

# Information design against petty corruption

Grégory Dannay

## Abstract

This paper explores how information design can help reducing petty corruption. By creating a framework in which a bureaucrat tries to extort a privately known profit of a firm, we look for the optimal way of releasing information about the firm such that it maximizes its expected profit. A principal which controls the flow of information will use wage payment and information design to attain this goal. We will explore how the optimal salary and corruption evolve as information design is introduced in the basic framework.

**Supervisor:** Eduardo Perez-Richet

*I would like to thank professor Eduardo Perez-Richet for his insightful advices, guidance and help throughout the writing of this thesis. I also want to thank my parents and my brothers Tony and Johann for their moral support since the beginning of my studies. Finally, I am grateful for Nicolas, Eva, Simon, Victor, Tuna, Florian and Manola for the time we spent together and for their help and support. All errors are mine.*

# 1 Introduction

Corruption is a factor hindering wealth creation and redistribution. Typically appearing in contexts of government monopoly and lack of direct accountability, (Lambert-Mogiliansky, Majumdar and Radner, 2008) [19], it has negative impacts on poverty, education and health. It represents therefore a concern for the public opinion, for governments and international organizations (Burguet, Ganuza and Montalvo, 2016) [5].

Transparency international currently distinguishes three types of corruption. Grand corruption and political corruption involve higher hierarchies that benefit from distorting policies to acquire power, status and wealth. An example involves former South Korean presidents who were found guilty of accepting bribes from leading firms in exchange for unfair business advantages in 1997. On the other hand, petty corruption refers to power abuse from low- and mid-level bureaucrats in their daily interactions with citizens. Common situations like getting a license or accelerating an administrative process through bribing fall into this category. (Transparency International, 2009) [13]. This paper will focus on the latter type.

Petty corruption often involves only small amounts of money. Nevertheless, in most of the cases it affects the poorest households and smallest firms which must bear additional costs for a proper access to public services. A 1999 survey of 1,164 enterprises and 1,800 households in Ecuador reported in the World Development Report (2011) illustrates this phenomenon. Bribe costs represented around 1% of a rich household's income (more than 329\$ monthly) whereas 4.5% of a poor household's income (less than 110\$ monthly). On the firm level, this effect is stronger: bribe cost represents 8% of a small firm's revenue (less than 11 employees) while it accounts for 1% of a larger firm's revenue (more than 99 employees) [16]. Depending on which country they are operating in, firms are differently affected by bribe requests for licences, permits and access to utilities. Some states like Israel, Estonia and Bhutan display a 1% occurrence of bribe payments by firms during 6 transactions dealing with public services. For other countries like Syria and Liberia, this statistic is close to 70%. Petty corruption operates in these cases as a "regressive tax" where the burden "typically falls disproportionately on the poor".[23]

We explore how information design can help fighting these cases of petty corruption. We will consider an interaction between a bureaucrat (she) and a firm (he) that applies for a project. We assume that the firm meets the regulatory standards when applying and that he will make a certain profit out of it. The bureaucrat has to accept the application and can abuse her power to extract the profit made by the firm. This scenario is a typical case of extortion. Extortion defines cases of "legitimate" applications that are refused if a bribe is not paid. It stands in opposition to capture which are characterized by "illegitimate" applications that are accepted in exchange for money (Lambert-Mogiliansky et al. 2008) [19]. We further consider that the bureaucrat gets a fixed salary paid by the government. She will face

a risk for demanding a bribe because a firm that does not want to pay will report her. We assume that this results in a lay-off and a salary loss.

In the concrete example of Ecuador as well as in our model, information plays a role because low level administrators face an information asymmetry in these day-to-day interactions with citizens. Assuming that they do not know the party that they are dealing with, they extort rather uniformly according to their beliefs and expectations. Our goal will be to study the benefits granted by information design in this context. We will look how this information asymmetry can be optimally used and how it affects the government's strategy in terms of salary payment. As a benchmark, we will first study the optimal salary in a framework of no information control and the resulting corruption level. We will hence be able to observe how optimal information release affects the needed salary as well as the demanded bribes.

This paper joins the developed literature of corruption. On the applied side, several studies have been undertaken on bribes paid by firms and their impact. Svensson (2003) [28] inspects bribe payments of firms to public officials in Uganda thanks to the 1998 Ugandan enterprise survey. He observes that the amount paid by firms depends mostly on their refusal power and their outside option, i.e. their ability to reallocate business somewhere else. Furthermore, he notes that profits and capital stock has a weak relationship with the amount of bribes. Hence, an increase of 1\$ US in profits per employee raises additional bribes by 0.004 \$ US. Similarly, an increase in 1\$ US in capital stock leads to a raise of 0.004 \$ US in bribe payment. Bribe demands resembles a flat tax that is paid by every firm in the same way in this case. Fisman and Svensson (2007)[9] used the same dataset to observe that a one-percentage point increase in the bribery rate leads to a decrease of the firm growth of three percentage point. This effect is therefore three times greater than that of taxation. Finally, Sequeira and Djankov (2013)[27] observe the effect of corruption on firm behaviour by using data on bribe payments in the ports of Durban in South Africa and Maputo in Mozambique. They managed to distinguish two types of corruption: "collusive" corruption that leads to higher activity with a port and "coercive" corruption that contributes to a decrease usage of a port. In the most extreme cases of the second type, corruption can increase firm costs by three times the amount requested initially by public officials through avoiding a port and going the long way around. More generally, Olken (2012)[22] proposes a rich survey on corruption in developing countries around the questions of the amount of corruption, the efficiency consequences and the sources.

On the theory side, Tirole (1986)[29] first used agency theory to model an illegal collusion between a supervisor and an entrepreneur in his seminal paper. He shows that a three-tier hierarchy (principal/supervisor/agent) is a convenient framework to study basic mechanisms of corruption and creates a first insightful model of collusion between a bureaucrat and an entrepreneur that is supervised. Ever since his contribution, corruption has been analyzed through numerous and various angles.

Asymmetry of information characterizes relationships in a principal-agent model and hence also in a corruption framework. Indeed, asymmetry of information between the principal and the supervisor gives the latter enough room for maneuver to collude with the agent. The principal who can not control for the agent's actions has to create the right incentives to make him undertake the desired action. Laffont and Tirole (1991)[18] paved the way in their model where a Congress wants to regulate an organization with privately known costs. A monitor can collect the information for the Congress but also has the power to hide it when the right incentives are not present. Paying a bonus helps the principal to get truthful information in this context. Random incentives in principal-agent relationship in organizations has also been studied by Rahman (2012)[25], Ederer et al. (2013) [20], Jehiel (2014)[14]. Rahman (2012) gives an optimal strategy for a principal to "monitor his monitor" by using "trick questions" to detect deviations. Random messages enable the principal to enforce the monitor to execute his mission. In the second paper, the authors study settings in which a principal with informational disadvantage can use ambiguous contracts to introduce uncertainty in the agent's framework. Jehiel (2014) analyze settings in organizations in which full transparency or no disclosure is optimal for a principal who wants to induce an action to an agent.

Asymmetry of information between the monitor and the agent is also a characteristic of models with illegal collusion. Mookherjee and Png (1995)[21] analyze a framework where the monitor has to put effort in order to gather information from a firm potentially active in illegal activities. The prospect of corruption may motivate the monitor to engage in information gathering if he can profit from it. Nevertheless, inducing a non optimal punishment would lead the monitor to leave the firm alone and let it engage in a deviant behavior. Lambert-Mogiliansky et al. (2008) [19] study an interaction between a bureaucrat and a firm applying for a project with an unknown profit. By looking at the optimal bribe demand and the firm's best strategy, they show that only a repeated interaction can hold an equilibrium in which agents can cooperate. Not respecting an agreement causes future losses. Hence, the benefits that come from "trust" create incentives to respect arrangements. We will consider a similar framework as in their paper.

Furthermore, asymmetries of information between the monitor and the agent where the former has private information has also been analyzed. Chassang and Padró-i-Miquel (2014)[6] examine policies on whistle-blowing and its limitation. In this framework, a monitor posses information about a potential deviating agent and may or may not denounce it to a principal. By always intervening against an agent active in illegal activities, the latter can infer that a supervisor reported him to the principal and can retaliate. The authors analyze how the principal must mix his strategy and garble information in order to better protect potential whistleblowers and keep incentives to report. The paper closest to ours is from Ortner and Chassang (2014) [24] who examine how randomizing over the supervisor's incentives

can reduce illegal agreement. Asymmetric information is here added in order to prevent side-contracting between a monitor and an agent. Compared to Ortner and Chassang who add asymmetric information in the relationships, we take it as given and we use information design to take advantage from it.

Our paper also joins the growing literature on information design. Introduced by Kamenica and Gentzkow (2011) [15], they study how an information Sender can influence the action of agents who observe the designed signal. Starting with a two player (Sender-Receiver) static model, this framework has been developed in several directions since. Dynamic settings, for instance, are analyzed by Renault, Solan and Vieille (2014) [26], Ely (2015) [8], Basu (2017) [1] and Bizzotto, Rüdiger and Vigier (2018) [4]. The first two papers study a framework in which the state is evolving exogenously, the sender is the only player releasing information and the receiver maximizes his short-run payoff. Basu (2017) examines a model in which the Receiver has private information and the Sender dynamically releases information taking into account this asymmetry. Bizzotto et al. (2018) consider a fixed state in which there are exogenous public information and the Receiver takes decisions with respect to future incoming information. Methods introduced by these extensions have been used in our multiple bureaucrats framework.

Models with multiple receivers are surveyed in Bergemann and Morris (2018) [3] and multiple senders by Kamenica and Gentzkow (2017) [11]. Frameworks with an infinite set of states have been approached by Gentzkow and Kamenica (2016) [10], Kolotilin (2018) [17] and Dworzak and Martini (2019) [7]. The first paper characterizes the optimal space of signals and defines a method for finding the optimal signal structure in a framework with a small action space. Kolotilin (2018) uses a linear programming approach in a model where the Sender's utility relies on the mean of the Receiver's posterior expectation of the Sender's type. Dworzak and Martini (2019) analyze a consumer who buys at the price of the posterior belief with the prior as endowment in a framework with a general action set.

Finally, Bayesian Persuasion has also found applications in several concrete areas. Applications closest to our paper are given by Hernandez and Neeman (2018) [12] and Bergemann, Brooks and Morris (2015) [2]. Hernandez and Neeman (2018) study how to reduce undesirable behavior through optimal allocation of enforcement resources across locations. The principal can additionally send a binary message to improve deterrence and persuade the Receiver to act in the right manner. Bergemann, Brooks and Morris (2015) use a method close to Bayesian Persuasion in a framework of a monopolist using price discrimination for selling a good. They develop an optimal information strategy for buyers with different valuation for that good in order to maximize their expected payoff. We will use their approach in our model to get a tractable solution.

First, we will introduce the model and compute the optimal bribe demand as well as the optimal salary in a framework where the information flow can not be controlled in order to have a benchmark.

Second, we study the concept of information design and solve the model in which this tool is added. We compare the results and analyze the optimum from both cases. Finally, we introduce a model with multiple bureaucrats and present its setting.

## 2 The model

### 2.1 Framework

Consider a model with three players: a government, an bureaucrat (she) and a firm (he). The firm has a project which grants a potential profit  $p_k$  that can take  $K > 1$  possible values which are equally distributed on a set  $[0, 1]$ . The firm learns this value while the other players only know its distribution. We denote  $P = \{0, \dots, p_k, \dots, 1\}$  the set of possible profits which are increasing in the index  $k$  so that:

$$p_0 = 0 < \dots < p_k < \dots < p_{K-1} = 1$$

Each value  $p_k$  is therefore equal to  $\frac{k}{K-1}$  and each possible profit follows the distribution:

$$f_p(x) = \begin{cases} \frac{1}{K} & \text{if } p_j \in P \\ 0 & \text{otherwise} \end{cases}$$

with c.d.f.:

$$F_p(x) = \begin{cases} 0 & x < 0 \\ \frac{p_k(K-1)+1}{K} & x \in [p_k, p_{k+1}[ \in P \\ 1 & x \geq 1 \end{cases}$$

The bureaucrat has to approve the project and can ask for a bribe. We denote  $b \in \mathbb{R}^+$  the amount she asks. We assume this offer to be a take-it-or-leave-it bribe, i.e. the bureaucrat only has one shot that is either accepted or rejected by the firm. Additionally, she gets a fixed wage denoted  $s \in \mathbb{R}^+$ . If the firm accepts to pay the bribe, the project is accepted, carried out and profits are made. Otherwise, if the firm refuses, the project is called off and the firm gets nothing. We also make the assumption that the firm reports the bureaucrat in case of a refusal. She would then be laid off and be deprived from her salary  $s$ .

We note that the firm has an obvious dominant strategy to pay the bribe if the amount is below the profit and to refuse otherwise. We assume, for simplicity, that he accepts to pay when he is indifferent between both options. Hence, the bureaucrat's payoff is:

$$\begin{cases} (s + b) & b \leq p \\ 0 & b > p \end{cases}$$

Given any  $K$  possible profits, the maximum feasible surplus is

$$\mathbb{E}_{F_p}[w^*] = \sum_{p_j \in P} p_j f_p(p_j) = \frac{1}{K} \sum_{k=0}^{K-1} \frac{k}{K-1} = \frac{1}{K} \frac{K^2 - K}{2(K-1)} = 0.5$$

Given a certain bribe  $b$ , the bureaucrat's expected return from corruption is:

$$\mathbb{E}_{F_p}[v_b(b)] = b(1 - F_p(b))$$

$$\mathbb{E}_{F_p}[v_b(b)] = \begin{cases} 0 & b = 0 \\ b(1 - \frac{p_k(K-1)+1}{K}) & b \in ]p_k, p_{k+1}] \\ 0 & b > 1 \end{cases}$$

and the firm's expected profit is:

$$\mathbb{E}_{F_p}[u_f(b)] = \sum_{p_j \geq b} (p_j - b)(f_p(p_j))$$

$$\mathbb{E}_{F_p}[u_f(b)] = \begin{cases} 0.5 & b = 0 \\ \sum_{p_j \geq p_{k+1}} (p_j - b)(\frac{1}{K}) & b \in ]p_k, p_{k+1}] \\ 0 & b \geq 1 \end{cases}$$

Finally, the principal, here the government, wants to maximize the firm's profit under the cost of paying the bureaucrat. Its utility is given by:

$$z_g(s) = \mathbb{E}[u_f(b(s))] - \lambda c(s)$$

where  $c(\cdot) : \mathbb{R}^+ \rightarrow \mathbb{R}^+$  is an increasing cost function and  $\lambda \geq 0$  is the weight of the cost function.

The timing of this game is thus the following:

1. Nature determines  $P$  with the corresponding distribution  $F_p$  observed by all players and the firm learns its magnitude.
2. The government commits to a salary  $s$ .
3. The firm applies for the project and the bureaucrat makes a take-it-or-leave-it bribe offer.
4. The firm pays the bribe and the project is accepted or refuses to pay and the bureaucrat loses her salary.

## 2.2 Equilibrium

**Proposition 1.** *The equilibrium is defined by  $\{b^*, s^*\}$  such that it maximizes respectively the bureaucrat's expected payoff from being corrupt and the government's best response to that strategy. With  $K$  approaching infinity and the set  $P$  becoming continuous on the set  $[0, 1]$ , we have:*

$$b^* = \frac{1-s}{2}$$

and  $s^*$  is the solution to the equation

$$\frac{s+1}{4} - \lambda c'(s) = 0$$

We find these strategies by using backward induction. We first analyze optimal strategies with a finite  $K$  and let it approach infinity afterwards in order to get a continuous set. Starting with the bureaucrat, she has to maximize the following payoff:

$$b^*(a) = \arg \max_b (s+b)(1-F_p(b))$$

$$b^*(s) = \begin{cases} s & b = 0 \\ \arg \max_b (s+b)(1 - \frac{p_k(K-1)+1}{K}) & b \in ]p_k, p_{k+1}] \end{cases}$$

We see here a trade-off in the bribe demand's amount. Requesting more money will directly improve the utility while also lowering the probability of being paid. Given the structure of the payoff, we can state the following proposition

**Proposition 2.** *For every bribe demand  $b \in ]p_k, p_{k+1}[$ , the amount  $p_{k+1}$  gives a strictly better payoff than  $b$ . Hence, for every set  $]p_k, p_{k+1}[$ , the bribe demand  $p_{k+1}$  maximizes the expected outcome.*

*Proof.* The proof is very intuitive. For every  $b \in ]p_k, p_{k+1}[$ , the probability of the firm accepting remains the same since the cumulative distribution is a step function. For a fixed  $(1 - F_p(b))$  for  $b \in ]p_k, p_{k+1}[$ , the objective function  $(s+b)(1 - F_p(b))$  will increase linearly in  $b$  until reaching the bound  $p_{k+1}$ . Going further will alter the probability of the firm accepting and we would end up in the next subset  $]p_{k+1}, p_{k+2}[$ . We can clearly see this trend in Figure 1, where the highest expected outcome for every set is at the bound, i.e. the filled dot.  $\square$

Thus, we reduce the set of optimal strategies to

$$b^* \in P$$

Now that the set of possible solutions is narrowed down, we can pin down the maximizing values with



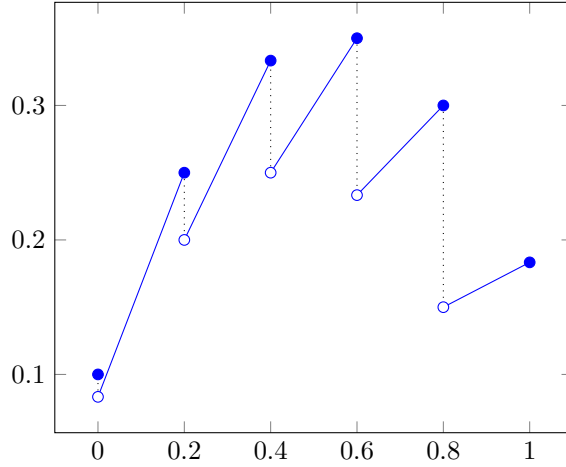


FIGURE 1: Expected bureaucrat's outcome for  $K = 6$  and  $a = 0.1$

respect to  $s$ . We do that by treating the distribution function as continuous in order to grasp the possible maximizers.

By defining

$$k^* = \left\lceil \frac{K - s(K - 1)}{2} - 0.5 \right\rceil$$

where  $\lceil x \rceil$  stands for the least integer greater than or equal to  $x$ , we get the following proposition:

**Proposition 3.** *The optimal bribe demand is equal to*

$$b^* = \frac{k^*}{K - 1}$$

*Proof.* Appendix □

We observe here an important fact: the optimal bribe demand is decreasing with the salary. In a world in which a bureaucrat gets reported and punished, the burden of a salary loss gets heavier with an increased income which makes it riskier to be corrupt. When the salary is equal to the maximum possible value of the project,  $s = 1$ , there is no benefit anymore to ask for a bribe and corruption vanishes. Nevertheless, that is also the most expensive solution.

Finally, we do some calculations to get the following equality:

$$\frac{k^*}{K - 1} = \frac{1 - s}{2}$$

which gives us the equilibrium that we were looking for. As long as  $\frac{1-s}{2}$  is between two points in  $P$ , the bureaucrat will ask for the upper bound of the set she is in. When this value reaches one point in  $P$ , she will ask for this particular amount. When  $K$  approaches infinity, the set  $P$  becomes continuous such that the above equality can take any particular value on this set.

Now that the government knows the bureaucrat's best strategy, it can choose the optimal salary by maximizing its utility function with respect to  $s$ :

$$\max_s \mathbb{E}[u_f(b^*(s))] - \lambda c(s)$$

rewrite the firm's utility function with

$$\mathbb{E}[u_f(s)] = \begin{cases} 0.5 & s = 1 \\ \sum_{p_j \geq p_{k+1}} (p_j - \frac{k+1}{K-1})(\frac{1}{K}) & \frac{1-s}{2} \in ]p_k, p_{k+1}] \end{cases}$$

$$\mathbb{E}[u_f(s)] = \begin{cases} 0.5 & s = 1 \\ \sum_{n=k+1}^K (\frac{n}{K-1} - \frac{k+1}{K-1})(\frac{1}{K}) & \frac{1-s}{2} \in ]p_k, p_{k+1}] \end{cases}$$

which gives

$$\mathbb{E}[u_f(s)] = \begin{cases} 0.5 & s = 1 \\ \sum_{n=0}^{K-(k+1)} \frac{n}{K(K-1)} & \frac{1-s}{2} \in ]p_k, p_{k+1}] \end{cases}$$

and hence

$$\mathbb{E}[u_f(s)] = \frac{(K - k(s)^*)^2 - K + k(s)^*}{2K(K-1)}$$

**Proposition 4.** *It is optimal for the government to make an offer  $s$  such that*

$$\frac{1-s}{2} = \frac{k}{K-1}$$

or

$$\frac{1-s}{2} \in P$$

*Proof.* We proved that a bureaucrat will always ask for a bribe  $b \in P$ . We have also showed that an optimal bribe remains constant as long as  $s$  does not reach a point that does not attain the equality stated above. When the equality is reached, increasing  $s$  will not change  $b^*$  whereas it will increase the cost  $c(s)$  which will in turn decrease the government's utility. Thus, the optimal point must be when the equality is attained or simply put, when  $\frac{1-s}{2}$  is in  $P$ . Looking at Figure 2, we can again see this fact. The dotted points represent cases when this is true. When moving away from one of this points, the government's utility has to decrease.  $\square$

We can finally look at the optimum given the firm's utility function and the bureaucrat's best strategy. We have maximize the following function with respect to  $s$ :

$$\max_s \frac{(K - \lceil \frac{K-s(K-1)-1}{2} \rceil)^2 - K + \lceil \frac{K-s(K-1)-1}{2} \rceil}{2K(K-1)} - \lambda c(s)$$

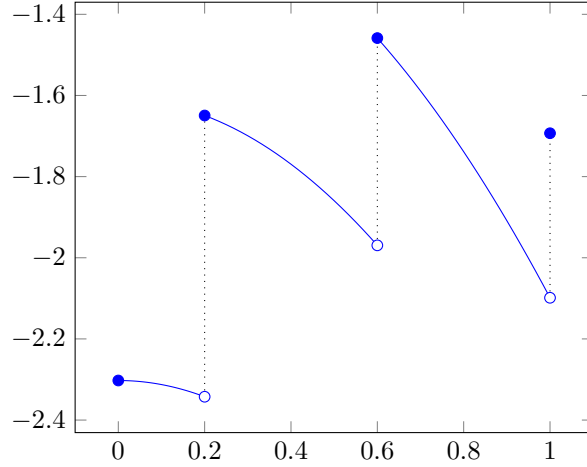


FIGURE 2: Expected bureaucrat's outcome for  $K = 6$

We are again facing a step function whose maximum changes with respect to  $K$ . As  $K$  increases and reaches infinity, the set  $P$  becomes continuous and so do the strategies. We can therefore treat the objective function as a continuous one when  $K$  approaches infinity in order to grasp the solution:

$$\begin{aligned} \max_s \lim_{K \rightarrow \infty} & \frac{(K - \lceil \frac{K-s(K-1)-1}{2} \rceil)^2 - K + \lceil \frac{K-s(K-1)-1}{2} \rceil}{2K(K-1)} - \lambda c(s) \\ \max_s \lim_{K \rightarrow \infty} & \frac{s^2(K-1)^2 + 2s(K^2 - K) + K^2 - 1}{8K(K-1)} - \lambda c(s) \end{aligned}$$

which yields

$$\max_s \frac{s^2 + 2s + 1}{8} - \lambda c(s)$$

Maximizing yields that  $s^*$  must solve the following equation:

$$\frac{s^* + 1}{4} - \lambda c'(s^*) = 0 \tag{1}$$

(Details in the appendix)

This leads us to the following proposition:

**Proposition 5.** *A solution  $s^*$  that satisfies (1) exists if:*

$$c'(0) \leq \frac{1}{4\lambda} \tag{2}$$

$$c'(1) \geq \frac{1}{2\lambda} \tag{3}$$

are fulfilled. It is unique if conditions (2) and (3) are strict inequalities and

$$c''(s) > \frac{1}{4\lambda} \quad (4)$$

is respected for a subset of  $[0, 1]$  such that there is at most one value for which

$$c''(s) = \frac{1}{4\lambda} \quad (5)$$

Furthermore, condition (4) is required for the solution to be a maximizer.

*Proof.* The optimal salary  $s^*$  has to be in the set  $[0, 1]$ . Condition (2) and (3) ensures that equation (1) takes the value 0 at least once thanks to the intermediate value theorem. Furthermore, uniqueness is ensured by conditions (4) and (5). Strict inequalities for (2) and (3) are also required for uniqueness to rule out possible solution at the bound. If the cost function  $c(s)$  is strictly concave, and fulfills equation (4) for all values of  $s$ , we know that function (1) is strictly decreasing with respect to  $s$ . Monotonicity ensures that point 0 is crossed only once. Nevertheless, if condition (4) is not respected for all values of  $s$  but that there is one inflexion point, we know that the derivative will increase in a first time and decrease after this critical point. Point 0 will again be crossed only once if condition (1) and (2) are fulfilled. Finally, to ensure that the solution maximizes the objective function, it must be that the objective function is concave at this point, i.e. that condition (4) is respected.  $\square$

Condition (4) rules out any possible strictly concave and linear function for which the second derivative is respectively negative and equal to zero. In these cases, the solution would be a corner solution that follows:

$$s^* = \{0, 1\} \text{ s.t. } s^* = \arg \max_s z_g(s)$$

These conditions are nonetheless not enough to characterize all possible cost functions, especially those that have multiple concave and convex subsets. Nevertheless, it enables to prove that cost functions that are increasing and strictly convex with respect to condition (4) like the quadratic cost function attains interior solutions.

Function (1) enables us to see how the optimal salary reacts with a change in  $\lambda$ . By imposing the restriction of strictly increasing and convex cost function, an increase in  $\lambda$  would result in a decrease in  $s^*$ . Since the equation has to hold the equality with 0, an increase in  $\lambda$  decreases the whole function below 0 because of the second term. Reduce the salary would increase the whole function because on the convexity of the cost function until it reaches a level that is back to point 0. Naturally, as the weight of the cost function increases, the government would find it harder to pay the bureaucrat. As  $\lambda$  tends to infinity, the optimal salary will approach zero whereas it will approach 1 as  $\lambda$  decreases.

If we take for instance  $c(x) = x^2$ , we have:

$$s^* = \frac{1}{8\lambda - 1}$$

which illustrates the relationship between  $s^*$  and  $\lambda$ . As  $\lambda$  approaches infinity,  $s^*$  becomes smaller. On the other hand, as soon as  $\lambda$  reaches  $\frac{1}{4}$ , the optimal solution becomes 1.

### 3 Optimal information design

#### 3.1 Bayesian Persuasion

We will now assume that the government can design the information given to the bureaucrat. From a concrete point of view, this situation can be pictured by the design of an administrative form. When applying for this project, the firm will have to fill a particular form that will be handed to the bureaucrat. The question will be what kind of information to ask on it and the precision of this information. This scenario is modeled through Bayesian Persuasion.

Bayesian persuasion, introduced by Kamenica and Gentzkow (2011), is defined as "influencing behavior via provision of information". We will take the same notation as in their paper. The basic model takes two players: a Receiver (bureaucrat) and a Sender (government). The former has to take a decision that gives him a different utility depending on an unknown state of the world  $p \in P$ . The latter gets a payoff that depends on the Receiver's action and has the ability of choosing a signal structure that will depend on the true state of the world. We denote  $S$  the set of signal realization and  $\Pi$  the set of all signals. A signal is a function that maps the state to the distribution of signal realization  $\pi : P \rightarrow \Delta(S)$ . Following Kamenica and Gentzkow, we now have the following timing:

1. The government chooses a signal  $\pi$  and a salary  $s$ .
2. The bureaucrat observes which signal was chosen and learns her salary  $s$ .
3. Nature determines  $P$  observed by all players and the firm learns its magnitude.
4. Nature chooses the signal  $m$  according to  $\pi(p)$  observed by the bureaucrat.
5. The firm applies for the project and the bureaucrat makes a take-it-or-leave-it bribe offer.
6. The firm pays the bribe and the project is accepted or refuses to pay and the bureaucrat loses her salary.

Given a certain  $\pi$ , the bureaucrat uses the Bayes' rule to update her belief from the prior  $\mu_0$  to the posterior

$$\mu_\pi = \frac{\pi(m|p)\mu_0(p)}{\sum_{p'} \pi(m|p')\mu_0(p')}$$

Now, the optimal bribe demand  $b^*(s, \mu_\pi(\cdot|m))$  will also depend on the belief and will maximize the

expected payoff with respect to the new distribution induced by a particular signal  $\mathbb{E}_{p \sim \mu_\pi(\cdot|m)} v_b(b, p)$ . Finally, the government solves:

$$\max_s \max_{\pi \in \Pi} \mathbb{E}_{p \sim \mu_0} \mathbb{E}_{m \sim \pi(p)} z_g(s, b^*(s, \mu_\pi(\cdot|m)), p)$$

Kamenika and Gentzkow note that choosing a signal  $\pi$  leads to a set of posteriors  $\mu_\pi(\cdot|m)$  each induced by a realization  $m$ . They use the notation  $\tau = \langle \pi \rangle$  to indicate that a distribution of posteriors  $\tau$  is induced by signal  $\pi$ . The problem comes down to find the right posterior that maximizes the objective. Nevertheless, by the law of iterated expectations, "every distribution of posteriors induced by a signal is Bayes-plausible". Bayes-plausibility is defined as a distribution of posteriors  $\tau$  that equals the prior in expectation, i.e  $\mathbb{E}_{\mu \sim \tau} \mu = \mu_0$ . When finding the right posterior, we have to make sure that this rule is respected. The problem is therefore reduced to:

$$\begin{aligned} \max_s \max_{\tau} \mathbb{E}_{\mu \sim \tau} z_g(s, b^*(s, \mu)) \\ s.t. \mathbb{E}_{\mu \sim \tau} \mu = \mu_0 \end{aligned}$$

### 3.2 Direct segmentation

The issue here is that we are dealing with many states and thus Kamenika and Gentzkow's concavification approach can hardly be used. Instead, we are going to use Bergemann, Brooks and Morris' (2015) method to get a tractable solution. In their paper, they explain how consumers with different valuations for a good have to manage the flow of information to influence the price chosen by a monopolist so that it maximizes their utility. Consumers can control the information through the means of segmentation. A segmentation is defined as a division of the whole market into smaller groups of consumers. There is a parallel between a signal structure and this notion of segmentation: a signal induces a new posterior distribution according to a signal structure as well as a segment with respect to a segmentation. For instance, full information corresponds to a segmentation where every segment contains consumer with the same valuation whereas no information corresponds to an only segment with all valuation.

The core of their paper is to prove that every outcome in the shaded area of Figure 3 is attainable. First, they show that the lower bound on the monopolist's expected payoff is attained by the uniform price. This price maximizes his expected outcome given his prior belief of uniform distribution and no additional information. A monopolist "must get at least the surplus that he could get if there was no segmentation and he charged the uniform price". Releasing no information will end up in an outcome at point A. Nevertheless, the main proof of this paper is that given a certain uniform price, point O which maximizes the consumer's outcome is attainable through a segmentation: the direct segmentation.

**Proposition 6.** *We define  $\pi_b^*$  as the monopolist's profit when charging the uniform price. Direct*



FIGURE 3: Feasible payoffs

*segmentation that is uniform profit preserving can achieve efficiency such that the monopolist's expected profit is  $\pi_b^*$  and the consumers' expected outcome is  $w^* - \pi_b^*$*

*Proof.* The proof is given by Bergemann et al. (2015) They first show that this statement is true for extremal segmentation which is the segmentation that they use during the whole proof. Through a geometrical analysis, they are able to demonstrate that every outcome in the "surplus triangle" can be attained by a certain extremal segmentation. Moreover, they state that "any segmentation and optimal pricing rule  $(\sigma, \phi)$ , there exist: (i) an extremal segmentation and an optimal pricing rule  $(\sigma', \phi')$  and (ii) a direct segmentation  $\sigma''$  (and associated direct pricing rule  $\phi''$ ) that achieve the same joint distribution over valuation and prices. As such, they achieve the same producer surplus, consumer surplus [and] total surplus". Hence, knowing that extremal segmentation can achieve the efficient outcome, direct segmentation can attain the same result. Finally, they show that at the efficient point, the monopolist gets his equilibrium profit  $\pi^*$  and the consumer obtains  $w^* - \pi^*$ .  $\square$

Direct segmentation describes a division of the market such that

1. "consumers' valuations are always greater than or equal to the price of the segment"
2. "in each segment, the producer is indifferent between charging the price for that segment or charging the uniform monopoly price."

It is constructed iteratively. We first start with the "lowest price segment where a price equal to the lowest valuation will be charged". In this segment, we fit all consumers with the lowest valuation as well as a share of all other consumers with higher valuation. The relative share of these valuations (with respect to each other) must be the same as in the prior and is computed such that the monopolist

is indifferent between charging the equilibrium price or the segment price. This procedure is further iterated until the uniform monopoly price is reached. Formally, Bergemann, Brooks and Morris show that this segmentation is attainable by the following equations:

$$x_i^k = \begin{cases} 0 & \text{if } i < k \\ 1 - \gamma_k \sum_{j=k+1}^K x_j^* & \text{if } i = k \\ \gamma_k x_i^* & \text{if } i > k \end{cases}$$

where  $\gamma_k$  in  $[0, 1]$  uniquely solves:

$$v_k \left( x_k^* + \gamma_k \sum_{j=k+1}^K x_j^* \right) = \gamma_k v^* \sum_{j=i^*}^K x_j^*$$

where  $x_i^k$  stands for the proportion of consumers with valuation  $i$  in the segment  $k$ .  $x_k^*$  denotes the prior probability of valuation  $k$ ,  $v^*$  is the optimal uniform price and  $i^*$  is the index of the equilibrium price with respect to the set of valuations.

Also, each segmentation has the following probability of being chosen:

$$\sigma(x^1) = \frac{x_1^*}{x_1^1}$$

and

$$\sigma(x^k) = \frac{x_k^* - \sum_{j=1}^{k-1} \sigma(x^j) x_k^j}{x_k^k}$$

Making again the link with signal structure, the construction of this segmentation respects the Bayes-Plausibility. Indeed, the probability of realization of each segment is computed such that the expected distribution of posterior is equal to the distribution of the prior. Knowing that this segmentation attains the efficient point O, we can use their method to create the optimal signal structure. We illustrate it with an example.

**Example:** We take  $K = 6$ . We therefore have  $P = \{0, \frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\}$  with probability  $\frac{1}{6}$  for each. We assume that  $s = 0.2$  such that  $b^* = \frac{2}{5}$ . The corresponding optimal direct segmentation is:

	Profit 0	Profit 0.2	Profit 0.4	Profit 0.6	Profit 0.8	Profit 1	Bribe	Payoff	Proba
Segment 1	$\frac{7}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	$\frac{1}{12}$	0	0.2	$\frac{2}{7}$
Segment 2	0	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	0.2	0.4	$\frac{3}{7}$
Segment 3	0	0	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0.4	0.6	$\frac{2}{7}$
Total	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$			1



In this example, the government can send three different signals corresponding to three different segments. If the bureaucrat receives the first signal, she is indifferent between asking nothing and asking for the equilibrium bribe 0.4 in which case she gets 0.2. The same reasoning holds for signal 2 and 3 where she gets respectively 0.4 and 0.6 by asking for the equilibrium bribe or the segment bribe.

Now direct segmentation enables us to get the best signal structure given a particular optimal bribe  $b^*$ . Knowing this optimum, the government only has to look for the optimal salary. The bureaucrat's best strategy with respect to her prior is given in the first part of the paper. We can take this strategy as the optimal uniform price given by Bergemann et al. Furthermore, for each signal, she is indifferent between charging the uniform bribe and the signal's recommended bribe. We assume for simplicity that the bureaucrat always chooses the signal's recommendation. This reduces the problem to the following maximization:

$$\begin{aligned} & \max_s \mathbb{E}_{\mu \sim \tau^*} z_g(b^*(s, \mu), s) \\ & \max_s w^* - \mathbb{E}_{\mu \sim \tau^*} v_b(b^*(s, \mu)) - \lambda c(s) \end{aligned}$$

where  $\tau^*$  is the optimal posterior. Taking the definition of  $v_b$  and putting the optimal  $b^*$ , we get:

$$\max_s 0.5 - \frac{\left\lceil \frac{K-s(K-1)-1}{2} \right\rceil}{K-1} \left( 1 - \frac{\left\lceil \frac{K-s(K-1)-1}{2} \right\rceil}{K} \right) - \lambda c(s)$$

We are facing again a step function. In order to get a tractable solution, we let  $K$  approach infinity and have a continuous set of  $P$  and therefore actions. Treating the function as continuous, we get:

$$\begin{aligned} & \max_s \lim_{K \rightarrow \infty} 0.5 - \frac{\left\lceil \frac{K-s(K-1)-1}{2} \right\rceil}{K-1} \left( 1 - \frac{\left\lceil \frac{K-s(K-1)-1}{2} \right\rceil}{K} \right) - \lambda c(s) \\ & \max_s \lim_{K \rightarrow \infty} 0.5 - \frac{K^2 - s^2(K-1)^2 - 2s(K-1) - 1}{4K(K-1)} - \lambda c(s) \\ & \max_s 0.5 - \frac{1-s^2}{4} - \lambda c(s) \end{aligned}$$

Maximizing yields that  $s^*$  must solve the following equation:

$$\frac{s^*}{2} - \lambda c'(s^*) = 0 \tag{6}$$

(Details in the appendix)

This leads us to the following proposition:

**Proposition 7.** *A solution  $s^*$  that satisfies (6) exists if:*

$$c'(0) \leq 0 \tag{7}$$

for at least one value of  $s \in [0, 1]$

$$c'(1) \geq \frac{1}{2\lambda} \tag{8}$$

are fulfilled. It is unique if condition (7) and (8) are strict inequalities and

$$c''(s) > \frac{1}{2\lambda} \tag{9}$$

is respected for a subset of  $[0, 1]$  such that there is at most one value for which

$$c''(s) = \frac{1}{2\lambda} \tag{10}$$

Furthermore, condition (9) is required for the solution to be a maximizer.

*Proof.* The proof is the same as before. Condition (7) and (8) ensures that equation (6) takes the value 0 at least once thanks to the intermediate value theorem. Furthermore, uniqueness is ensured by conditions (4) and (5) and the strict inequalities of (7) and (8). If the cost function  $c(s)$  is strictly concave, and fulfills equation (9) for all values of  $s$ , we know that function (6) is strictly decreasing with respect to  $s$ . Monotonicity ensures that point 0 is crossed only once. Nevertheless, if condition (9) is not respected for all values of  $s$  but that there is one inflexion point, we know that the derivative will increase in a first time and decrease after this critical point. Point 0 will again be crossed only once if condition (7) and (8) are fulfilled. Finally, to ensure that the solution maximizes the objective function, it must be that the objective function is concave at this point, i.e. that condition (9) is respected.  $\square$

As before, condition (8) rules out any strictly concave or linear cost functions if we are looking for a maximizing solution. These functions would lead to a corner solution that will be either  $s = 1$  or  $s = 0$ .

In this context however, common cost functions like the quadratic cost function can have at least two solutions. This is due to the fact that these function typically have  $c'(0) = 0$ . In order to ensure that there exist a second solution that is not at a bound, we must have that

$$c''(0) < \frac{1}{2\lambda}$$

so that the derivative increases right away and crosses the 0 point for sure if (8) is respected.

We can again observe how a change in  $\lambda$  would affect the optimum. By restricting the set of cost functions to the functions that are strictly convex and respect condition (9), we observe again that an increase in  $\lambda$  would decrease the optimal salary. Indeed, if the second term  $\lambda c'(s)$  increase the function decreases and we have to decrease  $s$  in order to attain the constant 0.

Here, we have however that the optimal salary is equal to 0 or 1 when we take the conventional quadratic cost functions  $c(x) = x^2$  depending on the value of  $\lambda$ . When  $\lambda > \frac{1}{4}$ , the optimal salary becomes 1.

### 3.3 Results

At the optimum, the following equation hold:

$$\frac{s^*}{2} + \frac{1}{2} - 2\lambda c'(s^*) = 0$$

$$\frac{s^*}{2} - \lambda c'(s^*) = 0$$

for the framework without information design and with it respectively.

It is difficult to analyze the differences between both optima. Indeed, the first equation differs from the second through its term  $\frac{1}{2}$ . This term increases the optimal salary  $s^*$  as it would take a higher cost to outweigh the marginal benefit of a wage increase. On the other hand, we also have the term  $2\lambda c'(s)$  that acts in the same manner as in increase of  $\lambda$ , i.e. it decreases the salary.

In order to have a first grasp of the differences between both function, we assume a specification for  $c(s)$ . Since all the polynomials respect the condition for a interior solution in both function, we take  $c(s) = s^\alpha$  where  $\alpha \geq 2$ . With that in hand, we can plot the solution on a graph and have a first approach of the solutions.

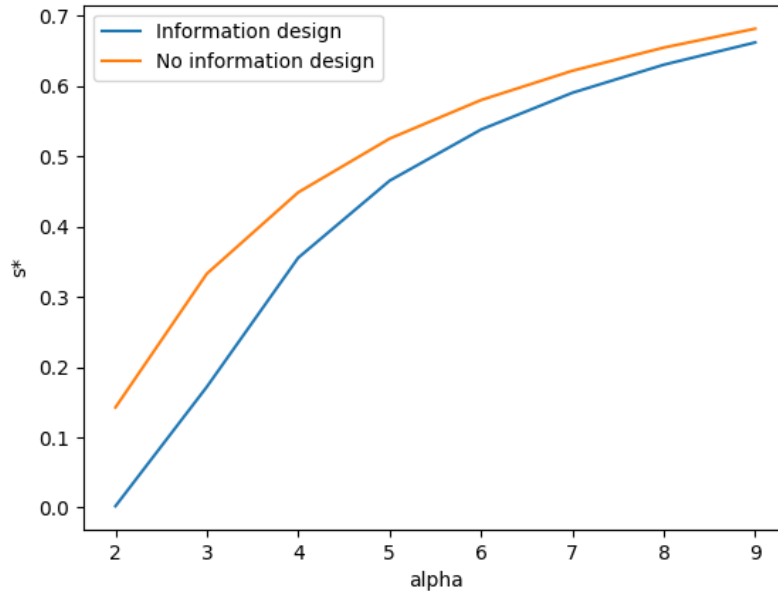


FIGURE 4: Optimal salary with  $\lambda = 1$

As we can see in Figure 4, the optimal salary is always greater without information design than with it in the realm of this specification. Nevertheless, the gap between both salaries becomes smaller as  $\alpha$  increases. This is due to a low marginal cost of wage increase when the salary is low. In the same

manner as a decrease in  $\lambda$ , a increase in  $\alpha$  reduces the salary costs and gives the government a bigger opportunity to reduce corruption.

An explanation for the fact that governments pay their bureaucrat a lower wage when they can control the flow of information is that information design grants a huge utility benefit even without any salary. Indeed, with  $s = 0$ , governments without information design have an utility of  $\frac{1}{8} - \lambda c(0)$  and with it, it becomes  $\frac{1}{4} - \lambda c(0)$ . Increasing the salary is therefore less effective in the second framework. Indeed, increasing the salary gives a marginal benefit of  $\frac{s}{2}$  whereas without Bayesian persuasion, the marginal benefit of increasing the wage is  $\frac{s+1}{4}$  which is greater than the former for all  $s \leq 1$ . The direct implication of a lower salary is however a higher bribe demand. Indeed, in the second framework bureaucrats are held to the utility they would get with no information. Decreasing the wage would directly lead to an increase in corruption. On the other hand, the benefit granted by information design is that no firm would have to pay more than they have and that no firm would see their project refused. Bayesian persuasion hence results to bribing that is more "equitable" but nonetheless increased.

## 4 Multiple bureaucrats

One intuitive extension that we could bring to this paper is additional bureaucrats. This would follow the work done by Lambert-Mogiliansky et al (2008).

In this setup, there is a track of bureaucrats. An entrepreneur has to face each of them sequentially and get the approval of everyone of them to get the project accepted. As before, low level civil servants have the power to ask for a bribe that has to be paid in order to get the approval. On the other hand, the government has the power of designing an experiment which will produce a signal observed by all the players who will infer a posterior distribution. Once it is observed, the bureaucrat who is interacting with the entrepreneur makes a demand that is either accepted or refused. Finally, going to the next bureaucrat, she will again update her belief of the existing distribution by taking into account the action of the last bureaucrat. At every step, the government can design a new experiment that will take into account the new posterior distribution.

We will make some notation changes. There are now  $N$  bureaucrats. Each bureaucrat asks for bribe  $b_j$  and gets the salary  $s_j$  with  $j \in \{1, \dots, N\}$ . We also denote  $d_{i,j}$  the choice of the entrepreneur with profit  $p_i$  in his interaction with the bureaucrat  $j$ :  $d_{i,j} = 1$  if he pays the bureaucrat  $j$  and  $d_{i,j} = 0$  if not. For each bureaucrat  $j$ , we denote the history up to her as  $h_j$  consisting of all previous beliefs, signal realization and bribe demand. The government chooses a policy  $\sigma(h_j)$  that determines the signal structure inducing a posterior  $\tau_j$  of distributions  $\phi_j$  for the bureaucrat  $j$  given his prior  $\mu_j$  for every history  $h_j$ . We assume that the signal is publicly observed so that every bureaucrat share the same belief. We also make the assumption that low level civil servants can observe the salary of their peers

and therefore know that bribe asked by their peers before them.

The timing of this game is the following

1. The government and bureaucrats observe the set  $P$  of possible profits and the firms learns its magnitude.
2. The government decides on the salary of every bureaucrat and an optimal informational policy.
3. The optimal policy gives a signal structure.
4. Nature chooses a signal observed by all players.
5. Bureaucrat  $j$  updates her belief and demands a bribe.
6. The firm refuses and the game ends or accepts and interacts with the next bureaucrat  $j + 1$ .
7. Players update their beliefs according to the bribe demanded.
8. The game starts over at step 3 until bureaucrat  $N$  is reached.

We analyze the optimal strategies in this framework. Starting with the firm, he has to take into account every possible occurrence along the track of future bureaucrats. Indeed, every payed bribe is now a loss and represents a risk if the project is not approved at the end. Hence, if he expects that the total amount when reaching the last civil servant will greater than the profit of the project, he will refuse to continue paying. The new strategy becomes:

$$d_{i,j} = \begin{cases} 1 & \sum_{k=1}^{j-1} b_k + \sum_{n=i}^N \mathbb{E}[b_n | \sigma, s_j] \leq p_i \\ 0 & otherwise \end{cases}$$

When an entrepreneur takes a decision, he has to take into account the future strategy of the government in term of information design and salary in order to infer an expected amount that he will have to pay.

The bureaucrat must also take into account the updated strategy of the firm. Indeed, an entrepreneur might refuse to pay a bribe that he is able to pay because his expected loss greater than his profit. Hence, the bureaucrat's payoff becomes:

$$\mathbb{E}_{\phi_j}[v_j(b_j)] = (s_j + b_j)d_{i,j}$$

When a bureaucrat asks for a bribe, she automatically changes the distribution that has to be updated by the future civil servants. We denote  $x_{i,\phi_i}$  the probability of having a firm with profit  $p_i$  in the distribution  $\phi_i$ . As in the first part, it is nevertheless optimal to ask for a bribe that is in the

set  $P$  since distributions are still discrete. We denote  $k^*$  the index of the optimal bribe demand. The updated distribution after a bribe demand is:

$$g(\phi_j, b) = \begin{cases} 0 & p_i > 1 - c \\ x_{i+k^*} d_{i,j} & 0 < p_i \leq 1 - c \\ x_0 + \sum_{i=0}^{K-1} x_i (1 - d_{i,j}) & p_i = 0 \end{cases}$$

The distribution shifts towards 0 with respect to the bribe demand. Additionally, every firm that refuses because the demand is above the profit or the expected amount from the future bureaucrats will be too high, is added to the mass 0 because they are now of no value for the next bureaucrat and the government. Hence, by observing the signal inducing the posterior  $\phi$  and the salary  $s_i$ , the next bureaucrat can infer the optimal bribe  $b$  and the posterior distribution:

$$\mu_i = g(\phi_i, b(\phi_i, s))$$

The government's policy is given by a rule  $\sigma(h_j)$  which will map the history to a probability distribution over signals. Following Ely's (2018) obfuscation principle, any stochastic process  $(\mu_j, \phi_j)$  with initial belief  $\mu_0$  satisfying

$$E[\phi_j | \mu_j] = \mu_j$$

$$\mu_{j+1} = g(\phi_j)$$

can be generated by a policy  $\sigma$  which depends only on the current belief  $\mu_j$  and the current state  $p_i$ . In our case, the optimal policy will also depend on the chosen salary. The optimal policy is denoted  $\sigma(\mu_j, p_i, a_j)$  and solves the following equation:

$$V_j(\mu_j) = \max_{s_j} \max_{\tau_j} \left\{ \mathbb{E}_{\phi_N \sim \tau_N} [u_f(s_N, \phi_N)] - c(s_j) + \mathbb{E}_{\phi_j \sim \tau_j} [V_{j+1}(g(\phi_j, b(s_j, \phi_j)))] \right\}$$

$$s.t. E_{\phi \sim \tau_j}[\phi] = \mu_j$$

The government wants to maximize its utility with respect to the last distribution of firms. For every bureaucrat, it uses the salary power and information design in order to get the best distribution of posterior for the next bureaucrat given the current bureaucrat's belief and optimal strategy. For very paid salary, it has to bear again the cost  $c(s_j)$ .

The difficulty of this framework is the presence of interdependent strategies. The firm's strategy depends on the government's optimal information design and salary policy. The policy also depends on the bureaucrat's strategy which finally relies upon the firm's strategy. One way to solve it will be to use backwards induction. By starting with the last bureaucrat, the firm has a clear strategy given that there is no future uncertainty once the last demand has been made. Hence by fixing the salary and the belief of the last bureaucrat, we find the government's best strategy. Once we find the optimum, we

can design the optimal choices of all players in the preceding round. Going so on so forth, we would be able to find solve the model for all agents.

We can observe a trade-off in the government's strategy. As it tries to fight corruption aggressively with the first bureaucrats with for example a high salary and no information release, the next bureaucrat will be aware of the remaining potential profits and the government would have to fight as aggressively in order to keep a high utility. On the other hand, it would be strategic to let the first bureaucrats take a share in order to increase uncertainty in the next ones and profit from a more advantageous belief. Furthermore, intuitively, as the number of bureaucrats increases, there will be one point where the belief will attain an equilibrium and the government will not release information any further. This point is optimal when the government is able to pay the lowest salary, i.e.  $\frac{1}{K-1}$  and the bureaucrat will not ask any bribe given her belief.

## 5 Conclusion

This paper analyzes the optimal strategy of releasing information to an agent in the context of corruption. We found out that information design is a useful tool when there is asymmetry of information between a public official and a firm. Indeed, this mechanism enhances the expected profit of a firm and makes sure that no entrepreneur is left out. Nevertheless, information design also reduces the optimal wage since increasing wages does not have the same influence on corruption level anymore. This consequence leads in turn to an expected increase in bribe demand and hence corruption. Firm would tend to pay more even if it is always below or equal to the profit than in the context in which Bayesian persuasion is not used. This effect depends nonetheless on the weight of salary costs on the government: as the cost of paying the bureaucrat decreases, the wage discrepancy between both framework declines. Finally, we propose an extended model in which a firm has to meet a track of bureaucrat in order to get a project approved. In this framework, the government's strategy for a particular bureaucrat will affect the belief of the bureaucrats and therefore their strategy. There is an intuitive reason to think that accepting corruption at the beginning of the chain enables reducing bribe demands for the following bureaucrats. By taking existing analysis on dynamic Bayesian persuasion, we would be able to approach a more concrete solution since the defined framework resembles optimal release of information with multiple periods.

## References

- [1] P. Basu. “Dynamic Bayesian Persuasion with a Privately Informed Receiver”. In: 2017.
- [2] Dirk Bergemann, Benjamin Brooks, and Stephen Morris. “The Limits of Price Discrimination”. In: *American Economic Review* 105.3 (Mar. 2015), pp. 921–57. DOI: [10.1257/aer.20130848](https://doi.org/10.1257/aer.20130848). URL: <http://www.aeaweb.org/articles?id=10.1257/aer.20130848>.
- [3] Dirk Bergemann and Stephen Morris. “Information Design: A Unified Perspective”. In: 2075 (Feb. 2017). URL: <https://ideas.repec.org/p/cwl/cwldpp/2075.html>.
- [4] Jacopo Bizzotto, Jesper RRDiger, and Adrien Vigier. “Dynamic Persuasion With Outside Information”. In: *SSRN Electronic Journal* (Jan. 2018). DOI: [10.2139/ssrn.3154313](https://doi.org/10.2139/ssrn.3154313).
- [5] Roberto Burguet, Juan-José Ganuza, and José Garcia Montalvo. “The microeconomics of corruption. A review of thirty years of research”. In: (2016). URL: <https://EconPapers.repec.org/RePEc:upf:upfgen:1525>.
- [6] Sylvain Chassang and Gerard Padró i Miquel. “Corruption, Intimidation, and Whistle-blowing: a Theory of Inference from Unverifiable Reports”. In: Working Paper Series 20315 (July 2014). DOI: [10.3386/w20315](https://doi.org/10.3386/w20315). URL: <http://www.nber.org/papers/w20315>.
- [7] Piotr Dworzak and Giorgio Martini. “The simple economics of optimal persuasion”. In: (2018).
- [8] Jeffrey C. Ely. “Beeps”. In: *American Economic Review* 107.1 (Jan. 2017), pp. 31–53. DOI: [10.1257/aer.20150218](https://doi.org/10.1257/aer.20150218). URL: <http://www.aeaweb.org/articles?id=10.1257/aer.20150218>.
- [9] Raymond Fisman and Jakob Svensson. “Are corruption and taxation really harmful to growth? Firm level evidence”. In: *Journal of Development Economics* 83.1 (2007), pp. 63–75. URL: <https://EconPapers.repec.org/RePEc:eee:deveco:v:83:y:2007:i:1:p:63-75>.
- [10] Matthew Gentzkow and Emir Kamenica. “A Rothschild-Stiglitz Approach to Bayesian Persuasion”. In: *American Economic Review* 106.5 (May 2016), pp. 597–601. DOI: [10.1257/aer.p20161049](https://doi.org/10.1257/aer.p20161049). URL: <http://www.aeaweb.org/articles?id=10.1257/aer.p20161049>.
- [11] Matthew Gentzkow and Emir Kamenica. “Bayesian persuasion with multiple senders and rich signal spaces”. In: *Games and Economic Behavior* 104.C (2017), pp. 411–429. URL: <https://EconPapers.repec.org/RePEc:eee:gamebe:v:104:y:2017:i:c:p:411-429>.
- [12] Penélope Hernández. “How Bayesian Persuasion can Help Reduce Illegal Parking and Other Socially Undesirable Behavior”. In: 2018.
- [13] Transparency International. “The Anti-Corruption Plain Language Guide”. In: (2009). URL: [https://www.transparency.org/whatwedo/publication/the\\_anti\\_corruption\\_plain\\_language\\_guide](https://www.transparency.org/whatwedo/publication/the_anti_corruption_plain_language_guide).
- [14] Philippe Jehiel. “On transparency in organizations”. In: *The Review of Economic Studies* 82.2 (2014), pp. 736–761.
- [15] Emir Kamenica and Matthew Gentzkow. “Bayesian Persuasion”. In: *American Economic Review* 101.6 (Oct. 2011), pp. 2590–2615. DOI: [10.1257/aer.101.6.2590](https://doi.org/10.1257/aer.101.6.2590). URL: <http://www.aeaweb.org/articles?id=10.1257/aer.101.6.2590>.



- [16] Ravi Kanbur et al. *World development report 2000/2001 : attacking poverty*. Vol. 1. Mar. 2013.
- [17] Anton Kolotilin. “Optimal information disclosure: A linear programming approach”. In: *Theoretical Economics* 13.2 (2018), pp. 607–635.
- [18] Jean-Jacques Laffont and Jean Tirole. “The Politics of Government Decision-Making: A Theory of Regulatory Capture”. In: *The Quarterly Journal of Economics* 106.4 (1991), pp. 1089–1127. ISSN: 00335533, 15314650. URL: <http://www.jstor.org/stable/2937958>.
- [19] Ariane Lambert-Mogiliansky, Mukul Majumdar, and Roy Radner. “Petty corruption: A game-theoretic approach”. In: *International Journal of Economic Theory* 4.2 (2008), pp. 273–297. DOI: [10.1111/j.1742-7363.2008.00078.x](https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1742-7363.2008.00078.x). eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1742-7363.2008.00078.x>. URL: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1742-7363.2008.00078.x>.
- [20] Margaret Meyer, Florian Ederer, and Richard Holden. *Gaming and Strategic Ambiguity in Incentive Provision*. Economics Series Working Papers 640. University of Oxford, Department of Economics, Jan. 2013. URL: <https://ideas.repec.org/p/oxf/wpaper/640.html>.
- [21] Dilip Mookherjee and Ivan Png. “Corruptible Law Enforcers: How Should They Be Compensated?” In: *Economic Journal* 105.428 (1995), pp. 145–59. URL: <https://EconPapers.repec.org/RePEc:ecj:conj1:v:105:y:1995:i:428:p:145-59>.
- [22] Benjamin A Olken and Rohini Pande. *Corruption in Developing Countries*. Working Paper 17398. National Bureau of Economic Research, Sept. 2011. DOI: [10.3386/w17398](https://doi.org/10.3386/w17398). URL: <http://www.nber.org/papers/w17398>.
- [23] Esteban Ortiz-Ospina and Max ROser. *Corruption*. Ed. by Our World in Data. 2016. URL: <https://ourworldindata.org/corruption> (visited on 05/10/2019).
- [24] Juan Ortner and Sylvain Chassang. “Making Corruption Harder: Asymmetric Information, Collusion, and Crime”. In: *Journal of Political Economy* 126.5 (2018), pp. 2108–2133. DOI: [10.1086/699188](https://doi.org/10.1086/699188). eprint: <https://doi.org/10.1086/699188>. URL: <https://doi.org/10.1086/699188>.
- [25] David Rahman. “But Who Will Monitor the Monitor?” In: *The American Economic Review* 102.6 (2012), pp. 2767–2797. ISSN: 00028282. URL: <http://www.jstor.org/stable/41724671>.
- [26] Jérôme Renault, Eilon Solan, and Nicolas Vieille. “Optimal Dynamic Information Provision”. In: (July 2014). URL: <https://hal.archives-ouvertes.fr/hal-01025797>.
- [27] Sandra Sequeira and Simeon Djankov. “Corruption and firm behavior: Evidence from African ports”. In: *Journal of International Economics* 94.2 (2014), pp. 277–294. URL: <https://EconPapers.repec.org/RePEc:eee:inecon:v:94:y:2014:i:2:p:277-294>.
- [28] Jakob Svensson. “Who Must Pay Bribes and How Much? Evidence from a Cross Section of Firms”. In: *The Quarterly Journal of Economics* 118.1 (2003), pp. 207–230. ISSN: 00335533, 15314650. URL: <http://www.jstor.org/stable/25053902>.
- [29] Jean Tirole. “Hierarchies and Bureaucracies: On the Role of Collusion in Organizations”. In: *Journal of Law, Economics, Organization* 2.2 (1986), pp. 181–214. ISSN: 87566222, 14657341. URL: <http://www.jstor.org/stable/765048>.

## 6 Appendix

### 6.1 Optimal bribe demand

Our goal is to solve the following equation:

$$y(b) = \arg \max_b (s + b)(1 - F_p(b))$$

So far, we have shown that the maximizer must be at an upper bound of a set  $]p_k, p_{k+1}] \in P$  and that it must therefore be in  $P$ . It will take the following form:

$$\frac{k}{K-1}$$

where  $k$  denotes the index in the set  $P$ . We are interested in finding the  $k$  that defines the optimal strategy. Knowing that we are interested in upper bounds of sets, we are going to take the following distribution function:

$$F_u(p) = \frac{p(K-1)}{K}$$

rather than the function

$$F_l(p) = \frac{p(K-1) + 1}{K}$$

which gives output at lower bounds. The difference between both function can be seen in Figure 6.

Putting the c.d.f. into the equation yields:

$$\begin{aligned} & \left( s + b \right) \left( 1 - \frac{b(K-1)}{K} \right) \\ & \left( s + b \right) \left( \frac{K - b(K-1)}{K} \right) \end{aligned}$$

Also, changing  $b$  to  $\frac{k}{K-1}$  gives us:

$$\left( s + \frac{k}{K-1} \right) \left( \frac{K-k}{K} \right)$$

Deriving with respect to  $k$  and setting the solution to 0:

$$\begin{aligned} -\frac{s}{K} + \frac{1}{K-1} - \frac{2k}{K(K-1)} &= 0 \\ \frac{2k}{K(K-1)} &= \frac{1}{K-1} - \frac{s}{K} \\ k^{**} &= \frac{K - s(K-1)}{2} \end{aligned}$$

Testing for concavity yields:

$$\frac{\partial^2 y(\frac{k}{K-1})}{\partial k^2} = -\frac{2}{K(K-1)} < 0$$

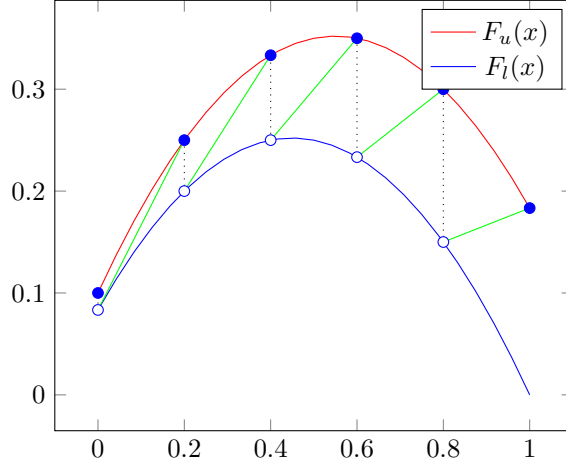


FIGURE 5: Expected bureaucrat's outcome for  $K = 6$  and  $s = 0.1$

which ensures that the given solution is a maximum.

Now that we have our optimal  $k^{**}$ , we must correct for the fact that  $k$  must be an integer and the true distribution is not continuous. We therefore simply assign  $k^{**}$  to its closest integer  $k$ . This holds because the function  $F_u$  with respect to which we maximized our objective has a constant concavity. Thus, we know that for each value  $\epsilon$ , we have that:

$$k^{**} + \epsilon = k^{**} - \epsilon$$

For simplicity, we assume that if a bureaucrat is indifferent between two values, i.e. the maximizer lands on the mid-point of two values in  $P$ , she will ask for the lower value. Finally, we modify the function  $k^{**}$  into the following one:

$$k^{**} = \frac{K - s(K - 1)}{2} - 0.5$$

so that the solution can be written in a more simple way. The optimal  $k^*$  is therefore:

$$k^* = \left\lceil \frac{K - s(K - 1)}{2} - 0.5 \right\rceil$$

where  $\lceil x \rceil$  stands for the least integer greater than  $x$ .

## 6.2 Optimal salary without information design

We maximize the following function with respect to  $s$ :

$$\max_s \frac{(K - \lceil \frac{K - s(K - 1) - 1}{2} \rceil)^2 - K + \lceil \frac{K - s(K - 1) - 1}{2} \rceil}{2K(K - 1)} - c(s)$$

Treating it as continuous leads to:

$$\max_s \frac{\left(\frac{K + s(K - 1) + 1}{2}\right)^2 - \frac{K + s(K - 1) + 1}{2}}{2K(K - 1)} - c(s)$$

$$\max_s \frac{2s(K^2 - 1) + s^2(K - 1)^2 + (K + 1)^2 - 2K - 2s(K - 1) - 2}{8K(K - 1)} - c(s)$$

$$\max_s \frac{s^2(K - 1)^2 + 2s(K^2 - K) + K^2 - 1}{8K(K - 1)} - c(s)$$

### 6.3 Optimal salary with information design

We want to maximize the following objective function:

$$\max_s 0.5 - \frac{\left\lceil \frac{K - s(K - 1) - 1}{2} \right\rceil}{K - 1} \left( 1 - \frac{\left\lceil \frac{K - s(K - 1) - 1}{2} \right\rceil}{K} \right) - c(s)$$

Considering the function as continuous yields

$$\max_s 0.5 - \frac{K - s(K - 1) - 1}{2(K - 1)} \left( \frac{K + s(K - 1) + 1}{2K} \right) - c(s)$$

$$\max_s 0.5 - \frac{K^2 + sK(K - 1) + K - sK(K - 1) - s^2(K - 1)^2 - s(K - 1) - K - s(K - 1) - 1}{4K(K - 1)} - c(s)$$

$$\max_s 0.5 - \frac{K^2 - s^2(K - 1)^2 - 2s(K - 1) - 1}{4K(K - 1)} - c(s)$$