does not feature in (5.2), we know that α remains unchanged.

Suppose now that penalty p_L increases. The effect is the same. Since the denominator is greater than the numerator, but both feature αp_L, an increase of this penalty leads to an increase in β. It follows as before that therefore γ must decrease and α must stay constant.

Now suppose an increase in q. Starting with (5.2), it is easy to see that an increase in q results in a decrease of α. Looking at (5.1), a decrease in α decreases the numerator and increases the denominator (because $p_L - p_H < 0$) and thus leads to a decrease in β. Finally, since $r_H - r_L + v + d > 0$, a decrease in β leads to an increase of γ.

This analysis shows that penalties on clients have the opposite effect of penalties on officials. In fact, we can validate that γ and β must move in opposite directions by totally differentiating (5.3):

$$\frac{d\gamma}{d\beta} = -\frac{\gamma(r_H - r_L + v + d)}{\beta(r_H - r_L + v + d) + r_L} \tag{5.9}$$

Proposition 13. *In a completely mixed equilibrium, where $\alpha, \gamma, \beta \in (0, 1)$, an increase of either penalty on the client (p_H,p_L) decreases the probability of bribery and increases the probability of reciprocation (while the probability of detection remains constant). Analogously, an increase of the penalty on the official (q) increases the probability of bribery and decreases both the probability of reciprocation and the probability of inspection.*

Now, consider what happens to the probability of corruption, which we define here as the probability of reciprocated bribery ($\gamma\beta$). The above analysis has shown that γ and β must move in opposite directions. We can now totally differentiate (5.3):[11]

$$\frac{d\gamma\beta}{d\gamma} = -\frac{r_L}{r_H - r_L + v + d} \tag{5.10}$$

The sign is also negative, meaning that the probability of bribery moves in the opposite direction to the probability of reciprocated bribery. So, the sign of the change in the probability of reciprocation (β) determines the sign of the change in the probability of reciprocated bribery ($\gamma\beta$).

Proposition 14. *In a completely mixed equilibrium, where $\alpha, \gamma, \beta \in (0, 1)$, a decrease of γ must be accompanied by a proportionally greater increase of β, and vice versa,*

[11]Before differentiating we rearranged equation (5.3) as follows: $\gamma\beta(r_H - r_L + v + d) + \gamma(r_L) - c = 0$

such that the probability of reciprocated bribery ($\gamma\beta$) moves in the same direction as the probability of reciprocation (β).

So, within the confines of a completely mixed equilibrium, corruption is deterred optimally, if punishment on clients is minimised and punishment on officials is maximised and thus indeed asymmetrical.

Finally, consider the following comparative statics analysis of the partially mixed equilibrium when marginally changing the size of the penalty p_H. Note that by definition a marginal change in q has no effect and that p_L does not feature in equations (5.7) and (5.8). So, suppose we marginally increase p_H. Looking at (5.7) and (5.8), it is easy to see that this will decrease the probability of inspection, while the probability of corruption remains unchanged. By supposing that the official always reciprocates, the game effectively reduces to a two-player game between the client and the inspector. It is thus no surprise that the comparative statics are identical to those found in the inspection game by Tsebelis (1989).

Proposition 15. *In a partially mixed-stratey equilibrium, where $\alpha, \gamma, \in (0, 1)$ and $\beta = 1$, a marginal increase in penalty p_H on the client decreases the incidence of inspection, while the incidence of corruption remains unchanged.*

We show the existence of the partially mixed equilibrium and the related comparative statics for completeness. Since our experimental work is based on a small pilot, we only consider the completely mixed equilibrium type, both in the experimental setup and in the data analysis.

5.3 Experimental methodology

We decided for the following setup. We ran a pilot with two sessions and nine subjects per session. Each session was planned to last for about one hour and covered a practice game to learn the setting of probabilities for about five minutes, three practice periods of the baseline treatment, and 15 periods each for three paid treatments. Subjects were randomly rematched into a different triplet after each period. Detailed instructions were given in print, and some brief instructions were provided on screen. We conducted two sessions, which were three hours apart from each other in order to be able to adjust the setup in case of unexpected events. This was indeed a useful move; we will discuss this in the next section. Subjects were recruited using ORSEE and the experiment was programmed in z-Tree (Greiner, 2004; Fischbacher, 2007). Payment averaged roughly £12.00 per hour. Supposing that we would observe reciprocated bribery, the purpose of the experiment was generally to find out whether subjects behave according to either of the two mixed-strategy equilibrium predictions in a three player game, and specifically, whether the optimal deterrence predictions of our model remain true in the laboratory.

As discussed in the literature review, most experiments that test for mixed-strategy equilibrium play in the lab do so by letting participants make repeated pure choices in strictly competitive games. Probabilities are then derived by counting frequencies of play per action across periods. In order to be able to measure how subjects mix between their strategies, we decided to construct a slider as a means of strategy input. The slider ran from zero to 100 percent and featured a live gauge of the probability set on it. To familiarise subjects with this device, we let them play a slider practice game prior to letting them play the actual corruption game. Subjects were instructed to set the slider and then initiate a random draw of a new ball from the bag by use of a button. The percentage chosen on the slider reflected the amount of purple balls being replaced by orange balls in an opague bag. Zero percent thus meant that all balls remained purple and 100 percent meant that all balls in the bag were replaced by orange balls. The computer randomised the outcome with the probability inputted by subjects. This exercise was supposed to teach subjects the notion of choosing a probability mix between two actions. No further explanation with regards to the concept of a mixed strategy was provided. Clarifying questions in the questionnaires at the end of each session showed that all subjects seemed to have understood the purpose and function of the slider.

All three treatments consisted of two screens, an input screen and a results screen. For the input screen we used the strategy method (Selten, 1967). The obvious reason for using this method lies in the fact that we were interested in subject behaviour when playing a one-shot game many times over, rather than playing a repeated game. Using the strategy method had three further advantages. First, it allowed us to gather triple the amount of data. Given the small number of subjects and periods in our pilot sessions, this was particularly useful. Second, we could make sure that subjects were aware of the antagonistic nature of the three roles. Third, using the strategy method removed potential distributional concerns, since the average payoff is not equal among the three roles. In theory there is no equilibrium in pure strategies in which reciprocated bribery should take place. So, to let subjects develop an intuition for mixing strategies, we let them choose probabilities on three sliders (one per role) in separate boxes on the screen. Each box included a picture of the character (described below), brief instructions about the available actions as well as the resulting conditional payoffs. After making a conditional choice for each role, subjects were not only rematched by z-Tree's stranger setting, but a ranking algorithm randomly assigned a different role to each subject in each triplet.[12] The computer then randomly generated a 'real' action from the inputted probability choices of the three realised roles.

The results screen displayed what role a subject has been assigned to, the probability chosen for that role from the input screen and a table with some information. The table showed what actions were taken[13] on the previous screen, what payoffs were generated for each player as a result for the current period, as well as the total payoff of the current treatment (also for each player, since we wanted subjects to maintain a sense of competition). All subjects had to confirm by pressing "OK" to enter the next period.

We decided for a within-subject design mainly for practical reasons. In hindsight, the practical advantage did not outweigh the fact that we were later unable to make any statements about the sequence of treatments, let alone whether subjects' behaviour was independent of it.

Finally, we decided for a neutral framing. While there is mixed evidence on the effect of framing in corruption related experiments, we chose to use neutral language to preserve the ability to generalise our results with regards to testing mixed-strategy equilibrium play.[14]

Considering the use of sliders as opposed to pure action choices, the use of neutral language and the use of the strategy method, the game is fairly complex and thus difficult for subjects to comprehend. To facilitate understanding of the game structure, we decided to give the game a neutral, but well-known theme. Alluding to a famous game console game, we dubbed the three players as the characters Mario, Luigi and Toad, and used 'coins' as experimental currency. Subjects were thus instructed that Mario could 'offer' or 'not offer' three coins to Luigi, that Luigi could 'accept' or 'reject' these coins, and that Toad could 'check' or 'not check', whether any coins were sent and if any coins had been transferred from her to Mario.

Payoff sizes were determined according to the following design choices. First, the baseline treatment (T1) was set up to be a quasi equal-sum game with the exception of the deadweight loss, which meant that the reciprocated bribery case had a smaller total payoff (i.e. across the three players). Second, to allow for the same comparative statics analysis as in the theoretical game, treatments 2 and 3 (henceforth T2, T3) needed to

[12]Having two layers of randomisation – the use of the strategy method as well as z-Tree's random rematching procedure – made it easy for subjects to hide. This might have removed the need for randomisation and therefore distorted results significantly. When running a larger experiment this aspect will be reconsidered.

[13]This included the action generated from one's own probability choice and the two actions from the other two roles (but not the probabilities chosen by the other two matched subjects). To clarify, subjects were, of course, able to choose the corners of the sliders if they wanted to make pure choices.

[14]See for example Barr & Serra (2009) and Lambsdorff & Frank (2010) on the effects of framing in corruption games.

vary in only the treatment variables q (T2) and p_H (T3) respectively.[15] Third, since the currency was in coins, payoffs had to be in integers. We therefore defined parameter sizes according to the smallest parameter, the efficiency loss ($d = 1$). Table 13 gives a list of all parameter sizes used during this pilot. We used these to calculate the mixed-strategy equilibrium probabilities for risk-neutral, self-interested, utility-maximising behaviour. The probabilities are also displayed in Table 13. Figure 23 illustrates the normal form game with coin payoffs and language as it was used in the experiment. Given the theo-

TABLE 13: Parameter sizes in experimental coins and equilibrium probability predictions

Parameter	Parameter size in T1	Parameter size in T2	Parameter size in T3
m	10	10	10
b	3	3	3
v	8	8	8
p_H	**8**	**8**	**9**
p_L	2	2	2
q	**6**	**10**	**6**
c	2	2	2
d	1	1	1
r_H	14	14	14
r_L	2	2	2
γ (Mario)	0.16	0.3	0.125
β (Luigi)	0.5	0.188	0.667
α (Toad)	0.5	0.337	0.5
$\gamma\beta$	0.08	0.063	0.083

retical analysis of the previous section, we did not expect subjects to play according to the exact mixed-strategy probabilities. There are at least two reasons for this. First, it is fair to assume that subjects are not risk-neutral. We chose not to employ a binary lottery to cancel out risk preferences to avoid placing further computational demand on subjects.[16] Second, because of the game's (if remote) similarity to a trust game, there was some reason to anticipate other-regarding preferences. We addressed this

[15] Our choice of the size of the change of the parameters q (T2) and p_H (T3) was guided by maximising the difference in the resulting mixed-strategy equilibrium probabilities between treatments. It turns out that we should have chosen the lowest common denominator, because, in contrast to the predicted probability changes, actual probabilities in the experiment changed in the same direction. This will be discussed in the results section.

[16] Supposing that subjects are not risk-neutral, we cannot expect them to maximise expected utility. Only with the additional information about subjects' subjective probabilities could we infer whether expected utility was in fact maximised. As initially proposed by Smith (1961) and later by Roth & Malouf (1979), a binary lottery mechanism should help to induce risk-neutral preferences. In the context of this experiment, it would have been possible to pay subjects for a random selection of periods of play, rather than cumulatively. If this had been done, subjects would not maximise with respect to the size of payoffs and given their risk preferences, but instead with respect to the probability of the expected payoffs of the rounds that were randomly selected for payment. So, having the same payoffs for different subjects (with different risk preferences each) is not problematic, because paying for some random rounds would render the payoffs probabilities. Harrison et al. (2013) revisit the binary lottery technique.

	Inspect ($\alpha = 1$)		Not inspect ($\alpha = 0$)	
	Accept ($\beta = 1$)	Reject ($\beta = 0$)	Accept ($\beta = 1$)	Reject ($\beta = 0$)
Offer ($\gamma = 1$)	7 (T3: 6) 7 (T2: 3) 12	8 10 10	15 13 1	10 10 10
Not offer ($\gamma = 0$)	10 10 8	10 10 8	10 10 10	10 10 10

FIGURE 23: Normal form game with numerical values

with our questionnaire at the end of each session. The questionnaire and its responses to questions about other-regarding preferences is in the appendix. It shows that in both sessions and for all three roles, other-regarding preferences played either none or a very small role. Interestingly, other-regarding preferences mattered more to subjects in Session 1, in which more time, pen, and paper were provided, which allowed subjects to deliberate on their choices.

So, nobody (including the experimenters) could know the exact nature of any potential mixed-strategy equilibrium in the laboratory. This is not unusual, but given the complicated nature of the game this restricts our expectations with regards to equilibrium play. Assuming that subjects do, nevertheless, maximise expected utility, and assuming that subjects would have some way of inferring other subjects' behaviour, we deemed it reasonable to predict at most the qualitative change in average equilibrium probabilities of play across subjects when comparing treatments. On this basis we (tentatively) derive the following hypotheses:

Hypothesis 1. *In T2 we increase the punishment on officials compared to T1. Theory predicts for this case that the probability of bribery (γ) increases, that the probability of reciprocation (β) decreases, and that the probability of inspection (α) also decreases.*

Hypothesis 2. *In T2 we increase the punishment on officials compared to T1. Theory predicts for this case that the probability of reciprocated bribery ($\gamma\beta$) decreases.*

Hypothesis 3. *In T3 we increase the punishment on clients compared to T1. Theory predicts for this case that the probability of bribery (γ) decreases, that the probability of reciprocation (β) increases, and that the probability of inspection (α) remains constant.*

Hypothesis 4. *In T3 we increase the punishment on clients compared to T1. Theory predicts for this case that the probability of reciprocated bribery ($\gamma\beta$) increases.*

In the experiment, the data for Hypotheses 1 and 3 will be gathered directly, while the data for Hypotheses 2 and 4 will be generated by multiplying the relevant probabilities. Due to the influence of possible risk-preferences and other-regarding preferences, we thus anticipate that Hypotheses 2 and 4 are less likely to hold.

5.4 Results

We ran two small pilot sessions in order to be able to adapt the experiment in case of any unforeseen events. As mentioned earlier, the first session was planned to consist of time for reading the instructions, five minutes for the slider practice game, three unpaid practice periods of T1, and then 15 paid periods of T1, T2 and T3 each.

TABLE 14: Mean across all periods and all subjects. $^{*}p < 0.05$ *and* $^{**}p < 0.01$ *by Wilcoxon (matched-pairs) signed-ranks test*

		Theory		
	γ	β	α	$\gamma\beta$
T1	0.16	0.50	0.5	0.08
T2	0.3	0.188	0.337	0.063
T3	0.125	0.667	0.5	0.083
		Session 1		
	γ	β	α	$\gamma\beta$
T1	0.46	0.39	0.51	0.18
T2	0.49	0.17^{**}	0.43	0.08^{**}
T3	0.29^{*}	0.39	0.50	0.11^{*}
T2 sign prediction	$\gamma \uparrow$? true	$\beta \downarrow$? true	$\alpha \downarrow$? true	$\gamma\beta \downarrow$? true
T3 sign prediction	$\gamma \downarrow$? true	$\beta \uparrow$? true	α constant (+− 10%)? true	$\gamma\beta \uparrow$? false
		Session 2		
	γ	β	α	$\gamma\beta$
T1	0.35	0.35	0.75	0.12
T2	0.23^{*}	0.12^{**}	0.67	0.03^{**}
T3	0.23^{*}	0.26^{*}	0.53^{*}	0.06^{*}
T2 sign prediction	$\gamma \uparrow$? false	$\beta \downarrow$? true	$\alpha \downarrow$? true	$\gamma\beta \downarrow$? true
T3 sign prediction	$\gamma \downarrow$? true	$\beta \uparrow$? false	α constant (+− 10%)? false	$\gamma\beta \uparrow$? false

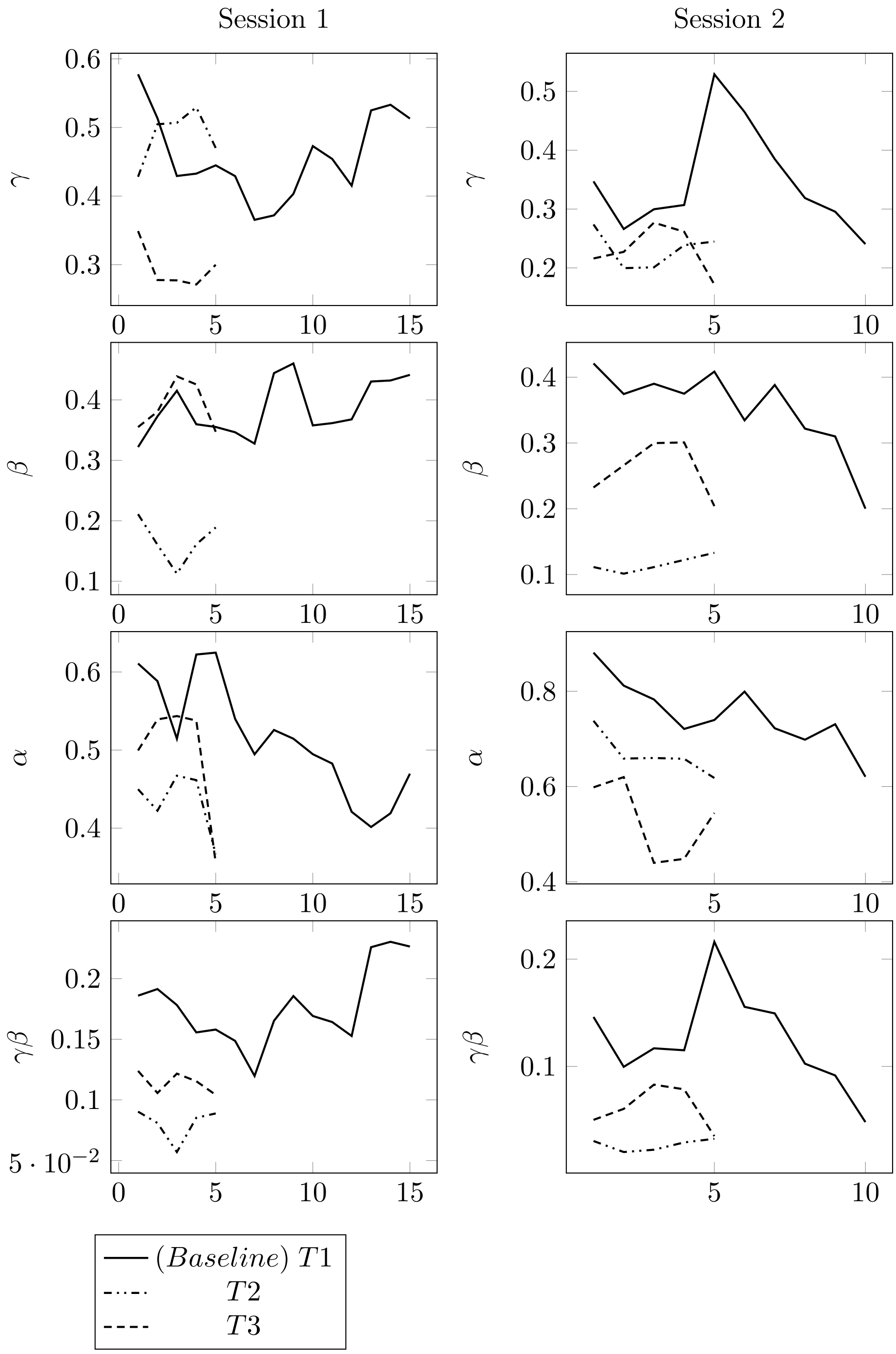


FIGURE 24: Treatment variation of mean per period across subjects for γ, β, α, and $\gamma\beta$

To give subjects time to familiarise themselves with the game in early periods, progression to further periods was only possible after all subjects had confirmed that they were ready. Because of the complicated nature of the game, we decided to provide subjects with a pen and some rough paper in order to let them take notes during the game if they wanted to.

The lack of a time limit on periods combined with the well-used rough paper for notes led (some) subjects to take an overly long time in many consecutive periods. In fact, almost all subjects in session 1 took extensive notes on their progress within the game. The majority drew tables containing their assigned roles and payoffs, as well as everybody's actions after each period. This created not only long delays for other subjects, but it forced us to adapt the lengths of T2 and T3 impromptu to five periods each instead of the planned 15. After making concessions on the amount of periods per treatment, session 1 still overran by more than 30 minutes. Consequently, we reduced the amount of periods per treatment to T1=10 periods and T2,T3=5 periods and did not hand out rough paper for note taking in the second session. While this had the desired effect of keeping the session length to within the time limit of one hour, it had significant influence on the results. This will be shown in the following analysis.

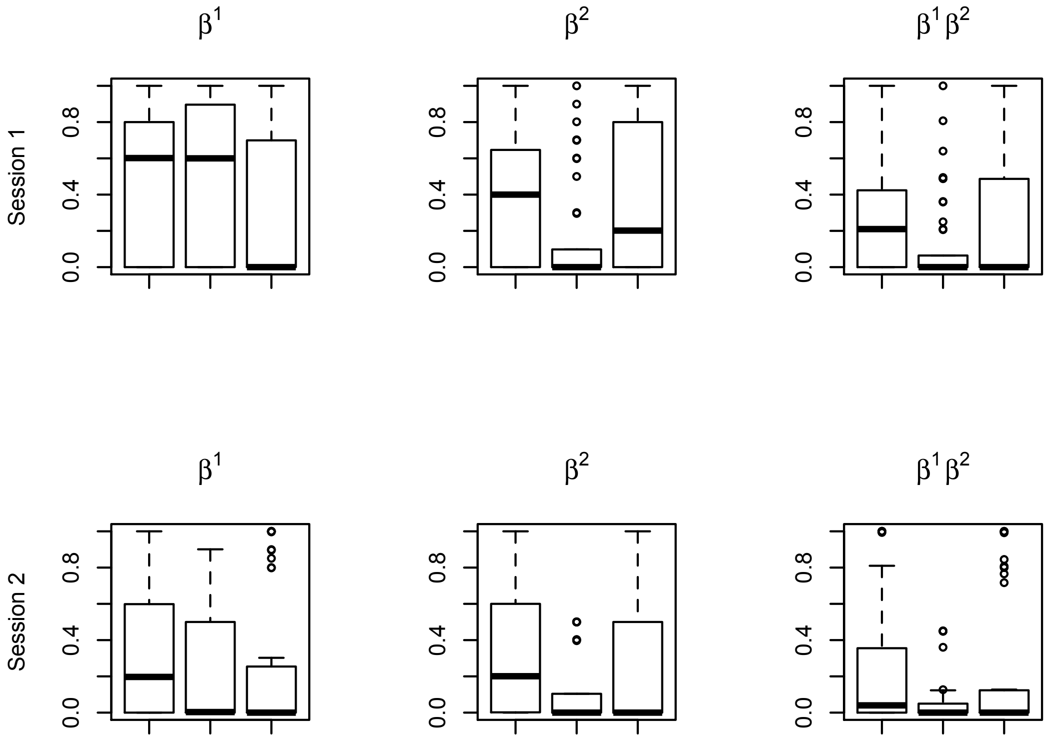
To test our hypotheses, we first examine the treatment variation of the central tendency of probabilities across all subjects and all periods. This is shown in Table 14 and Figure 25, where we illustrate treatment variation in box plots. Second, we illustrate the treatment variation of the mean of probabilities across all subjects as it develops over periods in Figure 24, where the two sessions are in columns and and the probabilities of bribery (γ), reciprocation (β), inspection (α) and reciprocated bribery ($\gamma\beta$) in rows.

The data provided allows for two conclusions. First, where the direction of a probability change coincides with equilibrium predictions (which it does in several cases), its magnitude does not. This is in line with our expectations. Second, results differ greatly between the two sessions. We discuss both in turn.

As shown in Figure 26 and 27, parameters γ, β, α and $\gamma\beta$ are not normally distributed, but resemble (if anything at all) bimodal distributions. This is due to several subjects choosing probabilities either close to or exactly at zero or one. Consequently, we conduct non-parametric Wilcoxon signed-rank tests to compare the central tendencies of related samples. The relevant p-values (see Table 14) indicate, which parameters have changed significantly for an across subjects and periods comparison between treatments.

Consider session 1 first. Looking at the mean across subjects (and periods for Table 14) per treatment, both the data in Table 14 and Figure 24 largely confirm Hypotheses 1 (higher punishment on the official) and 3 (higher punishment on the client). As

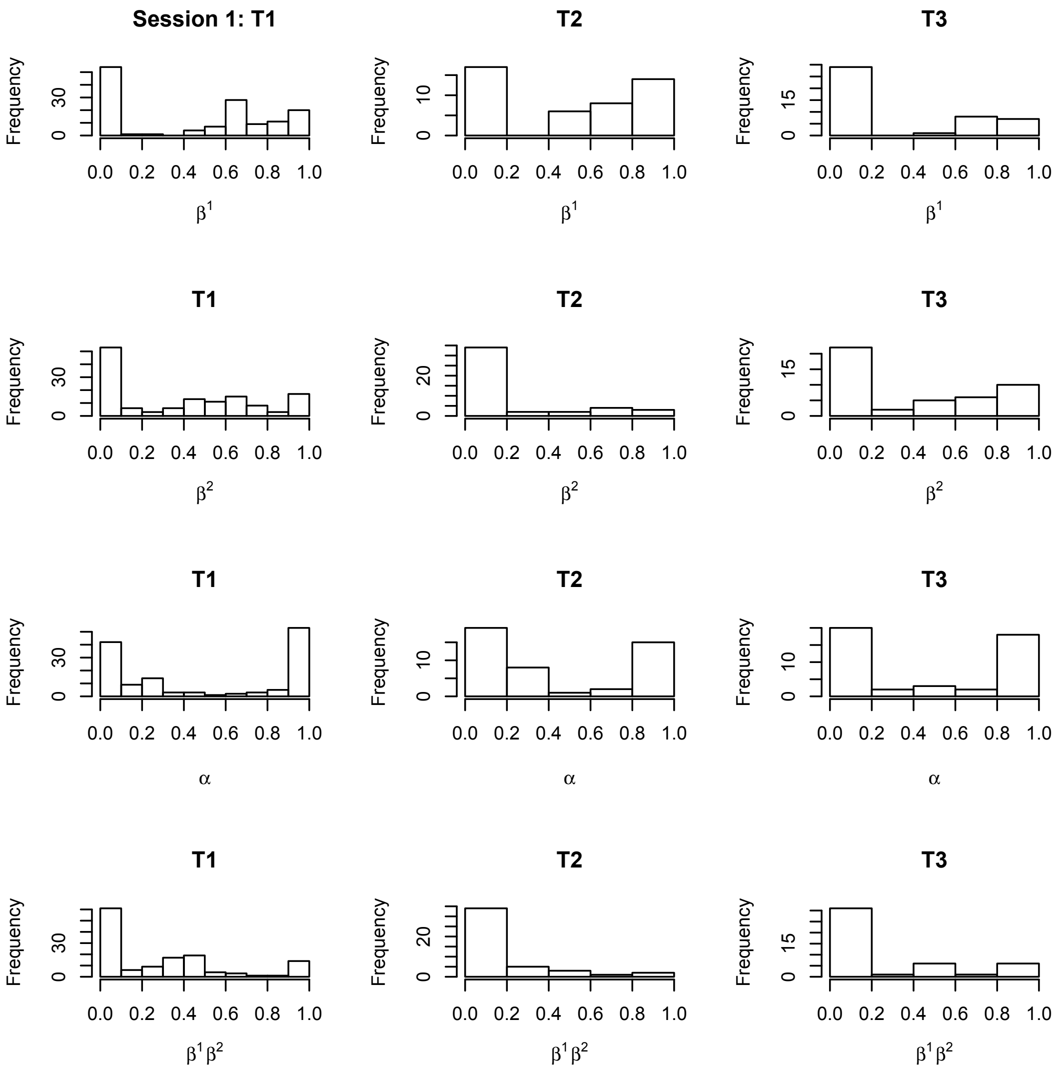
FIGURE 25: Boxplots of Treatments 1, 2 and 3 for γ, β and $\gamma\beta$



predicted, it is true across subjects and periods that the mean of the probability of bribery goes up in T2 and down (significantly) in T3. Further, it is true that the mean of the probability of reciprocation goes down (significantly) in T2 and up in T3. Moreover, the mean of the probability of inspection decreases strongly in T2, but it does so also (though to a lesser extent) in T3. Note that for the latter it was predicted that it should remain constant. Hypothesis 2 is also confirmed by the data. Higher punishment on the official does result in (significantly) less reciprocated bribery (corruption). However, while the the change in the probabilities conforms with the predictions in qualitative terms, the changes do not correspond entirely with the predictions in quantitative terms. As a result we are unable to reject Hypotheses 1-3 (at least as far as direction of change is concerned), but have to reject Hypothesis 4: in contrast to predictions, we find that increasing the punishment on clients *also* (significantly) decreases the probability of reciprocated bribery (corruption).

Now consider session 2. Here, the data shows that ordinal predictions for probabilities in T2 were only true for reciprocation (β) and inspection (α), but not so for bribery (γ). In T3, only the ordinal prediction for bribery (γ) can be confirmed, while the change of the other variables is opposite to the theoretical prediction. Thus, Hypothesis 4 (more corruption in T3) must be rejected, Hypotheses 1 and 3 must be rejected in part, and only Hypothesis 2 (less corruption in T2) cannot be rejected.

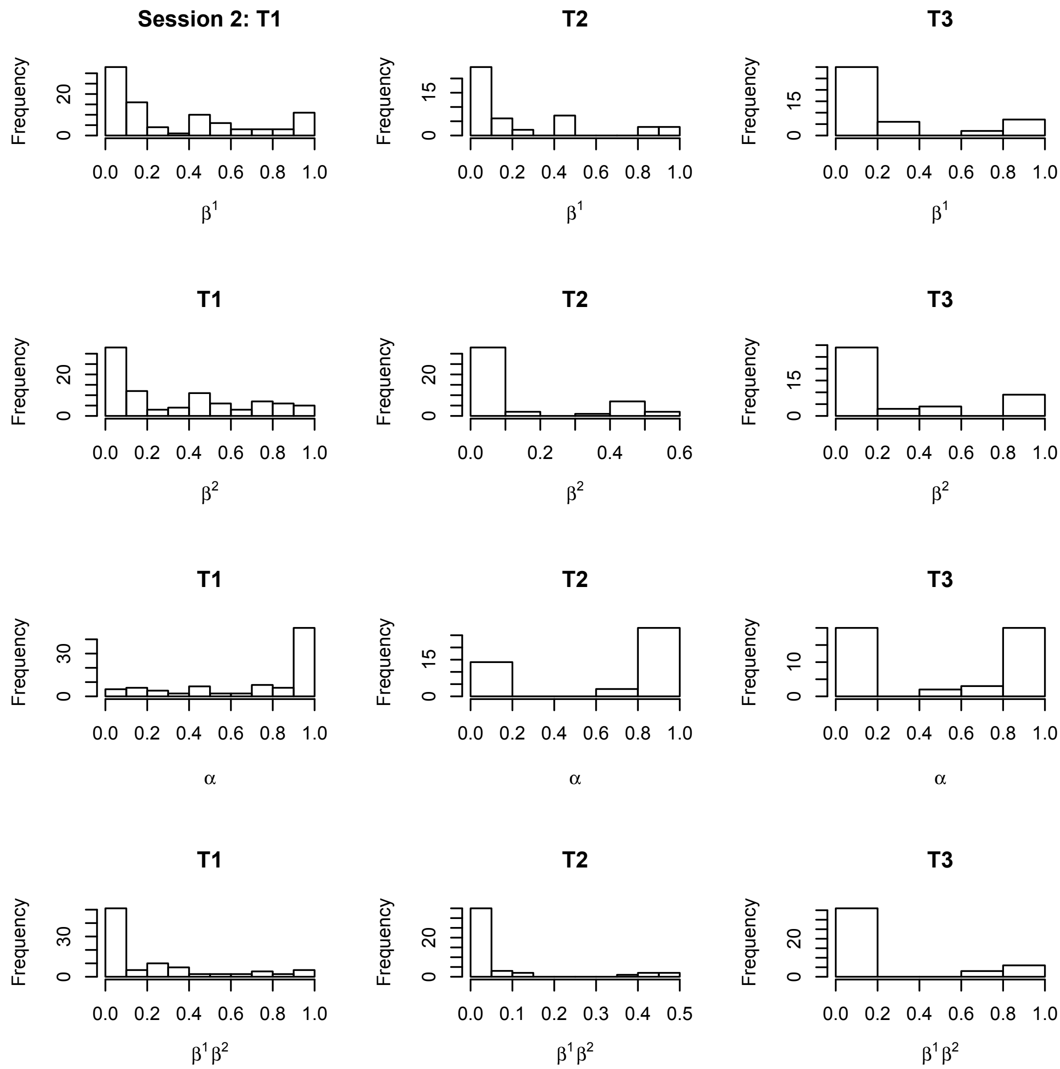
FIGURE 26: Histograms of treatments 1, 2 and 3 for γ, β, α and $\gamma\beta$ for session 1



Interestingly, both sessions provide the same results for Hypotheses 2 and 4, proposing that both, increased relative punishment on officials *as well as* on clients reduces the probability of reciprocated bribery (corruption) substantially. This is nicely illustrated in Figure 24. In both sessions, both the means and the p-values suggest that the effect of T2 was more significant than that of T3. This seems obvious given that the change in the treatment variable was 4 in T2 and only 1 in T3. Because of our false anticipation that $\gamma\beta$ would move in the predicted directions (that is in opposite directions in T2 and T3 in contrast to T1), we did not change the treatment variables in equal amounts in T2 and T3. Due to this design flaw it is not possible to compare the deterrent effect of T2 and T3 under ceteris paribus condition. The only possible conclusion is thus what intuition might have told us: the higher the punishment, the more effective its deterrent effect. This seems true independent of the recipient of the punishment.

The histograms in Figures 26 and 27 show that out of all probability intervals zero or

FIGURE 27: Histograms of treatments 1, 2 and 3 for γ, β, α and $\gamma\beta$ for session 2



close to zero probability choices have occurred most frequently. This suggests that at least some subjects played (at least in part) the pure strategy equilibrium in which no corruption occurs. In fact, when looking at the data, we found that, apart from many occasional probability-zero or one choices, some subjects consistently converged to the $[0, 0, 0]$ Nash equilibrium on all three sliders and for a number of periods.

The results suggest that behaviour in session 1 was significantly closer to mixed-strategy equilibrium predictions than in session 2. Session 1 involved more periods for T1, and the same number of periods for T2 and T3. Comparing only the first 5 rounds of each Treatment across sessions in Figure 24, it is clear that the number of periods does not explain the differences between the two sessions. Since the only other difference between sessions was the provision of rough paper for note taking in session 1 (but not so in session 2), we believe that this equipment was a crucial aid to subjects when making their decisions. As mentioned before, the game is very complex for at least three reasons: 1. The equilibrium prediction for corrupt collaboration is in mixed-strategies only; 2. Subjects were both randomly rematched (to keep the game a one-shot game) and assigned a random role after each period; 3. Subjects could not know each other's risk preferences and/or other-regarding preferences. It is therefore plausible that significantly more time and a log of past events make a substantial difference to subjects' abilities to calculate equilibrium probabilities. Of course, it is not clear that this is what individual subjects were doing. In fact, data from the questionnaire suggested that, while subjects understood the purpose of the slider, they did not understand the concept of a mixed-strategy equilibrium as it is defined game-theoretically.

An additional follow-up questionnaire revealed that several subjects had strong 'hunches' about what would happen as a result of the current period, and thus felt almost certain about what action to choose. However, to insure themselves against the then supposedly less probable event, close to zero/one actions were chosen. The underlying logic seemed to have been some sort of superstitious belief in a match between the small chance of playing the supposedly incorrect action and the supposedly unlikely or unwanted event. To give an example, a subject would set Mario's slider to close to 100% (i.e. 'offer'), believing that there would be no inspection, but 'hoped' that in the supposedly unlikely event of inspection his Mario character would then 'not offer'.

Other subjects suggested that they were the probabilities they thought other people were setting as points of reference. In studying frequencies of events and inferring probabilities, they would for example play high probabilities for Mario, when their inferences told them that Luigi was unlikely to reciprocate. Generally, it seemed that subjects did not adapt their probability choices via the effect of a higher punishment on the probability choices of other players, but instead they adapted it directly. For example, subjects would choose a lower probability for Luigi in T2, not because this was necessary in order to keep the client indifferent, but instead because Luigi was now facing a higher potential punishment. This would explain why in both sessions punishment primarily had a decreasing effect on the probability choice of the respective offender with the increased punishment.

Neither of these classes of reasoning resemble the theory of mixed-strategy equilibrium. Nevertheless, we conclude here that allowing for more deliberation on the part of subjects (paper for notes) improves equilibrium probability calculations with respect to mixed-strategy equilibrium predictions. This is so at least with respect to the direction of probability changes and as far as averages across all subjects are concerned.

5.5 Conclusion

Both the theoretical and the experimental literature on corruption largely models the probability of inspection as an exogenous parameter. In some previous work (Spengler, 2014; Bone & Spengler, 2014) we argued that this is a limitation of the theoretical literature. In this paper we provide results from testing our theory in the lab. We construct a three-player game almost with strictly opposed payoffs.[17] A client decides whether to bribe an official or not, the official decides whether to reject or accept, and an inspector decides whether to inspect or not. Accepting on the part of the official initiates a transfer from the inspector to the client. Payoffs are structured such that bribing and accepting pays off if there is no inspection, but inspection is costly and thus only pays off if there is at least an attempted bribe. While the game has a pure strategy equilibrium without corrupt interaction, corruption only occurs in mixed-strategy equilibria. There are two types of mixed-strategy equilibria, a completely mixed one and a partially mixed one. We focus our analysis on the completely mixed type. Marginally changing penalties in the completely mixed equilibrium gives rise to 4 hypotheses. 1. Increasing punishment on officials, ceteris paribus, *increases* the probability of bribery, but *decreases* the probability of reciprocation. 2. It also *decreases* the probability of reciprocated bribery (corruption). 3. Increasing punishment on clients, ceteris paribus, *decreases* the probability of bribery, but *increases* the probability of reciprocation. 4. It also *increases* the probability of corruption. We test this theory in three treatments, a baseline treatment, a treatment testing for Hypotheses 1 and 2, and a treatment testing for Hypotheses 3 and 4. We ran two pilot sessions with 9 subjects (in three triplets) with repeated one-shot games. Subjects were randomly rematched after each period and made conditional choices using the strategy method. Importantly, we provided subjects with sliders on which they could explicitly choose genuine strategy mixes, if they wanted. Neutral language was employed throughout. Our pilot results give a flavour of expected outcomes of a larger experiment. What we find is partly in line with previous experimental evidence on testing mixed-strategy behaviour. For example, like O'Neill (1987), our data provide little evidence of mixed-strategy play on the individual level, but central tendencies across subjects and periods suggest that, at least for the first session, treatment effects by and large conformed with the direction of change of the theoretical predictions. Given that we could not account for risk-preferences and other-regarding preferences we neither anticipated nor observed that the sizes of change corresponded to theoretical predictions. In session 1 we could not reject Hypotheses 1-3, but had to reject Hypothesis 4. In session 2 subjects were given less time to make choices and, importantly, were not explicitly told that they were able

[17] Corrupt activity induced an efficiency loss.

to use rough paper to make notes during the experiments if they wanted. This seemed to have made all the difference, since the data in session 2 leads us to, at least partly, reject all four hypotheses. Nevertheless, it was true for both sessions that both treatments lead to significantly less corruption. Analysing both the data and information from follow-up questionnaires suggests that subjects did not comprehend the concept of a mixed-strategy equilibrium *despite* choosing probability mixes on their sliders rather than zero or one. Instead, some less than rational (potentially superstitious) strategies were followed. We therefore conclude that, in the context of corruption deterrence, limited rationality works in our favour. While theory predicts that asymmetric penalties (with severe punishment on officials and low punishment on clients) are the best setup, our data shows that, what matters for corruption deterrence, is simply higher punishment, no matter on which offender.

Appendix A

Appendix to "Lab-Testing Mixed-Strategy Play in a Corruption Game with Endogenous Detection"

A.1 Instructions:

The Game

You will play the game in three stages. Each stage has a slightly different version of the game. These versions will be described in more detail later. For now, all you need to know about the game structure is that:

- The game is between three players, called Mario, Luigi and Toad.
- Each player wins coins; the amount depends on actions taken by all three players.
- Each player has two actions, labelled purple and orange.

In each stage, you play that version fifteen times. There are three versions of the game.

Game 1: structure

The game is played between three players, called Mario, Luigi and Toad. At the start of the game each player is given 10 coins. In the game, the two actions available to each player are, with their colour-coding:

	Purple	Orange
Mario	not offer	offer 15 coins to Luigi
Luigi	reject	accept the 15 coins (if offered)
Toad	not check	check the actions of the other two

In outline:

- Mario gains coins by offering, if and only if Luigi accepts and Toad does not check
- Luigi gains coins by accepting, if and only if Mario offers and Toad does not check
- Toad gains coins by checking, if and only if Mario offers and Luigi accepts

In detail, suppose firstly that Toad does not check the actions of the other two.

A: If Mario does not offer, then nothing happens. So the players finish the game as they started, winning:

Mario, 10 coins Luigi, 10 coins Toad, 10 coins

B: If Mario offers, and Luigi rejects, then the players finish as they started, winning:

Mario, 10 coins Luigi, 10 coins Toad, 10 coins

C: If Mario offers, and Luigi accepts, then 3 coins are transferred from Mario to Luigi. But also 6 coins are transferred from Toad to Mario, and Toad loses a further 2 coins. So the players win:

Mario, 15 coins Luigi, 13 coins Toad, 1 coin

Now suppose instead that Toad checks the actions of the other two. This costs Toad 10 coins, whatever the other playersÕ actions. By comparison with A-C above:

A': If Mario does not offer, then the outcome is as in A, except that Toad loses 2 coins as the price of checking. So the players win:

Mario, 10 coins Luigi, 10 coins Toad, 8 coins

B': If Mario offers, and Luigi rejects, then the outcomes is as in B, except that Toad loses 2 coins as the price of checking, but also 2 coins are transferred from Mario to Toad. So the players win: So the players win:

Mario, 8 coins Luigi, 10 coins Toad, 10 coins

C': If Mario offers, and Luigi accepts, then the outcome is as in C, except that Toad loses 2 coins as the price of checking, but also 8 coins are transferred from Mario to Toad, and 6 coins transferred from Luigi to Toad. So the players win:

Mario, 7 coins Luigi, 7 coins Toad, 12 coins

Game 1: procedures[1]

You will play Game 1 fifteen times, i.e. over fifteen 'rounds'. The coins you win in each round accumulate over the fifteen rounds. So, for example, if you win coins won in each round accumulate in each round:

The participants in the lab will be randomly sorted, by the computer, into groups of three. You will not know who are the other two members of your group, which will change from each round to the next.

The three members of each group play the game with each other, one member being assigned the position of Mario, another the position of Luigi and the third the position of Toad. This assignment of positions will be made randomly by the computer.

[1]Note that instructions were identical for treatments 2 and 3 (in front of subjects, treatments 1-3 were called Game 1, Game 2, and Game 3), except for a change in the numerical value of the treatment variable. Subjects were told that this was the only change between "games" when handed the new instructions before each treatment.

However you will make your choice for each of the three player-positions before knowing which position you are assigned in that round.

Thus you will make a choice as if you are Mario, another separate choice as if you are Luigi, and another choice as if you are Toad. Only one of these choices will actually take effect, depending on which of the three positions you are actually assigned.

For each of the three positions, using the slider, you choose a value from 0% to 100%. This represents the probability that your action will be orange, if you are assigned that position. (Remember that you can ensure that your action, in that position, will be orange by choosing 100%, or you can ensure that it will be purple by choosing 0%.)

When all group members have made their three choices, the computer assigns a position to each member and then determines that member's action according to the probability value chosen, for that position, by that member.

You will then see a 'results' screen for that round. This shows the position you were assigned in that round, together with the actions taken by you and by the other two members of your group, in the positions they were assigned. You will also see the number of coins won by each player/member in that round, together with the number of coins you have accumulated over all rounds so far in the game.

A.2 Questionnaire and summary of responses:

The bold headers are titles of the separate screens of the questionnaire, questions are numbered, and responses are provided in summary in italics.

While we are preparing payments, please can you complete the following questionnaire?

Personal Information:

1. What is your gender?
   Session 1: 4 males, 5 females. Session 2: 5 males, 4 females.
2. How old are you?
   Average age was approx. 26 years in session 1 and 24 years in session 2.

3. What is your nationality?
   Session 1: 2x Chinese, German, Romanian, 3x British, Canadian, Indian. Session 2: Latvian, Chinese, 4x British, Taiwan, Canadian, Greek.

Comprehension of the experiment:

1. In the initial colours game with the slider and the balls, please explain what you could do with the slider (if you feel that you did not understand it, please explain what was unclear):
   Except for one individual in session 1, all subjects seem to have had a good grasp of the slider in the practice game. Some explanations were very precise, others less so. Here are two examples:
   - Clear: "You could slide it to change the proportion of balls in the virtual bag."
   - Unclear: "Well understood."
   One individual, 28 years of age, had two complaints: A) that the slider game was pointlessly easy and B) that sometimes when she chose 95%, the computer still picked the "other" probability.

2. In the real game, how well did you understand the function of the sliders?
   Responses varied between 'very well' and 'well'

3. When choosing a probability on Mario's slider, did it trouble you that the only way you could benefit was by making Toad worse off?
   Session 1: No, not very much. Session 2: No, not at all

4. When choosing a probability on Mario's slider, what mattered most: your own payoff, being nice to Luigi, or not harming Toad? (Check more than one box if you like.)
   Both sessions: My own payoff.

5. When choosing a probability on Luigi's slider, did you feel an urge to reciprocate to Mario, because he has entrusted you with 3 coins?
   Session 1: No, not very much. Session 2: No, not at all.

6. When choosing a probability on Luigi's slider, did it trouble you that the only way you could reciprocate to Mario was by making Toad worse off?
   Session 1: No, not very much. Session 2: No, not at all.

7. When choosing a probability on Luigi's slider, what mattered most: your own payoff, helping Mario, or not harming Toad? (Check more than one box if you like.)
   Both sessions: My own payoff.

8. When choosing a probability on Toad's slider, what mattered most: your own payoff, punishing Mario, punishing Luigi, or punishing both? (Check more than one box if you like.)
   Both sessions: My own payoff.

9. In the second part, of the main game, where punishment was higher on Luigi, how did this affect your slider choices? Did it influence you choice on... (Check more than one box if you like.)
   Session 1: 3x Mario's slider, 6x Luigi's slider, 1x Toad's slider. Session 2: 2x Mario's slider, 8x Luigi's slider, 3x Toad's slider.

Final payoff:

1. Your total payoff in coins from today's experiment is: [...]

2. Your total payoff in pounds from today's experiment is: [...]

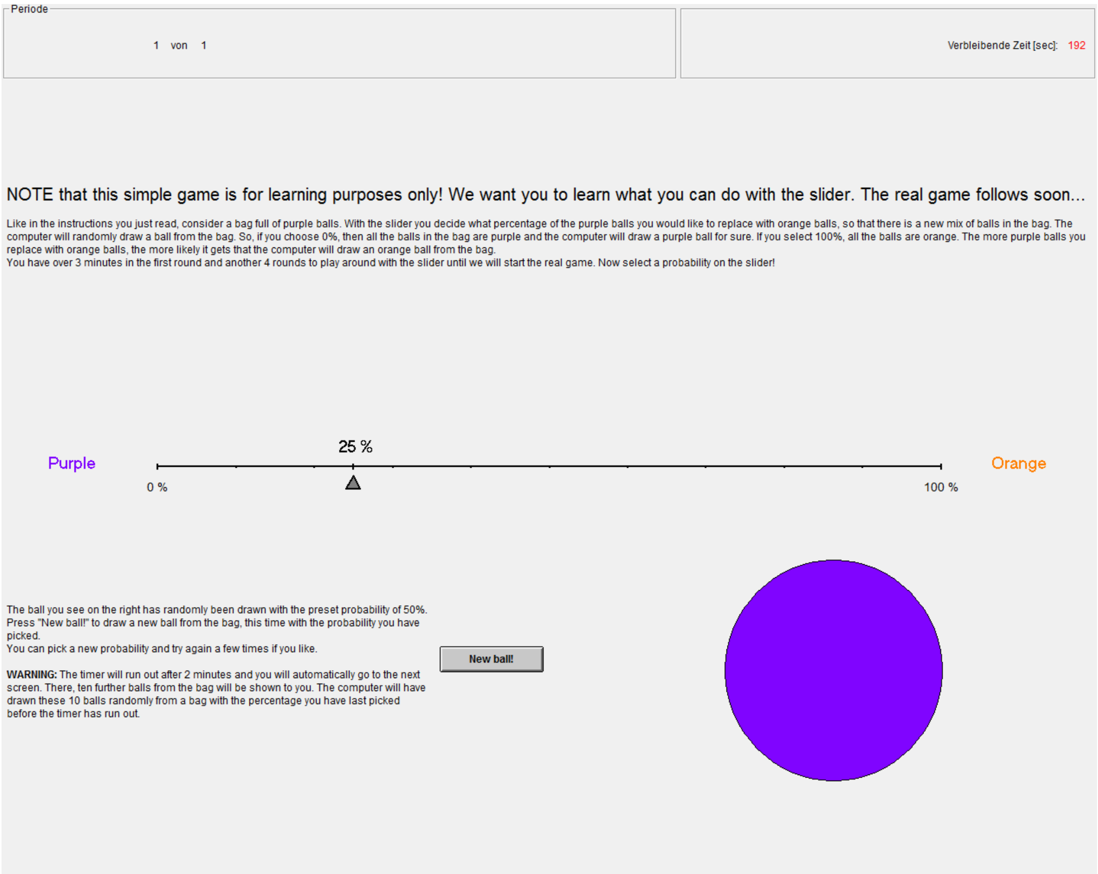
3. Thank you very much for participating in the experiment!

A.3 Screenshots of slider practice game and paid game:

Figure 28 and 29 show the slider practice game as it was used during the pilot. It consists of two separate screens. The first screen (figure 28) teaches subjects the functionality of the slider (i.e. the purpose of the slider game). In this context, the slider can be used to set the composition of a virtual, opaque bag of orange and purple balls, where the set percentage translates into the amount of purple balls that are replaced by orange balls. The "New ball!"-button can be used to draw (and replace) a ball from the virtual bag. In the example the slider is set to 25%. So, drawing a new ball should result in a purple ball drawn in 75% of the cases (and in an orange ball drawn in 25% of the cases). The second screen (figure 29) displays an array of ten independently drawn (and replaced) balls. Subjects went through five rounds of the two screens of slider practice.

The paid game also consists of two screens, one input screen and one output screen. Figure 30 shows the input screen which, divided into three boxes, requires subjects to make three separate hypothetical choices (strategy method), one for each player. Pressing "OK" would confirm the choices, randomly assign a role, and generate pure actions based on the subjects' probability choices. Results of this procedure are displayed on the output screen. Figure 31 contains the output screen for player "Toad" in this case. In this example 15% was chosen for Toad, then the role of "Toad" as well as the action "Not check" were realised. The screen displays all three realised actions, drawn from all

FIGURE 28: First screen of the slider practice game



three realised roles for a given random group of three subjects, additionally displaying the amount of coins won per player at the end of the current round as well as the total amount of coins won per player so far in the treatment. Pressing “OK" on the output screen would lead subjects into the next period.

A.4 Session 1 & 2 - mean of $\gamma\beta$ across subjects & periods, both in mixed-strategy probabilities and in generated pure action choices:

We generated pure strategy plays from all probability mixes played by subjects by assuming that a probability below 50% would have been a zero choice and a probability above 50% would have been a one choice. Probabilities of exactly 50% were treated as $\frac{1}{2}$. We compared this generated pure strategy data with the actual mixed strategies in the mean over periods of play and across treatments as illustrated in ??.

Figure 29: Second screen of the slider practice game

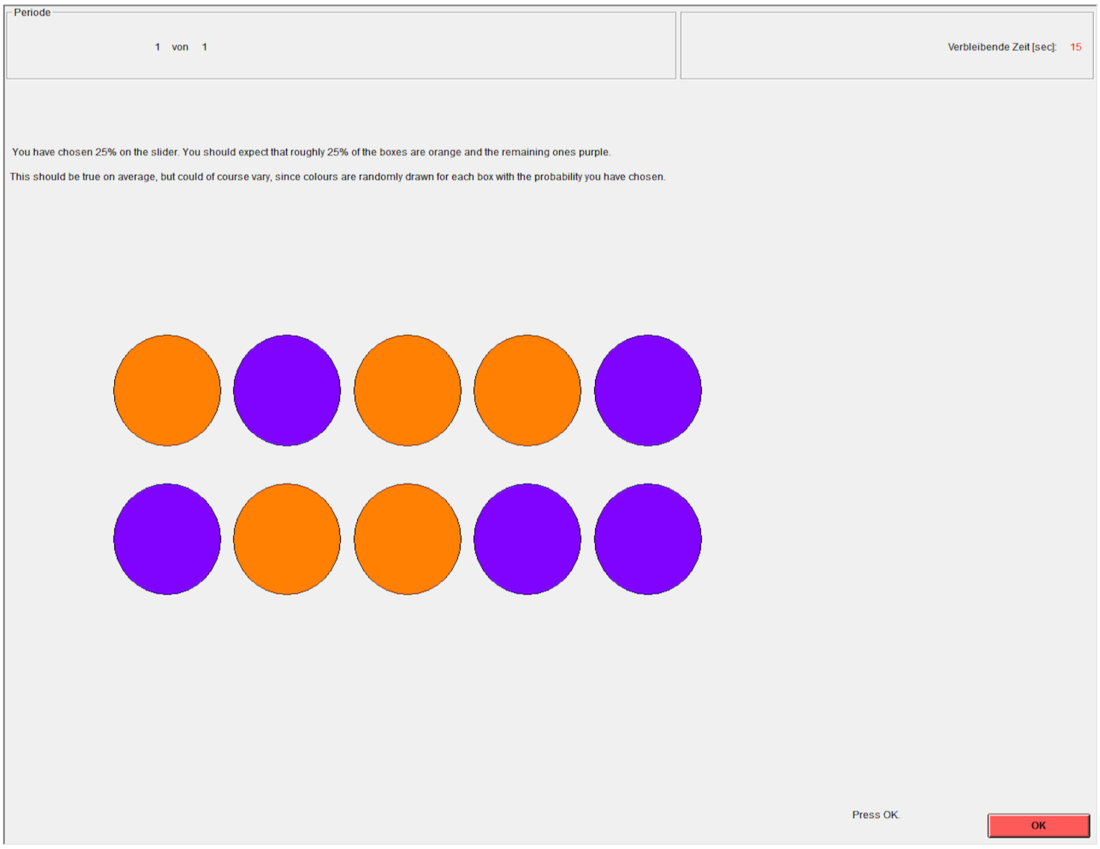


FIGURE 30: First screen of the paid corruption game

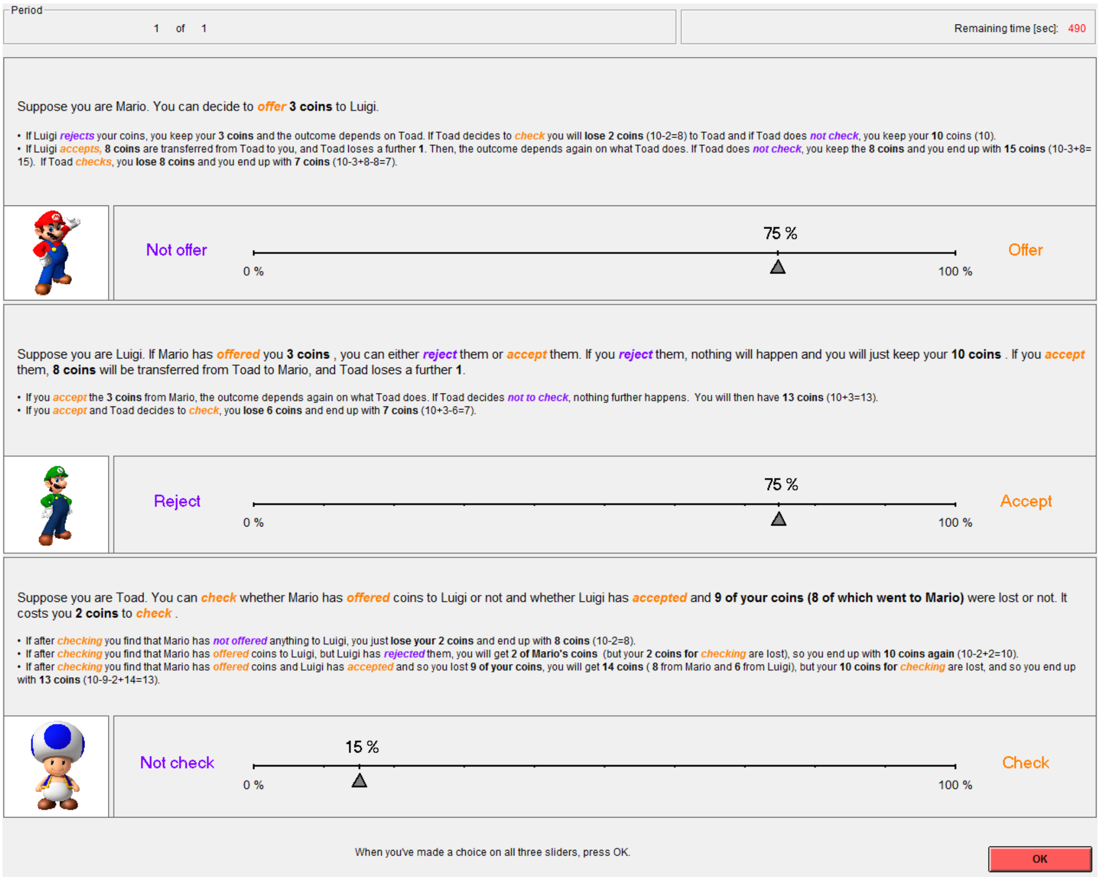
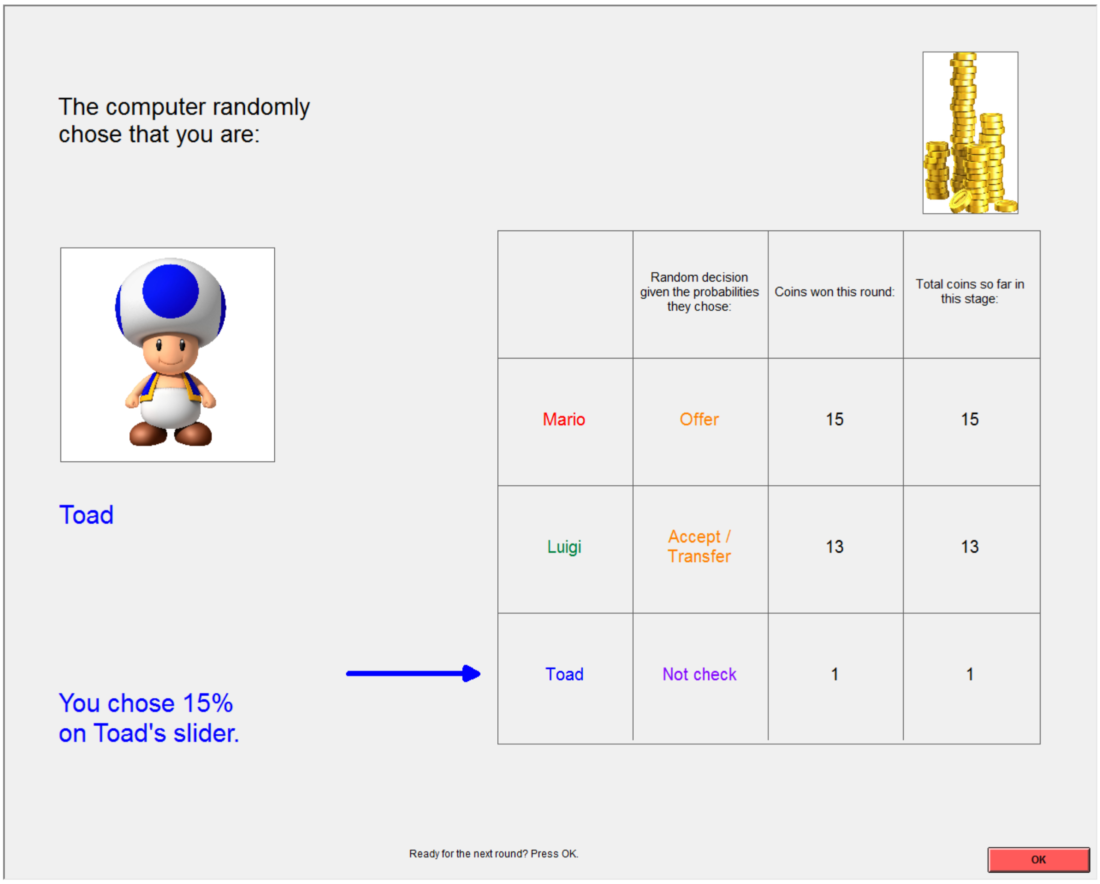
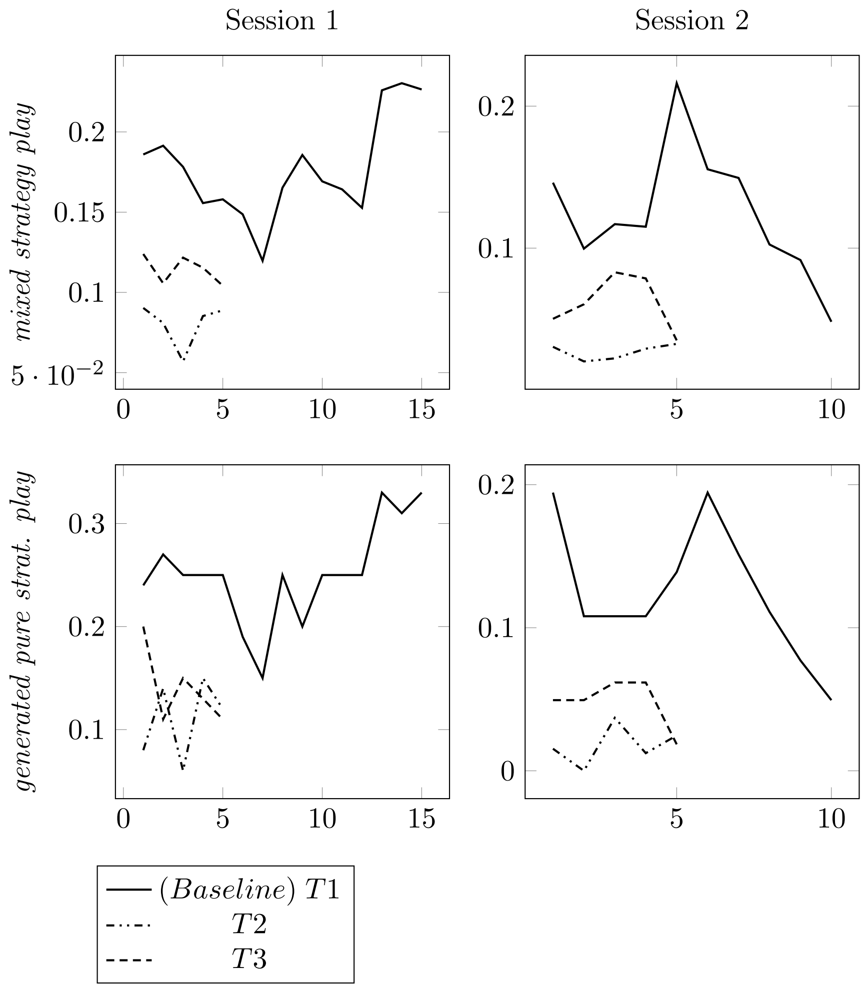


FIGURE 31: Second screen of the corruption game as player "Toad"





Session 1
Session 2
mixed strategy play
generated pure strat. play
0.2
0.15
0.1
5 · 10⁻²
0
5
10
15
0.3
0.1
0
(Baseline) T1
T2
T3

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