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Essays on Corruption, Leniency Programmes and Delegation

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To my mother, father and brother
who mean the world to me

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by

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Abstract

This thesis explores two topics. Chapter 1 evaluates leniency programmes in light of crime and corruption. Chapters 2 and 3 explore the issue of delegation of authority in the presence of non-contractible costs.

In chapter 1, we evaluate Leniency Programmes (LPs): forgiving self-reporting criminals, in a society of heterogeneous criminals and heterogeneous bureaucrats. Social welfare goes up immediately after the LP is introduced as supply (size and composition of bureaucrats) is held fixed. In the intermediate run, some bureaucrats leave the agency because they lose a source of income (bribe) causing a dip in the welfare. However, we observe that welfare can go up in the long run.

Chapter 2 focuses on delegation of authority using a principal-agent model. Agents have private information (signals) relevant for making a correct decision. Agents and principal incur non-contractible costs if a wrong decision is made. We characterize truth-telling equilibria. Among other cases, we see what happens when agents have asymmetrical non-contractible costs and the principal also incurs a non-contractible cost. Our main result is that there are situations where the principal delegates the decision making authority to the agent whom she is less aligned with in terms of preferences (non-irrelevancy) provided there is a sufficient degree of information asymmetry between the two agents.

Chapter 3 extends the analysis of chapter 2 to situations where truth-telling equilibria does not exist. Information is not aggregated efficiently under non truth-telling because of the incentive constraints of the agents. We show that the non irrelevancy result arises in this chapter when the signal precisions of the two agents are equal.

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Introduction

This thesis explores two different themes in decision-making. The first theme evaluates Leniency Programs (LPs): forgiving self-reporting criminals in a model with corruptible bureaucrats. Our analysis points out that timing is key while evaluating LPs. The second theme is on delegation of decision making authority in the presence of non-contractible costs. We find that there are situations where the delegating authority might actually find it optimal to give the decision making power to an agent who is less aligned with them in terms of preferences.

In the area of antitrust enforcement, Leniency Programs (LPs) have been used to fight cartels and organised crime like drug dealing, terrorism and even the Sicilian Mafia. A previously unexplored theme in the existing literature is the timing with which these LPs are implemented which can have potential welfare implications. This is where our analysis contributes in the form of a theoretical investigation. We propose that timing is crucial while evaluating LPs. In chapter 1, we build a theoretical model of heterogeneous criminals and heterogeneous bureaucrats hired by an agency, to evaluate LPs. There heterogeneity in criminals is in their differential expectation (high and low) of continuing future criminal activity and maintaining their reputation with the bureaucrats. Criminals can offer to bribe a bureaucrat (described as corruption) and commit a crime and risk detection by the monitoring mechanism of the agency. LP or Leniency in our model is offered by the agency as an option for forgiveness given to self-reporting criminals who engaged in corruption with the bureaucrats. Forgiveness in our model means that fines are completely waived for the self-reporting criminals who engaged in corruption. We find that not all criminals take advantage of the Leniency Programme and do not report. The high type criminals with certain valuation of crime continue to commit crimes and do not report thereby retaining the possibility of committing future crimes. Just as

there are criminals who do not take advantage of LPs and self-report, there are also bureaucrats who do not stop taking bribes after the introduction of LP.

We find that in the short run after the introduction of LP when the supply of bureaucrats is still fixed, social welfare is high with reduced crime and corruption. After allowing for some time to pass, self-selection of bureaucrats happens as the expected income from corruption to a proportion of bureaucrats falls to zero and they leave for outside job offers. The size and composition of the bureaucrats varies. As a result, in this intermediate case under a LP, we find that there is a systematic adverse effect and the welfare falls below that under the no leniency regime. This effect might persuade policy makers to pessimistically cancel the LP. Here is where our analysis strikes a cautionary note to policy makers and law enforcement agencies. We propose that while evaluating LPs, timing is crucial. The changing composition of the bureaucrats leave the agency with a surplus budget. The agency thus announces increase in wages in the long run and welfare goes up compared to that under no Leniency.

Chapter 2 builds a theoretical model of delegation of decision making authority with a principal and two agents. Both agents receive private information, relevant for making one decision. The principal needs to delegate the decision making power to one of the two agents. The agents and the principal privately suffer from a non-monetary, non-contractible cost when a wrong decision (mistake) is made. These costs, for example, can be thought of as psychological costs or reputation costs. We show that the principal finds it irrelevant who she delegates the decision making power to if the agents have identical non-contractible costs. Suppose, one of the agents has a higher non-contractible cost than that of the other and the principal is more closely aligned to one of the agents. Due to the misalignment in their preferences, we find that the agents end up following different decision rules under cases where there is enough informational asymmetry. The question we ask in this chapter is, whether it is ever optimal for the principal to delegate the decision making power to the agent who is less aligned with her in terms of preferences. We find that under certain conditions, the principal may delegate the decision making power to the agent with whom she is less aligned in terms of preferences provided there is a sufficient degree of asymmetry in information of the two agents.

Chapter 3 extends the analysis of chapter 2 to situations where truth-telling equilibria does not exist. We focus on babbling equilibria where no information is transmitted. In chapter 2, under truth-telling equilibrium, when the two agents have identical signal precisions, they would always take the same decision even when their preferences are different. However, when there is no truth-telling equilibria and the preferences of the two agents are not aligned, we find that even when the signal precisions of the two agents are exactly the same, they follow different decision rules. Under this symmetric signal precision case, we analyse the optimal delegation rule of the principal and find that there are certain conditions under which she strictly prefers to delegate the decision making power to the agent with whom her preferences are less aligned. In this chapter, we essentially arrive at the non-irrelevancy result we got in chapter 2 even when the two agents have exactly the same signal precision.

Chapter 1

Corruption and Leniency

Programmes: Should Criminals be Forgiven?

Chapter Abstract

We build a theoretical model to evaluate Leniency Programmes (LPs): forgiving self-reporting criminals. We consider a society of heterogeneous criminals and heterogeneous bureaucrats. Social welfare goes up immediately in the short run after the LP is introduced when the supply of the bureaucrats is fixed. Introduction of LP affects a major source of income (bribe) of a proportion of corruptible bureaucrats. As a result, in the intermediate run, the size and composition of the bureaucrats vary leading to a low welfare situation. This effect may cause policy makers to pessimistically withdraw LPs. Our analysis contributes at this junction by showing that in the long run welfare is higher after the introduction of the LP than without the LP. We point out that time horizon is crucial while evaluating LPs.

1.1 Introduction

It is widely known that organised crime and corruption are a threat to the society and hinder its development with huge economic costs. For an overview of the literature on corruption and its effects, see Bardhan (1997), Shleifer and Vishny (1993), Mauro (1995), Tanzi (1998), Bardhan and Mookherjee (2000), Bardhan (2002), Fisman and

Wei (2004), Reinikka and Svensson (2004) and Olken (2005). Economists have been investigating optimal amount of law enforcement to curtail criminal activities since the seminal paper by Becker (1968). However, the corruptibility of law enforcers themselves also remains a huge problem (Burlando and Motta, 2016) and there are bureaucrats who often rely on bribes as one of the major sources of their income. Any attempt to clamp down on corruption is going to affect the income of the corruptible bureaucrats (Banerjee and Hanna, 2012). In this chapter we focus on one type of anti-corruption policies, the Leniency Programme (LP): forgiveness given to self-reporting criminals who engaged in corruption with the bureaucrats. A previously unexplored line of analysis in the theoretical literature on Leniency Programmes is the time horizon within which they are implemented and the consequent dynamic welfare implications. We offer such a theoretical investigation in our chapter. In this chapter, we evaluate the Leniency Programme in light of corruptible bureaucrats.

In our chapter, in the model that we build to evaluate LPs, we have potential criminals and bureaucrats hired by an agency responsible for stopping crime. Criminals potentially commit a crime and can offer to bribe a bureaucrat (described as corruption) and risk detection by the monitoring mechanism of the agency. We consider a heterogeneity among the potential criminals. This heterogeneity comes in two dimensions. One is the value of the crime itself to the criminals and the other is how much they value their future relationship with the bureaucracy. Whether or not a criminal is inclined to bribe and take advantage of this LP and report on the bureaucrats will depend on these two values: the crime and the possibility of their continuation with the bureaucracy. We address potential criticisms in theoretical literature in our model by taking both these dimensions into account.

Secondly, we also consider heterogeneity among bureaucrats in this chapter. There is a supply of bureaucrats and whether or not they join the agency depends on the income they can get in outside job opportunities. The LP is going to affect the income of the bureaucrats differentially. The bureaucrats who are more inclined to be corruptible have a higher tendency to remain in the bureaucracy. There is a systematic way in which the composition of the bureaucracy is affected. Since all corruptible bureaucrats cannot be detected and punished, the bureaucrats will be affected differentially and adversely. The more corruptible bureaucrats are the ones

who see a lesser fall in their income. This can have an effect on the efficacy of the LP and this is what we investigate in our model. We start with a benchmark case, that is, the case as soon as the LP is introduced where the composition and size of the bureaucrats is fixed. We evaluate the welfare after the introduction of the LP in this short run. However as we mentioned earlier some of the bureaucrats will leave as their income from corruption is affected and that will change the effectiveness of the LP. If one evaluates the LP at that point, they will find a pessimistic view. We show that in the long run the composition of the bureaucrats is changed and now the LP can perform better. We show conditions under which the LP is properly evaluated.

There is also a third effect. Basu (2011) argues that the act of bribing should be made legal for a class of bribed called “Harassment bribes”. This proposal is suggestive of tools such as leniency policies in antitrust and whistleblower schemes. There was informal criticism over this suggestion.¹One of the main criticisms of the Leniency Programme is that not all criminals will take part in it. Another criticism is that the anticipation of forgiveness might incentivize some criminals to start committing crimes. Yet another criticism is that Leniency Programmes are not effective in the sense that not all bureaucrats stop taking the bribe even after the Leniency Programme is introduced. However, a detailed understanding of the advantages and disadvantages of such a programme requires a formal model. Our theoretical model contributes at this juncture. We do take into account in our welfare comparison about all these forces and account for all possible types of criticisms. We find that there are some criminals who will actually take advantage of the LP in the way it is designed to work. They commit the crime and report.

In the following part of this section, we look at some related literature and discuss the findings of our work. Organized illegal transactions and crime networks involve more than one party and are often required to trust other wrongdoers. Traditionally, one way in which law enforcement agencies have been fighting organised crime is by shaping incentives of these parties to play against one another thereby undermining the trust between them. Law enforcers undermine the trust among wrongdoers by

¹<http://archive.indianexpress.com/news/the-bribing-game/780094/0> and <http://www.thehindu.com/opinion/columns/sainath/bribes-a-small-but-radical-idea/article1712689.ece>.

awarding leniency. Leniency could take the form of reduced or fully waived legal sanctions to self-reporting wrongdoers that help convict their fellow wrongdoers (Buccirossi and Spagnolo, 2006).

The last two decades have seen an increasing amount of antitrust enforcement. Leniency Programmes (LPs) have been used to fight cartels and organised crime like drug dealing, terrorism and the Sicilian Mafia (Spagnolo, 2006). Malik (1993) uses a principal-agent framework in the context of environmental regulations which require firms to self-report their compliance, to derive and compare incentive-compatible regulatory policies with and without self-reporting. He finds the firm needs to be audited less often when self-reporting is required, but punished more often. Kaplow and Shavell (1994) add self-reporting to the model of probabilistic law enforcement and show that schemes with self-reporting are superior to schemes without self-reporting due to reduced enforcement costs. Motta and Burlando (2007) modify the standard beckerian model to produce a trade off between law enforcement costs and corruption. They show that in a self reporting equilibrium law enforcers do not earn rents and the social planner can use self reporting as a way to clean corrupt enforcement agencies thus increasing welfare through an improvement in deterrence.

Motta and Polo (2003) investigate the effect of Leniency Programmes when the Antitrust Authority has limited resources. Innes (2000) studies the merits of self-reporting when violators face heterogeneous probabilities of apprehension. He finds that even when self-reporting enjoys none of the advantages identified elsewhere, efficiency can often be enhanced by inducing those violators who have a sufficiently high risk of apprehension to self-report. In their recent paper, ‘Trust, leniency and deterrence’, Bigoni et al. (2014) present experimental evidence for leniency being crucial to the design of optimal law enforcement.

However, the existing literature in Leniency Programmes has not explored the timing effect, effect on the corruption income of the bureaucrats and the change in their composition. All of these have consequences for the working of the Leniency Programme and consequently on social welfare.

A relevant example for the model in this chapter is tax evasion by citizens. Bureaucrats audit citizens who could be potential tax evaders. The citizen who is audited has a choice to corrupt the bureaucrat and evade tax. As mentioned earlier,

we find that not all criminals take advantage of the Leniency Programme in the way it is designed to work. One type of criminals with a certain valuation of crime continue to commit crimes and do not report thereby retaining the possibility of committing future crimes. There are also a proportion of criminals that did not offer the bribe in the no leniency case, but are incentivised to commit crimes after the introduction of the LP just to report on the bureaucrats. Our model with heterogeneous criminals and the supply fluctuation of bureaucrats allows for a variety of interesting effects.

We find that in the short run after the introduction of Leniency Programme when the supply of bureaucrats is still fixed, social welfare is high with reduced crime and corruption. After allowing for some time to pass, self-selection of bureaucrats happens as the expected income from corruption to a proportion of bureaucrats falls to zero and they leave for outside job offers. The size and composition of the bureaucrats vary. In this intermediate run after the introduction of the Leniency Programme, those bureaucrats who are relatively less corruptible leave the agency as they experience a higher loss in their income. We find that the welfare after the introduction of the LP in the intermediate run falls below than that in the no leniency case. This systematic adverse effect might persuade policy makers to pessimistically cancel the LP. Here is where our analysis strikes a cautionary note to policy makers and law enforcement agencies. We propose that while evaluating LPs, timing is crucial. The changing composition of the bureaucrats leaves the agency with a surplus budget. The agency may announce increase in wages in the long run and welfare goes up compared to that in no Leniency. In particular, the condition which facilitates this effect leads to a situation where the interaction of self-reporting criminals with bribe-taking bureaucrats increases thereby leading to increased welfare after the introduction of the Leniency Programme in the long term.

The remainder of the analysis is organised as follows. Section 1.2 describes the model and sets up the no leniency and the Leniency Programme corruption games. We also characterize the equilibria in both regimes. Section 1.3 analyses the welfare in both regimes and with varying time horizon and changing composition of the bureaucrats. Section 1.4 concludes and discusses possible future extensions.

1.2 Model

We consider a society in which a population of potential criminals have an opportunity to commit a crime. There is an agency in charge of checking the potential criminals and stopping the crime. This agency is a branch of a higher administration that is responsible for the overall welfare of the society. The higher administration endows the agency with a given budget which the agency uses to hire bureaucrats. The welfare of the agency will be illustrated after we have characterized the corruption games in the two alternative policy regimes of no leniency and the Leniency Programme. Bureaucrats can only check a certain number of potential criminals, given the resource constraints. Each bureaucrat has the power to prevent the crime of just one potential criminal. However there is scope for corruption if the criminal manages to corrupt (bribe) the bureaucrat. The agency has a monitoring mechanism to detect the corruption. We denote with $\alpha \in [0, 1]$ the exogenous probability that corruption is detected. If corruption is detected by the monitoring mechanism, the agency collects fines $F_C > 0$ and $F_B > 0$ from the potential criminals and bureaucrats who engaged in corruption, respectively. The mode in which the Leniency Programme works in our model will be shown in detail later on. Henceforth potential criminals are just called criminals.

The current value of the crime to a criminal, v , is private information to the criminal. v is distributed on $[0, \bar{v}]$ according to the cumulative distribution $\Phi(v)$. Each criminal also values his or her reputation with the bureaucracy and the criminal world. Preserving the reputation allows a criminal to commit crimes in the future. The intensity of a criminal's expectation of future crime is measured by $\gamma > 0$ which is private information to the criminal. A criminal will lose reputation if and only if in the Leniency Programme regime, he or she reports the corruption. We formalize a criminal's value of preserving reputation and being in a position of committing a crime in the future by $G(v, \gamma)$ which is common knowledge. $G(v, \gamma)$ is monotonically increasing in the current value of the crime, v and in $\gamma > 0$. For simplicity, we assume that there are only two types of criminals, high and low types which differ in their future value of the criminal activity characterized by γ_i , $i = \{\ell, h\}$ where $\gamma_h > \gamma_\ell$. Henceforth we specify $G(v, \gamma_i)$ as $\gamma_i v$.

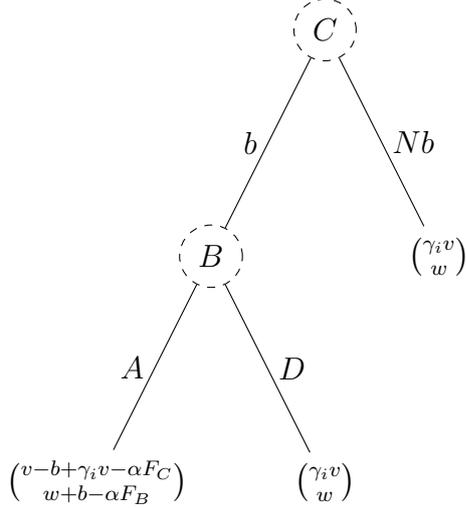


Figure 1.1: No Leniency game tree

1.2.1 Beliefs of bureaucrats and criminals

There is also heterogeneity among the bureaucrats with respect to the assessment of the probability of encountering a high type criminal (with respect to γ_h). This heterogeneity in bureaucrats comes in only two types namely optimistic and pessimistic types. The optimistic bureaucrats believe that with probability, λ^o they meet a high type criminal. The pessimistic bureaucrats are those who believe that with probability λ^p they meet a high type criminal. We assume $\lambda^o > \lambda^p$. The bureaucrats' beliefs about the type of criminals in general are denoted by λ^i , $i = \{o, p\}$.

Criminals also differ in their assessment of the probability of encountering an optimistic bureaucrat given by μ . μ may differ according to the criminal's type. However, as our analysis shows later criminal's beliefs will not play any role.

1.2.2 No Leniency: Corruption game without the Leniency Programme

In this sub section, we look at a game where potential criminals of any type are audited by bureaucrats(of any type). For the basic game we analyze here, we have bureaucrats auditing criminals for which the bureaucrats are paid a certain wage by the agency. The criminals who are being audited have two options. One option is to offer the bribe, if the bureaucrat accepts the bribe, then commit the crime thereby risking detection by the monitoring mechanism of the agency. Another option is to

not offer the bribe and not commit the crime thereby losing the current value of the crime however retaining the possibility of committing a future crime. When the bribe has been offered, bureaucrats have two choices: either to accept the bribe and allow the criminal to commit the crime also risking detection by the agency or to decline the bribe and stop the criminal from committing the crime in the current period.

The basic game tree for this analysis is shown in figure (1.1). At the first node, the criminals, denoted by C , have a choice to offer the bribe (b), or not offer the bribe (Nb). For the present model, we take the bribe, $b \geq 0$ as exogenously given. Note at branch Nb , that is, if the criminal does not offer the bribe to the bureaucrat, (bureaucrats are denoted by B), bureaucrats stop the crime in which case the criminal loses the current value of the crime, v . However, he retains the option value of committing future crime, $\gamma_i v$. The bureaucrat's payoff is w , wage paid by the agency. Now in branch b , that is, if the criminal offers the bribe to the bureaucrat, the bureaucrat has two choices - to accept the bribe (A) or decline (D) it. If the bureaucrat declines the bribe (branch D), it means that the crime is stopped. The criminal loses the current value of the crime, v but retains $\gamma_i v$. In the other branch A , the bribe is offered and accepted. So corruption happens and crime is committed. Recall that the agency detects corruption with a probability α and in the event that it is detected, the agency extracts fine of F_B from bureaucrats and a fine F_C from the criminals. Hence by accepting the bribe, the bureaucrat gets expected income from engaging in corruption(accepting the bribe) and the wage given by the agency. The expected income from accepting the bribe is $b - \alpha F_B$, that is the value of the bribe, b net of the fine, αF_B if the corruption is detected. The expected income from corruption part to the bureaucrat is 0 if he does not engage in corruption. If the bribe is accepted, the criminal gets a payoff of $v - b + \gamma_i v - \alpha F_C$.

To solve the game by backward induction, let us look at the final node. The bureaucrat compares the expected payoffs of accepting the bribe($w + b - \alpha F_B$) versus not accepting the bribe(w). The condition for the bureaucrat to accept the bribe is given by

$$b \geq \alpha F_B \tag{1.1}$$

Assume condition (1.1) holds, then all bureaucrats of all types accept the bribe.

Therefore, if the criminal offers the bribe, the payoff of the criminal is $v - b + \gamma_i v - \alpha F_C$. If the criminal does not offer the bribe, he or she gets $\gamma_i v$.

The comparison for offering the bribe versus not offering it is thus given by

$$v - b + \gamma_i v - \alpha F_C \geq \gamma_i v$$

. that is,

$$v \geq b + \alpha F_C$$

which, for notational convenience, rewritten as

$$v \geq v_b \tag{1.2}$$

where $v_b \equiv b + \alpha F_C$. The criminal types who are above the threshold value v_b strictly prefer to offer the bribe. The condition for a fraction of criminals to not offer the bribe is $0 < v_b < \bar{v}$. In our analysis, we focus on an equilibrium where there is crime and corruption and the monitoring mechanism is weak to tackle all the crime and corruption. A crucial condition, $v_b < \bar{v}$ ensures that some degree of crime and corruption is present.

The expected surplus from engaging in corruption for the two types of bureaucrats is calculated using the same threshold, v_b . Both optimistic and pessimistic bureaucrats work with the same cut off, v_b , so their expected surpluses are also same. Assume equation (1.1) holds, then all the bureaucrats will be better off accepting the bribe.

We collect the results from the above discussion and characterise the equilibrium of the no leniency case in the following corollary.

Corollary 1.2.1 *Suppose $0 < v_b < \bar{v}$, $b \geq \alpha F_B$, then in equilibrium the following holds*

1. *All bureaucrats, that is, bureaucrats of every type, accept the bribe when it is offered*
2. *The types of criminals who offer the bribe have a valuation of $v \geq b + \alpha F_C$.*

1.2.3 the Leniency Programme

We analyze what happens when an option for forgiveness is given to the criminals who self-report corruption. Introduction of the Leniency Programme means that the agency announces that if the criminals who have engaged in corruption come forward and self-report it, then the fine F_C will be completely waived for the self-reporting criminals.

the Leniency Programme game is exactly the same game as in no leniency but with the additional option of reporting given to the criminals. Bureaucrats audit the criminals. Criminals have an option to offer the bribe and commit the crime or not offer the bribe losing the current value of the crime. If criminals choose to offer the bribe, the bureaucrats have the option of accepting the bribe or declining it. If the bureaucrats decline the bribe, the crime is stopped. If the bureaucrats choose to accept the bribe, they allow the criminals to commit the crime. If the bribe is accepted, the criminals now have the option of reporting corruption and getting a waiver on their punishment. However they lose reputation with the bureaucracy and hence the possibility of committing future crime. On the other hand, the criminals may choose to not report the corruption and save their future reputation with the bureaucrats and the criminal world. The game tree in figure (1.2) represents corruption game after the introduction of the Leniency Programme.

We solve the game by backward induction. At the last decision node, C_2 , provided the bribe has been offered and it has been accepted, a criminal now has two choices: to report (R) or not report (N). If he reports the corruption, the criminal is forgiven the fine but he loses the option value of committing future crime and that explains the payoff $v - b$. The criminal will not report if the following condition holds.

$$v - b + \gamma_i v - \alpha F_C \geq v - b$$

That is

$$\gamma_i v \geq \alpha F_C \tag{1.3}$$

If, on the contrary, the condition given by equation (1.3) does not hold, that is, $\gamma_i v < \alpha F_C$, then the criminals choose to report (R) on reaching the end node. Now

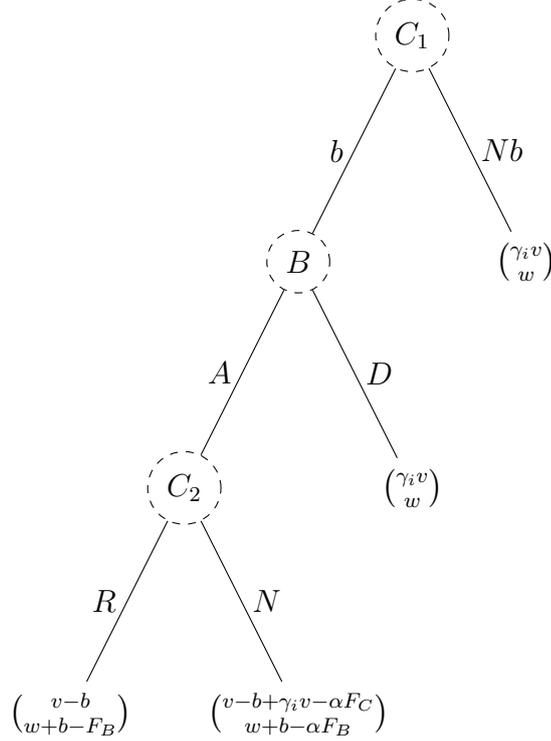


Figure 1.2: the Leniency Programme game tree

as per backward induction, we consider at node B where the bureaucrats decide whether to accept the bribe (A) or not accept, that is decline (D).

At this decision node, B , the bureaucrats face the task of updating their beliefs about criminals who offer the bribe at the first node, C_1 . Each type of bureaucrat has some strategy. It will be easier to understand as to what strategy the bureaucrat follows once we determine which criminals offer the bribe and which do not at the first stage. So we first analyze this part of the game where criminals decide to offer or not offer the bribe by assuming some conjecture about the equilibrium strategy of the bureaucrats in the second decision node, B . We now see what happens if the criminals plan to report on reaching the end node. Given the bureaucrat's response, let θ be the probability that the bribe offered by the criminal is accepted by whichever type of bureaucrat he encounters.²

Now if the bribe is offered and accepted and criminal reports, he gets $v - b$. If the criminal does not offer the bribe he gets $\gamma_i v$. On the other hand, if the bribe is not accepted, the criminal gets $\gamma_i v$. The comparison of offering and not offering the

²Let x^o and x^p be the probabilities that the bribe is accepted by optimistic and pessimistic bureaucrats respectively. We know that μ gives the probability of the criminals meeting an optimistic bureaucrat. So, θ , the compound probability of any type of bureaucrat accepting the bribe is $\theta = \mu x^o + (1 - \mu)x^p$.

bribe for the criminal who is planning to report is thus given by

$$\theta(v - b) + (1 - \theta)(\gamma_i v) \geq \gamma_i v$$

That is,

$$v - b \geq \gamma_i v \tag{1.4}$$

The equation (1.4) is the condition for offering the bribe if the criminal plans to report. The conjecture of the criminals about the equilibrium strategy of the bureaucrats is washed out. We now derive the condition to offer the bribe, for the criminals who are planning not to report. If the bribe has been offered and accepted and if the criminals do not report, they get $v - b + \gamma_i v - \alpha F_C$. If the criminal does not offer the bribe he gets $\gamma_i v$. The comparison for offering versus not offering the bribe for a criminal planning to not report is thus given by

$$\theta(v - b + \gamma_i v - \alpha F_C) + (1 - \theta)(\gamma_i v) \geq \gamma_i v$$

That is,

$$v - b \geq \alpha F_C \tag{1.5}$$

The equation (1.5) is the condition for offering the bribe if the criminal plans to not report on reaching the end node. To summarize,

For the criminals to offer the bribe and report , the following conditions must hold true.

$$\gamma_i v < \alpha F_C \tag{1.6}$$

$$v - b \geq \gamma_i v \tag{1.7}$$

For the criminals to offer the bribe and not report , the following conditions must hold true.

$$\gamma_i v \geq \alpha F_C \tag{1.8}$$

$$v - b \geq \alpha F_C \tag{1.9}$$

Notice that the beliefs of the criminals are washed away in both the cases. Irrespec-

tive of the equilibrium strategy followed by the bureaucrats, the criminals decide whether to offer the bribe or not according to the above conditions and here the criminals' beliefs drop out.

We look at how the Leniency Programme works to affect the equilibrium strategies of the two types of criminals. It will be useful to analyze a case where one type of criminals value their future reputation highly and hence does not report whereas the other type of criminals have a comparatively lower valuation of their future reputation and offer the bribe only to take advantage of the Leniency Programme and report. So for simplicity of analysis and presentation, we focus on a case in the Leniency Programme where the high type never reports and where low type criminals with valuation such that conditions (1.6) and (1.7) are simultaneously satisfied, offer the bribe to commit a crime and eventually report if caught. We assume $\gamma_h > 1$ to have the high type of criminals never reporting and $\gamma_\ell < 1$ to have a fraction of the low type criminals with valuation as specified in equations (1.6) and (1.7) offering the bribe to commit the crime and eventually report if caught.³

Using conditions derived in equations (1.6), (1.7), (1.8) and (1.9), we plot a graph to analyze the case just described. For the case we are analyzing, that is, $\gamma_h > 1$ and $\gamma_\ell < 1$, we have the line $\gamma_h v$ not intersecting $v - b$ below αF_C and $\gamma_\ell v$ intersecting $v - b$ below αF_C .

What follows is a discussion about the threshold value of crime to high type criminals who offer the bribe and never report and the threshold value of crime for low type criminals offering the bribe to commit the crime and eventually report if caught. We implicitly assume that the threshold value of low type criminals to offer the bribe is lower than the threshold value of high type criminals to offer the bribe and assume these are lower than the threshold for a low type criminal to offer the bribe and not report.

³There are other combinations of cases in which both the types of criminals can possibly behave. However, those cases might not provide much insight into the working of the Leniency Programme. It is clear that if criminals of both types value their future reputation (option value of committing a crime in future) highly, then no criminal of any type would report. That is, if the intensity of the expected value of committing future crime, γ_i is high for both types of criminals, then no type takes advantage of the Leniency Programme and report. It is therefore uninteresting to look at a case where neither type of criminals report.

It is possible to have a fraction of both types of criminals to have low valuation for their future criminal activity. It makes sense to look at a case where we have a positive fraction of both high and low types of criminals who report. Such a case might be interesting for welfare calculations but again it will not help in understanding the working of the Leniency Programme.

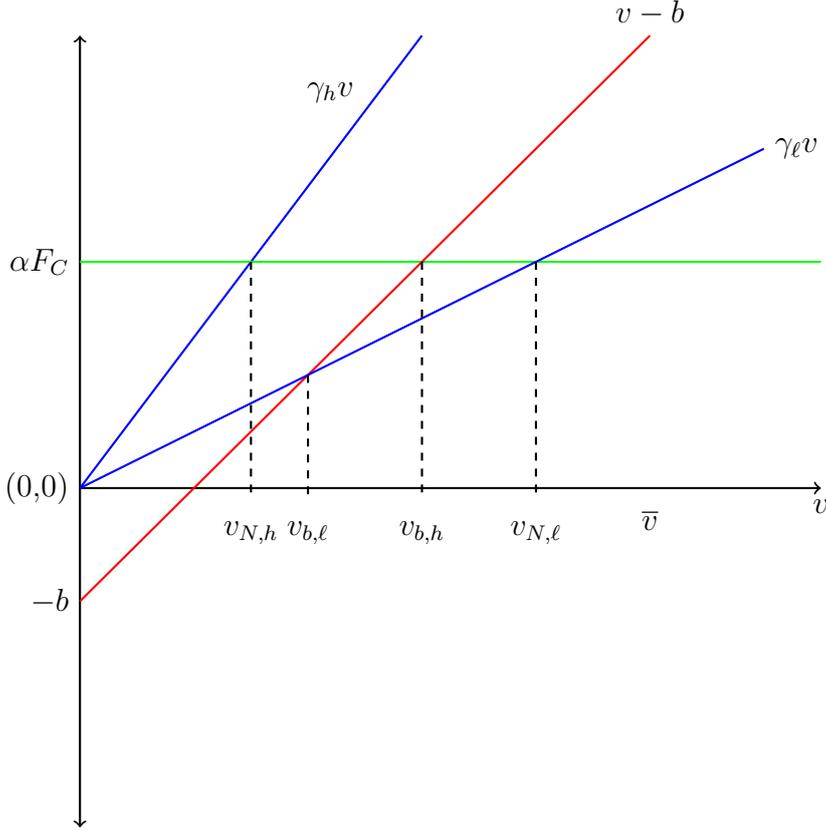


Figure 1.3: The Cut-offs

In the figure 3, it is clear that with $\gamma_h > 1$, conditions (1.6) and (1.7) can never be satisfied for a high type criminal which means that a high type criminal who offers the bribe will never report at the last node. Consider the lines $\gamma_h v$, αF_C and $v - b$ for a high type criminal from the figure 3. The relevant conditions for a high type criminal are (1.8) and (1.9) which are clearly satisfied for $v = b + \alpha F_C$. Hence high type criminals will offer the bribe and do not report when the current value of the crime exceeds the same threshold as in the no leniency case, v_b . Otherwise, he does not offer the bribe.

For the low type criminals with valuation such that conditions (1.6) and (1.7) are satisfied and $\gamma_\ell < 1$, from figure 3, consider the lines $\gamma_\ell v$, αF_C and $v - b$. Let $v_{b,\ell}$ denote the threshold value of a low type criminal to offer the bribe. It is clear from condition (1.7), if the valuation of the low type criminal is such that $v \in [0, v_{b,\ell}]$, then he does not offer the bribe.

The threshold for a low type criminal to offer the bribe and not report is denoted by $v_{N,\ell}$. As seen from conditions (1.8) and (1.9), If the valuation of the low type

criminal is such that $v \in [v_{N,\ell}, \bar{v}]$, then he finds it optimal to not report if he offers the bribe. If the valuation of the low type criminal is such that $v_{b,\ell} < v < v_{N,\ell}$, he reports if he were to offer the bribe. From the graph, this is exactly the region where $\gamma_\ell v < \alpha F_C$ and $v - b \geq \gamma_\ell v$. Recall that from equations (1.6) and (1.7), we have the conditions for the case of a criminal to offer the bribe and report. From (1.7), we have that at the threshold value $v_{b,\ell}$ for a low type criminal

$$v_{b,\ell} - b = \gamma_\ell v_{b,\ell}$$

That is,

$$\begin{aligned} v_{b,\ell} - \gamma_\ell v_{b,\ell} &= b \\ v_{b,\ell} &= \frac{b}{1 - \gamma_\ell} \end{aligned} \tag{1.10}$$

Similarly, from the equation (1.6), for a low type criminal at the threshold value $v_{N,\ell}$,

$$\begin{aligned} \gamma_\ell v_{N,\ell} &= \alpha F_C \\ v_{N,\ell} &= \frac{\alpha F_C}{\gamma_\ell} \end{aligned} \tag{1.11}$$

The above discussion was made implicitly assuming that the ranking $v_{b,\ell} < v_{b,h} < v_{N,\ell} < \bar{v}$ holds. A condition needs to be imposed on the size of b for the ranking to hold true and that is $b < \frac{1-\gamma_\ell}{\gamma_\ell} \alpha F_C$, proof of which follows.

Lemma 1.2.1 *Suppose $b < \frac{1-\gamma_\ell}{\gamma_\ell} \alpha F_C$. Then $v_{b,\ell} < v_{b,h} < v_{N,\ell}$.*

Proof Rearranging $b < \frac{1-\gamma_\ell}{\gamma_\ell} \alpha F_C$, we have

$$\begin{aligned} b\gamma_\ell &= \alpha F_C - \alpha F_C \gamma_\ell \\ (b + \alpha F_C)\gamma_\ell &< \alpha F_C \\ b + \alpha F_C &< \frac{\alpha F_C}{\gamma_\ell} \end{aligned}$$

Therefore,

$$v_{b,h} < v_{N,\ell} \tag{1.12}$$

From the inequality (1.12), we have

$$b + \alpha F_C < \frac{\alpha F_C}{\gamma_\ell}$$

$$b\gamma_\ell + \alpha F_C\gamma_\ell < \alpha F_C$$

$$b + b\gamma_\ell + \alpha F_C\gamma_\ell < b + \alpha F_C$$

$$b < b(1 - \gamma_\ell) + \alpha F_C(1 - \gamma_\ell)$$

$$\frac{b}{1 - \gamma_\ell} < b + \alpha F_C$$

Therefore,

$$v_{b,\ell} < v_{b,h} \tag{1.13}$$

Hence from (1.12) and (1.13) we have that

$$v_{b,\ell} < v_{b,h} < v_{N,\ell} \tag{1.14}$$

□

From equation (1.1) and the assumption $b < \frac{1-\gamma_\ell}{\gamma_\ell}\alpha F_C$, we have the following condition imposed on the size of the bribe, b . That is

$$\alpha F_B < b < \frac{1-\gamma_\ell}{\gamma_\ell}\alpha F_C \tag{1.15}$$

Suppose the assumption $b < \frac{1-\gamma_\ell}{\gamma_\ell}\alpha F_C$ is reversed, that is $b \geq \frac{1-\gamma_\ell}{\gamma_\ell}\alpha F_C$. Then even the low types criminals with valuations in the region $v_{b,\ell} < v < v_{N,\ell}$ behave as high type criminals who offer the bribe and do not report and both types of criminals behave as under no leniency. All the three threshold values $v_{b,\ell}$, $v_{b,h}$, $v_{N,\ell}$ will collapse to the same threshold value v_b under no leniency, that is, $v_{b,\ell} = v_{b,h} = v_{N,\ell} = v_b$.

Recall that the analysis of bureaucrats' decision was not yet discussed. We now characterize the behaviour of the bureaucrats. To know the optimal strategy of the bureaucrats, it is useful to compute the probability of not being reported conditional on being offered the bribe. It is given by the following expression.

$$Prob[NBR/Bribe] = \frac{\lambda^i(1 - \Phi(v_{b,h})) + (1 - \lambda^i)(1 - \Phi(v_{N,\ell}))}{\lambda^i(1 - \Phi(v_{b,h})) + (1 - \lambda^i)(1 - \Phi(v_{b,\ell}))}$$

Let it be denoted by η^i , the notation we used before where i can denote optimistic or pessimistic type of bureaucrat. Then, the conditional probability of being reported on being offered the bribe is given by

$$1 - \eta^i = 1 - \frac{\lambda^i(1 - \Phi(v_{b,h})) + (1 - \lambda^i)(1 - \Phi(v_{N,\ell}))}{\lambda^i(1 - \Phi(v_{b,h})) + (1 - \lambda^i)(1 - \Phi(v_{b,\ell}))} \quad (1.16)$$

after the introduction of the LP, the optimistic bureaucrats accept the bribe and the pessimistic bureaucrats do not. It is therefore, useful to rank η^o and η^p . The following lemma does that.

Lemma 1.2.2 *The conditional probability of not being reported for optimistic bureaucrats is strictly greater than the conditional probability of not being reported for the pessimistic bureaucrats, that is, $\eta^o > \eta^p$.*

Proof The following two equations give the probability of not being reported conditional on being offered the bribe for optimistic and pessimistic bureaucrats respectively.

$$\eta^o = \frac{\lambda^o(1 - \Phi(v_{b,h})) + (1 - \lambda^o)(1 - \Phi(v_{N,\ell}))}{\lambda^o(1 - \Phi(v_{b,h})) + (1 - \lambda^o)(1 - \Phi(v_{b,\ell}))}$$

$$\eta^p = \frac{\lambda^p(1 - \Phi(v_{b,h})) + (1 - \lambda^p)(1 - \Phi(v_{N,\ell}))}{\lambda^p(1 - \Phi(v_{b,h})) + (1 - \lambda^p)(1 - \Phi(v_{b,\ell}))}$$

Recall here the assumption, $\lambda^o > \lambda^p$. We know that $v_{b,\ell} < v_{b,h} < v_{N,\ell}$. So, $\Phi(v_{b,h}) < \Phi(v_{N,\ell})$ which implies that $(1 - \Phi(v_{b,h})) > (1 - \Phi(v_{N,\ell}))$ and also since $\lambda^o > \lambda^p$, we can say that the numerator of η^o is greater than the numerator of η^p . Using the same reasoning ($v_{b,\ell} < v_{b,h}$ which means $\Phi(v_{b,\ell}) < \Phi(v_{b,h})$ implying that $(1 - \Phi(v_{b,h})) < (1 - \Phi(v_{b,\ell}))$), we can say that the denominator of η^o is less than the denominator of η^p . The preceding analysis allows us to rank η^o and η^p in the following way

$$\eta^o > \eta^p \quad (1.17)$$

□

Now, we proceed to find the expected payoffs to the bureaucrat from accepting or

not accepting the bribe.

The equation below gives the expected payoff to the bureaucrat from accepting the bribe .

$$Ep_A = \eta^i(w + b - \alpha F_B) + (1 - \eta^i)(w + b - F_B)$$

$$Ep_A = w + b - F_B(\alpha\eta^i + 1 - \eta^i) \quad (1.18)$$

Expected payoff to the bureaucrats from not accepting the bribe is w .

In general , the condition for bureaucrat to accept the bribe is given by

$$w + b - F_B(\alpha\eta^i + 1 - \eta^i) > w$$

$$b > F_B(\alpha\eta^i + 1 - \eta^i)$$

$$\frac{b}{F_B} > \alpha\eta^i + 1 - \eta^i \quad (1.19)$$

η^i is the probability that the bureaucrat is not being reported conditional on accepting the bribe. If η^i is 1, then it is the no leniency case where no one is reporting.

As a consequence of the lemma 1.2.1, we have the ranking $\eta^o > \eta^p$. We assume $\frac{b}{F_B}$ to lie in the between $\alpha\eta^o + 1 - \eta^o$ and $\alpha\eta^p + 1 - \eta^p$ which is consistent with the ranking of η^o and η^p .

It is interesting to look at the case where at least one type of bureaucrats being corrupt and some bureaucrats prevent the crime. Such a case also addresses one of the criticisms of the LP that not all the bureaucrats stop being corrupt. This is why we focus on the equilibrium where the optimistic type of bureaucrats accept the bribe and the pessimistic type of bureaucrats do not accept the bribe. The equilibrium we are looking in the LP is characterized in the following proposition

Proposition 1.2.1 *Suppose $\lambda^o > \lambda^p$, $\gamma_h > 1$ and $\gamma_\ell < 1$. Suppose also that*

$$\alpha\eta^o + 1 - \eta^o < \frac{b}{F_B} < \alpha\eta^p + 1 - \eta^p < 1$$

and

$$\alpha F_B < b < \frac{1 - \gamma_\ell}{\gamma_\ell} \alpha F_C$$

. Then in equilibrium, the following holds.

1. *Optimistic bureaucrats accept the bribe and pessimistic bureaucrats do not accept the bribe;*
2. *The high type criminals will offer the bribe and do not report only if their valuation is such that $v > v_{b,h}$ and do not offer the bribe otherwise,*
3. *The low type criminals do not offer the bribe if $v < v_{b,\ell}$, they offer the bribe and report if $v_{b,\ell} < v < v_{N,\ell}$, and offer the bribe and do not report if $v > v_{N,\ell}$.*

Note that if the left hand side of the inequality given by $\alpha F_B < b < \frac{1-\gamma_\ell}{\gamma_\ell} \alpha F_C$ is violated, the first and third points of proposition 1.2.1 are no longer valid. On the other hand if the bribe, b is very big violating the right hand side of the inequality, then point 3 of the proposition 1.2.1 would still hold true but it is no more interesting.

1.2.4 Notes on the two equilibria

As we discussed in the introduction, there are different criticisms that were raised against leniency policies. This section highlights how our analysis addresses some of those criticisms and points out the key trade-offs in introducing the LP. Without the Leniency Programme, bureaucrats of every type accept the bribe when it is offered. The types of criminals who take part in corruption have a valuation of $v \geq b + \alpha F_C$. Please refer to 1.2.1. As pointed out in the proposition 1.2.1 that characterizes the equilibrium of the Leniency Programme regime, high type criminals who have valuations $v \in [v_{b,h}, \bar{v}]$ continue to take part in corruption, commit crimes and do not report thereby retaining the future possibility of committing crimes. Thus, they do not take advantage of the Leniency Programme as they place more weight on the future criminal activity. On the other hand, low type criminals (with valuation such that $v_{b,\ell} < v < v_{N,\ell}$) that did not offer the bribe in the no leniency case who after the introduction of the Leniency Programme are incentivized to commit crimes just to report on the bureaucrats. They however lose the option value of committing future crimes. There are some criminals who offered the bribe in no leniency regime. But in the Leniency Programme regime, those criminals offer the bribe only to report losing the possibility of committing future crimes. Another effect as pointed out in proposition 1.2.1 is that the pessimistic bureaucrats stop taking the bribe only after the Leniency Programme is introduced and prevent crimes. However, the

optimistic bureaucrats continue to take the bribe. Our analysis which is based on the heterogeneity of criminals and bureaucrats allows for these rich set of effects in the parametrization discussed above.

From the discussion above, the welfare implications are not straightforward and this is precisely what we look at in our next section.

1.3 Welfare Analysis

In this section, we discuss the welfare implications of the Leniency Programme to the agency and compare the welfare in both the regimes - no leniency and the Leniency Programme. Recall from the description of the model that we indicated that the agency is responsible for the overall welfare of the society. In what follows, we analyse welfare of the agency and we make no distinction between agency and society. However, there is no apriori reason to believe that the welfare of the agency will reflect the welfare of the society. Keeping this caveat in mind, henceforth we call the agency's payoff as society's(or social) payoff. We establish a sufficiency condition which helps us to unambiguously sign the welfare effects of the two regimes. For the sake of understanding, this section is organized in to two sub sections. *a)* Static Welfare Effects: where the number of bureaucrats who join the force is assumed to be exogenously given. *b)* Dynamic Welfare Effects: where the endogenous supply of the bureaucrats is discussed and wherein the way in which Leniency Programme endogenously affects the composition of bureaucrats who join the bureaucracy is also considered.

1.3.1 Static Welfare Effects of the Leniency Programme

In this subsection, we assume that the supply of the bureaucrats is fixed and call it the Short Run. This is when the Leniency Programme has just been introduced. Criminals value the current crime committed as v and not being able to commit it as loss of v . Society may value stopping the crime differently from what the criminals value committing the crime. We consider that the society values the crime not committed as sv . Similarly, the criminals and society may differ about how they value future crime. That is, the payoff to the society from stopping the possibility

of a criminal of both types committing future criminal activity may be different from the criminals' payoff of having the option of committing future crime. In our analysis so far, we defined criminal's option value of committing future crime as $\gamma_i v$ (where $i = \ell, h$). Now, we define the society's payoff of preventing the future criminal activity as $\gamma_{i,s} v$.

For the short run case, we take m as exogenously given. We consider the case of $m \leq n$ - this is a relevant case where the agency has scarce resources to tackle crime. In which case, m number of criminals are audited by the bureaucrats. So $n - m$ gives the number of undetected crimes. We know that $m = m_o + m_p$. Recall that λ is the agency's belief about the proportion of high type criminals. m_o and m_p denote the number of optimistic and pessimistic bureaucrats respectively

Welfare in the No Leniency case in the short run

For welfare calculations under no leniency, the two possibilities whenever the criminals are audited are that the criminals offer the bribe or they do not. Amongst the criminals who are audited, those criminals of low and high type who have a cut-off $v \leq v_b$ do not offer the bribe and do not commit crimes. So, the society recovers the current value of the crime, sv . The payoff to the society when criminals do not offer the bribe is thus given by $m \left\{ s \int_0^{v_b} v d\Phi(v) \right\}$.

Recall here from the equilibrium characterized in corollary 1.2.1 under no leniency that when $b \geq \alpha F_B$, all types of bureaucrats accept the bribe when offered. The low type and high type criminals offer the bribe when $v \geq v_b$ and it is accepted by the bureaucrats of both types whoever is encountered by the criminal. Hence number m_p and m_o do not matter in this calculation. Crime is committed in the current period. If corruption is detected by the monitoring mechanism, then F_C and F_B are the fines collected by the agency from the criminals and bureaucrats respectively. The payoff to the agency when the criminals offer the bribe in the no leniency case is thus given by $m \{ \alpha (F_C + F_B) (1 - \Phi(v_b)) \}$. The agency collects nothing when the criminals are unaudited.

Hence, the welfare to the agency under No Leniency (R_{NL}) is given by

$$R_{NL} = (n - m)(0) + m \left\{ s \int_0^{v_b} v d\Phi(v) \right\} + m \{ \alpha(F_C + F_B)(1 - \Phi(v_b)) \}$$

As discussed above, numbers m_o and m_p don't matter in the welfare calculation under no Leniency regime and the following expansion shows the same

$$\begin{aligned} R_{NL} = & \\ & m_p \left\{ s\lambda \int_0^{v_b} v d\Phi(v) + s(1 - \lambda) \int_0^{v_b} v d\Phi(v) \right\} \\ & + m_o \left\{ s\lambda \int_0^{v_b} v d\Phi(v) + s(1 - \lambda) \int_0^{v_b} v d\Phi(v) \right\} \\ & + m_p \{ \lambda[\alpha(F_C + F_B)(1 - \Phi(v_b))] + (1 - \lambda)[\alpha(F_C + F_B)(1 - \Phi(v_b))] \} \\ & + m_o \{ \lambda[\alpha(F_C + F_B)(1 - \Phi(v_b))] + (1 - \lambda)[\alpha(F_C + F_B)(1 - \Phi(v_b))] \} \end{aligned} \tag{1.20}$$

Welfare in the Leniency Programme regime in the short run

In the LP among the criminals who are audited, there are some high type and low type criminals who do not offer the bribe in which case it does not matter which type of bureaucrat they encounter. The current crime is stopped and the society's payoff is the value from stopping the current crime, sv .

Recall the equilibrium characterization of the Leniency Programme. Due to the introduction of the Leniency Programme, the incentives of both types of criminals and both types of bureaucrats change. The pessimistic bureaucrats always reject the bribe when offered by either a high type or low type criminal, hence resulting in the prevention of current crime and a payoff of sv to the society. The optimistic bureaucrats accept the bribe when offered by both types of criminals. There are various effects happening here. Described below are the sub cases where both types of criminals encounter optimistic bureaucrats.

There are some low type criminals who did not offer the bribe under no leniency but do so now only to take advantage of the Leniency Programme and report. There are yet some more low type criminals who offered the bribe in the no leniency case

and committed crimes, but now offer the bribe only to report. The low type criminals who report lose their option value of committing future crime and this results in a payoff of $\gamma_{\ell,s}v$ to the society which is a crucial payoff to the society. Society also collects fines F_B from the optimistic bureaucrats who are being reported. Some low type criminals do not report on offering the bribe and society will not be able to extract their optional value of future criminal activity. High type criminals behave in the same way in the LP as they did in the no leniency case. The high type criminals who offer the bribe do not report and commit current crime and also have the option value of committing future crimes. The only payoff to the society in such a case comes through fines F_B and F_C in the event of detection of corruption.

When any type of criminal who is audited does not offer the bribe to bureaucrat of any type, the crime is stopped. Society's payoff is the current value of the crime being stopped. The payoffs to the society when each type of criminal encountering the pessimistic and optimistic bureaucrats is discussed below.

Criminal encounters a pessimistic bureaucrat

When a criminal high type or low type encounters a pessimistic bureaucrat and offers the bribe, the crime is stopped. In the case where the criminal does not offer the bribe, the crime is stopped as well. The payoff to the agency is given by $m_p \left\{ s \int_0^{\bar{v}} v d\Phi(v) \right\}$. Refer to the first term of (1.20).

Criminal encounters an optimistic bureaucrat

There are three possibilities in this case.

(a) Criminals do not offer the bribe: Low type criminals who have a valuation $v \in [0, v_{b,\ell}]$ and high type criminals who have a valuation $v \in [0, v_{b,h}]$ do not offer the bribe. In this case when any type of criminal does not offer the bribe, the payoff to the agency is given by $m_o s \left\{ \lambda \int_0^{v_{b,h}} v d\Phi(v) + (1 - \lambda) \int_0^{v_{b,\ell}} v d\Phi(v) \right\}$.

(b) Criminals offer the bribe and report: Low type criminals with valuation $v \in [v_{b,\ell}, v_{N,\ell}]$ offer the bribe and report losing the possibility of future criminal activity which is the crucial recovery by the agency. Also a fine F_B is collected from the bureaucrats who are being reported. The payoff to the agency in this case is given by

$$m_o \left\{ (1 - \lambda)[\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})]F_B + (1 - \lambda) \left[\int_{v_{b,\ell}}^{v_{N,\ell}} \gamma_{\ell,s} v d\Phi(v) \right] \right\}.$$

(c) Criminals offer the bribe and do not report: If the valuation for a high type criminal is such that $v > v_{b,h}$, he offers the bribe and does not report. A low type criminal with valuation $v > v_{N,\ell}$ offers the bribe and does not report. Crime is committed and the criminals also retain their future possibility of committing crimes. Fines F_C and F_B are collected from the criminals and bureaucrats detected in corruption respectively. In this case, payoff to the agency is given by

$$m_o \{ \lambda(1 - \Phi(v_{b,h})) + (1 - \lambda)(1 - \Phi(v_{N,\ell})) \} \{ \alpha(F_B + F_C) \}.$$

All three payoffs are already weighted by probability of occurrence. The welfare of the agency after the introduction of the LP in the short run, R_S is given by

$$\begin{aligned} R_S = & \\ & m_p \left\{ s \int_0^{\bar{v}} v d\Phi(v) \right\} \\ & + m_o s \left\{ \lambda \int_0^{v_{b,h}} v d\Phi(v) + (1 - \lambda) \int_0^{v_{b,\ell}} v d\Phi(v) \right\} \\ & + m_o \left\{ (1 - \lambda)[\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})]F_B + (1 - \lambda) \left[\int_{v_{b,\ell}}^{v_{N,\ell}} \gamma_{\ell,s} v d\Phi(v) \right] \right\} \\ & + m_o \{ \lambda(1 - \Phi(v_{b,h})) + (1 - \lambda)(1 - \Phi(v_{N,\ell})) \} \{ \alpha(F_B + F_C) \} \end{aligned} \quad (1.21)$$

Welfare Comparison between No Leniency and the Leniency Programme in the short run

In this section, we compare the welfare obtained under No Leniency and the Leniency Programme in the short run case where the supply of bureaucrats is fixed. A note about s before we proceed further. As already discussed, the benefit to the society of preventing current criminal activity is sv . Notice this incorporates the fact that society may value stopping of crime differently from what the criminals value committing the crime. Similarly, the payoff to the society from stopping future crime, given by $\gamma_{i,s}v$ may be different from the criminals' value of having the option of committing future crime, given by $\gamma_i v$. There is an interesting welfare comparison between the two policies even if they value it in the same way. So, we

first investigate the case where both the society and criminals value it in same way.

We set $s = 1$ and $\gamma_{i,s} = \gamma_i$.

When s is some value other than 1, the comparison might lead to other interesting results; the analysis of which is deferred to later sections.

Rewriting the R_{NL} from equation (1.20), we have

$$\begin{aligned}
R_{NL} = & \\
& m_p \left\{ \lambda \int_0^{v_b} v d\Phi(v) + (1 - \lambda) \int_0^{v_b} v d\Phi(v) \right\} \\
& + m_o \left\{ \lambda \int_0^{v_b} v d\Phi(v) + (1 - \lambda) \int_0^{v_b} v d\Phi(v) \right\} \\
& + m_p \{ \lambda [\alpha(F_C + F_B)(1 - \Phi(v_b))] + (1 - \lambda) [\alpha(F_C + F_B)(1 - \Phi(v_b))] \} \\
& + m_o \{ \lambda [\alpha(F_C + F_B)(1 - \Phi(v_b))] + (1 - \lambda) [\alpha(F_C + F_B)(1 - \Phi(v_b))] \}
\end{aligned} \tag{1.22}$$

Rewriting the R_S from equation (1.21), we have

$$\begin{aligned}
R_S = & \\
& m_p \left\{ \int_0^{\bar{v}} v d\Phi(v) \right\} \\
& + m_o \left\{ \lambda \int_0^{v_{b,h}} v d\Phi(v) + (1 - \lambda) \int_0^{v_{b,\ell}} v d\Phi(v) \right\} \\
& + m_o \left\{ (1 - \lambda) [\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})] F_B + (1 - \lambda) \left[\int_{v_{b,\ell}}^{v_{N,\ell}} \gamma_\ell v d\Phi(v) \right] \right\} \\
& + m_o \{ \lambda (1 - \Phi(v_{b,h})) + (1 - \lambda) (1 - \Phi(v_{N,\ell})) \} \{ \alpha(F_B + F_C) \}
\end{aligned} \tag{1.23}$$

A brief note on what the comparison yields. Society gets a higher payoff after the introduction of the LP compared to no leniency in the short run provided a certain sufficient condition is satisfied, which is discussed in detail further in this subsection. Society gets a higher payoff after the introduction of the LP from the encounter of a

pessimistic bureaucrat with a high type or low type criminal than in the no leniency case. Society gets the same payoff in both the Leniency Programme and no leniency from the encounter of optimistic bureaucrats with high type criminals. Society gets a higher payoff after the introduction of the Leniency Programme from the encounter of an optimistic bureaucrat with low type criminals than that in no leniency provided a sufficiency condition is satisfied.

Welfare comparison - High type or low type criminals encounter a pessimistic bureaucrat

The payoff to the society from high type or low type criminals encountering pessimistic bureaucrats in the no leniency case (from equation (1.22)) is $\int_0^{v_b} v d\Phi(v) + \{\alpha(F_C + F_B)(1 - \Phi(v_b))\}$ and that from the Leniency Programme in the short run, that is from equation (1.23) is $\int_0^{\bar{v}} v d\Phi(v)$ which is

$$\int_0^{\bar{v}} v d\Phi(v) = \int_0^{v_b} v d\Phi(v) + \int_{v_b}^{\bar{v}} v d\Phi(v)$$

Taking the difference between these payoffs from the Leniency Programme and that from the no leniency case in the short run yields

$$\int_{v_b}^{\bar{v}} v d\Phi(v) - [1 - \Phi(v_b)][\alpha(F_C + F_B)]$$

which is

$$\int_{v_b}^{\bar{v}} [v - \alpha(F_C + F_B)] d\Phi(v)$$

For every, $v \in [v_b, \bar{v}]$, we have

$$v - b \geq \alpha F_C$$

$$v \geq b + \alpha F_C$$

Recall here the equilibrium condition in corollary 1.2.1, which is $b \geq \alpha F_B$. From

$b \geq \alpha F_B$ and $v \geq b + \alpha F_C$, we have that

$$v \geq \alpha(F_B + F_C) \quad (1.24)$$

So in this case, the payoff to the society is always higher after the introduction of the LP than that in the no leniency case in the short run when the criminals of any type encounter a pessimistic bureaucrat. Hence, this leads to a gain, $R_S - R_{NL} > 0$.

Now, we look at the payoff to the society for the encounter between both types of criminals and an optimistic bureaucrat after the introduction of the LP and compare it with that obtained in the no leniency case.

Welfare comparison - High type or low type criminals encounter an optimistic bureaucrat

The encounter of any type of criminal with an optimistic bureaucrat in the short run gives different payoffs according to the different valuations of criminal types. It is broken down into the following sub cases.

Welfare comparison - High type criminals encounter an optimistic bureaucrat

The payoff to the society from the optimistic bureaucrats meeting a high type criminal in the no leniency case (from equation (1.22)) is

$$m_o \cdot \lambda \left\{ \int_0^{v_b} v d\Phi(v) + (1 - \Phi(v_b))\alpha(F_C + F_B) \right\}$$

The payoff to the society from the optimistic bureaucrats meeting a high type criminal after the introduction of the LP (from equation (1.23)) is

$$m_o \cdot \lambda \left\{ \int_0^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h}))\alpha(F_C + F_B) \right\}$$

But recall that the threshold value v_b in the no leniency case is just equal to

the $v_{b,h}$ after the introduction of the LP. Hence, the payoff to the society from the optimistic bureaucrats meeting a high type criminal is same in the no leniency case and after the introduction of the LP in the short run.

Welfare comparison - Low type criminals encounter an optimistic bureaucrat

The payoff obtained in the no leniency case when low type criminals of valuation $v \in [0, v_{b,\ell}]$ meet an optimistic bureaucrat is

$$m_o.(1 - \lambda) \left\{ \int_0^{v_{b,\ell}} v d\Phi(v) \right\}$$

and the payoff after the introduction of the LP from the encounter of low type criminals of valuation $v \in [0, v_{b,\ell}]$ meet an optimistic bureaucrat is

$$m_o.(1 - \lambda) \left\{ \int_0^{v_{b,\ell}} v d\Phi(v) \right\}$$

So, payoff to the society when a low type criminal with valuation $v \in [0, v_{b,\ell}]$ meets an optimistic bureaucrat is exactly the same in the no leniency case and the Leniency Programme.

A similar comparison in the no leniency case and the Leniency Programme when the low type criminal with valuation $v \in [v_{N,\ell}, \bar{v}]$ shows that they are exactly the same, that is

$$m_o.(1 - \lambda)(1 - \Phi(v_{N,\ell}))\alpha(F_B + F_C)$$

. The only difference in the payoffs comes from the encounter of low type criminals and optimistic bureaucrats when the valuation of the low type criminals is such that $v_{b,\ell} < v < v_{N,\ell}$. This region of valuation be broken down into two parts. a) $v \in [v_{b,\ell}, v_{b,h})$, and b) $v \in [v_{b,h}, v_{N,\ell}]$.

When the valuation of the low type criminals is $v \in [v_{b,\ell}, v_{b,h})$, previously in the no leniency case, criminals did not offer the bribe and now after the Leniency Programme is introduced they are better off by offering the bribe and reporting.

In the no leniency case, the payoff to the society when a low type criminal of

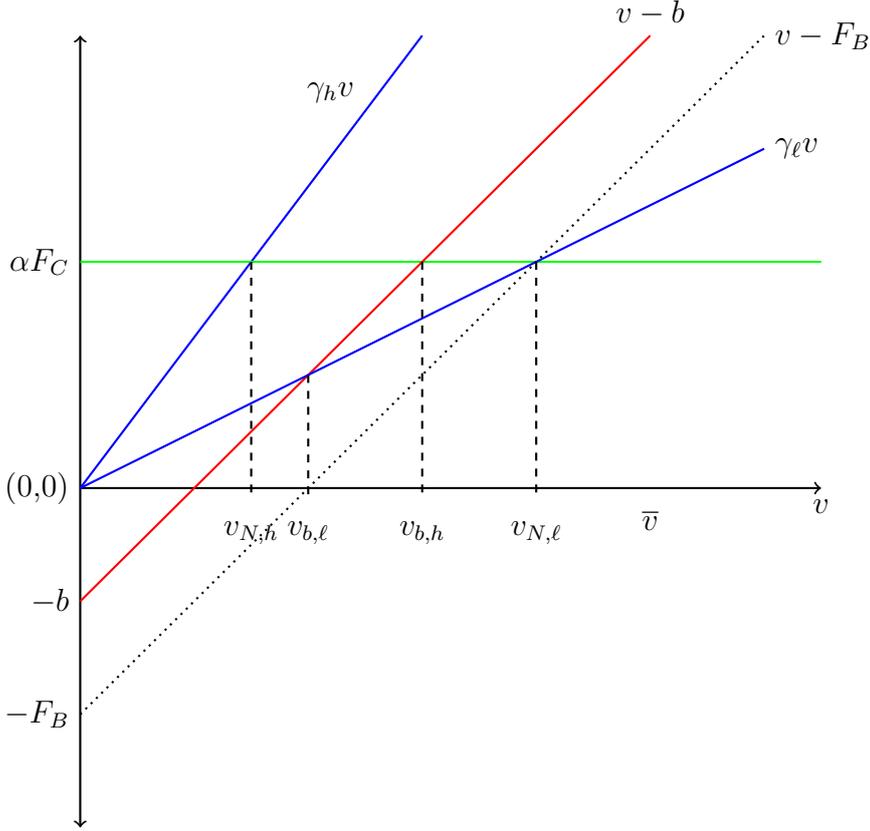


Figure 1.4: The Cut-offs for welfare comparison

valuation $v \in [v_{b,\ell}, v_{b,h})$ encounters an optimistic bureaucrat is

$$m_o.(1 - \lambda) \left\{ \int_{v_{b,\ell}}^{v_b} v d\Phi(v) \right\}$$

and after the introduction of the LP,

$$m_o.(1 - \lambda) \left\{ [\Phi(v_{b,h}) - \Phi(v_{b,\ell})]F_B + \int_{v_{b,\ell}}^{v_{b,h}} \gamma_\ell v d\Phi(v) \right\}$$

If we look at the difference $R_S - R_{NL}$ for an encounter of an optimistic bureaucrat with a low type criminal when $v \in [v_{b,\ell}, v_{b,h})$, it is given by

$$Z_1 = m_o.(1 - \lambda) \left\{ \int_{v_{b,\ell}}^{v_{b,h}} (F_B + \gamma_\ell v - v) d\Phi(v) \right\} \quad (1.25)$$

When the valuation of the low type criminals is such that $v \in [v_{b,h}, v_{N,\ell}]$, in the no

leniency case, they offer the bribe, whereas after the introduction of the LP, they offer the bribe and report.

In the no leniency case, the payoff to the society when a low type criminal of valuation $v \in [v_{b,h}, v_{N,\ell}]$ encounters an optimistic bureaucrat is

$$m_o \cdot (1 - \lambda) (1 - \Phi(v_{b,h})) \alpha (F_C + F_B)$$

and after the introduction of the LP,

$$m_o \cdot (1 - \lambda) \left\{ [\Phi(v_{N,\ell}) - \Phi(v_{b,h})] F_B + \int_{v_{b,h}}^{v_{N,\ell}} \gamma_\ell v d\Phi(v) \right\}$$

If we look at the difference $R_S - R_{NL}$ for an encounter of an optimistic bureaucrat with a low type criminal when $v \in [v_{b,h}, v_{N,\ell}]$, it is given by

$$Z_2 = m_o \cdot (1 - \lambda) \left\{ \int_{v_{b,h}}^{v_{N,\ell}} (F_B + \gamma_\ell v - \alpha(F_B + F_C)) d\Phi(v) \right\} \quad (1.26)$$

If we have to sign $R_S - R_{NL}$ in the short run in both the regions, that is essentially signing Z_1 and Z_2 , a sufficient condition for the welfare after the introduction of the LP in the short run to be greater than that under no leniency is

$$F_B \geq v_{N,\ell} - \alpha F_C \quad (1.27)$$

From the welfare comparison of the Leniency Programme and no leniency in the short run, we see that the payoff to the society after the introduction of the LP from the encounter of pessimistic bureaucrats with any type of criminals is higher than that under no leniency. However, we are unable to determine if the payoff to the society from the encounter of optimistic bureaucrats with all types of criminals after the introduction of the LP is higher than that under no leniency or not. We prove that if the condition given by equation (1.27) holds, then society also gains from the interaction of optimistic bureaucrats and the two types of criminals, that is for every value of v of criminals and for all l, h . Sufficiency condition given by the inequality (1.27) requires that the fine levied on the bureaucrats be sufficiently

higher than the difference between the low type criminal's valuation of crime under no leniency and the fine he should pay on being caught.

The following proposition characterizes the welfare effects of the Leniency Programme and no leniency in the short run.

Proposition 1.3.1 *Assume the conditions of Corollary 1.2.1 and proposition 1.2.1 hold in particular such that the equilibria in the no leniency case and the Leniency Programme are as described in corollary 1.2.1 and proposition 1.2.1 respectively. Suppose further that $F_B \geq v_{N,\ell} - \alpha F_C$ and that $s = 1$, then*

in the short run, the Leniency Programme is unambiguously better than no leniency, that is, the welfare to the society after the introduction of the LP in the short run is greater than that under no leniency, $R_S > R_{NL}$.

Proof We need Z_1 and Z_2 (equations (1.25) and (1.26)) to be both positive in order to proof this claim.

Equation (1.27) is a sufficient condition because of the following reasons. If (1.27) holds and when the valuation of a low type criminal is such that $v \in [v_{b,\ell}, v_{b,h})$, then for every v , $\gamma_\ell v$ is bigger than $v - F_B$, that is $F_B + \gamma_\ell v - v < 0$. For this reason, we have Z_1 as positive. So, when the low type criminal with valuation $v \in [v_{b,\ell}, v_{b,h})$ meets an optimistic bureaucrat, if the condition given by (1.27) holds, then the payoff to the society is strictly greater after the introduction of the LP in the short run than in the no leniency case.

Now, we look at Z_2 . Once again, we try to determine if the payoff to the society after the introduction of the LP is greater than that in the no leniency case when a low type criminal now with a valuation $v \in [v_{b,h}, v_{N,\ell}]$ encounters an optimistic bureaucrat.

As a consequence of the conditions in proposition 1.2.1, we have $F_B > b$. When the valuation of a low type criminal is such that $v \in [v_{b,h}, v_{N,\ell}]$, the payoff to the society under no leniency is $\alpha F_B + \alpha F_C$. after the introduction of the LP when the low type criminal meets an optimistic bureaucrat the payoff is $\gamma_\ell v + F_B$.

From (1.11), we have that $\gamma_\ell v_{N,\ell} = \alpha F_C$. Using $\gamma_\ell v_{N,\ell} = \alpha F_C$ and the sufficiency condition, $F_B \geq v_{N,\ell} - \alpha F_C$, we arrive at $\gamma_\ell v_{N,\ell} + F_B \geq v_{N,\ell}$. That is, $F_B \geq v_{N,\ell}(1 - \gamma_\ell)$. From (1.24), we have that $v \geq \alpha F_B + \alpha F_C$.

From the above conditions, we have $F_B \geq v(1 - \gamma_\ell)$. Hence, it follows that $\gamma_\ell v + F_B \geq$

$\alpha F_B + \alpha F_C$. This implies that the positive part of Z_2 in (1.26) is greater than the negative part. Since we have Z_1 and Z_2 as positive, we have $R_S - R_{NL} > 0$. So, the payoff to the society after the introduction of the LP in the short run is greater than the payoff in the no leniency case. \square

To summarize, we have that when the high type and low type criminals meet pessimistic bureaucrats, payoff to the society after the introduction of the LP is strictly greater than the payoff to the society in the no leniency case. When high type criminals meet optimistic bureaucrats, there is no difference in the payoff to the society after the introduction of the LP and no leniency. Similarly, when the low type criminals with valuation $v \in [0, v_{b,\ell}]$ and $v \in [v_{N,\ell}, \bar{v}]$ meet optimistic bureaucrats, there is no difference in the payoffs to the society after the introduction of the LP and no leniency. The only difference in the payoffs to the society after the introduction of the LP and no leniency occurs when the low type criminals with valuation $v \in [v_{b,\ell}, v_{b,h})$ and $v \in [v_{b,h}, v_{N,\ell}]$ encounter optimistic bureaucrats. We proved that this difference is greater after the introduction of the LP than in the no leniency case given the sufficiency condition (1.27) holds.

Note in particular under the sufficient condition, we can have a stronger result than proposition 1.3.1. The result is that

For all types of criminals, that is for every value of v of criminals and for all l, h , society's payoff after the introduction of the LP is strictly greater than the payoff in the no leniency case in the short run irrespective of the type of the bureaucrat the criminals are audited by.

If the sufficiency condition is violated, society incurs a loss after the introduction of the LP in the short run from each encounter of the low type of criminals in the valuation region $v \in [v_{b,\ell}, v_{N,\ell}]$ with an optimistic bureaucrat. So in order to determine if the Leniency Programme is better than no leniency or if the opposite is true, that is, if the net effect is positive or negative, we need to know the size of that region. We need to know precisely the number of low type criminals with valuation $v \in [v_{b,\ell}, v_{N,\ell}]$. If this number is very large, then the gain in the payoff to the society from the pessimistic bureaucrats after the introduction of the LP is not enough to compensate the loss in the payoff from the optimistic bureaucrats.

1.3.2 Dynamic Welfare Effects of the Leniency Programme

Throughout the previous subsection, the welfare calculations have been done by taking the supply of the bureaucrats as exogenously given. In this subsection, we look at the welfare after the introduction of the LP against that in the no leniency case when enough time has passed after the introduction of the Leniency Programme for the size and composition of the bureaucrats to vary. We call this stage the intermediate run where the supply of the bureaucrats is endogenous. Let M be a fixed amount of money allocated to the agency for the purpose of hiring the bureaucrats. The budget constraint of the agency is

$$M = m.w \tag{1.28}$$

where m is the number of bureaucrats hired at wage, w per bureaucrat. Let K denote the total population of bureaucrats looking for jobs. The bureaucrats draw outside wage offers from the distribution $H(w)$ where $w \in [\underline{w}, \bar{w}]$. The total expected income of every bureaucrat accepting the agency offered job is $w + e$, where e is the expected income from engaging in corruption. Not engaging in corruption means $e = 0$. The bureaucrats who join the agency are those that have outside wage offers lower than $w + e$. Hence, $w + e$ is the cut-off wage. If K is the total general population of bureaucrats, then out of that K , $H(w + e)$ is the fraction of bureaucrats who accept the agency offered job. The total number of bureaucrats hired by the agency, m , is therefore given by the expression, $K.H(w + e)$.

In the general population of bureaucrats, K , the two types are half each (half are optimistic and half are pessimistic, that is $K/2$ each). Here an additional point is being made, that is in the original population the composition of bureaucrats consists of half optimistic bureaucrats and the other half is pessimistic bureaucrats. In the no leniency case, since the bureaucrats face the same incentives in equilibrium, they join the force at the same rate. So, among the bureaucrats hired into the agency, half of them are optimistic and half are pessimistic, that is $m_p = m_o = m/2$.

Recall that the incentives for the two types of bureaucrats joining the agency are to accept the bribe in the no leniency equilibrium and in this case, $e = (b -$

$\alpha F_B)(1 - \Phi(v_b))$. In the case of no leniency (R_{NL}), the following are the number of pessimistic (m_{pN}) and optimistic bureaucrats (m_{oN}) hired respectively.

$$m_{pN} = m_{oN} = \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))$$

In the Leniency Programme case, in the short run (R_S), that is just after the policy is introduced, the bureaucrats who are in the bureaucracy are the same as in the no leniency case, that is $\frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))$

However, when certain time is allowed from the introduction of the Leniency Programme, the expected incomes of the pessimistic and optimistic bureaucrats change and the composition of the bureaucrats starts changing. The expected income from corruption to the pessimistic bureaucrats after the introduction of the LP equilibrium is 0 in the intermediate run. So, some of them start leaving based on the outside job offers. Hence the total number of bureaucrats in the intermediate run (discussion of which is postponed to the later subsections) is lower than that in the short run. So, the budget constraint is no longer satisfied. There is some money left over. The agency can now announce a wage rise which we call as the long run. In the long run (R_L), agency announces an increase in the wages of bureaucrats by an amount Δw . In the Leniency Programme long run, the number of pessimistic and optimistic bureaucrats is given by

$$m_{p3} = \frac{K}{2} \cdot H(w + \Delta w)$$

$$\begin{aligned} m_{o3} = & \\ & \frac{K}{2} \cdot H(w + \Delta w) \\ & + \lambda^o (b - \alpha F_B)(1 - \Phi(v_b)) \\ & + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) \\ & + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))] \end{aligned}$$

The expression for welfare after the introduction of the LP in the long run denoted

by R_L can be given as

$$\begin{aligned}
R_L = & \\
& \frac{K}{2} \cdot H(w + \Delta w) \left\{ \int_0^{\bar{v}} v d\Phi(v) \right\} \\
& + \frac{K}{2} \cdot H(w + \Delta w + \lambda^\circ(b - \alpha F_B)(1 - \Phi(v_b))) \\
& + (1 - \lambda^\circ)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))] \\
& \left\{ \lambda \int_0^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h})) \right\} + (1 - \lambda) \left\{ \int_0^{v_{b,\ell}} v d\Phi(v) \right\} \\
& + [\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})]F_B + \int_{v_{b,\ell}}^{v_{N,\ell}} \gamma_\ell v d\Phi(v) \\
& + (1 - \Phi(v_{N,\ell}))\alpha(F_B + F_C)
\end{aligned} \tag{1.29}$$

Let the payoff to the society from the pessimistic bureaucrats encountering all types of criminals in the Leniency Programme be a_L and that from the optimistic bureaucrats encountering all types of criminals be $b_L + c_L + d_L$ in the Leniency Programme (where b_L is a payoff to the society resulting from the encounter of optimistic bureaucrats and high type criminals, c_L - payoff from optimistic bureaucrats encountering low type criminals with valuation $v \in [v_{b,\ell}, v_{N,\ell}]$, d_L - payoff from optimistic bureaucrats encountering low type criminals with valuation $v \in [0, v_{b,\ell}]$ and $v \in [v_{N,\ell}, \bar{v}]$).

$$\begin{aligned}
a_L &= \int_0^{\bar{v}} v d\Phi(v) \\
b_L &= \lambda \left\{ \int_0^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h}))(\alpha(F_B + F_C)) \right\} \\
c_L &= (1 - \lambda) \left\{ \int_0^{v_{b,\ell}} v d\Phi(v) + [\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})]F_B + \int_{v_{b,\ell}}^{v_{N,\ell}} \gamma_\ell v d\Phi(v) \right\} \\
d_L &= (1 - \lambda)(1 - \Phi(v_{N,\ell}))\alpha(F_B + F_C)
\end{aligned}$$

$$\begin{aligned}
R_L - R_S = & \\
& \frac{K}{2} \cdot H(w + \Delta w)(a_L) \\
& + \frac{K}{2} \cdot H(w + \Delta w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\
& + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell}))] \\
& + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))(b_L + c_L + d_L) \\
& - \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(a_L) \\
& - \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(b_L + c_L + d_L)
\end{aligned} \tag{1.30}$$

The budget constraint in the long run would look like

$$\begin{aligned}
M = & \\
& \left(\frac{K}{2} \cdot H(w + \Delta w) \right. \\
& + \frac{K}{2} \cdot H(w + \Delta w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\
& + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell}))] \\
& \left. + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell})) \right) (w + \Delta w)
\end{aligned} \tag{1.31}$$

It is the same budget we expressed in the equation (1.28) using the number of bureaucrats in the no leniency case. Equating that with the budget in equation (1.31) and re-arranging, the number of optimistic bureaucrats in the long run can be expressed as

$$\begin{aligned}
\frac{K}{2} \cdot (H(w + \Delta w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\
+ (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell}))] \\
+ (b - F_B)(\Phi(v_{N,\ell}) \\
- \Phi(v_{b,\ell}))) = \\
\frac{K}{2} \cdot (2H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \frac{w}{w + \Delta w} \\
- H(w + \Delta w))
\end{aligned} \tag{1.32}$$

Rewriting the expression for $R_L - R_S$ gives

$$\begin{aligned}
R_L - R_S = & \\
& \frac{K}{2} \cdot (2H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \frac{w}{w + \Delta w} \\
& - H(w + \Delta w))(b_L + c_L + d_L) \\
& + \frac{K}{2} \cdot H(w + \Delta w)(a_L) \\
& - \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(a_L) \\
& - \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(b_L + c_L + d_L)
\end{aligned} \tag{1.33}$$

$$\begin{aligned}
R_L - R_S = & \\
& \frac{K}{2} \cdot \{H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \\
& \{ \frac{w - \Delta w}{w + \Delta w} (b_L + c_L + d_L) - a_L \} \\
& + H(w + \Delta w \{ a_L - (b_L + c_L + d_L) \}) \}
\end{aligned} \tag{1.34}$$

Now, comparing the welfare after the introduction of the LP in short run (R_S) and that in long run (R_L) gives the result that

Proposition 1.3.2 *Suppose the sufficiency condition given by equation (1.27) and the assumption $a_L > b_L + c_L + d_L$ (that is, in the Leniency Programme, payoff from the pessimists encountering all types of criminals of all valuations is greater than payoff from the optimists encountering all types of criminals of all valuations) hold, then welfare in the short run is greater than that in the long run, that is, $R_S > R_L$.*

Proof In the equilibrium in the Leniency Programme that we look at, surplus income of the pessimistic bureaucrats is 0 as opposed to a positive surplus optimistic bureaucrats get. It is impossible for the agency to have more pessimists than there are optimists. The surplus income of pessimists in the Leniency Programme is 0 and is lesser than that under no leniency. Hence there are lesser pessimists in the Leniency Programme long run than there are in the Leniency Programme short run. If the budget constraint has to be maintained, it is also impossible that the agency hires more total number of bureaucrats in the Leniency Programme long run giving

higher wages simultaneously than under no leniency.

par The agency is losing pessimists, if it also loses optimists thus having less total number of bureaucrats in the Leniency Programme long run than in the short run (case: $\Delta w < (b - \alpha F_B)(1 - \Phi(v_b))$ and $\Delta w < \lambda^o(b - \alpha F_B)(1 - \Phi(v_b)) + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))]$), then it is proved that the Leniency Programme short run is better than the Leniency Programme long run, that is, $R_S > R_L$.

Another case which is possible is that there are more number of optimists in the the Leniency Programme long run than there are in the short run which is a case where: $\Delta w < (b - \alpha F_B)(1 - \Phi(v_b))$ and $\Delta w > \lambda^o(b - \alpha F_B)(1 - \Phi(v_b)) + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))]$. Taking the difference between the welfares after the introduction of the LP in the short run and that in the long run, provided the conditions given by equation (1.27) and the assumption that $a_L > b_L + c_L + d_L$ hold, we have $R_S - R_L > 0$. Hence, welfare after the introduction of the LP in the short run is better than that in the long run. \square

Comparison between welfare under no leniency(R_{NL}) and welfare in the long run(R_L) after the introduction of the LP: If R_L is lower than that under no leniency, then it would be best to not introduce the Leniency Programme in the first place. par The difference in welfare after the introduction of the LP in the long run and that in the no leniency case is

$$\begin{aligned}
R_L - R_{NL} = & \\
& \frac{K}{2} \cdot \{ (2H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \frac{w}{w + \Delta w} \\
& - H(w + \Delta w))(b_L + c_L + d_L) \\
& + H(w + \Delta w)(a_L) \\
& - H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(b_N + c_N + d_N) \\
& - H(w + (b - \alpha F_B)(1 - \Phi(v_b)))(a_N) \}
\end{aligned} \tag{1.35}$$

where $b_N + c_N + d_N$ is the payoff obtained from the meeting between optimistic bureaucrats and all types of criminals, low and high of all valuations v in the no leniency case (where b_N is a payoff to the society resulting from the encounter of optimistic bureaucrats and high type criminals , c_N - payoff from optimistic bureaucrats

encountering low type criminals with valuation $v \in [v_{b,\ell}, v_{N,\ell}]$, d_N - payoff from optimistic bureaucrats encountering low type criminals with valuation $v \in [0, v_{b,\ell}]$ and $v \in [v_{N,\ell}, \bar{v}]$) and a_N is the payoff obtained from the meeting between pessimistic bureaucrats and all types of criminals in the no leniency case. Also, $b_N + c_N + d_N = a_N$

$$\begin{aligned}
a_N &= \int_0^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h}))(\alpha(F_B + F_C)) \\
b_N &= \lambda \left\{ \int_0^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h}))\alpha(F_C + F_B) \right\} \\
c_N &= (1 - \lambda) \left\{ \int_{v_{b,\ell}}^{v_{b,h}} v d\Phi(v) + (1 - \Phi(v_{b,h}))\alpha(F_C + F_B) \right\} \\
d_N &= (1 - \lambda)(1 - \Phi(v_{N,\ell}))(\alpha(F_B + F_C))
\end{aligned}$$

Rearranging the equation (1.35), we have

$$\begin{aligned}
R_L - R_{NL} &= \\
&= \frac{K}{2} \cdot \{ (2H(w + (b - \alpha F_B)(1 - \Phi(v_b)))) \\
&\quad \{ (b_L + c_L + d_L) \frac{w}{w + \Delta w} - (b_N + c_N + d_N) \} \\
&\quad + H(w + \Delta w) \{ a_L - (b_L + c_L + d_L) \} \}
\end{aligned} \tag{1.36}$$

Now, comparing the welfare after the introduction of the LP in the long run (R_L) and that in no leniency (R_{NL}) gives the result that

Proposition 1.3.3 *Suppose the sufficiency condition given by equation (1.27), the assumptions $a_L > b_L + c_L + d_L$ and $(b_L + c_L + d_L) \frac{w}{w + \Delta w} > (b_N + c_N + d_N)$ hold, then welfare after the introduction of the LP in the long run is greater than that in the no leniency case (that is, $R_L > R_{NL}$).*

Proof Recall the proof of proposition 1.3.2. There are fewer number of pessimists than there are optimists in the bureaucracy after the introduction of the LP in the long run than in the no leniency case. With the same budget constraint, it is also the case that there are never more total number of bureaucrats after the introduction of the LP in the long run than there were in the no leniency case. The number of

optimists could be greater or lesser after the introduction of the LP in the long run than in the no leniency case. If $a_L > b_L + c_L + d_L$, in the Leniency Programme long run, payoff from the pessimists is greater than that from the optimists. The sufficiency condition given by (1.27) tells us that payoff from the optimists meeting all types of criminals after the introduction of the LP is greater than that under no leniency. If the scale effect is dominated by the individual gain from the optimists ($(b_L + c_L + d_L)\frac{w}{w+\Delta w} > (b_N + c_N + d_N)$), then the welfare after the introduction of the LP in the long run will be greater than that under no leniency. \square

We now look at the welfare after the introduction of the LP in the intermediate run, (R_M). The number of pessimistic and optimistic bureaucrats in this run are given by

$$m_{p2} = \frac{K}{2}.H(w)$$

$$\begin{aligned} m_{o2} = \frac{K}{2}.H(w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\ + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) \\ + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))] \end{aligned}$$

The expression for welfare after the introduction of the LP in the intermediate run is

$$\begin{aligned} R_M = \\ \frac{K}{2}.H(w)(a_L) \\ + \frac{K}{2}.H(w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\ + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) \\ + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))](b_L + c_L + d_L) \end{aligned} \tag{1.37}$$

$$\begin{aligned}
R_S - R_M = & \\
& \frac{K}{2} \cdot \{ \{ H(w + (b - \alpha F_B)(1 - \Phi(v_b))) - H(w) \} (a_L) \\
& + \{ H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \\
& - H(w + \lambda^o(b - \alpha F_B)(1 - \Phi(v_b))) \\
& + (1 - \lambda^o)[(b - \alpha F_B)(1 - \Phi(v_{N,\ell})) \\
& + (b - F_B)(\Phi(v_{N,\ell}) - \Phi(v_{b,\ell}))] \} \} (b_L + c_L + d_L)
\end{aligned} \tag{1.38}$$

Comparison of the welfare after the introduction of the LP in the short run with that in the intermediate run can be summarized in the following proposition

Proposition 1.3.4 *Welfare after the introduction of the LP in the short run is greater than that in the intermediate run, that is, $R_S > R_M$.*

Proof The expected surplus to the pessimists after the introduction of the LP in the intermediate run is 0, less than that in the no leniency case (and the Leniency Programme short run). The expected surplus of the optimists after the introduction of the LP in the intermediate run is also lower compared to that in the no leniency case. So there are less total number of bureaucrats in the intermediate run giving the same payoff as that in the short run. Because of the size effect or the scale effect here (reduced total number of bureaucrats), the welfare after the introduction of the LP falls in the intermediate run when compared to that after the introduction of the LP in the short run. \square

When we compare welfare after the introduction of the LP in the intermediate run (R_M) with that in the no leniency case (R_{NL}), the result is unambiguous. This is because although the collective payoff from pessimists and optimists after the introduction of the LP is greater than that in the no leniency case ($a_L + b_L + c_L + d_L > a_N + b_N + c_N + d_N$), there are lesser total number of bureaucrats now in the intermediate run. So, $R_M > R_{NL}$ is the case if the scale effect is overcome by the income from the two types of bureaucrats.

Comparing welfare after the introduction of the LP in the long run and that in the intermediate run gives the following result

Proposition 1.3.5 *Welfare after the introduction of the LP in the long run is greater than that in the intermediate run, that is, $R_L > R_M$.*

Proof The expected income of both types of bureaucrats is greater in the long run with the wage rise, ($\Delta w > 0$). Thus there are more total number of bureaucrats after the introduction of the LP in the long run than there were in the intermediate run. Hence the welfare goes up in the long run compared to that in the intermediate run. \square

So far, it has been assumed that the sufficiency condition given by equation (1.27) holds true. It is interesting to look at the welfare comparisons when it is not the case, that is, when it is reversed. Then we can see that the Leniency Programme is bad in the short run than it was in the no leniency case. And in the long run, the welfare could be greater or lesser than it was in the no leniency case based on the scale effect of the bureaucrats.

If the sufficiency condition given by (1.27) is violated, then $b_L + c_L + d_L < b_N + c_N + d_N$.

Comparing the welfare under no leniency and that after the introduction of the LP in the short run gives

$$\begin{aligned} R_S - R_{NL} &= \frac{K}{2} \cdot H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \\ &\quad \{a_L + b + L + c_L + d_L - (a_N + b_N + c_N + d_N)\} \end{aligned} \quad (1.39)$$

If $b_L + c_L + d_L < a_N + b_N + c_N + d_N - a_L$ (if the payoff from the optimistic bureaucrats meeting all types of criminals of all valuations in the Leniency Programme is very less compared to that in the no leniency case and this negative payoff dominates the positive difference in payoffs from the pessimistic bureaucrats after the introduction of the LP compared to that in the no leniency case), then the welfare after the introduction of the LP in the short run is worse compared to that in the no leniency case.

It is interesting to see if the welfare goes up in the long run (R_L). If that is the case, it is good to continue with the policy without getting disappointed with the initial decrease in welfare. However, if it is the case that it is worse in the long run,

then it is best to not introduce the policy.

Comparing the welfare after the introduction of the LP in the long run and the Leniency Programme short run (reusing (1.34)) gives

$$\begin{aligned}
R_L - R_S = & \\
& \frac{K}{2} \cdot \{H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \\
& \left\{ \frac{w - \Delta w}{w + \Delta w} (b_L + c_L + d_L) - a_L \right\} \\
& + H(w + \Delta w) \{a_L - (b_L + c_L + d_L)\} \}
\end{aligned} \tag{1.40}$$

Under the assumption that $a_L > b_L + c_L + d_L$, we get that $R_L < R_S$.

If $\frac{w - \Delta w}{w + \Delta w} (b_L + c_L + d_L) > a_L$, then we have that welfare after the introduction of the LP in the long run is higher than that in the short run, that is, $R_L > R_S$.

The number of optimists can be lower or higher after the introduction of the LP in the long run than that in the short run. The number of pessimists is lower after the introduction of the LP in the long run compared to that in the short run. If the number of both types of bureaucrats are lower in the long run of the LP than that in the short run, then it is the case that welfare after the introduction of the LP in the long run is lower than that in the short run ($R_L < R_S$). If on the other hand however, there are less total number of bureaucrats but more number of optimists after the introduction of the LP in the long run than that in the short run, there is a possibility that if the payoff from these optimists overcomes the scale effect coming from the pessimists, then the welfare after the introduction of the LP in the long run might be better than that in the short run.

Reusing the equation (1.36) to compare the welfare after the introduction of the LP in the long run and that in the no leniency case.

$$\begin{aligned}
R_L - R_{NL} = & \\
& \frac{K}{2} \cdot \{2H(w + (b - \alpha F_B)(1 - \Phi(v_b))) \\
& \{(b_L + c_L + d_L) \frac{w}{w + \Delta w} - (b_N + c_N + d_N)\} \\
& + H(w + \Delta w) \{a_L - (b_L + c_L + d_L)\} \}
\end{aligned} \tag{1.41}$$

With the violation of sufficiency condition, we have that welfare after the introduc-

tion of the LP in the long run is worse than that in the no leniency case ($R_L < R_{NL}$)

The calculations and comparisons with respect to welfare after the introduction of the LP in the intermediate run, R_M still give the same results. There is a dip in the welfare from the Leniency Programme short run to intermediate and then there is a rise from intermediate run to the long run.

To summarise the results of our analysis, when we compare the No Leniency regime and the Leniency Programme in the short run, we find a rise in the welfare. The short run is when the size of the bureaucracy is kept unchanged. However after certain time is allowed to pass after the introduction of LP, we observe a change in the size and composition of the bureaucrats. This is because a proportion of the bureaucrats, in particular those who are less inclined to be corrupt leave the agency as they experience a loss in their bribe income. Those bureaucrats who are more inclined to be corrupt do not experience a huge loss and they are more likely to stay behind in the agency. This differential effect in the size and composition of the bureaucrats in the agency leads to a systematic adverse effect and this stage is what we call the intermediate run. As a result of this adverse effect the welfare after the introduction of the LP is worse than in the no leniency case. However, because of the decrease in the number of bureaucrats the agency will have excess money and they can announce a wage raise in the long run. We show that welfare after the introduction of the LP in the long run could be better than in the no leniency case.

It is possible that even in the intermediate run the Leniency Programme might be working when the scale effect of bureaucrats is overcome by the income from two types of bureaucrats (less likely and more likely to be corrupt). However, it is also quite possible that the reverse will be true in which case the outcome in the intermediate run is lower than that under no leniency. So evaluation of LP at that stage will give a pessimistic view of the LP. Here, it is important to consider that if the agency were to anticipate that the Leniency Programme without a corresponding wage change may have the kind of adverse effect that we found in the intermediate run.

These Leniency programmes by themselves might be effective but actually what policy makers need to keep in mind is that the programme of Leniency combined with wage increase might give good effects. Instead of just introducing LP, we

propose that the policy makers need to think creatively about how combination of policies which are feasible within the budget can give a much better outcome. The agency doesn't have to wait for bureaucrats to leave. It is possible that combining LPs and other rewarding schemes which are budget feasible can give rise to better outcomes. Simply changing the wage is one tool but it may not be the best tool at the disposal of the agency. We will postpone this discussion until the conclusion section.

1.4 Conclusion

Since the last couple of decades, we have seen an increase in the detection and prosecution of cartels and organised crime networks by law enforcement agencies in the light of the Leniency Programme. The law enforcement agencies implementing these Leniency Programmes do it with the help of bureaucrats. A proportion of the bureaucrats who are responsible for monitoring and preventing crime turn out to be corruptible. They engage in bribery (corruption) and not report a violation of law and let criminals have the possibility of committing future crimes. Our paper analyses and evaluates the Leniency Programme in the presence of corruptible bureaucrats. Bribe forms a major source of income for this section of the bureaucrats. In the immediate short run after the introduction of the Leniency Programme, we find that social welfare is higher than without the Leniency Programme, when the supply of bureaucrats is still fixed. But in the intermediate run when enough time for adjustment to LP is given, we find that LP affects the source of income of the bureaucrats differentially. This is to say that those bureaucrats who are less inclined to be corrupt experience a greater loss in their source of income earned through corruption. These type of bureaucrats are more likely to exit the bureaucracy leading to a systematic adverse effect. This leads to a change in the size and composition of bureaucrats thereby creating a low welfare situation than in the no leniency case. Our analysis contributes at this junction to warn policy makers of potentially withdrawing a LP without waiting for the adjustment in the supply of bureaucrats to happen. We get a situation where the interaction of self-reporting criminals with bribe taking bureaucrats increases thereby leading to increased welfare in the long

term. Thus we point out that while evaluating the merits of LPs, the time horizon is crucial.

In our analysis, the increase in wage was rewarding both optimistic and pessimistic bureaucrats equally. That is, it is rewarding the bureaucrats who are more inclined to continue with corruption and those who are not in the same way. For LP to have maximal effect what we need is a differential rewarding scheme that rewards the two types differently. For example, one could have think of a system of bonus payment for a bureaucrat who has no criminal charges and the bureaucrat with charges doesn't get the bonus. We propose to policy makers that combining LP along with other programmes can be more effective. There are other programmes than what we looked at in this the chapter that we think can achieve this. But we postpone a complete analysis of these programmes for future research.

Chapter 2

Delegation of Authority in Non-contractible Cost Setting

Chapter Abstract

We build a model of delegation of authority with a principal and two agents. Each agent has private information (signals) relevant to assess the consequence of a binary decision i.e, taking or not taking action under binary states of uncertainty. taking action turns out to be a mistake when the low state materialises. Agents incur non-contractible costs on making a mistake. Agents share monetary payoffs symmetrically but may have different non-contractible costs. We characterize truth-telling equilibria. When agents have the same non-contractible cost and principal may (or not) incur a non-contractible cost, it is irrelevant whom she delegates the decision making authority to despite the fact that agents may have very different signal precisions. Results are dramatically different when agents have asymmetrical non-contractible costs and the principal also incurs a non-contractible cost. In particular, there are situations where the principal delegates the decision making authority to the agent whom she is less aligned with in terms of preferences provided there is a sufficient degree of information asymmetry between the two agents.

2.1 Introduction

During the past three decades, there has been a growing body of work in economics and political science focusing on delegation of decision-making power. In the real world, lack of expertise and uncertainty about the state of nature are major reasons why delegation becomes necessary. Many firms choose to decentralise decision making because of costs of communication and limitations in the abilities of the agents to communicate and process information efficiently. According to Drazen (2002), “Substantial delegation of authority characterizes all governments” and there are many reasons as to why such delegation from a principal to an agent might have significant effects on what decisions are taken.

There are many works of literature that considered delegation in various settings. For example, Schelling (1960) presents strategic delegation and discusses the role of delegates as a commitment device in the context of bargaining. Vickers (1985) uses a principal-agent setting to characterize the conditions under which strategic delegation is most advantageous and discusses the implications for the theory of the firm. Fershtman and Judd (1987) and Sklivas (1987) formalise this idea of commitment through delegation.

The role of private information of the agents relative to the principal is one of the crucial aspects involved in the choice of delegation. One of the central questions of delegation theory is in case when the principal can choose between heterogeneous agents, to which agent she should delegate. We particularly focus on the case where agents can be heterogeneous in two crucial ways. Firstly, agents can have different private information. Secondly, agents may suffer from a disutility effect in a setting where crucial decision must be taken and wrong decisions (mistakes) can be made when the wrong state of the world is materialised. Delegating party may have differential alignment with the agents with respect to this disutility effect. On the other hand, one of the agents can potentially have superior information relevant to the decision that needs to be made. We model these differential preferences in our setting using non-monetary non-contractible costs. It is interesting because of a crucial trade-off. We look at the trade-off the principal faces between nominating the agent more similar to her preferences for making mistakes versus the agent better informed about the consequences of taking a decision for the organisation as

a decision maker.

When there are agents with heterogeneous private information and the principal wants to choose an agent to delegate the decision making power, then there arises a need for transmission of information between the agents. One agent has to send the information and the other agent who is the delegated agent needs to receive it. This setting is essentially a cheap talk game. So our work is also closely related to cheap talk literature. However, this chapter differs from the standard sender-receiver cheap-talk games literature Crawford and Sobel (1982) in a crucial way. In the standard cheap talk games setting, it is assumed that the preferences of both the sender and the receiver always have a bias. Utility of one agent is a shift of what the other agent gets. However, in our setting both the sender and the receiver share the same preferences if a correct decision is made. The bias in preferences exists only when a mistake is made.

In this chapter, we would like to distinguish these heterogeneous preferences (differential concerns or disutility effects) of agents and capture these differences by modelling them as non-contractible costs. We define preferences as a non-monetary, non-contractible cost (for example, a psychological cost) incurred by an agent and/or principal when a mistake has been committed and look at the delegation choice of the principal.

We focus on the following scenario. Suppose there are two agents with private information relevant to make a decision and a principal needs to delegate the decision making power to one of the two agents. The question we ask is that when one of the agents is less aligned with the principal in terms of preferences and the other more closely aligned, whether it is ever optimal for the principal to delegate the decision making power to the agent who is less aligned with her. We find that under certain conditions, there are situations where the principal delegates the decision making power to the agent with whom she is less aligned in terms of preferences provided there is a sufficient degree of asymmetry in information of the two agents.

There are two other relevant papers that look at preference biases. Che and Kartik (2009) study a setting in which a decision maker consults an expert before making a decision. They address the question of whether a decision maker should select an adviser with a different opinion or a like minded one. In their setting,

the decision maker and the adviser initially have the same fundamental preferences but have a difference of opinions about unknown state. They explore incentives for information acquisition and transmission when there is a difference of opinion about the underlying state of the world. They find that difference of opinion entails a loss of information through strategic communication but creates incentives for information acquisition. Furthermore, they find that difference of preferences can be valuable in the presence of a difference of opinion. They show that an adviser with a different opinion has more incentive to acquire information if he also has a preference bias in the direction congruent to his opinion. Jackson and Tan (2013) use a setting of experts and voters to examine the choice of a voting rule. In this setting deliberation takes place before the vote. Experts observe private signals about the values of the alternatives and can reveal or conceal it but cannot lie. They examine how disclosure and voting vary with preference biases, signal precision and voting rule. They find that a simple majority rule can be the efficient rule in some relevant settings.

Previous literature has looked at delegation when there are agents with private information and expertise which the principal lacks. In most organisations, expertise is shared across multiple agents and the agents themselves differ in terms of their preferences. For example in federal bureaucracy in the United States, this could be due to the nature of their appointments (political appointments or career bureaucrats/civil service appointments) or due to their ideologies (Eg: conservative vs. liberal). These differences would affect the way they make decisions if delegated with the power of decision-making. For instance, a political appointee bureaucrat, as a supporter of the elected official, may care more about the voter base and hence be more careful about not making a decision that would hurt their prospects of winning the next election. On the other hand, a career bureaucrat, having been in service for longer than a political appointee and knows a lot more about the workings of the agency might have more information or receive better signals about the state of nature. The career bureaucrat may not necessarily belong to the same political group as the political appointee and hence need not share the same ideology or the same preferences as them.

Most often elected officials will have to choose between political appointees and

career bureaucrats to delegate the authority to make a decision Richard Clay Wilson (2013). Question arises as to whom does the principal delegate authority to: to the agent whose preferences are aligned with her's (ideologically closest agent) or to an agent who is informationally richer.

Joshua et al. (2012) present estimates for agency preferences which confirmed that career professionals differ from political appointees. They point out that "... [the] majority of career professionals were more liberal than their appointee counterparts as well as congressional republicans and the president." Gallo and E.Lewis (2011) compare the performance of federal programs administered by appointees against those run by other appointees or career professionals and conclude that although political appointees provide presidents a source of political capital and improves accountability, it has costs for agency performance.

Dessein (2002) developed a model where agent has private information on a project and principal can choose to delegate or do it himself after recommendation from the agent. Communication will provide some information but the signal is noisy. Delegation is preferred if the bias is sufficiently small (i.e. the preferences of the principal and the agent are closely aligned) compared to his informational advantage.

Alonso and Matouschek (2008) analyse the design of optimal delegation rules in a principal-agent setting where the principal faces an informed but a biased agent. The principal who is unable to commit to contingent transfers, commits to a set of decisions from which the agent chooses his preferred one. They characterize the optimal decision rules which in practice are often very simple. They showed that such simple decision rules are optimal when the agent is sufficiently aligned with the principal. When this is not the case, they show that, optimal decision rules may contain gaps which may be optimal. This is a case when the Ally Principle (Principal delegating power to the agent whose preferences are more aligned) does not hold.

This study is relevant for a range of economic settings. As an example, consider a head of the department deciding whether she should delegate the decision making authority for the allocation of courses to TAs to either a colleague or to an administrative staff member. The colleague will likely have more information about the

courses, however might be less inclined to care about the hours of the TAs. His preferences are more likely to be aligned with that of the head of the department as they have higher chances of interacting with each other. On the other hand, the administrative staff member might not know the course details exactly but cares more about the hours of the TAs and their previous experience, though his preferences might be less aligned with that of the head of the department.

A relevant example for the model in this chapter is of a firm deciding to invest in a new and risky venture. The firm's CEO or the uninformed principal would like to delegate the decision making power to one of the two managers (agents). The managers have relevant private information to take the decision. The managers' benefits depend on the success or failure of the venture. Investing in the venture in a bad state is considered as a mistake (wrong decision). Each manager has different preferences (concerns)- which may or may not be aligned with the CEO's own concerns about making a wrong decision. These concerns can be thought of as reputation costs that are tied to their potential promotions/ bonus increments. This can also be viewed as the agents having different degrees of risk aversion. The CEO herself might have a high or low risk aversion which might be closely aligned with one of the managers and misaligned with respect to that of the other manager. These differential concerns are modelled as non-contractible costs suffered by the agents and/or the principal when a wrong decision is made. Once the CEO chooses to delegate the decision making authority to one of the managers, he will be the receiver. The other manager will now be the sender who sends his private information to the receiver. the receiver then makes the final decision of whether or not to invest in the risky venture. He makes this decision based on the aggregate information and his own non-contractible cost. We show that given sufficient degree of asymmetry in the information possessed by these different agents, there exist cases where the principal might actually delegate the decision making power to an agent who is more misaligned with her in terms of preferences.

The remainder of the chapter is organised as follows. Section 2.2 describes the model and the preferences of the agents and the principal. Section 2.3 analyses the case where both the agents have equal non-contractible costs and characterise truth-telling equilibria. In section 2.4, the case where the non-contractible cost of one of

the agents (agent A) is increased in a way that the prior biases of all the players are aligned is described and the new truth-telling equilibria are characterised. Here, we arrive at our main result: the principal under certain conditions finds it optimal to delegate the decision making power to an agent less aligned with her in terms of preferences. Section 2.5 describes an extension case where the non-contractible cost of the agent A is further increased such that there is a misalignment of prior biases. Truth-telling equilibria are characterised for this scenario. Section 2.6 concludes.

2.2 The Model

This chapter looks at the delegation of decision making authority by an uninformed principal to one of the two privately informed agents working for the principal's organisation, and at the efficient transmission of information within the organisation between the un-delegated agent and the delegated agent (i.e., the decision maker).

To fix ideas, think of a firm which can decide whether to undertake a risky venture. Uncertainty is binary: L denotes the low (i.e., the bad) state of the world, H the high (i.e., the good) state. The actors of the model are generically denoted by $i \in \{P, A, B\}$, where A and B are the two agents, P is the principal. Both agents and the principal share a common prior, $\pi \in [0, 1]$, that the good state, H , will materialise. Before the investment decision is taken, each agent (but not the principal) can observe a private signal on the realisation of uncertainty. Specifically, each agent separately receives from nature a signal $j \in \{l, h\}$ about which state of the world will realise. The precision of an agent's signal is modelled as the probability that a given realisation of the signal corresponds to a future realisation of the signalled state. Hence, the precision of the signal of agent A , $\alpha \in [\frac{1}{2}, 1]$, ranges between $\frac{1}{2}$ (fully uninformative signal) to 1 (fully informative signal). Similarly, we denote the precision of signal of agent B by $\beta \in [\frac{1}{2}, 1]$. We assume that the signals of the agents are not correlated.

The decision to be taken is also binary: to take action, that is, to undertake the risky venture, or not to take action, that is, not undertake it. The other agent will be in the position of communicating (truthfully or not) his private information to the the decision maker. In the terminology of the signalling games, the delegated

agent will act as the receiver, while the not-delegated agent will act as the sender of a “cheap talk”, transmission of information within the organisation.

Not taking action will not carry any cost or benefit to the organisation, and hence to any of the parties involved in it. This option can therefore be interpreted as a “default” or “status quo” option with no consequences for the organisation.

On the contrary, taking action carries costs and benefits, which depend on the subsequent realisation of uncertainty. Specifically, A_c requires a monetary cost (i.e., a monetary investment), c , which is borne irrespective of the state of the world. We assume that this cost is divided among the principal and the agents according to the share $\eta_i \geq 0$, $i \in \{P, A, B\}$ where

$$\sum_{i=\{P,A,B\}} \eta_i = 1$$

The same shares apply to the monetary returns, $\Delta > 0$, which A_c will affect only if the good state of the world, H materialises. Throughout this chapter, we assume that the agents share their monetary costs and benefits equally, $\eta_A = \eta_B$.

Finally, one of the main contributions of our model is to consider additional non-monetary and non-contractible costs,

$$\gamma_i \geq 0, i \in \{P, A, B\}$$

the principal and the agents will bear only if the bad state of the world, L materialises and action was taken. In other words, undertaking the action turns out to be a mistake if the “wrong” state of the world materialises, and this mistake carries non-contractible costs to the parties involved in the organisation.

Summarising, each player’s payoff is equal to zero under decision N , and under any state $\{L, H\}$. If A_c is chosen, then player i ’s payoff is:

$$\begin{aligned} &\eta_i(\Delta - c) \quad \text{if } H \\ &-\eta_i c - \gamma_i \quad \text{if } L \end{aligned}$$

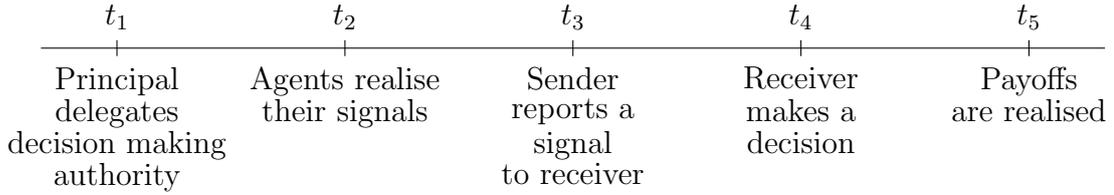


Figure 2.1: Timeline

2.2.1 Timeline of the game

The timing of the game is summarised in Figure 2.1. At time t_1 , the principal delegates the decision making authority thereby also making one of the agents the sender and the other the receiver of the internal transmission of information. At time t_2 , each agent $i \in \{A, B\}$ observes his signal $j \in \{l, h\}$. At $t = t_3$, the sender reports to the receiver about his signal. At $t = t_4$, the receiver takes a decision between (A_c, N) . At $t = t_5$, one of the two states of the world, $\{L, H\}$ materialises and the payoffs are fully realised.

2.2.2 Decision Rules

j^A	j^B	D_1	D_2	D_3	D_4	D_5	D_6
h	h	A_c	A_c	A_c	A_c	A_c	N
l	h	A_c	N	A_c	N	A_c	N
h	l	N	A_c	A_c	N	A_c	N
l	l	N	N	N	N	A_c	N

Table 2.1: Decision Rules

In this subsection, we put forward an elaboration of the model and instruments useful to understand the analysis. In what follows in this chapter, we characterise truth-telling equilibria. Table 2.1 shows the list of the relevant decision rules that can possibly happen in a truth-telling equilibrium for a possible realisation of a pair of signals.¹A decision rule maps a pair of signals into actions. Under truth-telling equilibrium, information of the sender will be reported in a truthful way to the receiver. the receiver will use the correct realisation of the two signals and map the possible realisation of the two signals into actions.

¹A complete list of all the decision rules in pure strategies is shown in the appendix 4.1.7 including the ones that never show up in any truth-telling equilibria.

Note that in the table 2.1, agent A is the sender and agent B is the receiver. Under decision rule, D_1 , the receiver takes the decision according to his own signal, i.e. he does A_c whenever he gets h and N when he gets l . Under D_2 , the receiver takes the decision according to the sender's signal, i.e. he does A_c whenever the sender reports h and N when the sender reports l . Under D_3 , he does A_c if either he gets signal ' h ' from nature or the sender reports h . He does N he get ' l ' and the sender also reports l . Under D_4 the receiver decides to do A_c only when he gets ' h ' and also the sender reports h , else he does N . Under D_5 , the receiver does A_c in all signal configurations. Similarly, under D_6 decision rule, the receiver does N in all signal configurations.

2.2.3 Fundamental inequality

In this subsection, we present another important tool which is used to solve the model. The principal and the agents may have their prior biased toward taking one of the actions in $\{A_c, N\}$.

Definition 1 (Action Biased Prior) *An agent i is said to have an Action Biased Prior (respectively No Action Biased Prior) if his expected benefits from doing A_c outweigh (resp., fall short) the expected costs, where expectations are taken according to the agent's prior beliefs on the two states of the world. Equations (2.1) and (2.2) below formalise Action Biased Prior and No Action Biased Prior respectively.*

$$\pi(\Delta - c) > (1 - \pi)\left(c + \frac{\gamma_i}{\eta_i}\right) \quad (2.1)$$

$$(1 - \pi)\left(c + \frac{\gamma_i}{\eta_i}\right) > \pi(\Delta - c) \quad (2.2)$$

In the following sections, we fix B 's non-contractible cost at $\gamma_B > 0$ and his prior bias as *Action Biased Prior*. We proceed to characterize truth-telling equilibria under the following alternative assumptions in agent A 's preferences.

a) When A 's non-contractible cost is equal to that of agent B , $\gamma_A = \gamma_B$ (so agent A exhibits an *Action Biased Prior*). Under this case, we show that truth telling equilibrium always exists (in all parametric configurations) and is the only other equilibrium besides the babbling one. We show that it is irrelevant whom the prin-

principal chooses to delegate the decision making power to even when the signal precision is asymmetric.

b) When $\gamma_A > \gamma_B$ but agent A still exhibits an *Action Biased Prior*. Under this case, we show that the principal may delegate the decision making authority to the agent who is less aligned with her in terms of preferences, provided there is a sufficient degree of asymmetry in the precision of the signals of the two agents.

c) When $\gamma_A > \gamma_B$ in such a way that A now exhibits a *No Action Biased Prior*. We show that the principal finds it optimal to delegate the decision making power to the agent who is closely aligned with her in terms of preferences when the signal precisions of the two agents are very low.

2.3 Symmetrical Non-contractible Costs Case ($\gamma_A = \gamma_B$)

We begin by characterizing the truth-telling equilibria in the benchmark case where:

- 1) The preferences of the two agents are identical, that is, the non-contractible costs of both the agents are equal, $\gamma_A = \gamma_B$.
- 2) The prior bias of both the agents is the same, *Action Biased Prior*.
- 3) Agents share the monetary payoffs in the same proportion, $\eta_A = \eta_B$.

With no loss of generality, let us assume that agent B is the receiver who makes the decision while agent A is the sender. Graph 2.2 shows all the truth-telling equilibria in the signal precision space $(\alpha, \beta) \in [0.5, 1]$.² As we can see in the graph, the entire signal precision space is covered. Different colored regions correspond to truth-telling equilibria with different decision rules. There is no over-lapping of regions and there is complete coverage, meaning that for each signal precision pair, there is a unique truth-telling equilibrium. The aggregation of information is efficient when there is no misalignment of preferences between the two agents. Each agent takes the same decision with the same probability for any arbitrary combination of signal precisions (α, β) .

For example, consider the truth-telling region occupied by the blue region when

²The analytical derivations of the truth-telling equilibria is detailed in the Appendix 4.1. Also refer to table 2.2 where the crucial conditions for the decision rules are outlined.

agent B is the decision maker (refer to the graph on the left side of figure 2.2). The region is characterised by a relatively high β compared to α . Agent B 's signal is relatively more informative. Here, truth-telling equilibrium is characterised by the decision rule, D_1 , whereby the decision maker just follows what is suggested by his own signal. Agent B trusts his own signal completely and takes action only when he receives $j_B = h$ and no action whenever he receives $j_B = l$ regardless of the information sent by agent A .

Notice that by lying, agent A cannot change the decision of B and hence he does not have an incentive to deviate from truth-telling. Intuitively, as β becomes very high (i.e., close to 1), agent B 's trust in his own signal strengthens and naturally D_1 will continue as the decision rule under truth-telling. Suppose, under the same signal precision configuration the roles of the sender and the receiver are swapped and that agent A is made the decision maker. Then, agent A would follow decision rule D_2 (refer to the yellow region in the right graph of figure 2.2). Under D_2 , the decision maker will take action only when the sender reports h and N whenever he reports l . He completely trusts the signal of the sender. In terms of outcome, this is equivalent to the sender (in this case, B , if made the decision maker) following decision rule D_1 .

On the contrary, by decreasing β by a sufficient amount, we will leave the truth-telling equilibrium region with decision rule D_1 and enter a truth-telling region with a different decision rule, D_3 (green region). Under this decision rule, the decision maker, agent B , does not trust his own signal as much as he trusted his signal under D_1 as it is relatively less informative than it was in the blue region. He starts paying attention to the information he receives via the sender, agent A 's signal thereby taking action also when agent A reports $j_A = h$ and no Action only when both the agents have a low signal, $j_i = l$ besides taking action when he gets a high signal, $j_B = h$. Suppose that the roles of the sender and the receiver are swapped and now agent A is made the receiver who takes the decision under this signal configuration, the incentives for agent A are also to follow decision rule D_3 .

Consider again the case where agent B is the receiver who will be the decision maker. If β is decreased further, we will end up in the truth-telling region characterised by decision rule D_2 (yellow region). The signal precision of the sender,

agent A is high, his signal is highly informative. In this case, the decision maker B takes the decision only according to the report of the sender A , that is, if the sender reports high, $j_A = h$, agent B decides to take action and if he reports low, $j_A = l$, he decides to do N . On the other hand, if A were the decision maker and B is the sender, then A would do the same, that is, listen only to himself and not pay attention to the report sent by B . So, agent B does not have an incentive to lie as he cannot influence the decision of the receiver. In terms of outcome, agent B following decision rule D_1 (D_2) when he is the decision maker is equivalent to agent A following decision rule D_2 (D_1). These decision rules map the signal configurations into actions with the same probability as outlined in table 4.2 in the Appendix 4.1.9.

Consider the truth-telling region characterised by D_5 (pink region). This is a small region at and around $[0.5, 0.5]$. Here the signals of both the sender and the receiver are relatively uninformative and whoever is the decision maker, they just decide according to their prior. Since both the agents have an *Action Biased Prior*, they decide to do A_c in all possible signal configurations in this pink region. Both the agents would again want to take the same decision with the same probability and hence there is no incentive to deviate from truth-telling. It is easy to see that if the agents don't suffer any non-contractible cost ($\gamma_A = \gamma_B = 0$), then they would always go by their prior and follow the decision rule D_5 , taking A_c under all signal precisions.

To summarize, under this symmetrical non-contractible costs case, whoever the decision maker is, they take the same action (A_c or N) with the same probability although the decision rule itself might be different depending on who is making the decision. Efficient aggregation of information takes place which means that, through different decision rules mapping pair of signals (truthfully reported to the decision maker) into actions, the same mapping of pair of signals into actions will be obtained irrespective of the identity of the decision maker (agent delegated to take the decision). Under this benchmark case, efficient aggregation of information takes place with identical preferences of agents. We show that regardless of the asymmetry in individual agents' precision of private information, the outcome to the principal is the same irrespective of who she delegates the decision making authority to.

Formally, this efficient information aggregation arises from the symmetric property of the decision rules regions as outlined in Lemma 1.

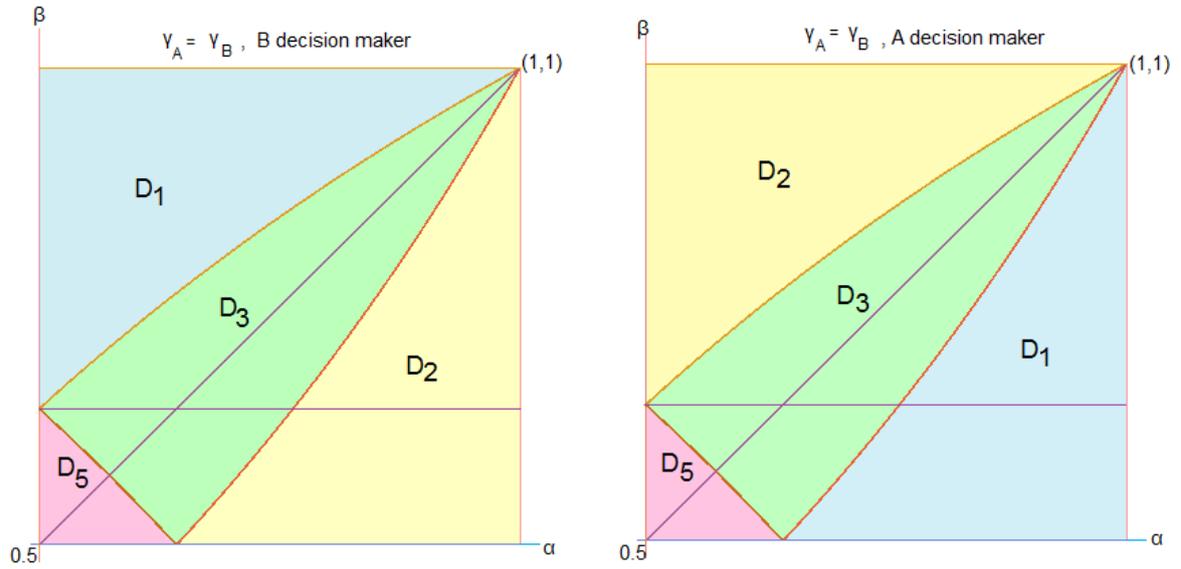


Figure 2.2: Symmetric case: $\gamma_A = \gamma_B$

Lemma 2.3.1 *The contours of the decision rules are symmetric about the 45 degree line.*

Proof See Appendix 4.1.8. □

We put forward the result of this symmetrical non-contractible costs case in the following proposition.

Proposition 2.3.1 *Assume that:*

1. *The agents have an Action biased Prior, that is, definition 1 holds for any $i \in \{A, B\}$*
2. *The agents are identical in their non-contractible costs, $\gamma_A = \gamma_B$.*

Then, regardless of the signal precisions of the agents, delegation is irrelevant in the sense that the principal is always indifferent about which of the two agents to delegate the decision making power.

Proof See Appendix 4.1.9. □

2.4 Symmetric Prior Bias $\gamma_A > \gamma_B$, A , B and P with Action Biased Prior

We now look at the case where the preferences of the agents are misaligned. In particular, the non-contractible cost of agent A is higher than that of agent B ($\gamma_A > \gamma_B$). However sufficiently low such that agent A still exhibits an *Action biased prior*. At the same time assume that, γ_B in this case is still equal to the γ_B used under the benchmark (symmetric non-contractible cost) case. Agent B and the principal still have an *Action biased prior*. Since both the agents and the principal have an *Action biased prior*, we call it Symmetric Prior Bias. The revenues between the two agents are still shared symmetrically, that is $\eta_A = \eta_B$. The ranking of the preferences are such that $\gamma_A > \gamma_B > \gamma_P$ where γ_P is closer to γ_B than it is to γ_A . We characterize the truth-telling equilibria for the above scenario.

Figure 2.3 shows the truth-telling equilibria for this case. One immediate observation can be made. This graph is similar to the graph of the benchmark case.

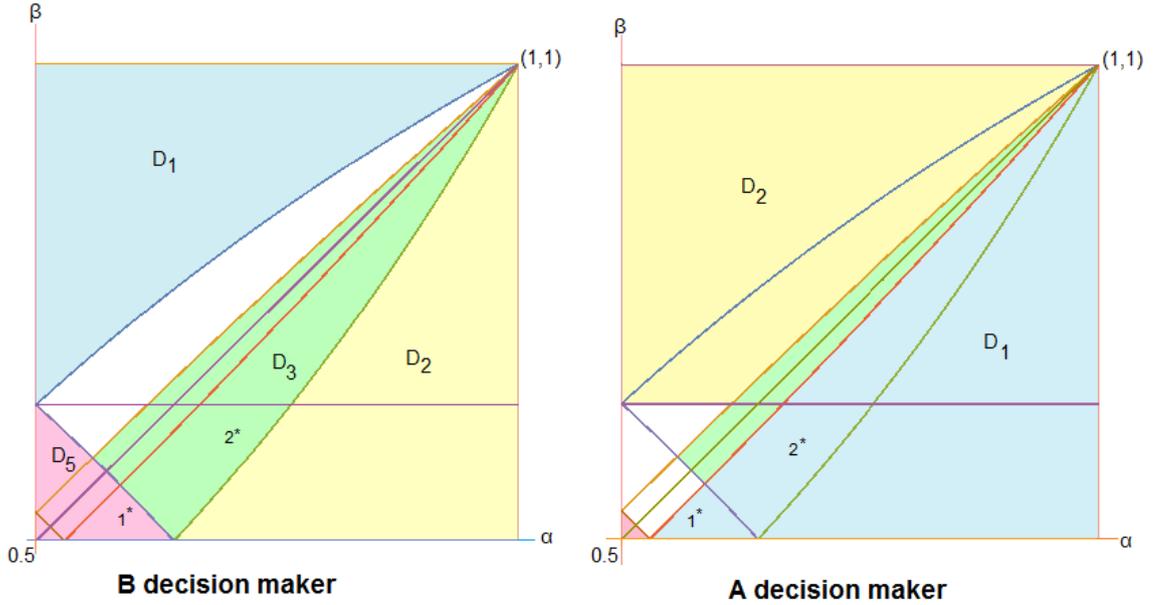


Figure 2.3: Symmetric Prior Bias: $\gamma_A > \gamma_B$

Truth-telling equilibria are characterised by different decision rules. However, with a Symmetric Prior Bias in the non-contractible costs of the agents, there are certain regions of the signal precision space where a truth-telling equilibrium does not exist. These regions are shown as the white regions in figure 2.3. In the following subsections, we explore the incentives of each agent to follow different decision rules when each of them are made the decision maker given the difference in their non-contractible costs.

2.4.1 B as decision maker

Consider first the case where agent B is the decision maker and agent A is the sender.³ Observe that in this case when agent B is made the decision maker, the truth-telling region where the decision rule is D_3 (where the decision maker always takes action always except when both agents receive $j_i = l$), is smaller compared to the area of truth-telling region has the decision rule D_3 under the benchmark case. Because the decision maker B 's non-contractible cost, γ_B is the same as it was under $\gamma_A = \gamma_B$ case, he would like to continue following the decision rule D_3 according to

³The crucial conditions from the analytical derivations of the decision rules under this case that characterise the truth-telling equilibria are given in table 2.3.

his incentive constraints. However, γ_A , A 's non-contractible cost has now increased and so he would like agent B to follow a decision rule that has lower probability of taking action under all the signal configurations. This can be understood in the following way.

Choose an arbitrary point (α, β) in the signal precision space of the truth-telling region where the decision rule is D_1 (see blue region of figure 2.3). Fix α and start lowering β until it crosses the contour of decision rule D_1 . Under the benchmark, $\gamma_A = \gamma_B$ case, we would be entering D_3 in this region of the signal precision space. Under this case too, the incentives of agent B did not change and he would like to continue following decision rule D_3 . However, now agent A has higher concern, $\gamma_A > \gamma_B$. Whenever he gets a high signal $j_A = h$, he has an incentive to lie and report $j_A = l$ in order to change the decision of agent B to take no action instead of A_c (possible when B also received an l). Agent B will take action if his private information is $j_B = h$ or he gets h from agent A , $j_A = h$ and takes no action if his signal is $j_B = l$ and gets l from agent A , $j_A = l$. The net expected benefits from taking action to agent A are lower than the expected benefit agent B would get from taking action because the non-contractible cost of agent A is higher than that of agent B .

Although, the incentive is still in favour of taking action because agent A exhibits an *Action biased prior* which is not as high as it was under the benchmark case for agent A . Therefore, there is no incentive for agent A to always tell the truth in a region where both the signals are good enough but the net expected benefits from doing A_c to A are not as high as they were under the benchmark case. Here agent B might still want to take action but agent A might not take the same decision if they were the decision maker. As γ_A keeps increasing, agent A 's concern increases further and the incentives for lying also increase thereby increasing the non truth-telling region (the white area).⁴This will keep decreasing the truth-telling area characterised by D_3 until the point that it completely vanishes when agent A 's concern is very large. This would happen at a much faster rate if agent A were the decision maker.

⁴There are babbling equilibria in the non truth-telling regions which are beyond the scope of this chapter and hence not discussed here.

2.4.2 A as decision maker

Consider now the case where we swap the roles of the sender and the receiver and let agent A be the receiver who will be the decision maker and agent B be the sender.⁵The truth-telling equilibria for this case are shown in the right side graph of the figure 2.3.

Consider a point (α, β) in the truth-telling equilibrium characterised currently by decision rule D_1 (any point in D_1 in the blue region which is very close to the contour of D_3) which was previously characterised by decision rule D_3 under the benchmark, $\gamma_A = \gamma_B$ case. The incentive constraints for agent A dictate that he follows decision rule D_1 because γ_A is now higher (thereby increasing his concern). But agent B 's incentives dictate him to continue carrying out decision rule D_3 as γ_B has not changed from the benchmark case. But notice that by lying, agent B cannot influence agent A 's decisions. The decision maker, agent A does not pay attention to B 's signal and takes the decision only according to his private information and follow the decision rule D_1 .

Consider a point in the white region (a region in the signal precision space which was previously characterised by D_3 under $\gamma_A = \gamma_B$ case) near the contours of decision rules, D_2 and D_3 . Under this signal configuration, if agent B was the decision maker, he would like to continue following D_3 . However, with increased Non-contractible cost, γ_A and with β falling, agent A would like to do continue following decision rule D_2 . But now B can lie and influence A 's decisions as A is completely relying on the information sent by B to take the decision. That is why there is a non truth-telling equilibrium here.

Now, consider a point in the white region between the truth-telling regions filled by D_3 and D_5 . In the pink region agent A is fine with executing decision rule D_5 until a small signal precision close to $\frac{1}{2}$. But if we start moving horizontally to the right or vertically up away from the pink region, the signal precisions increase and with increased γ_A , agent A has higher concern. So he would like to do D_3 instead of D_5 . However, if agent B were the decision maker whose concern didn't change from the $\gamma_A = \gamma_B$ case, he would like to continue executing D_5 which is now in the

⁵The crucial conditions from the analytical derivations of the decision rules under this case that characterise the truth-telling equilibria are given in table 2.4.

white region. So the sender, agent B has an incentive to lie and change agent A 's decision.

The expected costs of taking action to agent A are higher than they were under the $\gamma_A = \gamma_B$ case because of the higher non-contractible cost, γ_A . The size of the truth-telling region where the decision rule D_5 happens is smaller in this case than it was in the benchmark case and the case where B was the decision maker. This is the region where signals are uninformative. In the $\gamma_A = \gamma_B$ case or in the symmetric case with B as the decision maker, when the signals were uninformative, it was optimal to always take action because the expected benefits from doing A_c are higher compared to the expected costs of doing A_c .

In this case where agent A is the decision maker, the expected benefits from A_c are still higher than the expected costs from A_c . But the non-contractible cost (γ_A) of agent A is higher than it was in the $\gamma_A = \gamma_B$ case. This means that although the expected benefits to A from A_c are higher than the expected costs of A_c , they are not as high as they were in the $\gamma_A = \gamma_B$ case. Hence when A is given the decision making power, they would still take action in a small region where the signals are informative, but the incentive to always do A_c starts decreasing when the signals start becoming informative. But if agent B was the decision maker, then he would like to always do A_c in this region like in the benchmark case. This explains the reason for the white region in between the truth-telling regions D_3 and D_5 .

2.4.3 Delegation of Authority by Principal

Given the analysis in the above subsections, this subsection investigates the principal's choice of delegation of authority. For the sake of analysis, assume the principal's non-contractible cost, $\gamma_P < \gamma_B$ and that of agent B is closely aligned with her in terms of preferences. Who would she be better off delegating the decision making power to? We can see that under truth-telling with asymmetry in non-contractible costs, when the agents have equal signal precision (on the 45 degree line), they follow the same decision rule either D_5 or D_3 . However, they follow different decision rules when their signals have different precision. We show that under certain conditions, the principal would like to delegate the decision making authority to the agent

whose preferences are less aligned with her's. Please refer to table 2.5 for a list of decision rules that characterise the truth-telling equilibria when the decision maker is agent B or agent A in different regions of the signal precision space. Notice also that under certain signal precision space, the decisions taken are the same with the same probability (although the decision rules vary) even when the decision makers are swapped. We call these cases as neutrality cases as there is no outcome difference to the principal and she is irrelevant whoever the decision making authority is delegated to. In that case, there will not be any difference to the expected revenues to the principal.

Neutrality Cases

With equal signal precision, $\beta = \alpha$, the outcomes are exactly same whoever the decision maker is. They are D_5 and D_3 on the diagonal based on how informative the signals are. Therefore, it is irrelevant to the principal who the decision making power is given to. The expected revenues to the principal will be same whoever is the decision maker. There are also regions of the signal precision space where agent B if made the decision maker is following decision rule D_1 (taking the decision only according to his own signal β and not paying attention to A 's signal). Whereas for the same signal precision configuration, if agent A is the decision maker, then he would follow decision rule, D_2 . However, as you can notice from table 4.2, the signal configurations under the decision rule D_1 when agent B is the decision maker and decision rule D_2 when agent A is the decision maker map into the same actions. Thus, once again there is outcome indifference for the principal whoever the decision maker is. The analysis is similar in the case of agent B following decision rule D_2 (taking decision completely trusting the sender's signals and not paying any attention to his own) when made the decision maker or agent A following decision rule D_1 when he is the decision maker. Once again, it is irrelevant whom the principal chooses to delegate the decision making power to.

Non- Neutrality Cases

Comparing the cases where there is relevance (i.e., there is outcome difference to the principal depending on who the decision making authority is delegated to) will

give rise to conditions for the optimal delegation rule for the principal. These cases are called non-neutrality cases. If we consider the region below the diagonal, where the signal of agent A is relatively more informative than that of agent B 's, ($\alpha > \beta$), we observe that if B is the decision maker then he follows decision rule D_5 (see 1*) whereas agent A follows D_1 . In the region marked as 2*, agent B follows the decision rule D_3 if he is the decision maker whereas agent A follows the decision rule D_1 if he is given the role of the decision maker. Hence, there will be differences in the expected payoff to the principal based on whom she delegates the decision making authority to. We show the calculations in the appendix 4.1.10. The results of the analysis in this section with Symmetric Prior Bias in the non-contractible costs of the agents can be summarized in the following proposition.

Proposition 2.4.1 *Suppose the following conditions hold:*

1. *Both the agents and the principal have an Action Biased Prior, that is, definition 1 holds for any $i \in \{P, A, B\}$ and the non-contractible cost of one agent is higher than that of the other, $\gamma_A > \gamma_B$.*
2. *The principal's non-contractible cost is γ_P and it is lower than that of the agents' non-contractible costs, i.e., $\gamma_A > \gamma_B > \gamma_P$.*

Then, there exist non-degenerate intervals of the signal precisions α and β such that irrespective of the decision-making allocation, the agents share information truthfully. Nonetheless, the principal prefers to allocate the decision making authority to the agent with whom her preferences are less aligned.

Proof See Appendix 4.1.10. □

We show that it is possible for the principal to delegate the decision making power to an agent less aligned with her in terms of preferences when there is a sufficient degree of asymmetry between the signal precisions of the agents. The main intuition is that the principal may want to delegate the decision making authority to the agent who is less aligned to her in terms of preferences provided that the quality of information of the agent compared to the other agent's information is superior enough to outweigh the misalignment of preferences. Necessary to establish our result is that there is a sufficient degree of asymmetry in the signal precisions of the two agents. This along with the asymmetry in their non-contractible costs creates a

differential in the expected benefit to the principal. It is possible that the expected benefit of the principal from delegating the decision making authority to one agent (agent A in this case) is greater than the expected benefit derived from delegating to the agent closest to her in terms of preferences (agent B in this case).

The principal therefore faces a trade-off. The trade-off is between delegating the decision making authority to the agent (A) who is less aligned with her in terms of preferences and delegating it to the agent (B) closely aligned with her in terms of preferences. The agent who is misaligned with the principal in terms of preferences is also the agent with superior information and a higher non-contractible cost. If the decision making authority is delegated to this agent, he reduces the likelihood of taking action and thereby reducing the expected monetary revenues. However, this also reduces the likelihood of making a mistake. The other agent who is more closely aligned with the principal (agent B) if delegated with the decision making power increases the likelihood of taking action but has a lower signal precision and also increases the likelihood of making mistake due to lower non-contractible cost. We show that when there is a sufficient degree of asymmetry in the quality of information, it is possible that this trade-off resolves in favour of the agent less aligned with the principal in terms of preferences and she finds it optimal to delegate the decision making authority to this agent.

2.5 Asymmetric Prior Bias $\gamma_A > \gamma_B$

Under this case, the non-contractible cost of A , γ_A is so high that the fundamental inequality which was biased in favour of taking action in the Symmetric Prior Bias case is now reversed and is biased in favour of taking no action. The truth-telling equilibria when agents B and A are given the roles of the decision maker are depicted graphically in the figure 2.4. For notational convenience we use,

$$x = \Delta - c$$

$$z_i = c + \frac{\gamma_i}{\eta_i}$$

We find that the non-neutrality cases from the Symmetric Prior Bias case continue to exist here. Hence, the analysis from the Symmetric Prior Bias case holds good under this case too. Apart from these cases, unsurprisingly, we also find that there is another non-neutrality case where agent B always prefers to follow decision rule D_5 when he is the decision maker and agent A always prefers to follow decision rule D_6 when he is the decision maker. This is the region in the signal precision space where the signal precisions are very low (highly uninformative signals).⁶

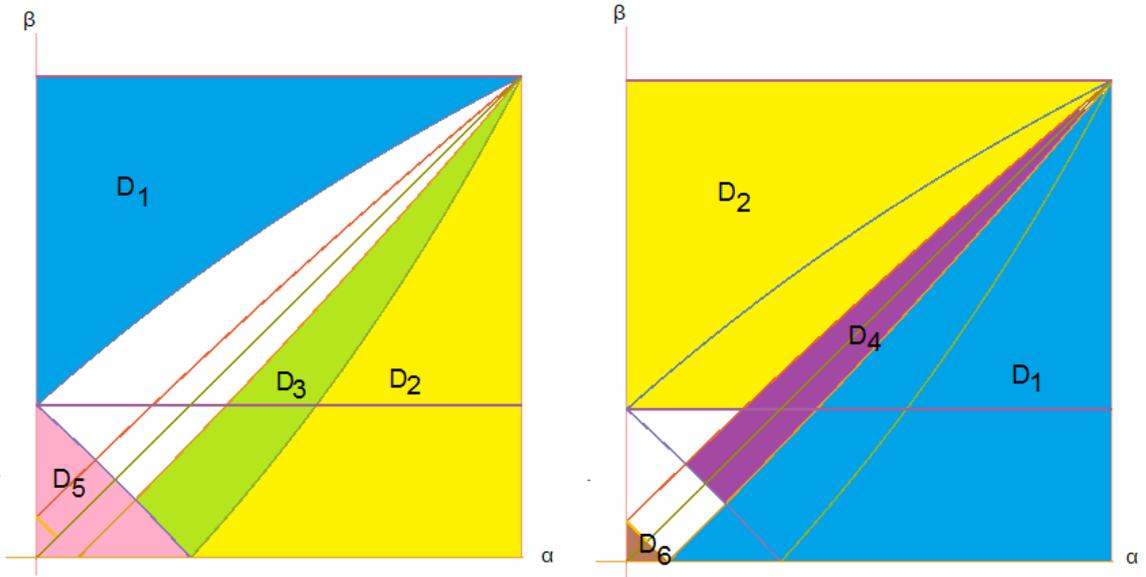


Figure 2.4: Asymmetric Prior Bias: $\gamma_A > \gamma_B$

Under the Asymmetric Prior Bias case, table 2.7 gives the decision rules that characterise the truth-telling equilibria when agent B is the decision maker and when agent A is the decision maker in the entire space of signal precisions.

Under the Asymmetric Prior Bias, to the principal D_5 vs D_6 gives

$$\pi x \geq (1 - \pi)z_P \quad (2.3)$$

where $x = \Delta - c$ and $z_P = c + \frac{\gamma_P}{\eta_P}$

From the above condition, it can be seen that if the signals are uninformative, the

⁶The crucial conditions for the decision rules that characterise the truth-telling equilibria under this case are given in table 2.6.

principal has to go by the prior bias while deciding on the optimal delegation rule. Since the principal exhibits an *Action Biased Prior*, she finds it optimal to delegate the decision making to the agent who is closely aligned with her in terms of preferences when the signal precisions of the two agents are very low.

2.6 Conclusion

This chapter builds a theoretical model of delegation of decision making authority with a principal and two agents. Both agents receive private information relevant for making one decision. The principal needs to delegate the decision making power to one of the two agents. The agents and the principal privately suffer from a non-monetary, non-contractible cost when a wrong decision (mistake) is made. These costs, for example, can be thought of as psychological costs or reputation costs. We assume the agents share the profits and monetary costs equally. We show that the principal finds it irrelevant to whom she delegates the decision making power if the agents have identical non-contractible costs. Suppose, one of the agents has a higher non-contractible cost than that of the other and the principal is more closely aligned to one of the agents. Due to the misalignment in their preferences, we find that the agents end up following different decision rules under cases where there is enough asymmetry in their signal precisions. When the signal precisions of the two agents is exactly identical, the principal is always indifferent whom to delegate the decision making power to. The question we ask in this chapter is whether it is ever optimal for the principal to delegate the decision making power to the agent who is less aligned with her in terms of preferences. We find that it is possible the principal delegates the decision making power to the agent with whom she is less aligned in terms of preferences provided there is a sufficient degree of asymmetry in signal precisions of the two agents.

Table 2.2: $\gamma_A = \gamma_B$

D_1	D_2	D_3	D_5
$\beta > \frac{1}{1 + \frac{\frac{\gamma_B}{\eta_B}(c + \frac{\gamma_B}{\eta_B})}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$\beta < \frac{1}{1 + \frac{\frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$i) \text{ if } \alpha > \frac{\pi x}{\pi x + (1-\pi)(c + \frac{\gamma_B}{\eta_B})}$	$\beta \leq \frac{1}{1 + \frac{\frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}}{\pi x} \frac{(1-\alpha)}{\alpha}}$
$\beta > \alpha$	$\beta < \alpha$	$\beta \leq \frac{1}{1 + \frac{\frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$\alpha < \frac{\pi x}{\pi x + (1-\pi)(c + \frac{\gamma_B}{\eta_B})}$
$\alpha \geq \frac{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}{\pi x + (1-\pi)(c + \frac{\gamma_B}{\eta_B})}$	$\alpha \geq \frac{\pi x}{\pi x + (1-\pi)(c + \frac{\gamma_B}{\eta_B})}$	$\beta > \frac{1}{1 + \frac{\frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}}{\pi x} \frac{(1-\alpha)}{\alpha}}$	
		$ii) \text{ if } \alpha < \frac{\pi x}{\pi x + (1-\pi)(c + \frac{\gamma_B}{\eta_B})}$	
		$\beta \leq \frac{1}{1 + \frac{\frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}}{\pi x} \frac{(1-\alpha)}{\alpha}}$	
		$\beta > \frac{\pi x}{1 + \frac{\pi x}{(1-\pi)(c + \frac{\gamma_B}{\eta_B})} \frac{(1-\alpha)}{\alpha}}$	

* $x = \Delta - c$, $z_i = c + \frac{z_i}{\eta_i}$

Table 2.3: $\pi x > (1 - \pi)z_A$ and $\pi x > (1 - \pi)z_B$, B as decision maker

D_1	$\beta > \frac{1}{1 + \frac{(1-\pi)z_B}{\pi x} \frac{(1-\alpha)}{\alpha}}$ $\beta > \alpha$ $\alpha \geq \frac{(1-\pi)z_B}{\pi x + (1-\pi)z_B}$	D_2	$\beta < \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\alpha)}{\alpha}}$ $\beta < \alpha$ $\alpha \geq \frac{\pi x}{\pi x + (1-\pi)z_B}$	D_3	$i)$ if $\alpha > \frac{\pi x}{\pi x + (1-\pi)z_B}$ $\beta \leq \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\alpha)}{\alpha}}$ $\beta > \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\alpha)}{\alpha}}$ $i i)$ if $\alpha < \frac{\pi x}{\pi x + (1-\pi)z_B}$ $\beta \leq \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\alpha)}{\alpha}}$ $\beta > \frac{\pi x}{\pi x + (1-\pi)z_B}$	D_4	$\beta < \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\alpha)}{\alpha}}$ $\beta > \frac{1}{1 + \frac{(1-\pi)z_B}{\pi x} \frac{(1-\alpha)}{\alpha}}$ $\alpha > \frac{\pi x}{\pi x + (1-\pi)z_B}$	D_5	$\beta \leq \frac{1}{1 + \frac{(1-\pi)z_B}{\pi x} \frac{(1-\alpha)}{\alpha}}$ $\alpha < \frac{\pi x}{\pi x + (1-\pi)z_B}$	D_6	$\beta \leq \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\alpha)}{\alpha}}$ $\alpha < \frac{(1-\pi)z_B}{\pi x + (1-\pi)z_B}$
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Table 2.4: $\pi x > (1 - \pi)z_A$ and $\pi x > (1 - \pi)z_B$, A as decision maker

D_2	D_1	D_3	D_4	D_5	D_6
$\alpha < \frac{1}{1 + \frac{\pi x}{(1-\pi)z_A} \frac{(1-\beta)}{\beta}}$ $\alpha < \beta$ $\beta \geq \frac{\pi x}{\pi x + (1-\pi)z_A}$	$\alpha > \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\beta)}{\beta}}$ $\alpha > \beta$ $\beta \geq \frac{\pi x}{\pi x + (1-\pi)z_A}$	$i)$ if $\beta > \frac{\pi x}{\pi x + (1-\pi)\sqrt{z_A z_B}}$ $\alpha \leq \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\beta)}{\beta}}$ $\alpha > \frac{1}{1 + \frac{\pi x}{(1-\pi)z_A} \frac{(1-\beta)}{\beta}}$ $ii)$ if $\beta < \frac{\pi x}{\pi x + (1-\pi)\sqrt{z_A z_B}}$ $\alpha \leq \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\beta)}{\beta}}$ $\alpha > \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\beta)}{\beta}}$	$\alpha < \frac{1}{1 + \frac{\pi x}{(1-\pi)z_B} \frac{(1-\beta)}{\beta}}$ $\alpha > \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\beta)}{\beta}}$ $\beta > \frac{\pi x}{\pi x + (1-\pi)z_A}$	$\alpha \leq \frac{1}{1 + \frac{(1-\pi)z_A}{\pi x} \frac{(1-\beta)}{\beta}}$ $\beta < \frac{\pi x}{\pi x + (1-\pi)z_A}$	$\alpha \leq \frac{1}{1 + \frac{\pi x}{(1-\pi)z_A} \frac{(1-\beta)}{\beta}}$ $\beta < \frac{1}{\pi x + (1-\pi)z_A}$

Symmetric Prior Bias Comparison of Decision Rules		
Signal Precision Space	B	A
$\beta > \alpha$	D_1 D_3 D_5 D_5	D_2 D_3 D_5 D_2
$\beta = \alpha$	D_3 D_5	D_3 D_5
$\beta < \alpha$	D_2 D_3 D_5	D_1 D_1 D_1

Table 2.5: Symmetric Prior Bias Comparison (Note: B-receiver, A-sender)

Table 2.6: $(1 - \pi)z > \pi x$

D_1	D_2	D_3	D_4	D_5	D_6
$\beta > \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$	$\beta < \frac{1}{1 + \frac{(1-\pi)z}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$\beta \leq \frac{1}{1 + \frac{(1-\pi)z}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$i)$ if $\alpha < \frac{(1-\pi)z}{\pi x + (1-\pi)z}$	$\beta \leq \frac{1}{1 + \frac{(1-\pi)z}{\pi x} \frac{(1-\alpha)}{\alpha}}$	$\beta \leq \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$
$\beta > \alpha$	$\beta < \alpha$	$\beta > \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$	$\beta < \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$	$\alpha < \frac{\pi x}{\pi x + (1-\pi)z}$	$\alpha < \frac{(1-\pi)z}{\pi x + (1-\pi)z}$
$\alpha \geq \frac{\pi x}{\pi x + (1-\pi)z}$	$\alpha \geq \frac{(1-\pi)z}{\pi x + (1-\pi)z}$	$\alpha > \frac{\pi x}{\pi x + (1-\pi)z}$	$\beta > \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$ $ii)$ if $\alpha > \frac{\pi x + (1-\pi)z}{\pi x + (1-\pi)z}$		
			$\beta < \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$		
			$\beta > \frac{1}{1 + \frac{\pi x}{(1-\pi)z} \frac{(1-\alpha)}{\alpha}}$		

Asymmetric Prior Bias Comparison of Decision Rules		
Signal Precision Space	B	A
$\beta > \alpha$	D_1	D_2
	D_5	D_2
	D_5	D_6
$\beta = \alpha$	D_5	D_6
$\beta < \alpha$	D_2	D_1
	D_3	D_1
	D_5	D_1
	D_5	D_6

Table 2.7: Asymmetric Prior Bias Comparison (Note: B-receiver, A-sender)

Chapter 3

Delegation of Authority in Non-contractible Cost Setting: Analysis of the non truth-telling equilibria

Chapter Abstract

This chapter builds on the model of delegation of authority with non-contractible costs developed in chapter 2. The earlier chapter examined this issue under truth-telling equilibria. This chapter extends the analysis to a situation when such equilibria do not exist. In particular, we show that the non irrelevancy result where the principal strictly prefers to delegate authority to the agent who is less aligned with her in terms of preferences can arise in this chapter under a different set of conditions. The result achieved in chapter 2 required an asymmetry in the signal precisions of the two agents. There, whenever the signal precision of the two agents was identical, we had irrelevancy, that is, the principal was indifferent between which of the two agents to delegate the decision making power to. In this chapter, we achieve a non-irrelevancy result when the signal precisions of the two agents are identical which was not possible in chapter 2.

3.1 Introduction

In this chapter, we build on the theory of delegation of authority with non-contractible costs using the principal agent model that we developed in chapter 2. The model has a principal looking to delegate authority to one of two agents at her disposal. Each agent has private information relevant to assess the consequence of a binary decision i.e, taking or not taking action under binary states of uncertainty. When an action is taken and the state of the world materialises to be low, it is defined as a mistake. Agents incur non-monetary, non-contractible costs when committing a mistake. Agents may have heterogeneous non-contractible costs. The payoff structure of the agents is exactly as described in the model description of chapter 2. We characterized truth-telling equilibria in chapter 2. When agents have the same non-contractible cost and share the profits and costs equally and the principal may (or not) incur a non-contractible cost, it is irrelevant whom she delegates the decision making authority to despite the fact that agents may have very different signal precisions. There are cases where different preferences (non-contractible costs) incentivised them to take different decisions provided there is a sufficient degree of asymmetry in the information of the two agents. Given this situation, we investigated the conditions under which the principal would delegate the decision making authority to the agent with whom her preferences are less aligned.

We extend the analysis of chapter 2 to situations where truth-telling equilibria does not exist. There are some parametric configurations for which information aggregation is not efficient and no truth-telling equilibria exist. We focus on the babbling equilibria. In chapter 2, under truth-telling equilibrium, when the agents have symmetric signal precisions, they would always take the same decision even when their preferences were different. However, when there are no truth-telling equilibria and the preferences of the two agents are not aligned, we find that even when the signal precisions of the two agents are exactly the same, they follow different decision rules. In this chapter, we analyse the optimal delegation rule of the principal and find that it is again possible that she strictly prefers to delegate the decision making power to the agent with whom her preferences are less aligned. In this chapter, we essentially arrive at the interesting result we got in chapter 2 when there is symmetry in the signal precisions of the two agents.

The rest of the chapter is organised as follows. Section 3.2 reminds the readers of the structure of the model. Section 3.3 describes the case of our interest and derives conditions for the decision rules the agents may follow under non truth-telling equilibrium. It also states and discusses the result. Section 3.4 concludes.

3.2 Model

The chapter looks at the delegation of decision making authority by an uninformed principal to one of the two privately informed agents working for the principal's organisation, and at the efficient transmission of information within the organisation between the un-delegated agent and the delegated agent (i.e., the decision maker).

To fix ideas, think of a firm which can decide whether to undertake a risky venture. Uncertainty is binary: L denotes the low (i.e., the bad) state of the world, H the high (i.e., the good) state. The actors of the model are generically denoted by $i \in \{P, A, B\}$, where A and B are the two agents, P is the principal. Both agents and the principal share a common prior, $\pi \in [0, 1]$, that the good state, H , will materialise. Before the investment decision is taken, each agent (but not the principal) can observe a private signal on the realisation of uncertainty. Specifically, each agent separately receives from nature a signal $j \in \{l, h\}$ about which state of the world will realise. The precision of an agent's signal is modelled as the probability that a given realisation of the signal corresponds to a future realisation of the signalled state. Hence, the precision of the signal of agent A , $\alpha \in [\frac{1}{2}, 1]$, ranges between $\frac{1}{2}$ (fully uninformative signal) to 1 (fully informative signal). Similarly, for the precision of signal of agent B , $\beta \in [\frac{1}{2}, 1]$. We assume that the signals of the agents are not correlated.

The decision to be taken is also binary: to take action, that is, to undertake the risky venture, or not to take action, that is, not undertake it. The other agent will be in the position of communicating (truthfully or not) his private information to the delegated agent (the decision maker). In the terminology of the signalling games, the delegated agent will act as the receiver, while the not-delegated agent will act as the sender of a "cheap talk", transmission of information within the organisation.

Not taking action will not carry any cost or benefit to the organisation, and hence

to any of the parties involved in it. This option can therefore be interpreted as a “default” or “status quo” option with no consequences for the organisation.

On the contrary, taking action carries costs and benefit, which crucially depend on the subsequent realisation of uncertainty. Specifically, A_c requires a monetary cost (i.e., a monetary investment), c , which is borne irrespective of the state of the world. We assume that this cost is divided among the principal and the agents according to the share $\eta_i \geq 0$, $i \in \{P, A, B\}$ where

$$\sum_{i=\{P,A,B\}} \eta_i = 1$$

The same shares apply to the monetary returns, $\Delta > 0$, which A_c will effect only if the good state of the world, H materialises. Like in the previous chapter, throughout this chapter too, we assume that the agents share their monetary costs and benefits equally, $\eta_A = \eta_B$. Finally, one of the main contributions of our model as previously discussed in chapter 2 is to consider additional non-monetary and non-contractible costs,

$$\gamma_i \geq 0, i \in \{P, A, B\}$$

the principal and the agents will bear only if the bad state of the world, L materialises and action was taken. In other words, undertaking the action turns out to be a mistake if the “wrong” state of the world materialises, and this mistake carries non-contractible costs to the parties involved in the organisation.

Summarising, each player’s payoff is equal to zero under decision N , and under any state $\{L, H\}$. If A_c is chosen, then player i ’s payoff is:

$$\begin{aligned} \eta_i(\Delta - c) & \text{ if } H \\ -\eta_i c - \gamma_i & \text{ if } L \end{aligned}$$

The time line of the game is as described in chapter 2.

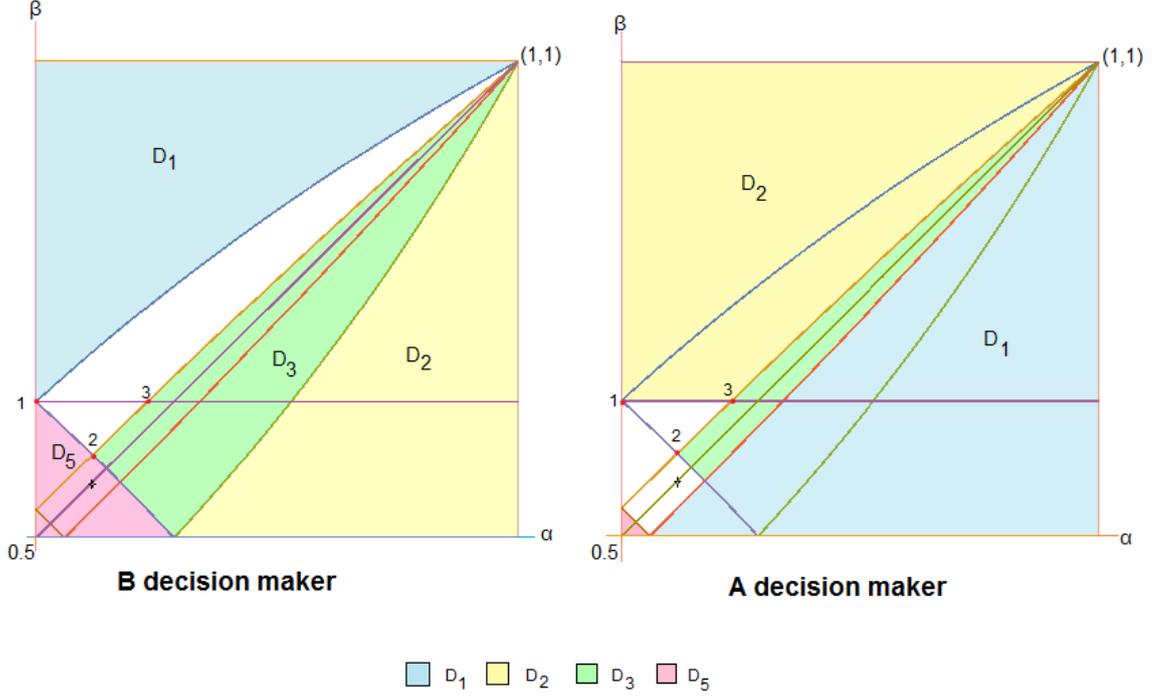


Figure 3.1: Symmetric Prior Bias: $\gamma_A > \gamma_B$

3.3 Symmetric Prior Bias ($\gamma_A > \gamma_B$) and symmetric signal precision ($\alpha = \beta$)

In this section, we look at the optimal delegation choice of the principal under the Symmetric Prior Bias case ($\gamma_A > \gamma_B$ such that both the agents have an *Action Biased Prior*)¹ where no truth-telling equilibrium exists when agent A was made the decision maker and D_5 (pink region - take action all the time) is the decision rule when the decision making power is delegated to agent B . Please refer to the figure 3.1. In the truth-telling equilibrium of the pink region, agent A follows decision rule D_5 (refer to the graph on the right side of figure 3.1), that is take action under all signal configurations. Note that under truth-telling the receiver has his

¹**Definition 1 (Action Biased Prior)** An agent i is said to have an *Action Biased Prior* (respectively *No Action Biased Prior*) if their expected benefits from doing A_c outweigh (resp., fall short) the expected costs, where expectations are taken according to the agent's prior beliefs on the two states of the world. Equations (3.1) and (3.2) below formalise *Action Biased Prior* and *No Action Biased Prior* respectively.

$$\pi(\Delta - c) > (1 - \pi)\left(c + \frac{\gamma_i}{\eta_i}\right) \quad (3.1)$$

$$(1 - \pi)\left(c + \frac{\gamma_i}{\eta_i}\right) > \pi(\Delta - c) \quad (3.2)$$

private information as well as the information sent by the sender. He continues to follow D_5 as long as α is under a certain threshold, $\alpha \in \left[\frac{1}{2}, \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta-c)} \frac{\beta}{1-\beta}} \right]$. But if we start moving horizontally to the right or vertically up away from the pink region, the signal precision increases and thereby becomes a bit more informative. Because agent A now has higher concern compared to that of agent B , his incentive constraints dictate that he follow decision rule D_3 instead which has lower probability of action than in decision rule D_5 . Agent A 's expected payoffs from doing A_c in all signal configurations has gone down compared to his expected payoffs he received in equal non-contractible costs case.² However, if B were the decision maker whose concern didn't change from the $\gamma_A = \gamma_B$ case, he would like to make agent A to continue executing D_5 through the white region - in particular as long as $\beta \in \left[\frac{1}{2}, \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}{\pi(\Delta-c)} \frac{\alpha}{1-\alpha}} \right]$. So agent B has an incentive to lie and change agent A 's decision.

Table 3.1 gives the action choices possible for agent A under non truth-telling given his signal precision α .

j_A	D_1'	D_2'	D_3'	D_4'
h	A	N	A	N
l	N	A	A	N

Table 3.1: Decision Rules, $j \in \{h, l\}$

Table 3.2 gives the necessary conditions under which agent A can take the action choices as given by these decision rules.

Under this scenario, we would like to see if there are cases where the principal would prefer an agent who is less aligned with her in terms of preferences. Let the principal also have an *Action Biased Prior*. The share of monetary revenues are such that

$$\eta_A + \eta_B + \eta_P = 1 \quad (3.3)$$

where $\eta_i > 0$ and let the share of revenues of the two agents be $\eta_A = \eta_B$.

Let the ranking of the preferences of the agents and the with respect to non-contractible costs be $\gamma_P > \gamma_A > \gamma_B$ (meaning Principal has the highest non-

² $\pi(\Delta - c) - (1 - \pi)(c + \frac{\gamma_A}{\eta_A}) < \pi(\Delta - c) - (1 - \pi)(c + \frac{\gamma_B}{\eta_B})$. In the Symmetric Prior Bias case $\gamma_A > \gamma_B$. Note that under the symmetric non-contractible case, $\gamma_A = \gamma_B$.

Decision Rules for agent A	
Decision Rule	A
D_1'	$\alpha \geq \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta-c)}}$
D_2'	$\alpha \leq \frac{1}{1 + \frac{\pi(\Delta-c)}{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}}$
D_3'	$\alpha \geq \frac{1}{1 + \frac{\pi(\Delta-c)}{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}}$ $\alpha \leq \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta-c)}}$
D_4'	$\alpha \leq \frac{1}{1 + \frac{\pi(\Delta-c)}{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}}$ $\alpha \geq \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta-c)}}$

Table 3.2: Decision rules conditions

contractible cost and further away from agent B in terms of preferences). We state and prove the main result of this section in the following proposition.

Proposition 3.3.1 *Suppose that both the agents and the principal exhibit Action Biased Priors, and the non-contractible costs of the principal and the agents are such that $\gamma_P > \gamma_A > \gamma_B$. Then, there exists sets of values of α and β such that the principal delegates to agent B (the agent with whom her preferences are less aligned) when truth-telling does not exist if agent A is the decision maker.*

Proof We proceed to prove this proposition by considering a point where the signal precisions of the two agents are exactly identical. We would like to focus on a point on the 45 degree line (marked with a cross, \dagger). Exactly at this point the signal precision of both the agents is $\alpha = \beta = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$. At this point, agent B follows decision rule D_5 . We would like to remind the reader that the condition on β for agent B for taking action under all signal configurations, that is to follow decision rule D_5 is:

$$\beta \in \left[\frac{1}{2}, \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}{\pi(\Delta-c)} \frac{\alpha}{1-\alpha}} \right] \quad (3.4)$$

It is easily seen from $\gamma_A > \gamma_B$ that $\beta = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}} > \frac{1}{2}$.

For $\beta = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$ to be lower than the upper limit of β in condition (4.32),

$$\frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}} < \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}{\pi(\Delta - c)} \frac{\alpha}{1-\alpha}}$$

which is

$$\frac{1}{1 + \frac{\sqrt{c + \frac{\gamma_B}{\eta_B}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}}}} < \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_B}{\eta_B})}{\pi(\Delta - c)} \frac{\alpha}{1-\alpha}}$$

Substituting for $\alpha = \frac{1}{1 + \frac{\sqrt{c + \frac{\gamma_B}{\eta_B}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}}}}$, we have

$$\frac{(1 - \pi) \sqrt{c + \frac{\gamma_A}{\eta_A}} \sqrt{c + \frac{\gamma_B}{\eta_B}}}{\pi(\Delta - c)} < \frac{\sqrt{c + \frac{\gamma_B}{\eta_B}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}}}$$

which is

$$\pi(\Delta - c) > (1 - \pi)(c + \frac{\gamma_A}{\eta_A})$$

Hence, it follows from the fundamental inequality, $\pi(\Delta - c) > (1 - \pi)(c + \frac{\gamma_A}{\eta_A})$, that the chosen point on the 45 degree line where $\beta = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$ satisfies condition (4.32).

At the point \dagger , where the signal precision of agent A , $\alpha = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$, his incentives dictate that he follow decision rule D_1' , that is do A_c if he receives high, h and do N if he receives low, l . The incentive constraint for agent A to do D_1' is as shown in row one, column two of table 3.2.³

$$\alpha \geq \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta - c)}} \quad (3.5)$$

For the point, $\alpha = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$ to satisfy condition (3.5), the following must hold

$$\frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}} < \frac{1}{1 + \frac{(1-\pi)(c + \frac{\gamma_A}{\eta_A})}{\pi(\Delta - c)}}$$

³Note how the condition of agent A 's decision making just depends on α . This is because under non truth-telling he cannot make use of the information sent by the sender who is lying (agent B in this case).

which is

$$\gamma_A > \left(\frac{\pi(\Delta - c)\sqrt{c + \frac{\gamma_B}{\eta_B}}}{1 - \pi} \right)^{\frac{2}{3}} \eta_A - \eta_{AC}$$

The upper bound on γ_A is given by the fundamental inequality for agent A , $\gamma_A < \frac{\pi(\Delta - c)\eta_A}{1 - \pi} - \eta_{AC}$.

The above conditions on γ_A can be written as

$$\gamma_A \in \left(\left(\frac{\pi(\Delta - c)\sqrt{c + \frac{\gamma_B}{\eta_B}}}{1 - \pi} \right)^{\frac{2}{3}} \eta_A - \eta_{AC}, \frac{\pi(\Delta - c)\eta_A}{1 - \pi} - \eta_{AC} \right) \quad (3.6)$$

Both the agents follow different decision rules at the chosen point \dagger .

From $\gamma_A > \gamma_B$ and condition (3.6), we know that the point, $\alpha = \beta = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$, satisfies the conditions (4.32) (for agent B to follow decision rule, D_5) and (3.5) (for agent A to follow decision rule, D_1').

The principal's expected payoff from delegating the decision making power to agent B is given by

$$\pi\eta_P(\Delta - c) - (1 - \pi)(\eta_{PC} + \gamma_P) \quad (3.7)$$

The principal's expected payoff from delegating the decision making power to agent A is given by

$$\pi\eta_P\alpha(\Delta - c) - (1 - \pi)(1 - \alpha)(\eta_{PC} + \gamma_P) \quad (3.8)$$

If the following conditions hold true,

$$\frac{\gamma_P}{\eta_P} < \frac{\gamma_A}{\eta_A} \quad (3.9)$$

from conditions (3.3) and $\eta_A = \eta_B$, we have that

$$\eta_P > \frac{\gamma_P}{\gamma_P + 2\gamma_A} \quad (3.10)$$

Then the following inequality is satisfied

$$\pi\eta_P(\Delta - c) - (1 - \pi)(\eta_{PC} + \gamma_P) > \pi\eta_P\alpha(\Delta - c) - (1 - \pi)(1 - \alpha)(\eta_{PC} + \gamma_P) \quad (3.11)$$

Substituting, $\alpha = \frac{\sqrt{c + \frac{\gamma_A}{\eta_A}}}{\sqrt{c + \frac{\gamma_A}{\eta_A}} + \sqrt{c + \frac{\gamma_B}{\eta_B}}}$, we have

$$\gamma_P > \eta_P \left(\frac{\pi(\Delta - c)}{1 - \pi} \sqrt{\frac{c + \frac{\gamma_B}{\eta_A}}{c + \frac{\gamma_A}{\eta_A}}} - c \right) \quad (3.12)$$

Hence, the condition for γ_P to give the decision making power to agent B is

$$\gamma_P \in \left(\frac{\pi(\Delta - c)\eta_P}{1 - \pi} \sqrt{\frac{c + \frac{\gamma_B}{\eta_A}}{c + \frac{\gamma_A}{\eta_A}}} - \eta_P c, \frac{\pi(\Delta - c)\eta_P}{1 - \pi} - \eta_P c \right) \quad (3.13)$$

Provided condition (3.10) is satisfied - which is the monetary share of the principal is sufficiently high, condition (3.11) will be satisfied, that is the principal's expected payoff from delegating the decision making authority to agent B is higher than her expected payoff from delegating it to agent A . Under that case, the principal strictly prefers to delegate the decision making power to agent B who is less aligned with her in terms of preferences. \square

We can see from the above analysis that under the non existence of truth telling, the two agents disagree on the decision rules even though both of them have exactly the same signal precision. In chapter 2, only parametrizations which lead to truth-telling irrespective of the decision-making power allocation are considered. Hence, information is always efficiently aggregated. Nonetheless, the less-aligned agent sometimes should have the decision making power. On the other hand, in this chapter the two agents cannot share their information efficiently because of their incentive constraints under Symmetric Prior Bias case for certain situations. The allocation of the decision making power is driven by informational concern. This result can have important implications to situations where there is a disagreement between the agents as to which decision must be taken. Under such situations, although the principal's non-contractible cost (γ_P) is the highest - say, she has high moral concerns, a high enough monetary share η_P can exist to make her overcome her moral concerns and delegate the decision making power to an agent who is less aligned with her in terms of preferences.

3.4 Conclusion

This chapter which is an extension of the 2nd chapter investigates if there exists a result like the one in chapter 2 under situations where truth-telling equilibria does not exist. We find that when there is no truth-telling equilibria and the preferences of the two agents are not aligned, even when the signal precision of the two agents is exactly the same, sometimes they follow different decision rules. We analysed the optimal delegation rule of the principal and found that there exist conditions such that she strictly prefers to delegate the decision making power to the agent with whom her preferences are less aligned. In this chapter, we arrived at the non irrelevancy result we got in chapter 2 even when the signal precisions of the two agents are identical which was not possible in chapter 2.

Conclusion

This thesis discusses two different decision-making themes. Chapter 1 evaluates Leniency Programs in a society of heterogeneous criminals and bureaucrats. A proportion of these bureaucrats who are responsible for monitoring and preventing crime turn out to be corruptible. They engage in bribery (corruption) and not report a violation of law and let criminals have the possibility of committing future crimes. Bribe forms a major source of income for this section of the bureaucrats. When LPs are introduced, it affects their source of income earned through corruption. This leads to a supply fluctuation of bureaucrats. In the immediate short run after the introduction of the leniency program, we find that social welfare is higher than without leniency. However, allowing for certain time to pass and the adjustment in the supply of bureaucrats (where some bureaucrats losing their bribe income leave for outside job offers), we end up in a low welfare situation under leniency. Our analysis contributes at this junction to warn policy makers of potentially withdrawing a LP without waiting for the adjustment in the supply of bureaucrats to happen. Thus we point out that while evaluating the merits of LPs, the time horizon is crucial.

Chapters 2 and 3 look at the problem of delegation of decision making authority using a principal agent model. There is a principal contemplating delegating decision making power to one of the two agents who have private information relevant for making one decision. The agents and the principal privately suffer from a non-monetary, non-contractible costs of taking a wrong decision. Chapter 2 characterizes truth-telling equilibria. We find that in the presence of sufficient amount of asymmetry in information and preferences, the two agents follow different decision rules. Under certain conditions, we discover through our analysis that it is indeed strictly optimal for the principal to delegate the decision making authority to the agent who is less aligned with her in terms of preferences, provided there is enough

informational asymmetry between the two agents. We call this the non-relevancy result. Chapter 3 extends the analysis of chapter 2 to situations where no truth-telling equilibria exist. We show that interestingly the non-irrelevancy result of chapter 2 exists in this setting when there is symmetry of information among the agents which was not possible in chapter 2.

Appendices

Chapter 4

Appendix to Chapter 2

4.1 Decision Rules

4.1.1 Decision rule D_1

B's decision making

When the report by *A* is h , i.e, $j^A = h$ and $j^B = h$, it is optimal for *B* to take Action if the following condition is satisfied.

$$E(\pi_B)(A_c|h, h) \geq E(\pi_B)(N|h, h)$$

$$\begin{aligned} & \frac{\pi\alpha\beta\{\eta_B(\Delta - c)\}}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)} \\ & + \frac{(1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_B(-c) - \gamma_B\}}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)} \\ & \geq \frac{\pi\alpha\beta}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)}\{0\} \\ & + \frac{(1 - \pi)(1 - \alpha)(1 - \beta)}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)}\{0\} \end{aligned}$$

which is

$$\frac{\pi\alpha\beta}{(1 - \pi)(1 - \alpha)(1 - \beta)} \geq \frac{c + \frac{\gamma_B}{\eta_B}}{\Delta - c}$$

$$\beta \geq \frac{(1 - \pi)(1 - \alpha)(c + \frac{\gamma_B}{\eta_B})}{\pi\alpha(\Delta - c) + (1 - \pi)(1 - \alpha)(c + \frac{\gamma_B}{\eta_B})} \quad (4.1)$$

When the report by A is l , i.e, $j^A = l$ and $j^B = h$, it is optimal for B to do A_c if the following condition is satisfied.

$$E(\pi_B)(A_c|l, h) \geq E(\pi_B)(N|l, h)$$

$$\beta \geq \frac{(1 - \pi)\alpha(c + \frac{\gamma_B}{\eta_B})}{\pi(1 - \alpha)(\Delta - c) + (1 - \pi)\alpha(c + \frac{\gamma_B}{\eta_B})} \quad (4.2)$$

When the report by A is h , i.e, $j^A = h$ and $j^B = l$, it is optimal for B to do N if the following condition is satisfied.

$$E(\pi_B)(A_c|h, l) < E(\pi_B)(N|h, l)$$

$$\beta \geq \frac{\pi\alpha(\Delta - c)}{\pi\alpha(\Delta - c) + (1 - \pi)(1 - \alpha)(c + \frac{\gamma_B}{\eta_B})} \quad (4.3)$$

When the report by A is l , i.e, $j^A = l$ and $j^B = l$, it is optimal for B to do N if the following condition is satisfied.

$$E(\pi_B)(A|l, l) < E(\pi_B)(N|l, l)$$

$$\beta \geq \frac{\pi(1 - \alpha)(\Delta - c)}{\pi(1 - \alpha)(\Delta - c) + (1 - \pi)\alpha(c + \frac{\gamma_B}{\eta_B})} \quad (4.4)$$

A 's decision making

The condition for truth-telling when A receives h from nature

$$E(\pi_A)(j^A = h|h, D_1) \geq E(\pi_A)(j^A = l|h, D_1)$$

$$\begin{aligned}
& \frac{\pi\alpha\{\beta\eta_A(\Delta - c) + (1 - \beta)(\eta_{A.0})\}}{\pi\alpha + (1 - \pi)(1 - \alpha)} \\
& + \frac{(1 - \pi)(1 - \alpha)\{(1 - \beta)(\eta_A(-c) - \gamma_A) + \beta(\eta_{A.0})\}}{\pi\alpha + (1 - \pi)(1 - \alpha)} \\
& \geq \frac{\pi\alpha\{\beta\eta_A(\Delta - c) + (1 - \beta)(\eta_{A.0})\}}{\pi\alpha + (1 - \pi)(1 - \alpha)} \\
& + \frac{(1 - \pi)(1 - \alpha)\{(1 - \beta)(\eta_A(-c) - \gamma_A) + \beta(\eta_{A.0})\}}{\pi\alpha + (1 - \pi)(1 - \alpha)}
\end{aligned}$$

The condition for truth-telling when A receives l from nature

$$E(\pi_A)(j^A = l|l) \geq E(\pi_A)(j^A = l|h)$$

$$\begin{aligned}
& \frac{\pi(1 - \alpha)\{\beta\eta_A(\Delta - c) + (1 - \beta)(\eta_{A.0})\}}{\pi(1 - \alpha) + (1 - \pi)\alpha} \\
& + \frac{(1 - \pi)\alpha\{(1 - \beta)(\eta_A(-c) - \gamma_A) + \beta(\eta_{A.0})\}}{\pi(1 - \alpha) + (1 - \pi)\alpha} \\
& \geq \frac{\pi(1 - \alpha)\{\beta\eta_A(\Delta - c) + (1 - \beta)(\eta_{A.0})\}}{\pi(1 - \alpha) + (1 - \pi)\alpha} \\
& + \frac{(1 - \pi)\alpha\{(1 - \beta)(\eta_A(-c) - \gamma_A) + \beta(\eta_{A.0})\}}{\pi(1 - \alpha) + (1 - \pi)\alpha}
\end{aligned}$$

Note: The left hand side and the right hand side of the above two conditions are exactly the same.

From conditions (4.1),(4.2),(4.3)and (4.4), we have :

$$\beta > \text{Max} \left[\frac{\pi\alpha(\Delta - c)}{\pi\alpha(\Delta - c) + (1 - \pi)(1 - \alpha)(c + \frac{\gamma_B}{\eta_B})}, \frac{(1 - \pi)\alpha(c + \frac{\gamma_B}{\eta_B})}{\pi(1 - \alpha)(\Delta - c) + (1 - \pi)\alpha(c + \frac{\gamma_B}{\eta_B})} \right] \quad (4.5)$$

$$\beta > \alpha \quad (4.6)$$

The rest of the decision rules conditions are also derived in the same fashion.

In the following subsections, we use the following for notational convenience.

$$x = \Delta - c$$

$$z_i = c + \frac{\gamma_i}{\eta_i}$$

4.1.2 Decision Rule- D_2

B 's decision making

When the report by A is h , i.e, $j^A = h$ and $y^B = h$, it is optimal for B to do A_c if the following condition is satisfied.

$$E(\pi_B)(A|h, h) \geq E(\pi_B)(N|h, h)$$

$$\begin{aligned} & \frac{\pi\alpha\beta\{\eta_B(\Delta - c)\}}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)} \\ & + \frac{(1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_B(-c) - \gamma_B\}}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)} \\ & \geq \frac{\pi\alpha\beta}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)}\{\eta_B \cdot 0\} \\ & + \frac{(1 - \pi)(1 - \alpha)(1 - \beta)}{\pi\alpha\beta + (1 - \pi)(1 - \alpha)(1 - \beta)}\{\eta_B \cdot 0\} \end{aligned}$$

which is

$$\begin{aligned} \frac{\pi\alpha\beta}{(1 - \pi)(1 - \alpha)(1 - \beta)} & \geq \frac{c + \frac{\gamma_B}{\eta_B}}{\Delta - c} \\ \frac{\pi\alpha\beta}{(1 - \pi)(1 - \alpha)(1 - \beta)} & \geq \frac{c + \frac{\gamma_B}{\eta_B}}{\Delta - c} \end{aligned} \quad (4.7)$$

When the report by A is l , i.e, $\hat{y}^A = l$ and $y^B = h$, it is optimal for B to not do A_c if the following condition is satisfied.

$$E(\pi_B)(A|l, h) < E(\pi_B)(N|l, h)$$

$$\frac{\pi(1 - \alpha)\beta}{(1 - \pi)\alpha(1 - \beta)} \leq \frac{z_B}{x} \quad (4.8)$$

When the report by A is h , i.e, $\hat{y}^A = h$ and $y^B = l$, it is optimal for B to do A_c if the following condition is satisfied.

$$E(\pi_B)(A|h, l) \geq E(\pi_B)(N|h, l)$$

$$\frac{\pi\alpha(1 - \beta)}{(1 - \pi)(1 - \alpha)\beta} \geq \frac{z_B}{x} \quad (4.9)$$

When the report by A is l , i.e, $\hat{y}^A = l$ and $y^B = l$, it is optimal for B to do N if the following condition is satisfied.

$$E(\pi_B)(A|l, l) < E(\pi_B)(N|l, l)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} < \frac{z_B}{x} \quad (4.10)$$

A's decision making

The condition for truth-telling when A receives h from nature

$$E(\pi_A)(\hat{y}^A = h|h) \geq E(\pi_A)(\hat{y}^A = l|h)$$

$$\begin{aligned} & \frac{\pi\alpha\{\beta\delta(\Delta - c) + (1-\beta)(\delta(\Delta - c))\}}{\pi\alpha + (1-\pi)(1-\alpha)} \\ & + \frac{(1-\pi)(1-\alpha)\{(1-\beta+\beta)(\delta(-c) - \gamma_A)\}}{\pi\alpha + (1-\pi)(1-\alpha)} \\ & \geq \frac{\pi\alpha\{\beta\delta(0) + (1-\beta)(\delta 0)\}}{\pi\alpha + (1-\pi)(1-\alpha)} \\ & + \frac{(1-\pi)(1-\alpha)\{(1-\beta)(\delta 0) + \beta(\delta 0)\}}{\pi\alpha + (1-\pi)(1-\alpha)} \\ & \frac{\pi\alpha}{(1-\pi)(1-\alpha)} \geq \frac{c + \frac{\gamma_A}{\delta}}{x} \\ & \frac{\pi\alpha}{(1-\pi)(1-\alpha)} \geq \frac{z_A}{x} \end{aligned} \quad (4.11)$$

The condition for truth-telling when A receives l from nature

$$E(\pi_A)(\hat{y}^A = l|l) \geq E(\pi_A)(\hat{y}^A = h|l)$$

$$\frac{\pi(1-\alpha)}{(1-\pi)\alpha} \leq \frac{z_A}{x} \quad (4.12)$$

From conditions (4.7),(4.8),(4.9),(4.10),(4.11) and (4.12), we have:

$$\alpha \geq \text{Max} \left[\frac{\pi x}{\pi x + (1-\pi)z_A}, \frac{(1-\pi)z_A}{\pi x + (1-\pi)z_A} \right] \quad (4.13)$$

$$\beta \leq \text{Min} \left[\frac{\pi\alpha x}{\pi\alpha x + (1-\pi)(1-\alpha)z_B}, \frac{(1-\pi)\alpha z_B}{\pi(1-\alpha)x + (1-\pi)\alpha z_B} \right] \quad (4.14)$$

$$\beta \leq \alpha \quad (4.15)$$

4.1.3 Decision Rule- D_3

B 's decision making

The conditions for B 's decisions to do A_c or N according to decision rule D_3 are:

$$\frac{\pi\alpha\beta}{(1-\pi)(1-\alpha)(1-\beta)} \geq \frac{z_B}{x} \quad (4.16)$$

$$\frac{\pi(1-\alpha)\beta}{(1-\pi)\alpha(1-\beta)} \geq \frac{z_B}{x} \quad (4.17)$$

$$\frac{\pi\alpha(1-\beta)}{(1-\pi)(1-\alpha)\beta} \geq \frac{z_B}{x} \quad (4.18)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} < \frac{z_B}{x} \quad (4.19)$$

A 's decision making

The condition for truth-telling when A receives h from nature

$$E(\pi_A)(\hat{y}^A = h|h) \geq E(\pi_A)(\hat{y}^A = l|h)$$

$$\frac{\pi\alpha(1-\beta)}{(1-\pi)(1-\alpha)\beta} \geq \frac{z_A}{x} \quad (4.20)$$

The condition for truth-telling when A receives l from nature

$$E(\pi_A)(\hat{y}^A = l|l) \geq E(\pi_A)(\hat{y}^A = h|l)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} \leq \frac{z_A}{x} \quad (4.21)$$

From all the conditions in this subsection, we have:

$$\beta \leq \text{Min} \left[\frac{\pi\alpha x}{\pi\alpha x + (1-\pi)(1-\alpha)z_A}, \frac{\pi\alpha x}{\pi\alpha x + (1-\pi)(1-\alpha)z_B} \right] \quad (4.22)$$

$$\beta > \text{Max} \left[\frac{\pi(1-\alpha)x}{\pi(1-\alpha)x + (1-\pi)\alpha z_A}, \frac{\pi(1-\alpha)x}{\pi(1-\alpha)x + (1-\pi)\alpha z_B}, \frac{(1-\pi)\alpha z_B}{\pi(1-\alpha)x + (1-\pi)\alpha z_B} \right] \quad (4.23)$$

4.1.4 Decision Rule- D_4

B 's decision making

The conditions for B 's decisions to do A_c or N according to decision rule D_4 are:

$$\frac{\pi\alpha\beta}{(1-\pi)(1-\alpha)(1-\beta)} \geq \frac{z_B}{x} \quad (4.24)$$

$$\frac{\pi(1-\alpha)\beta}{(1-\pi)\alpha(1-\beta)} < \frac{z_B}{x} \quad (4.25)$$

$$\frac{\pi\alpha(1-\beta)}{(1-\pi)(1-\alpha)\beta} < \frac{z_B}{x} \quad (4.26)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} < \frac{z_B}{x} \quad (4.27)$$

A 's decision making

The condition for truth-telling when A receives h from nature

$$E(\pi_A)(\hat{y}^A = h|h) \geq E(\pi_A)(\hat{y}^A = l|h)$$

$$\frac{\pi\alpha\beta}{(1-\pi)(1-\alpha)(1-\beta)} \geq \frac{z_A}{x} \quad (4.28)$$

The condition for truth-telling when A receives l from nature

$$E(\pi_A)(\hat{y}^A = l|l) \geq E(\pi_A)(\hat{y}^A = h|l)$$

$$\frac{\pi(1-\alpha)\beta}{(1-\pi)\alpha(1-\beta)} \leq \frac{z_A}{x} \quad (4.29)$$

From all the conditions in this subsection, we have:

$$\beta < Min \left[\frac{(1-\pi)\alpha z_A}{\pi(1-\alpha)x + (1-\pi)\alpha z_A}, \frac{(1-\pi)\alpha z_B}{\pi(1-\alpha)x + (1-\pi)\alpha z_B} \right] \quad (4.30)$$

$$\beta > Max \left[\frac{(1-\pi)(1-\alpha)z_A}{\pi\alpha x + (1-\pi)(1-\alpha)z_A}, \frac{(1-\pi)(1-\alpha)z_B}{\pi\alpha x + (1-\pi)(1-\alpha)z_B}, \frac{\pi\alpha x}{\pi\alpha x + (1-\pi)(1-\alpha)z_B} \right] \quad (4.31)$$

4.1.5 Decision Rule- D_5

B 's decision making

The conditions for B 's decisions to do A_c or N according to decision rule D_5 are:

$$\frac{\pi\alpha\beta}{(1-\pi)(1-\alpha)(1-\beta)} \geq \frac{z_B}{x} \quad (4.32)$$

$$\frac{\pi(1-\alpha)\beta}{(1-\pi)\alpha(1-\beta)} \geq \frac{z_B}{x} \quad (4.33)$$

$$\frac{\pi\alpha(1-\beta)}{(1-\pi)(1-\alpha)\beta} \geq \frac{z_B}{x} \quad (4.34)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} \geq \frac{z_B}{x} \quad (4.35)$$

Note: A 's decision making

Since, it is always do A_c , A 's decision making does not give rise to any conditions.

From the conditions in this subsection, we have:

$$\beta \leq \frac{\pi(1-\alpha)x}{\pi(1-\alpha)x + (1-\pi)\alpha z_B} \quad (4.36)$$

4.1.6 Decision Rule- D_6

R_B 's decision making

The conditions for B 's decisions to do A_c or N according to decision rule D_6 are:

$$\frac{\pi\alpha\beta}{(1-\pi)(1-\alpha)(1-\beta)} < \frac{z_B}{x} \quad (4.37)$$

$$\frac{\pi(1-\alpha)\beta}{(1-\pi)\alpha(1-\beta)} < \frac{z_B}{x} \quad (4.38)$$

$$\frac{\pi\alpha(1-\beta)}{(1-\pi)(1-\alpha)\beta} < \frac{z_B}{x} \quad (4.39)$$

$$\frac{\pi(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} < \frac{z_B}{x} \quad (4.40)$$

Note: A 's decision making

Since, it is always do N , A 's decision making does not give rise to any conditions.

From the conditions in this subsection, we have:

$$\beta < \frac{(1-\pi)(1-\alpha)z_B}{\pi\alpha x + (1-\pi)(1-\alpha)z_B} \quad (4.41)$$

4.1.7 Complete List of Decision Rules

This subsection (refer to table 4.1) provides a complete set of all possible decision rules including the ones that never happen in a truth-telling equilibrium. Decision rules D_7 - D_{16} never happen in any equilibrium as the incentive constraints are not satisfied simultaneously.

4.1.8 Proof of Lemma 1

Proof of Symmetry:

Proof The aim of this sub section is to prove that in the case of symmetric non-contractible costs ($\gamma_A = \gamma_B$), equal sharing of monetary benefits and costs, $\eta_A = \eta_B$ and the two agents exhibit an *Action Biased Prior*, i.e., $\pi(\Delta - c) > (1 - \pi)(c + \frac{\gamma_i}{\eta_i})$

where $i \in \{A, B\}$, the contours of the decision rules characterising the truth-telling equilibria are symmetric about the 45 degree line. That is, the curves $\frac{\pi x \alpha}{\pi x \alpha + (1 - \pi)z(1 - \alpha)}$ (function of the increasing concave curve separating D_1 and D_3 , henceforth $f(D_1 : D_3)$), $\frac{(1 - \pi)z\alpha}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$ (function of the increasing convex curve separating D_2 from D_3 , henceforth $f(D_2 : D_3)$), $\frac{\pi x(1 - \alpha)}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$ (function of the decreasing concave curve forming the upper boundary of D_5 , henceforth $f(D_5)$) are symmetric about the 45 degree lines where $x = \Delta - c$ and $z_i = c + \frac{\gamma_i}{\eta_i} = z$ for notational convenience.

$$f(D_1 : D_3) = \frac{\pi x \alpha}{\pi x \alpha + (1 - \pi)z(1 - \alpha)}$$

$$f(D_2 : D_3) = \frac{(1 - \pi)z\alpha}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

$$f(D_5) = \frac{\pi x(1 - \alpha)}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

Verifying if the inverse of $f(D_1 : D_3) = f(D_2 : D_3)$:

$$\beta = \frac{\pi x \alpha}{\pi x \alpha + (1 - \pi)z(1 - \alpha)}$$

$$\beta\{\pi x \alpha + (1 - \pi)z(1 - \alpha)\} = \pi x \alpha$$

$$\alpha(\pi x \beta) + (1 - \pi)z\beta - (1 - \pi)z\beta\alpha = \pi x \alpha$$

$$\alpha[\pi x(1 - \beta) + (1 - \pi)z\beta] = (1 - \pi)z\beta$$

$$\alpha = \frac{(1 - \pi)z\beta}{\pi x(1 - \beta) + (1 - \pi)z\beta}$$

$$\beta = \frac{(1 - \pi)z\alpha}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

Hence, $f^{-1}(D_1 : D_3) = f(D_2 : D_3)$

Determining if $f(D_1 : D_3)$ and $f(D_2 : D_3)$ are one-to-one functions:

$$\frac{\pi x \beta}{\pi x \beta + (1 - \pi)z(1 - \beta)} = \frac{\pi x \alpha}{\pi x \alpha + (1 - \pi)z(1 - \alpha)}$$

$$(\pi x \alpha + (1 - \pi)z(1 - \alpha))\beta = \alpha(\pi x \beta + (1 - \pi)z(1 - \beta))$$

$$(1 - \alpha)\beta = (1 - \beta)\alpha$$

$$\beta = \alpha$$

Therefore, $f(D_1 : D_3)$ is a one-to-one function

$$\frac{(1 - \pi)z\beta}{\pi x(1 - \beta) + (1 - \pi)z\beta} = \frac{(1 - \pi)z\alpha}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

$$\alpha\beta(1 - \pi)z + \alpha(1 - \beta)\pi x = \pi x\beta(1 - \alpha) + (1 - \pi)z\alpha\beta$$

$$\beta = \alpha$$

Therefore, $f(D_2 : D_3)$ is a one-to-one function. Hence, $f(D_1 : D_3)$ and $f(D_2 : D_3)$ are symmetric about the 45 degree line.

Inverse of $f(D_5)$:

$$\beta = \frac{\pi x(1 - \alpha)}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

$$\beta(\pi x(1 - \alpha) + (1 - \pi)z\alpha) = \pi x(1 - \alpha)$$

$$\alpha((1 - \pi)z\beta - \pi x\beta + \pi x) = \pi x - \pi x\beta$$

$$\alpha = \frac{\pi x(1 - \beta)}{\pi x(1 - \beta) + (1 - \pi)z\beta}$$

$$\beta = \frac{\pi x(1 - \alpha)}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

Therefore, $f^{-1}(D_5) = f(D_5)$

Determining if $f(D_5)$ is a one-to-one function:

$$\frac{\pi x(1 - \beta)}{\pi x(1 - \beta) + (1 - \pi)z\beta} = \frac{\pi x(1 - \alpha)}{\pi x(1 - \alpha) + (1 - \pi)z\alpha}$$

$$(1 - \alpha)[\pi x(1 - \beta) + (1 - \pi)z\beta] = (1 - \beta)[\pi x(1 - \alpha) + (1 - \pi)z\alpha]$$

$$(1 - \alpha)\beta = (1 - \beta)\alpha$$

$$\beta = \alpha$$

Hence, $f(D_5)$ is symmetric about the 45 degree line. □

4.1.9 Proof of Proposition 1

Proof Under the symmetric non-contractible costs, the decision rules followed by the agents A and B under truth-telling equilibrium when they are delegated the decision making authority respectively map the signal configurations into actions with the same probability as outlined in table 4.2. The irrelevance stems from the fact that both the agents are symmetric with respect to their monetary costs and revenues and non-contractible costs, that is their preferences are aligned. Irrespective of their signal precisions, agents A and B will choose to take the same decision of ‘Action’ or ‘No Action’ (A_c or N) if they were the decision maker and the other agent is the sender respectively.

$i \in \{A, B\}$ exhibits an *Action Biased Prior*, i.e., $\pi(\Delta - c) > (1 - \pi)(c + \frac{\gamma_i}{\eta_i})$ and there is equal sharing of monetary costs and revenues, $\eta_A = \eta_B = \eta$. Pick any arbitrary (α, β) . There are three possibilities for this signal configuration to lie in the signal precisions.

(i) $\beta > \alpha$

(ii) $\beta < \alpha$

(iii) $\beta = \alpha$

The agents A and B receive the signals h or l with the probabilities as outlined in the table 4.2.

Under case i) $\beta > \alpha$ (above the 45 degree line), we can see from the graphs in the 2.2 that the only part of the signal precision space that is different is where the truth-telling equilibrium is characterised by decision rule D_1 (blue region) when agent B is delegated the role decision maker whereas the truth-telling equilibrium is characterised by decision rule D_2 (yellow region) when agent A is delegated the role of decision maker. The expected revenues to the principal if agent B is made the decision maker and the decision rule is D_1 (blue region) are:

$$\begin{aligned}
& \pi\alpha\beta\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)\beta\{\eta_P(\Delta - c)\} + (1 - \pi)\alpha(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi\alpha(1 - \beta)\{0\} + (1 - \pi)(1 - \alpha)\beta\{0\} \\
& + \pi(1 - \alpha)(1 - \beta)\{0\} + (1 - \pi)\alpha\beta\{0\}
\end{aligned}$$

where $\eta(\Delta - c)$ is the realised payoff to the principal when the receiver take ‘Action’, A_c and true state of the world materialises to be H .

$\eta(-c) - \gamma_C$ is the realised payoff to the principal the receiver does A_c and the true state of the world materialises to be L .

0 is the realised payoff to the principal when the receiver takes ‘No Action’, N .

γ_P is the non-contractible cost incurred by the principal.

If agent A is made the decision maker instead, the decision rule is D_2 (yellow region) in the same signal precision space as above and the expected revenue to the principal is:

$$\begin{aligned}
& \pi\alpha\beta\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)\beta\{\eta_P(\Delta - c)\} + (1 - \pi)\alpha(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi\alpha(1 - \beta)\{0\} + (1 - \pi)(1 - \alpha)\beta\{0\} \\
& + \pi(1 - \alpha)(1 - \beta)\{0\} + (1 - \pi)\alpha\beta\{0\}
\end{aligned}$$

which is exactly the same as the expected revenue the principal would get if agent B was the decision maker and the decision rule was D_1 .

The rest of the signal precision space above the 45 degree line has truth-telling equilibria characterised by decision rules D_3 (green region) and D_5 (pink region) whoever is the decision maker. Therefore, the expected benefits to the principal is the same regardless of who she delegates the decision making authority to. Hence, when $\beta > \alpha$, it does not matter who the decision maker is since the outcome is the same.

Under case ii) $\beta < \alpha$ (below the 45 degree line), we can see from the graphs in the 2.2 that the only part of the signal precision space that is different is where the

truth-telling equilibrium is characterised by decision rule D_2 (yellow region) when agent B is delegated the role decision maker whereas the truth-telling equilibrium is characterised by decision rule D_1 (blue region) when agent A is delegated the role of decision maker. The expected revenues to the principal if agent B is delegated the role of the decision maker and under the signal precision space where he follows the decision rule D_2 are:

$$\begin{aligned}
& \pi\alpha\beta\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)\beta\{0\} + (1 - \pi)\alpha(1 - \beta)\{0\} \\
& + \pi\alpha(1 - \beta)\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)\beta\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)(1 - \beta)\{0\} + (1 - \pi)\alpha\beta\{0\}
\end{aligned}$$

The expected revenues to the principal if agent A is delegated the role of the decision maker in the same signal precision space where he follows the decision rule D_1 are:

$$\begin{aligned}
& \pi\alpha\beta\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)(1 - \beta)\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)\beta\{0\} + (1 - \pi)\alpha(1 - \beta)\{0\} \\
& + \pi\alpha(1 - \beta)\{\eta_P(\Delta - c)\} + (1 - \pi)(1 - \alpha)\beta\{\eta_P(-c) - \gamma_P\} \\
& + \pi(1 - \alpha)(1 - \beta)\{0\} + (1 - \pi)\alpha\beta\{0\}
\end{aligned}$$

In this case too, the expected revenues to the principal are exactly the same whoever the decision maker is among the two agents.

Under case iii) $\beta = \alpha$, the decision rules that characterise truth-telling are D_3 and D_5 regardless of who the decision maker is.

So, once again, the expected revenues to the principal are exactly the same with A or B as decision makers. Therefore, it is shown that when the preferences of the two agents are identical (and definition 2.1 holds) and there is equal sharing of monetary benefits and costs, it is indifferent who the principal chooses to delegate the decision making power to regardless of their signal precisions.

The above result is possible because of the assumption of symmetry of the contours of the decision rules about the 45 degree line.

Note: The same result of irrelevancy holds true even when the agents exhibit a *No Action Biased Prior*, i.e., $(1 - \pi)(c + \frac{\gamma_i}{\eta_i}) > \pi(\Delta - c)$, \square

4.1.10 Proof of Proposition 2

Proof We proceed by offering a numerical proof to this proposition. For this proof, we consider the non-neutrality cases, that is where the agents follow different decision rules when they are delegated the role of decision maker. This removes irrelevancy for the principal and there is outcome indifference to her depending on who the decision making power is delegated to. The following signal precision regions describe these two non-neutrality cases.

Scenario 1) Non- neutrality case D_5 vs D_1 :

i) The signal precision space enclosed by (see 1* in the figure 2.2)

$$\beta \leq \frac{\pi(\Delta-c)(1-\alpha)}{\pi(\Delta-c)(1-\alpha)+(1-\pi)\alpha(c+\frac{\gamma_B}{\eta_B})}, \beta \geq \frac{(1-\pi)(c+\frac{\gamma_A}{\eta_A})\alpha}{\pi(\Delta-c)(1-\alpha)+(1-\pi)(c+\frac{\gamma_A}{\eta_A})\alpha} \text{ and } \beta \geq \frac{1}{2}$$

$$\alpha \in \left[\frac{\pi(\Delta-c)}{\pi(\Delta-c)+(1-\pi)(c+\frac{\gamma_A}{\eta_A})}, \frac{\pi(\Delta-c)}{\pi(\Delta-c)+(1-\pi)(c+\frac{\gamma_B}{\eta_B})} \right]$$

ii) The preferences of the two agents are such that

$$\gamma_A \in \left(\frac{\pi(1-\alpha)\eta_A(\Delta-c)\beta}{(1-\pi)\alpha(1-\beta)} - \eta_{AC}, \frac{\pi\eta_A(\Delta-c)}{1-\pi} - \eta_{AC} \right)$$

$$\gamma_B < \text{Min} \left[\frac{\pi\eta_B(\Delta-c)}{1-\pi} - \eta_{BC}, \frac{\pi(\Delta-c)\eta_B(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} - \eta_{BC} \right]$$

The truth-telling equilibrium conditions for the two agents to follow decision rules as specified in scenario 1, that is for the relevant region to be region 1* along with the fundamental inequalities (*Action Biased Prior*) of the agents gives rise to the preference conditions as outlined above.

Scenario 2) Non- neutrality case D_3 vs D_1 :

i) The signal precision space enclosed by (see 2* in the figure 2.2)

$$\beta \geq \frac{\pi(\Delta-c)(1-\alpha)}{\pi(\Delta-c)(1-\alpha)+(1-\pi)\alpha(c+\frac{\gamma_B}{\eta_B})}, \beta \geq \frac{1}{1+\frac{\pi(\Delta-c)(1-\alpha)}{(1-\pi)(c+\frac{\gamma_B}{\eta_B})}\alpha}$$

$$\alpha \in \left(\frac{1}{1+\frac{(1-\pi)\sqrt{(c+\frac{\gamma_A}{\eta_A})(c+\frac{\gamma_B}{\eta_B})}}{\pi(\Delta-c)}}, 1 \right)$$

ii) The preferences of the two agents are such that

$$\gamma_A < \text{Min} \left[\frac{\pi(\alpha)(1-\beta)\eta_A(\Delta-c)}{(1-\pi)(1-\alpha)\beta} - \eta_{AC}, \frac{\pi(\Delta-c)\eta_A}{1-\pi} - \eta_{AC} \right]$$

$$\gamma_A > \frac{\pi(1-\alpha)\beta\eta_A(\Delta-c)}{(1-\pi)\alpha(1-\beta)} - \eta_{AC}$$

$$\gamma_B \in \left(\frac{\pi(\Delta-c)\eta_B(1-\alpha)(1-\beta)}{(1-\pi)\alpha\beta} - \eta_{BC}, \frac{\pi(\Delta-c)\eta_B}{1-\pi} - \eta_{BC} \right)$$

The truth-telling equilibrium conditions for the two agents to follow decision rules as specified in scenario 2, that is for the relevant region to be region 2* along with the fundamental inequalities (*Action Biased Prior*) of the agents gives rise to the preference conditions as outlined above. We proceed by showing one numerical example each that fits **Scenario 1** and **Scenario 2**. In Scenario 1, i.e., in the signal precision region specified by region 1*, decision rule D_5 characterises the truth-telling equilibrium when agent B is delegated the role of the decision maker and decision rule D_1 characterises the truth-telling equilibrium when agent A is made the decision maker.

Under Scenario 1, the following condition must hold if the principal (who also exhibits an *Action Biased Prior* and ranking of preferences is such that $\gamma_P < \gamma_B < \gamma_A$) should delegate the decision making power to agent A who is less aligned with her in terms of preferences. The following inequality represents higher expected benefits to the principal from delegating the decision making power to agent A than the expected benefits she would get from delegating the decision making power to agent B .

$$\gamma_P > \frac{\pi(1-\alpha)\eta_P(\Delta-c)}{(1-\pi)\alpha} - \eta_{PC} \quad (4.42)$$

Note that the following condition needs to hold if the decision rule followed by B in truth-telling equilibrium is D_5 .

$$\gamma_B < \frac{\pi(1-\alpha)(1-\beta)\eta_B(\Delta-c)}{(1-\pi)\alpha\beta} - \eta_{BC} \quad (4.43)$$

The following condition needs to hold if the decision rule followed by agent A in equilibrium is D_1

$$\gamma_A > \frac{\pi(1-\alpha)\beta\eta_A(\Delta-c)}{(1-\pi)\alpha(1-\beta)} - \eta_{AC} \quad (4.44)$$

Numerical Example (satisfies all the conditions of Scenario 1):

$$\pi = \frac{1}{2}, \beta = \frac{1}{2}, \alpha = \frac{2}{3}, \Delta = 36, c = 4, \gamma_P = 3.5, \gamma_B = 3.9, \gamma_A = 5.5, \eta_P = \frac{1}{4}, \\ \eta_A = \eta_B = \frac{1}{8}$$

Fixing the parameter values as given above, the feasible signal precision region is:

$$\alpha \in [0.631, 0.6896], \beta \in [0.5, 0.532]$$

We can verify whether condition (4.42) holds true by substituting the parametric configurations specified in the numeric example here. It is indeed the case that the numerical example satisfies the condition (4.42). In the following cases, we provide some comparative statics for the numerical example of Scenario 1.

Case 1: Increasing the signal precision of agent B , $\beta = 0.55$

The equilibrium conditions for agent B to follow decision rule D_5 when he is the decision maker and for agent A to follow decision rule D_1 when he is the decision maker (4.43 and 4.44) do not hold any more when β is increased beyond its upper limit of 0.532 for the given numerical example. If agent B who exhibits an *Action Biased Prior* was the decision maker, then the decision rule followed by him under truth-telling equilibrium was D_5 (i.e., to take ‘Action’ under all signal configuration) which is the case when the signals of both agents are relatively uninformative. If agent A was the decision maker, then the decision rule followed by him under truth-telling equilibrium was D_1 (to take ‘Action’ only when he receives a high $j_A = h$ signal, his signal precision, α is relatively much higher than β in this region). As the signal precision of agent B increases, then we are going out of the relevant region 1*. Both agents B and A will pay attention to the information of agent B . This is the reason, conditions for D_5 or D_1 decision rules are no longer satisfied β becomes higher (when the quality of the information of agent B improves).

Case 2: Increasing the prior $\pi = 0.6$

Conditions (4.42) and (4.44) break under this case. An increased prior indicates higher probability for true state of the world to be high, H . This will make the bias toward taking the Action stronger. So it is harder to satisfy the condition for principal to give the decision making power to the agent who in equilibrium will take Action less number of times. In this case, the condition giving the decision making power to A , (4.42) breaks. The reverse of the condition is satisfied however,

that is, the inequality to give the decision making power to the agent with lower non-contractible cost (agent B) who has higher incentive to take ‘Action’ and takes Action under more signal configurations in equilibrium (D_5). Similarly, the equilibrium condition for agent A (decision rule D_1), (4.44) also breaks as the bias toward taking the Action becomes stronger. However, if the non-contractible cost of agent A , γ_A increases, this condition still holds. Under this case where prior has increased, the relative concern of making the mistake compared to the monetary benefits is lower and hence the conditions for the principal to give the decision making power to A and the condition for agent A to follow decision rule D_1 breaks.

Case 3: Decrease the non-contractible cost of agent A , $\gamma_A = 3.7$

Decreasing the non-contractible cost of agent A breaks condition (4.44). This is because in this case, the non-contractible cost of agent A is lower than that of agent B and so if agent B is always taking the Action in equilibrium (D_5) with change in no other parameter, it cannot be the case that agent A with lower concern for making a mistake chooses a decision rule that takes Action less number of times. To compensate for this change, α has to increase even more for this condition to hold to make agent A listen to his own signal when the non-contractible cost has gone down.

Case 4: Increase the non-contractible cost of agent B , $\gamma_B = 6$

Increasing the non-contractible cost of agent B breaks condition (4.43). Agent B ’s concern for making a mistake has gone up with no change in the expected monetary payoffs. Hence it is not optimal for him to follow a decision rule that takes Action in all signal configurations. The interval of β values within which D_5 decision rule happens in equilibrium is becoming smaller now that the non-contractible cost of B has gone up.

Case 5: Increase in the share of monetary payoff of the principal, $\eta = \frac{1}{3}$

This change means that the share of monetary payoffs to the agents has decreased from the previous $\frac{3}{8}$. This change breaks the condition (4.42), the inequality which dictates that the principal delegates the decision making power to the agent with the higher non-contractible cost. Since the monetary share of the principal has gone

up in comparison to the relative concern, the principal has an incentive to actually give the decision making power to agent B instead. This is because agent B follows a decision rule D_5 which takes more Action. This change however did not break the condition (4.44) since the non-contractible cost for agent is still higher than the share of his monetary payoff which is lower than in the numerical example.

Case 6: Increasing the signal precision of A , $\alpha = 0.7$

This change will break the condition (4.43), the condition for agent B to take D_5 decision rule in equilibrium. Now the signal precision of agent A , α is so high that we are moving out of the relevant region and agent B needs to start paying attention to A 's signal. Hence he cannot always take Action as he was previously doing. Now the information content of agent A is so high that agent A would most probably make less mistakes and hence the principal also would find it optimal to delegate the decision making power to agent A . This is because agent A now has a higher signal precision and also a greater concern for making a mistake and hence would have higher chances of taking the right decision.

Numerical Example (satisfies all the conditions of Scenario 2):

In **Scenario 2**, i.e., in the signal precision region specified by region 2*, we have decision rule D_3 characterising the truth-telling equilibrium when agent B is delegated the role of the decision maker and decision rule D_1 characterising the truth-telling equilibrium when agent A is made the decision maker.

Under Scenario 2, the following condition must hold if the principal (who also exhibits an *Action Biased Prior* and ranking of preferences is such that $\gamma_P < \gamma_B < \gamma_A$) should delegate the decision making power to agent A who is less aligned with her in terms of preferences. The following inequality represents higher expected benefits to the principal from delegating the decision making power to agent A than the expected benefits she would get from delegating the decision making power to agent B .

$$\gamma_P > \frac{\pi(1-\alpha)\beta\eta_P(\Delta-c)}{(1-\pi)\alpha(1-\beta)} - \eta_{PC} \quad (4.45)$$

The following conditions need to hold for agent B to follow D_3 decision rule in

truth-telling equilibrium

$$\gamma_B > \frac{\pi(1-\alpha)(1-\beta)\eta_B(\Delta-c)}{(1-\pi)\alpha\beta} - \eta_{BC} \quad (4.46)$$

$$\gamma_B < \frac{\pi(1-\alpha)\beta\eta_B(\Delta-c)}{(1-\pi)\alpha(1-\beta)} - \eta_{BC} \quad (4.47)$$

$$\gamma_A < \frac{\pi\alpha(1-\beta)\eta_A(\Delta-c)}{(1-\pi)(1-\alpha)\beta} - \eta_{AC} \quad (4.48)$$

The following condition needs to hold for agent A to follow D_1 decision rule in truth-telling equilibrium

$$\gamma_A > \frac{\pi(1-\alpha)\beta\eta_A(\Delta-c)}{(1-\pi)\alpha(1-\beta)} - \eta_{AC} \quad (4.49)$$

Following is a numerical example that satisfies the equilibrium conditions for the agents to be in Scenario 2. $\pi = \frac{1}{2}$, $\beta = 0.6$, $\alpha = \frac{3}{4} = 0.75$, $\Delta = 36$, $c = 4$, $\gamma_P = 3.5$, $\gamma_B = 3.9$, $\gamma_A = 5.5$, $\eta_P = \frac{1}{4}$, $\eta_A = \eta_B = \frac{1}{8}$

We can verify whether condition (4.45) holds true by substituting the parametric configurations specified in the numeric example here. It is indeed the case that the numerical example satisfies the condition (4.45). In the following cases, we provide some comparative statics for the numerical example of Scenario 2.

Case 1: Increasing the signal precision of agent B , $\beta = 0.65$

Increasing the signal precision, β breaks conditions, (4.45) and (4.49). The signal precision of agent B has increased and agent B 's decision rule D_3 leads to taking 'Action', A_c under more signal configurations and hence higher expected monetary payoff. Taking into account the combination of better signal precision and higher expected payoff, the principal now has greater incentive to delegate the decision making power to agent B unless his non-contractible cost goes up. So the inequality (4.45) to delegate the decision making power to A breaks. The other condition that breaks is inequality (4.49), which is the condition for agent A to take D_1 decision rule in equilibrium. Since the signal precision β is increased, agent A should now start listening to agent B 's signal instead of just listening to his own signal. Agent B 's signal is now closer to agent A 's signal and the relevant region is now out of the

decision rule D_1 when A is the decision maker. It will now be in the truth-telling region characterised by the decision rule D_3 when both the signal precisions are relatively better.

Case 2: Increasing the prior $\pi = 0.6$ Conditions (4.45) and (4.49) break under this case. An increased prior indicates higher probability for true state of the world to be high, H . This will make the bias toward taking the Action stronger. So it is harder to satisfy the condition for principal to delegate the decision making power to the agent who in equilibrium will take Action less number of times. In this case, the condition delegating the decision making power to A , (4.45) breaks. The reverse of the condition is satisfied however, that is, the inequality to delegate the decision making power to the agent with lower non-contractible cost (agent B) who has higher incentive to take ‘Action’ and takes ‘Action’ under more signal configurations in equilibrium (D_3). Similarly, the equilibrium condition for A (decision rule D_1), (4.49) also breaks as the bias toward taking the Action becomes stronger. However, if the non-contractible cost of agent A , γ_A increases, this condition still holds. Under this case where prior has increased, the relative concern of making the mistake compared to the monetary benefits is lower and hence the conditions for the principal to delegate the decision making power to A and the condition for agent A to follow decision rule D_1 breaks.

Case 3: Increasing the signal precision of agent A , $\alpha = 0.8$

Increasing the signal precision, α breaks the equilibrium condition for agent B to follow decision rule D_3 , (4.47). This is the the condition for agent B to take D_3 decision rule in equilibrium. Now the signal precision of agent A , α is so high that we are moving out of the relevant region and agent B needs to starts paying more attention to A ’s signal. The relevant region will now be D_2 , the signal precision of agent A , α is so high that it is highly informative and agent B should now take decision rule D_2 and completely listen to the sender A . Now the information content of agent A is so high and also his concern for making mistakes is higher than that of agent B . Therefore, agent A has lower likelihood of making mistakes and hence the principal would find it optimal to delegate the decision making power to agent

A as he has higher likelihood of taking the right decision.

□

Table 4.1: Complete List of Decision Rules

j^A	j^B	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}
h	h	A_c	A_c	A_c	A_c	A_c	N	N	A_c	A_c	N	N	N	N	A_c	N	N
l	h	A_c	N	A_c	N	A_c	N	A_c	N	A_c	A_c	N	N	N	N	A_c	A_c
h	l	N	A_c	A_c	N	A_c	N	A_c	A_c	N	N	A_c	N	A_c	N	A_c	N
l	l	N	N	N	N	A_c	N	A_c	A_c	A_c	N	N	A_c	A_c	A_c	N	A_c

Bibliography

- Alonso, R. and N. Matouschek (2008). “Optimal Delegation”. *Review of Economic Studies* 75.1, pp. 259–293.
- Banerjee, A. and R. Hanna (2012). “Corruption”. In: *The Handbook of Organizational Economics*. Ed. by S. Mullainathan, R. Gibbons, and J. Roberts. Introductory Chapters. Princeton University Press.
- Bardhan, P. (1997). “Corruption and Development: A Review of Issues”. *Journal of Economic Literature* 35.3, pp. 1320–1346.
- Bardhan, P. (2002). “Decentralization of Governance and Development”. *Journal of Economic Perspectives* 16.4, pp. 185–205.
- Bardhan, P. and D. Mookherjee (2000). *Corruption and Decentralization of Infrastructure Delivery in Developing Countries*. Boston University - Institute for Economic Development 104. Boston University, Institute for Economic Development.
- Basu, K. (2011). *Why, for a Class of Bribes, the Act of Giving a Bribe should be Treated as Legal*. MPRA Paper. University Library of Munich, Germany.
- Becker, G. (1968). “Crime and Punishment: An Economic Approach”. *Journal of Political Economy* 76.
- Bigoni, M. et al. (2014). *Trust, Leniency and Deterrence*. Konkurrentverket Working Paper Series in Law and Economics 2014:2. Konkurrentverket (Swedish Competition Authority).
- Buccirossi, P. and G. Spagnolo (2006). “Leniency policies and illegal transactions”. *Journal of Public Economics* 90.6-7, pp. 1281–1297.
- Burlando, A. and A. Motta (2016). “Legalize, tax, and deter: Optimal enforcement policies for corruptible officials”. *Journal of Development Economics* 118.C, pp. 207–215.

- Che, Y.-K. and N. Kartik (2009). "Opinions as Incentives". *Journal of Political Economy* 117.5, pp. 815–860.
- Crawford, V. P. and J. Sobel (1982). "Strategic Information Transmission". *Econometrica* 50.6, pp. 1431–51.
- Dessein, W. (2002). "Authority and Communication in Organizations". *Review of Economic Studies* 69.4, pp. 811–838.
- Drazen, A. (2002). *Political Economy in Macroeconomics*. Princeton, New Jersey: Princeton University Press.
- Fershtman, C. and K. L. Judd (1987). "Equilibrium Incentives in Oligopoly". *American Economic Review* 77.5, pp. 927–40.
- Fisman, R. and S.-J. Wei (2004). "Tax Rates and Tax Evasion: Evidence from 'Missing Imports' in China". *Journal of Political Economy* 112.2, pp. 471–500.
- Gallo, N. and D. E. Lewis (2011). "The Consequences of Presidential Patronage for federal Agency performance". *Journal of Public Administration Research and Theory* 22(2), pp. 219–43.
- Innes, R. (2000). "Self-Reporting in Optimal Law Enforcement When Violators Have Heterogeneous Probabilities of Apprehension". *The Journal of Legal Studies* 29.1, pp. 287–300.
- Jackson, M. O. and X. Tan (2013). "Deliberation, disclosure of information, and voting". *Journal of Economic Theory* 148.1, pp. 2–30.
- Joshua, C. D. et al. (2012). "Separated Powers in the United States: The Ideology of Agencies, Presidents, and Congress". *American Journal of Political Science* 56.2, pp. 341–354.
- Kaplow, L. and S. Shavell (1994). "Optimal Law Enforcement with Self-Reporting of Behavior". *Journal of Political Economy* 102.3, pp. 583–606.
- Malik, A. S. (1993). "Self-Reporting and the Design of Policies for Regulating Stochastic Pollution". *Journal of Environmental Economics and Management* 24.3, pp. 241–257.
- Mauro, P. (1995). "Corruption and Growth". *The Quarterly Journal of Economics* 110.3, pp. 681–712.

- Motta, A. and A. Burlando (2007). *Self reporting reduces corruption in law enforcement*. MPRA Paper 5332. University Library of Munich, Germany.
- Motta, M. and M. Polo (2003). “Leniency programs and cartel prosecution”. *International Journal of Industrial Organization* 21.3, pp. 347–379.
- Olken, B. A. (2005). *Monitoring Corruption: Evidence from a Field Experiment in Indonesia*. NBER Working Papers 11753. National Bureau of Economic Research, Inc.
- Reinikka, R. and J. Svensson (2004). “Local Capture: Evidence from a Central Government Transfer Program in Uganda”. *The Quarterly Journal of Economics* 119.2, pp. 679–705.
- Richard Clay Wilson, J. (2013). *Rethinking Public Administration: The Case for Management*. Minneapolis: MillCity Press.
- Schelling, T. C. (1960). *The Strategy of Conflict*. Cambridge, MA: Harvard University Press.
- Shleifer, A. and R. W. Vishny (1993). “Corruption”. *The Quarterly Journal of Economics* 108.3, pp. 599–617.
- Sklivas, S. D. (1987). “The Strategic Choice of Managerial Incentives”. *The RAND Journal of Economics* 18.3, pp. 452–458.
- Spagnolo, G. (2006). *Leniency and Whistleblowers in Antitrust*. CEPR Discussion Papers 5794. C.E.P.R. Discussion Papers.
- Tanzi, V. (1998). “Corruption Around the World: Causes, Consequences, Scope, and Cures”. *IMF Staff Papers* 45.4, pp. 559–594.
- Vickers, J. (1985). “Delegation and the theory of the firm”. *Economic Journal* 95, pp. 138–147.