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A Computational Exercise on the Bureaucratic Corruption Within the Principal-Agent Approach with Lotteries

Um Exercício Computacional em Corrupção Burocrática com Loterias através da Abordagem de Agente-Principal

Danilo Hiroshi Matsuoka [1]
Universidade Federal do Rio Grande do Sul (UFRGS)

ABSTRACT

This paper models a corruption problem through the principal-agent framework with lotteries where the bureaucrat is regarded as the agent and the society, as the principal. The model contemplates three variables: bureaucratic efficiency, compensation and level of honesty. Solutions for the model were given using linear program algorithms. In order to evaluate the behavior of the model, a sensitivity analysis was made. The results obtained from the analysis indicate that: (1) under an unmonitored scenario, it is possible that the society be better off in the presence of extreme corruption; (2) risk-loving bureaucrats can provide more righteous conducts and increase the society's expected utility; (3) altruist bureaucrats make the society better off while spiteful bureaucrats makes the society worse off; and (4) higher reservation utility tends to increase the probability the bureaucrats receive a high compensation. The weak correlation found in our results between efficiency (or welfare) and corruption, and the optimality of having fractions of corrupt bureaucrats being highly efficient as well as being inefficient, undermined the discussion about whether corruption is beneficial for the economy, or not, in the presence of lotteries.

Keywords: Principal-agent; Corruption; Moral Hazard; Lotteries; Randomization.

JEL: D82; D73.

RESUMO

Este artigo modela um problema de corrupção estruturado pela abordagem de agente-principal com loterias, onde o burocrata é considerado como agente e a sociedade, como principal. O modelo contempla três variáveis: eficiência burocrática, compensação e nível de honestidade. As soluções para o modelo foram calculadas por meio de algoritmos de programação linear. Visando avaliar o comportamento do modelo, uma análise de sensibilidade foi realizada. Os resultados obtidos a partir da análise indicam que: (1) sob um cenário sem monitoramento, é possível que a sociedade fique melhor na presença de corrupção extrema; (2) burocratas propensos ao risco podem proporcionar condutas mais honestas e aumentar a utilidade esperada da sociedade; (3) burocratas altruístas fazem a sociedade estar em melhor situação enquanto os não altruístas, a faz piorar; e (4) uma maior utilidade de reserva tende a aumentar a probabilidade de burocratas receberem maiores compensações. A correlação fraca encontrada entre eficiência (ou bem-estar) e corrupção, adicionada à existência de frações ótimas de burocratas corruptos sendo eficientes assim como ineficientes, minou a discussão sobre a corrupção ser benéfica, ou não, para a economia na presença de loterias.

Palavras-chave: Agente-principal; Corrupção; Risco Moral; Loterias; Randomização.

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[1] E-mail: danilomatsuoka@gmail.com

1. Introduction

The first problem facing researchers engaged in studying corruption is to define it. Although it is hard to find *the* definition, there is a consensus that corruption refers to acts in which the power of public office is used for personal benefits so that it contravenes the rules of the game (JAIN, 2001). It requires: an individual with discretionary power over the allocation of resources; economic gains associated with this power; and an institutional system so that the probability of being caught and/or penalized is sufficiently low.

Much attention has been given to the corruption theory due to its consequences on the society's welfare. There are two opposite lines concerning to this topic. On one hand, there are the "grease-the-wheels-of-bureaucracy" arguments. It is argued that corruption: speeds up bureaucratic processes and, thus, promote economic growth (LEFF, 1964; LEYS, 1965); helps to mitigate bureaucratic rigidities which then promotes allocation efficiency (BARDHAN, 1997); and is essential to businesses operating in the informal economies (DE SOTO, 1989). On the other hand, corruption is considered as "sand-in-the-machine". Empirical works found evidence of positive effects of corruption on inequality (GUPTA; DAVOODI; ALONSO-TERME, 2002), positive correlation between incidents of bribery and time spent by managers of international firms with bureaucrats (KAUFMANN; WEI, 1999), negative impact of corruption on investment/GDP ratio (MAURO, 1995, 1996; BRUNETTI; WEDER, 1998) and negative impact of corruption on the quality and quantity of health care and education services (GUPTA; DAVOODI; TIONGSON, 2000). Indeed, the empirical research hardly support the grease-the-wheels hypothesis.

Rose-Ackerman (1997) argued that corruption can make government contracts, privatized firms and concessions to not be allocated to the most efficient bidders. In particular private investors' assessment can be changed, affecting relative prices, and then unbalancing the project's selection criteria to channels where it is easier to collect bribes. In this sense, corruption is a potential source of resource misallocation. Furthermore, if corruption raises the transaction costs, it could be thought as a tax, implying shifts in the market equilibrium (see SHLEIFER; VISHNY, 1993). In light of above considerations, there is a prevailing idea that reducing corruption will be economically beneficial. Contemporary anti-corruption programs generally follow the implications of the principal-agent framework including monitoring mechanisms, enhanced transparency, democratic election mechanisms, independence of anti-corruption agencies and wage increases for public officials (MARQUETTE; PEIFFER, 2015).

Another branch of economic research investigates the determinants of corruption rather than its consequences. Some historical variables have been suggested to explain corruption, for example, colonialism (SWAMY *et al.*, 2001; TREISMAN, 2000) and the existence of a common law legal system (LA PORTA *et al.*, 1999). The role of religion was examined by La Porta *et al.* (1997). They singled out that hierarchical forms of religion, such as Catholic, Eastern Orthodox and Muslim, are detrimental to civic engagement, a factor which should help reduce corruption. Treisman (2000) found that the percentage of Protestants in the total population is a robust predictor of lower corruption. The rent-seeking literature emphasizes the size of government activities (CHAFUEN; GUZMÁN, 1999; ACEMOGLU; VERDIER, 2000) due to the link between corruption and possibilities for agents to gain access to higher sources of rents, when state intervention prevents free entry. Rijckenghem and Weder (1997, 2001) found evidence of a negative relationship between wages and corruption. The idea is that low salaries induce servants to supplement their incomes illicitly while high salaries imply higher losses if he or she gets caught, in a cost-benefit analysis. Through an econometric analysis, Pellegrini (2011) found that long exposure (30 years) of uninterrupted democracy is associated with lower corruption, that political turnover tends to raise corruption and that the diffusion of newspapers is associated with lower corruption levels[2].

The corruption can be classified into two types[3]: bureaucratic and political. According to Pellegreni (2011), the latter involves a policy maker that influences policies in exchange for a side payment and the former, a bureaucrat that does not implement the tasks that were set by his/her superior for the same reason[4]. Regardless of whether type is considered, both can be seen from the principal-agent perspective, which has been prevailing to understand corruption (see UGUR; DASGUPTA, 2011).

The seminal articles of Becker (1968) and Becker and Stigler (1974) are regarded as the foundation of the microeconomics of corruption. Particularly, the key point of Becker and Stigler (1974) was to face the decision of accepting a bribery as an economic problem, avoiding subjective or moral matters. Their ideas of an efficiency wage and increasing monitoring is still actual in anti-corruption programs. Subsequently, most of the related studies were made within a viewpoint of the principal-agent model (BANFIELD, 1975; ROSE-ACKERMAN, 1975, 1978; TIROLE, 1986; KLITGAARD, 1988).

In parallel, a strand of principal-agent literature was interested to examine whether randomization is efficient (WEISS, 1976; STIGLITZ, 1982; ARNOTT; STIGLITZ, 1988). According to Prescott (1999), randomization is undesirable (i.e., cannot offer Paretto improvements) under certain strong conditions and desirable under certain weaker conditions. To the best of the author's knowledge, so far there is no study of corruption that evaluated randomized contracts (also known as *lotteries*).

In this paper, a corruption problem is modeled based on the principal-agent framework in which the agent accepts a contract, offered by the principal, with randomized actions and compensation schedules. To avoid letting our formulation of corruption too broadly, having generic principal and agent, the bureaucratic type of corruption is chosen. This way, one can specify the parties involved and build a concrete context for an easier interpretation of the results. The high dimensionality of our model makes analytical solutions infeasible. Therefore, the optimal contracts are obtained via numerical methods. In order to investigate the model's behavior (given the unavailability of analytical solutions), a sensitivity analysis is employed having two different sets of parametrizations as bases of comparison. That is, we evaluate how optimal contracts change in response of changes in a particular parameter through a computational exercise.

This paper is organized as follows: Section 2 describes the moral hazard model with lotteries; Section 3 contextualizes the corruption as a moral hazard problem; Section 4 describes the two scenarios under which the exercise will be done; Section 5 presents the optimal contracts as well as the results of the sensitivity analysis. A brief discussion is given in Section 6, and we conclude and provide some insights for future research in Section 7.

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[2] For a deeper discussion, see the Chapter 3 of Pellegrini (2011).

[3] The classification between bureaucratic and political corruption can be found in several works, including Amundsen (1999), Pellegrini (2011), Strîmbu and González (2018) and Tanzi (1998).

[4] Political and bureaucratic corruption are also referred to as grand and petty corruption, respectively, to the extent that the first instance generally involves high-level government officials (ROSE-ACKERMAN, 1999, p.27) and the second, people at low level of hierarchies (LAMBSDORFF, 2005).

2. The Moral Hazard Problem

Early authors who have investigated moral hazard problems in the economic literature include Arrow (1971), Ross (1973), Pauly (1968), Mirlees (1974) and Stiglitz (1974). A general moral hazard problem is formulated in terms of a contract between two elements: a principal and an agent. The agent works on a sort of task for the principal. The action chosen by the agent in the task affects the principal's utility. The problem arises when we assume that the principal is unable to observe the agent's action, regarded as a private information. The combination of private information and conflicts between the agent and the principal over the action that the agent should take, constitutes a moral hazard problem.

Under asymmetric information, anyone who has an informational advantage will be prone to use it to their own benefit. If the output of the task is assumed to be known, the principal makes use of it to employ a proper compensation in order to induce the agent to take a given action. That is, the principal designs a contract respecting some conditions such that the agent willingly accept the recommended action.

Much is known about the optimal deterministic contract. This kind of contract is a particular case of randomized contracts with degenerate lotteries. In general, moral hazard problems are solved via optimization. In what follows, it will be shown how the moral hazard problem with lotteries can be structured as a linear programming model.

2.1 The Moral Hazard Model with Lotteries

In this section, the moral hazard problem with lotteries will be modeled following Prescott (1999) and Karaivanov (2001).

The standard, or deterministic, model is set in the agreement between the principal and the agent for a contract. As an item within the contract, the principal recommends an action and then the agent must decide whether or not to accept it. The agent chooses an action and then the corresponding output is realized. The principal then compensates the agent.

The model encompasses three variables: an *action* h taken by the agent that lies in a set of possible actions $\mathcal{H} = \{h_1, \dots, h_l\}$; an *output* b such that $b \in \mathcal{B} = \{b_1, \dots, b_m\}$; and a *compensation* w such that $$w \in \mathcal{W} = \{w_1, \dots, w_r\}$. Assume that the sets $\mathcal{H}, \mathcal{B}$ and $\mathcal{W}$ are finite. Furthermore, assume that the output does not only depend on the agent's choice, but also on a random error for which both parties assign the same prior distribution. In its turn, the distribution of the random error induces a probability $\mu(b \mid h)$ of output b conditional on action h. This function is also known as the *technology*.

Let Φ and Ψ be the agent's and the principal's utility function, respectively. The agent only cares about his compensation and action, $\Phi(w, h)$. On the other hand, the principal cares about the surplus, $\Psi(b - w)$. These assumptions on their preferences constitute the source of the conflict of interests.

Prescott (1999) defines a contract with lotteries as a probability distribution over recommended actions, denoted here by $p(h)$, and a probability distribution overcompensation as a function of the output and the recommended action[5], $p(w \mid b, h)$. Possibly, the randomization

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[5] In contrast, the principal should choose a single action h and a compensation $c(b)$, in the deterministic case.

stipulated in the contract is the main criticism on this model, regarded as unrealistic or a mere hypothetical exercise. However, theoretical findings pointed to the existence of conditions with which randomization offers Pareto improvements (ARYA; YOUNG; FELLINGHAM, 1993; ARNOTT; STIGLITZ, 1988; FELLINGHAM; KWON; NEWMAN, 1984). Furthermore, Prescott (1999) argued that explicit terms in contracts are not necessarily an accurate guide to its true terms, and that lotteries may be indistinguishable from other state-contingent transfers and may represent unmodeled transactions. On the face of it, a comprehensive contract theory need not to be restricted to the space of contracts with degenerate lotteries.

Using the identity $p(w,b,h) = p(w \mid b,h)\mu(b \mid h)p(h)$ and applying some algebraic manipulations[6], the choice variables of the program become $p(w,b,h)$ instead of $p(h)$ and $p(w \mid b,h)$. This is necessary to make the moral hazard program (nonlinear, by construction) linear. Thus, we describe the moral hazard problem with lotteries by the following linear program:

$$\max_{p} \sum_{w,b,h} p(w,b,h)\Psi(b-w) \tag{1}$$

$$\text{subject to} \sum_{w,b,h} p(w,b,h)\Phi(h,w) \geq \mathcal{U} \tag{2}$$

$$\sum_{w,b} p(w,b,h)\Phi(h,w) \geq \sum_{w,b} p(w,b,h)\frac{\mu(b|\hat{h})}{\mu(b|h)}\Phi(\hat{h},w),\ \forall(h,\hat{h}) \in \mathcal{H}^2 : h \neq \hat{h} \tag{3}$$

$$\sum_{w} p(w,\bar{b},\bar{h}) = \mu(\bar{b}|\bar{h})\sum_{w,b} p(w,b,\bar{h}), \forall(\bar{b},\bar{h}) \in \mathcal{B} \times \mathcal{H} \tag{4}$$

$$\sum_{w,b,h} p(w,b,h) = 1 \text{ and } p(w,b,h) \geq 0, \forall(w,b,h) \in \mathcal{W} \times \mathcal{B} \times \mathcal{H} \tag{5}$$

where $\mathcal{U}$ is the reservation utility. The objective function in (1) consists in the expected utility of the principal. Constraint (2) is called *participation constraint* which ensures that the agent will only sign the contract if it is as good as the best alternative opportunity in the market. The *incentive compatibility constraints* in (3) say that the recommended action by the principal is optimal from the agent's perspective. Condition (4), called *mother nature constraints*, ensures that when a particular joint probability $p(w,b,h)$ is chosen, the principal is implicitly choosing only $p(h)$ and $p(w \mid b,h)$, keeping $\mu(b \mid h)$ exogenous. This makes the linear program consistent with the problem's original formulation. The last set of constraints (5) is required for p to be a probability measure.

The choice variable $p(w,b,h)$ has dimension lmr since the cardinals of the sets $\mathcal{H}, \mathcal{B}$ and $\mathcal{W}$ are l, m and r, respectively. Additionally, we have one participation constraint; $l(l-1)$ incentive compatibility constraints since for each action there are $(l-1)$ other actions; lm mother nature constraints; one adding-up-to-one constraint and lmr nonnegativity constraints associated to $p(w,b,h)$ as a probability measure.

Henceforward, we use the notations introduced in this section for convenience.

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[6] For more details, see Appendix B of Prescott (1999).

3. Corruption as a Moral Hazard Program

In this section, it will be presented how corruption can be related to the moral hazard model.

The relationship between the society (or the politician, as its political representative) and the bureaucratic body (or the public administrative office) can be thought as a contract. As the principal, the society demands a project/task to the bureaucratic official, here representing the agent. The latter, in turn, has to do the job following legal rules and codes of conduct. Depending on the bureaucrat's conduct, some economic inefficiencies may, or may not, be produced as discussed in Section 1.

Now, the problem will be formulated assuming that: (i) the prior beliefs, or technology, $\mu(b \mid h)$ are such that the highest efficiency is relatively more likely generated by righteous conducts and the lowest efficiency, by corrupt conducts; (ii) the economic efficiency gained from the bureaucratic activities is measured by an available index containing random measurement errors with a probability distribution known by both parties[7]; and (iii) the bureaucrat always works employing a fixed level of effort known by the society, and the only decision to be taken is whether the task will be done honestly or corruptly.

Under our assumptions, the society is guided by the efficiency index to compensate the bureaucrat. However, due to the presence of measurement errors, the society cannot infer from the index alone how honestly the bureaucrat has worked. Therefore, the society has limited ability to monitor the actions of the bureaucratic body, and so the latter has the discretion to pursue his own interests.

Assume a risk-neutral society whose utility function is given by

$$\Psi(b - w) = b - w \tag{6}$$

where b is an index of efficiency gains provided by the bureaucrat, or the efficiency for short, and w is a measurement for the amount of money spent on bureaucrats.

Regarding to the bureaucrat's utility Φ, it is commonly assumed that the agent only cares about the payment w and the degree of honesty h such that $\partial\Phi(w,h)/\,\partial w > 0$ and $\partial\Phi(w,h)/\,\partial h < 0$. By doing so, we infer that employing honest actions represents a disutility to the bureaucrat which can be justified by the fact that honest conducts imply the inability to get extra money, e.g., in the form of bribes. Behavioral economic studies have been pointing out the possibility to relax the self-interest assumption by incorporating elements such as altruism, reciprocity and fairness (RABIN, 2002; ENGLMAIER, 2005; MACHO-STADLER; PÉREZ-CASTRILLO, 2018). We allow the bureaucrat to have non-purely selfish preferences by defining

$$\Phi(h, b, w) = u\big(w + \delta(b - w)\big) - v(h), \quad 1 > \delta > 1, \tag{7}$$

where δ is a measurement of reciprocity, and the functions $u\colon \mathbb{R}^2 \to \mathbb{R}$ and $v : \mathbb{R} \to \mathbb{R}$ are increasing on each of its respective arguments with v taking only nonnegative values. If δ is positive, then the bureaucrat not only cares about the compensation but there is also a concern about the benefits of the efficiency on the society's well-being. In this case, we can interpret the bureaucrat as altruist. On the contrary, if δ is negative, the surplus $b - w$ represents a disutility to

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[7] This distribution induces the conditional probability $\mu(b \mid h)$.

the bureaucrat, now regarded as spiteful. Clearly, if $\delta = 0$, then we come up with $u(w)$ which is the usual purely selfish case.

It is known that if the principal is risk neutral and the agent is risk averse with a separable utility function, compensation lotteries are not optimal (ARNOTT; STIGLITZ, 1988; PRESCOTT, 1999). We then mainly focus on separable and convex utilities for the bureaucrats. To interpret the optimal contracts with lotteries, consider the following contextualization.

Instead of working with one bureaucrat, say i_0, who has agreed to a randomized contract, consider a bureaucratic body consisted of several homogeneous departments having i_0 as representative. The associated linear program remains unchanged.

A stipulated randomization process is achieved to draw an action recommendation and a compensation schedule for each administrative department according to the distribution $p(w, b, h)$. A solution for the linear program with lotteries answers how the compensation, the bureaucratic efficiency and the degree of honesty could be efficiently distributed over the entire bureaucratic body in order to maximize the society's expected utility. In this sense, optimal contracts represent equilibrium fractions of the population of bureaucratic departments.

4. Model Setups

To evaluate the behavior of our moral hazard model, a sensitivity analysis will be employed. This computational exercise requires the definition of a basic setting to serve as basis of comparison.

Two different settings are considered in our exercise, namely Case A and Case B. In what follows, we will specify the additional assumptions and parametrizations that define each setting.

Following the setup of Karaivanov (2001), the Case A assumes that: the parametrization presented in Table 1 holds; $\mathcal{H} = \{h_1, \ldots, h_l\}$ and $\mathcal{W} = \{w_1, \ldots, w_r\}$ are sets formed by evenly spaced points on $\mathbb{R}$ and $\mathcal{B} = \{b_1, b_2\}$; the bureaucrat has a separable[8] utility function given by

$$\Phi(h, w) = \frac{w^{1-\tau}}{1-\tau} + (1 - h), \quad \tau \leq 0; \tag{8}$$

the technology is described by

$$\mu(\, b = b_2 \mid h \,) = h^{\alpha}, \quad 0 < \alpha < 1; \tag{9}$$

and the society is risk-neutral so that (6) holds.

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[8] The class of preferences of the form $\Phi(h, w) = u(w) - v(h)$ isolates the agent's risk aversion from the action supplied.

Table 1. Parameter values – Case A

Parameter	Value	Description
τ	0	Bureaucrat's relative risk aversion in respect to wealth
$\mathcal{U}$	1	Reservation utility
α	0.5	Output's conditional distribution parameter
$\#\mathcal{H}$	50	Number of possible actions
$\#\mathcal{W}$	50	Number of possible compensations
$\#\mathcal{B}$	2	Number of possible outputs
h_1	10^{-8}	Minimum degree of honesty
h_l	$1-10^{-8}$	Maximum degree of honesty
b_1	1	Minimum bureaucratic efficiency
b_2	3	Maximum bureaucratic efficiency
w_1	1	Minimum compensation
w_r	2	Maximum compensation

Next, the Case B specifies that: the parameters of Table 2 holds; $\mathcal{H}$ and $\mathcal{W}$ are defined as in Case A, but now $\mathcal{B} = \{1, \ldots, b_m\}$ is a set of consecutive integers; the society is again risk neutral according to (6); the bureaucrat's utility function is given by

$$\Phi(h, b, w) = (1-\delta)\frac{w^{1-\tau}}{1-\tau} + \delta b + (1-h), \quad \tau \leq 0; \tag{10}$$

the technology is described by

$$\mu(b \mid h) = \frac{f(b \mid h, n, \beta)}{\sum_{i=1}^{m} f(b_i \mid h, n, \beta)}; \tag{11}$$

where

$$f(b \mid h, n, \beta) = \binom{n}{b}\frac{\mathbb{B}(b+h, n+\beta-b)}{\mathbb{B}(h, \beta)} \tag{12}$$

is the Beta-binomial probability mass function with parameters h, $n = \#\beta$ and $\beta = (\#\beta - h)(1 - h/\#\beta)$, where $\mathbb{B}$ denotes the Beta function.

Table 2. Parameter values – Case B

Parameter	Value	Description
τ	0	Bureaucrat's relative risk aversion in respect to wealth
δ	0	Degree of the bureaucrat's reciprocity
$\mathcal{U}$	0.5	Reservation utility
$\#\mathcal{H}$	50	Number of possible actions
$\#\mathcal{W}$	50	Number of possible compensations
$\#\mathcal{B}$	5	Number of possible outputs
h_1	10^{-8}	Minimum degree of honesty
h_l	$\#\mathcal{B} - 10^{-8}$	Maximum degree of honesty
w_1	1	Minimum compensation
w_r	$\#\mathcal{B}$	Maximum compensation

In both settings, both parties are risk-neutral with the bureaucrats being purely selfish. However, only in Case B it is possible to have an altruist bureaucrat as can be seen comparing equations (10) and (8). The main differences between the two cases are related to the number of outputs and the law of $\mu(b \mid h)$.

It is clear that $\mu(b \mid h)$ given by (9), in Case A, has the *monotone likelihood ratio property*[9]. As illustrated in Figure 1, the distribution of $\mu(b \mid h)$ defined by (11)-(12), in Case B, inherits the shape of a Beta-binomial distribution on every nonzero point of its support. Figure 2 depicts the skewness behavior of the Beta-binomial probability mass function $f\big(b \mid h, 5, (5-h)(1-h/5) \big)$ along values of $h \in (0,5)$, suggesting that $\mu(b \mid h)$ tends (monotonically) to be negatively skewed as h becomes larger[10].

Therefore, for each scenario, $\mu(b \mid h)$ satisfies the assumption that the highest value for b is relatively more likely generated by higher levels of honesty, and the lowest b, by dishonest conducts.

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[9] We say that μ has the monotone likelihood ratio property if for any $b_1 < b_2$ and any $h_1 < h_2$, we have that $\mu(b_2 \mid h_2) = \mu(b_2 \mid h_1) \geq \mu(b_1 \mid h_2) = \mu(b_1 \mid h_1)$. If the conditional probability is given by (9), clearly $\mu(b_2 \mid h_2) = \mu(b_2 \mid h_1) \geq \mu(b_1 \mid h_2) = \mu(b_1 \mid h_1)$ is equivalent to $h_2 \geq h_1$.

[10] Indeed, one can prove that the derivative of the skewness of $f\big(b \mid h, 5, (5-h)(1-h/5) \big)$ with respect to h is negative on the interval $(0,5)$.

Figure 1. Distributions of $\mu(b \mid h)$ under Case B.

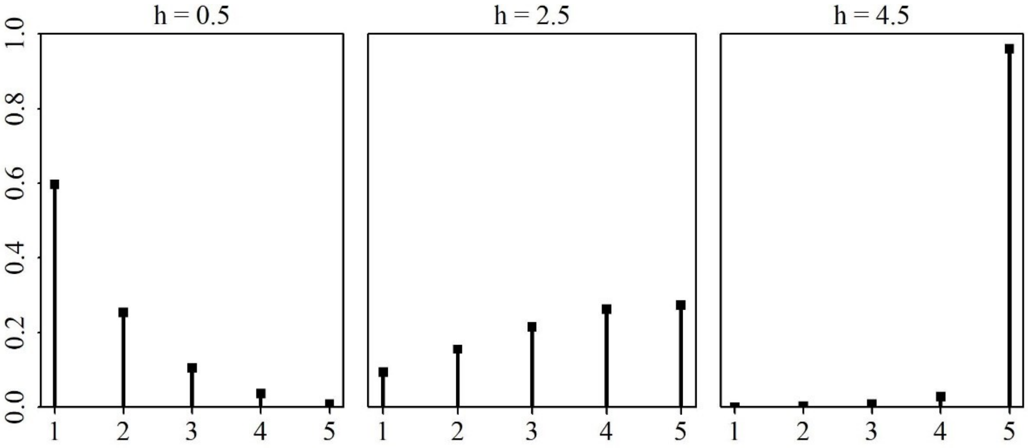
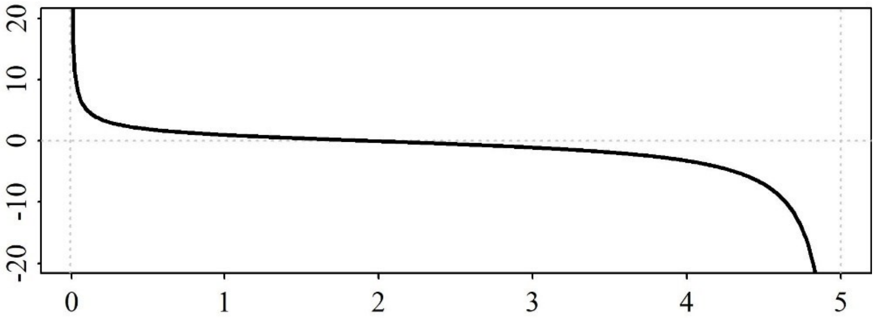


Figure 2. Skewness of the Beta-binomial f along $h \in (0,5)$.



5. Sensitivity Analysis

In this section, the solutions of the linear programs with lotteries discussed so far are shown and a sensitivity analysis for each case mentioned in Section 4 is made. For the latter purpose, Case A and Case B are chosen as bases of comparison in order to evaluate the solutions in response to changes in the value of a given parameter[11].

5.1 Optimal Contracts for Case A

The solution for the corruption problem under Case A is reported in Table 3. We observe that the bureaucrats are assigned to a moderately dishonest conduct $h \approx 0.25$ (out of 1), with probability one. Roughly, the compensations are splitted into two regimes, each with probability 0.5: high compensation with high efficiency and low compensation with low efficiency. Since both parties are risk-neutral under Case A, the trade-off between incentive provision and risk-sharing is eliminated, and the problem become an incentive problem. Hence, when the output is low, the

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[11] The R code used for providing the results of this section is available in https://github.com/danilomatsuoka/Econometrics/blob/master/Corruption/Corruption.R

compensation has to be punitive while a high output needs to be accompanied by a high compensation to reward the bureaucrat.

The following subsections present the solutions obtained from varying parameter values. For each case, we analyze the associated solution having Table 3 as basis of comparison.

5.1.1 Case A: Changes in the Parameter α

Changes in the value $0 < \alpha < 1$ of the conditional probability $\mu(b \mid h) = h^{\alpha}$ affects the *likelihood ratios*, $\mu(b_2 \mid h_i)/\mu(b_2 \mid h_j) = (h_i/h_j)^{\alpha}$, $i, j \in \{1, \ldots, l\}$. A high likelihood ratio means strong evidence that b_2 was achieved through h_i. When α increases, the ratios become even higher, i.e., more evident to the principal the cases in which the agent deviates a recommended action. We can then interpret α as a factor that controls the society's ability to punish or to provide incentives.

Table 4 shows that extreme corruption, $h \approx 0$, arises with probability one when the parameter α is changed to 0.1. In addition, with probability ≈ 0.97, the bureaucrats receive the minimum compensation ($w = 1$). The highest joint probability (0.65) occurs on the minimum compensation and maximum efficiency ($b = 3$). Therefore, comparing with Table 3, the contract when $\alpha = 0.1$ is characterized by a low compensation, high efficiency and extreme corruption, which lead to an increased society's expected utility.

Table 3. Solution for the program under Case A

$p(w,b,h)$	w	b	h
0.505	1	1	2.45
0.016	1	3	2.45
0.479	2	3	2.45
$E(\Psi^{*})^{a}$	0.51		

^{a} Principal's expected utility.

Perhaps it is more elucidating to explain this solution from the limiting situation $\mu(b_2 \mid h) \approx 1$ which occurs when α is nearly zero. Firstly, note that $\mu(b_1 \mid h) = 0$ if $\mu(b_2 \mid h) = 1$, and hence, the mother nature conditions in (4) imply that $\sum_w p(w, b_1, h) = 0, \forall h \in \mathcal{H}$. Since the probability measure is nonnegative, we must have $p(w, b_1, h) = 0$, for each $(w, h) \in \mathcal{W} \times \mathcal{H}$. This suggests that the low efficiency b_1 is constrained to happen with a nearly zero probability when α is also nearly zero.

Secondly, if we consider that $p(w, b_1, h) \approx 0$ and $\mu(b_2 \mid h)/\mu(b_2 \mid \hat{h}) \approx 1, \forall \hat{h} \neq h$, (which happen when α is nearly zero in our model), then the incentive compatibility inequalities in (3) restrict $p(w, b_2, h)$ in such a way that, for any $\hat{h} \neq h$,

$$\sum_{w} p(w, b_2, h)[\hat{h} - h] \geq 0. \tag{13}$$

Condition (13) says that the bureaucrat will accept the contract if the weighted average of the difference between a recommended action h and its alternatives $\hat{h}$ is nonnegative. In other words, low levels of honesty must be recommended with higher probability weights in most of times along w (with respect to high levels of action). Another important detail is that there is no restriction in (13) that forces the compensation to be high in order to have the contract accepted. As long as w is adequate to satisfy the participation constraint (2), the society's utility $\Psi(b, w) = b - w$ will push the solution to assign higher probabilities on low compensations, given that the society's expected utility is our objective function. In sum, when α is nearly zero, the society has no ability to provide incentives and the technology is such that a high efficiency can be obtained as likely from honest actions as from corrupt actions. Due to this fact and the above considerations, the bureaucrat will be willing to choose the lowest possible action h, accept low compensations and return high efficiencies.

In contrast, when α is increased to 0.9, the bureaucrats are assigned to the honesty level $h \approx 0.35$, higher than that of Table 3. We can identify the presence of two regimes in Table 4: one with low compensation and low efficiency, and the other with high compensation and high efficiency. This is consistent with the increased ability of the society to monitor the bureaucrats. However, we now find that the probabilities are more concentrated in the first regime mentioned above, leading to a decrease in the principal's expected utility (0.387 against 0.51). Interestingly, we come up with the result that the society would be better off ($E(\Psi^*) = 1.331$) in the unmonitored scenario with a generalized bureaucratic corruption.

Table 4. Solutions for different α's under Case A

$\alpha = 0.1$				$\alpha = 0.9$			
$p(w,b,h)$	w	b	h	$p(w,b,h)$	w	b	h
0.322	1	1	0.02	0.614	1	1	0.347
0.650	1	3	0.02	0.001	1	3	0.347
0.028	1.857	3	0.02	0.384	2	3	0.347
$E(\Psi^*)$	1.331			$E(\Psi^*)$	0.387		

5.1.2 Case A: Changes in the Relative Risk Aversion Coefficient $\boldsymbol{\tau}$

As the relative risk aversion decreases, the bureaucrats become more prone to risk. It can be checked that, in case A, risk-taking agents need more compensation to be as satisfied as risk-neutral agents[12], holding everything else fixed. From Table 5, we observe that this profile of bureaucrat makes the society better off in comparison with our baseline case (Table 3), since both expected utilities $E(\Psi^*)$ are greater than 0.51. Also, the society recommends conducts that are less corrupt: with probability one, $h \approx 0.29$ for $\tau = -0.2$ and $h \approx 0.37$ for $\tau = -0.5$. The joint probability masses become more concentrated on high compensations and high efficiencies: 0.58 and 0.67 for $\tau = -0.4$ and $\tau = -0.8$, respectively.

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[12] Let h be fixed and let agent i have utility $\Phi_i(w_i; h) = w_i + 1 - h$ and j have utility $\Phi_j(w_j, h) = w_j^{1+\tau}/(1+\tau) + 1 - h$. Then $\Phi_i(h, w_i) = \Phi_j(h, w_j)$ implies $w_i \geq w_j$ for all $w_i, w_j \in [1,2]$ and all $\tau \in (-1, 0)$. This is so because both utility functions are increasing in w and, for $\tau < 0$, $\partial^2 \Phi_j / \partial w_j^2 < 0$ and $w_i = w_j^{1+\tau}/(1+\tau)$ at the point $\sqrt[\tau]{1+\tau} > e > 2 = w_r$.

Table 5. Solutions for risk-taking agents under Case A

$\tau = -0.2$				$\tau = -0.5$			
$p(w,b,h)$	w	b	h	$p(w,b,h)$	w	b	h
0.465	1	1	0.286	0.394	1	1	0.367
0.016	1	3	0.286	0.012	1	3	0.367
0.519	2	3	0.286	0.594	2	3	0.367
$E(\Psi^*)$	0.55			$E(\Psi^*)$	0.618		

5.2 Optimal Contracts for Case B

The setup of Case B assumes that the bureaucrat has purely rational preferences, both society and bureaucrat are risk-neutral, the technology is given by a normalized Beta-binomial distribution and the bounds for the sets $\mathcal{H}, \mathcal{W}$ and $\mathcal{B}$ were expanded in comparison with that of Case A.

The solution of the program under Case B is presented in Table 6. Roughly, with probability one, the bureaucratic body is assigned to righteous actions, high efficiency and high compensations.

Table 6. Solution for the program under Case B

$p(w,b,h)$	w	b	h
0.471	3.939	5	5
0.529	5	5	5
$E(\Psi^*)$	0.5		

As both agent and principal are risk neutral, it is important to understand the incentive provision scheme. Figure 1 shows that $\mu(b \mid h)$ is consistent with the idea that low efficiency is more likely achieved by dishonest conducts ($h = 0.1$) and high efficiency, by honest conducts ($h = 4.9$). Statistically, this outlines that the conditional distribution of b is positive skewed when $h = 0.1$ and negative skewed when $h = 4.9$. Furthermore, Figures 1 - 2 show that the magnitude of the skewness is higher when $h = 4.9$. In words: (i) the society has a higher ability to provide incentives for high levels of honesty than it has for low levels[13]; and, analogously, (ii) the bureaucrat's beliefs (or technology) are such that a high efficiency is likely to be produced when it is conducted with high integrity. As a result, we see that the optimal contract assigns maximum efficiency and honesty, where a slightly more than a half of the bureaucratic departments work with compensation $w \approx 4$ benefiting the society ($\Psi(b,w) = 1$), and the other fraction, with maximum compensation $w = 5$, benefiting themselves ($\Phi(h,w) = 1$).

The following subsections adopt Table 6 as basis of comparison.

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[13] Therefore, the society has a high ability to reward highly honest conducts.

5.2.1 Case B: Changes in the Reciprocity Coefficient $\boldsymbol{\delta}$

Whenever $\delta > 0$, the bureaucrats cares about the society's welfare, weighting between their compensation and their efficiency. To enlighten the implication of this situation, consider the case without lotteries and suppose that there are two agents, i and j, such that the former is selfish $\Phi_i(w,h) = w + (1-h)$ and the latter is altruist $\Phi_j(w,b,h) = (1-\delta)w + \delta b + (1-h)$, $\delta > 0$. Further, let $(b, w_j) \in \mathcal{B} \times \mathcal{W}: b \geq w_j$, otherwise the principal would be better off without the contractual relationship. Clearly, if $\Phi_i(w_i,h) = \Phi_j(w_j,b,h) = \bar{U} \geq 0$, then $w_j \leq w_i$, for any $(w_j,h) \in \mathcal{W} \times \mathcal{H}$[14]. In words, the altruist bureaucrat j needs less compensation to be as satisfied as the selfish agent i, holding everything else equal.

Symmetrically, under the above conditions with the bureaucrat being spiteful ($\delta < 0$), $\Phi_i(w_i,h) = \Phi_j(w_j,b,h) = \bar{U} \geq 0$ implies $w_j \geq w_i$, for any w_j, h. That is, the spiteful bureaucrat j needs greater compensation to be as satisfied as the agent i, holding everything else equal.

In comparison with the solution of the standard Case B, Table 7 shows that the joint probability mass shifts to one on the lower compensations ($w = 1$ or $w \approx 3.4$) when $\delta = 0.5$, while it becomes higher (≈ 0.92) on the maximum compensation $w = 5$, when $\delta = -0.5$. These results corroborate with the reasoning in the argument above. In addition, when the bureaucrats care about the society, the optimal contract makes the society better off ($E(\Psi^*) = 1 > 0.333$).

Table 7. Solutions for altruist and spiteful agents under Case B

$\delta = 0.5$				$\delta = -0.5$			
$p(w,b,h)$	w	b	h	$p(w,b,h)$	w	b	h
0.613	3.367	5	5	0.085	1	5	5
0.387	1	5	5	0.917	5	5	5
$E(\Psi^*)$	1			$E(\Psi^*)$	0.333		

5.2.2 Case B: Changes in the Reservation Utility $\boldsymbol{\mathcal{U}}$

Table 8 shows that regardless of whether we increase or decrease the reservation utility to $\mathcal{U} = 0.2$ or $\mathcal{U} = 0.8$ respectively, the optimal contracts rely on the extreme point $(w = 5, b = 5, h = 5)$ or on a small neighborhood S of $(w = 4, b = 5, h = 5)$, like in Table 6.

We observe that by decreasing the reservation utility to 0.2, the probability mass becomes higher (≈ 0.82) when $w \approx 4$, and hence, lower (≈ 0.18) when $w = 5$. In contrast, when $\mathcal{U}$ is increased to 0.8, the probability mass becomes higher (≈ 0.81) on $w = 5$ and thus, lower (≈ 0.19) on $w \approx 4$. Therefore, the expected utility of the society is higher for the lower reservation utility.

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[14] It holds that $w_i = (1-\delta)w_j + \delta b \geq w_j$, by hypothesis.

Table 8. Solutions for lower and greater reservation utilities under Case B

$\mathcal{U} = 0.2$				$\mathcal{U} = 0.8$			
$p(w, b, h)$	w	b	h	$p(w, b, h)$	w	b	h
0.817	4.02	5	5	0.188	3.939	5	5
0.183	5	5	5	0.812	5	5	5
$E(\Psi^*)$	0.8			$E(\Psi^*)$	0.2		

When the reservation utility is increased, one is imposing a higher lower bound to the weighted average on the left-hand side of the participation constraint (2). Then, the probability weights also must be increased on higher values of (h, w) in order satisfy (2). The idea is that a high reservation utility means a high opportunity cost of accepting the contract in the bureaucrat's perspective so that a high compensation is required to make it worth it. If the bureaucrat's expected utility is lower than what is obtained in alternative tasks in the market, the contract would be rejected.

5.2.3 Case B: Changes in the Relative Risk Aversion Coefficient $\boldsymbol{\tau}$

We observe, from Table 9, that the maximum efficiency and maximum honesty levels are still assigned in the optimal contract and happen with probability one. However, the two regimes are now distinct due to the compensation extrema $w = 1$ and $w = 5$. These contracts lead to higher expected utilities for the society, especially when $\tau = -0.5$.

Table 9. Solutions for risk-taking bureaucrats under Case B

$\tau = -0.2$				$\tau = -0.5$			
$p(w, b, h)$	w	b	h	$p(w, b, h)$	w	b	h
0.254	1	5	5	0.435	1	5	5
0.746	5	5	5	0.565	5	5	5
$E(\Psi^*)$	1.016			$E(\Psi^*)$	1.741		

6. Discussion

In Section 3, we assumed that prior beliefs are such that the highest bureaucratic efficiency is relatively more likely generated by honest conducts and the lowest efficiency, by corrupt conducts. This condition is in line with the view that considers corruption as sand for the economy, as discussed in Section 1. It does not imply, however, that we cannot have bureaucrats being assigned to return a high efficiency corruptly. Indeed, results for Case A in Section 5.1 show cases where it is optimal to have a fraction of them being highly efficient while adopting corrupt actions. In particular, when the beliefs about the bureaucratic efficiency become nearly uncorrelated with the honest level ($\alpha = 0.1$), Table 4 shows that the bureaucrats are mostly assigned to work as efficiently and corruptly as possible.

Another aspect to be outlined is that a clear correlation between the society's expected utility $E(\Psi)$ and the corruption level h was not found in our analysis. The relations between the three choice variables (honesty, compensation and efficiency) are nonlinear in the model and then simple intuition is inappropriate to draw conclusions. Section 5 shows that these relations are highly affected by changes in parameters. In comparison with the baseline Case A (Table 3), we observed parameter changes that moved $E(\Psi)$ and h to opposite directions (see Table 4), as well as changes that made them move together (Table 5). The case where $\alpha = 0.1$ in Table 4 is interesting because the combination of high efficiency and low compensation made the society better off, even though in the presence of extreme corruption.

The above considerations suggest that the discussion about whether corruption acts, uniquely, as grease or sand for the economy does not make much sense in our framework. One reason is that the bureaucrat is always able to be efficient if so desired, in our model. Secondly, when lotteries are added in the contract, possibly there will be fractions of the population so that both views will coexist. One fraction where corruption is accompanied with efficiency, and the other, with inefficiency. The magnitude of each fraction will be determined by the model's settings. Furthermore, if we regard the society's utility as a measurement of social welfare, we are unable to outline a clear correlation between expected welfare and corruption from our results.

7. Conclusion

This paper analyzed the solutions of randomized contracts applied to the bureaucratic corruption problem. We computed linear program algorithms based on the setup of Karaivanov (2001) as well as on a setup where the output and the effort were related using a normalized Beta-binomial distribution. In order to evaluate the behavior of our model, we also inspected solutions obtained in response to changes in the optimization parameters. Under the specification model of Karaivanov (2001), it was found that the parameter α acts as a monitoring parameter.

We observed that when α was lowered, the bureaucratic corruption increased to the maximum, but the society became better off in terms of expected utility. In addition, optimal contracts for risk-taking bureaucrats tended to assign more honest conducts and to provide higher expected utilities for the society. The general result for the scenario where $\mu(b \mid h)$ is modeled as a normalized Beta-binomial distribution was that the bureaucratic body was assigned to work as efficiently and righteously as possible. Furthermore, it was found that altruist bureaucrats increased the society's expected utility while spiteful bureaucrats make the society worse off. Positive changes in the reservation utility tended to increase the fraction of the bureaucrats receiving maximum compensation and to increase the society's expected utility. When the bureaucrats were risk-taking, the optimal contracts made the society better off.

To keep the effort not part of the problem, it was assumed that the bureaucrat always do a task employing a fixed level of effort. This condition, certainly, oversimplifies the corruption problem (and rules out the shirking problem). For future work, one may include a new variable, say e, which should enter negatively in the bureaucrat's utility function. It is worth mentioning that this inclusion can increase the complexity of the model substantially, since it will affect the assumptions on how the output b is related to action h and effort e, on the preferences and, clearly, will increase the dimension of the problem.

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