An Agent-Based Model of Administrative Corruption in Hierarchical Organisations

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Abstract. Corruption is a familiar and pressing problem in the performance of administrative bureaucracies. Changing the organisational structure is one way ventured to combat corrupt practices within a hierarchical organisation. Previous works have studied organisational change from various lenses, including equation-based modelling. We address the question of what level of hierarchy is optimal in such an organisation by means of agent-based simulation. We argue that agent-based models are uniquely suited for the exploratory modelling of corruption due to their capturing of localised, individualised behaviours. Our findings are that a less hierarchical organisational structure: 1) tend to lead to less corrupt acts committed, and 2) tends to lead to more societal welfare generated – however, 3) less corruption and more societal welfare do not always go hand in hand. We begin to reconcile these seemingly paradoxical results using theories from developmental economics.

Keywords: Administrative Corruption · Agent-Based Models · Complex Adaptive Systems · Collusion · Organisation Structure

1 Introduction

Identified as at the heart of pressing societal problems "from economic uncertainty, to endemic poverty, to ... radicalisation and extremism" [6], corruption is old as human civilisation [20]. Indeed, corruption is almost universally accepted as a problem: the United Nations Convention Against Corruption has been ratified by more than 180 parties [23, 29].

All those who would benefit from an organization achieving its goals are impacted by misalignments in values, incentives, goals,and actions when these are manifest in corrupt acts: in case of a privately-owned company this is mainly the shareholders, but in case of a governmental agency this includes all citizens. This latter case has our attention, wherein corruption is defined as "the abuse of public office for private gain" [17]. This paper will critique an extant theoretical model of corruption using agent-based simulation.

While scholars debate the definition of corruption [26], this paper deals with an abstract notion of corruption: we understand corruption as any event in which an agent refuses to act in the way prescribed by the organisation of which it is a member, due to the (implicit) individual aims that the agent holds. While this

definition is arguably broad, as it can be understood to include other influence-seeking activities such as rent-seeking [1], it is fit for our theoretical investigation, which does not need to deal with the specific intricacies between different forms of problematic, self-serving governance.[1]

It has been observed that the structure of an organisation can have significant effect on its performance [8, 25]. Previous research has shown that people expect organisational structure to also effect corruption, specifically associating more hierarchical organisations a higher level of corruption [13]. There have also been economic models that found that organisational structure influences organisational corruption to a large degree [9]. Further, deducing organisational structures that are less conducive to corruption is a recognised approach in anti-corruption policy [25, 12].

Social scientists and governance experts have proposed policies intended to lead towards good governance, by building the integrity of public organisations [22]. However, testing whether such a posited policy works well in practice is problematic. It is hardly desirable to implement such measures without thorough study, as the societal cost of trying a new anti-corruption measure is high. Agent-Based Modelling (ABM) excels at handling the fluctuations inherent to corruption in society (as opposed to classical equilibrium theories), deals well with bounded rationality, and the heterogeneity of the actors present in the process of corruption [14, 30]. Indeed, there is successful precedent in using ABM to study corruption. Among these are works dealing specifically with administrative corruption [11]. These models proved useful in showing the endogenous dynamics of how corruption might arise or be reduced [16], and looking at both micro- and macro-level determinants of corruption. However, the role of hierarchical structures and organisational shapes has not been fathomed using ABM.

This paper takes as starting point the classical equation-based model of Duggar and Duggar [9]. We begin investigate the following questions using agent-based modelling and simulation:

Question 1 (Q1) *Does a less hierarchical organisational structure for an administrative bureaucracy lead to less corrupt acts committed?*

Question 2 (Q2) *Does a less hierarchical organisational structure for an administrative bureaucracy lead to more societal welfare generated (more wealth that is used effectively by society, and not impeded in its use by corruption)?*

Question 3 (Q3) *What is the relationship between the number of acts (cf. Q1) and the societal wealth generated (cf. Q2)? Does reducing the number of corrupt actions always lead to an increase in societal wealth?*

[1] In fact, one can note that these corrupt actions that go against the behaviour prescribed by the organisation do not necessarily go against the aims of the organisation. In some scenarios, individuals can more effectively help the organisation achieve its goal by going against the organisational directions – such as when the directions are misaligned with the actual goals of the organisational, while the individual incentives (possibly by chance) align with it.

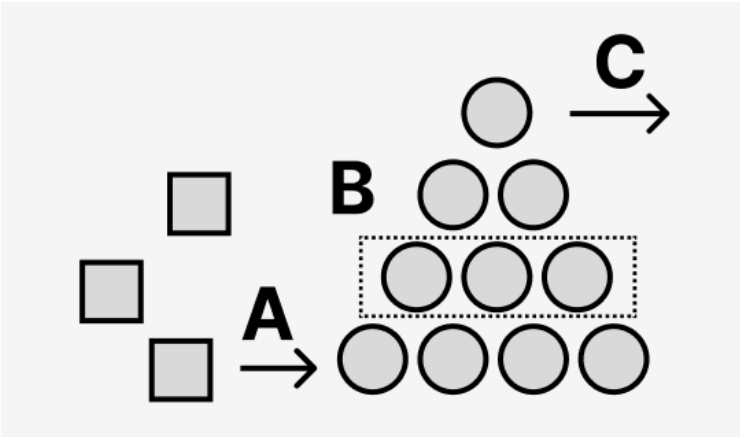

Fig. 1. Overview of the bureaucratic process, with circles representing bureaucrat agents, and squares representing applicant agents. The letters indicate the different stages of the process: A) the applicants submit their project proposals to the bureaucracy. B) the levels iteratively decide whether to pass on their project proposal. Each official on the level evaluates the proposal and makes a verdict, which might be corrupted by the applicant. C) If the highest level approves of the project proposal, it is implemented, adding its value minus its cost to the societal wealth.

The remainder of the paper is organised as follows. Section 2 describes the model design and the experiment setup. Section 3 presents the simulation results. Section 4 provides an overview of related work. Section 5 summaries our findings and possible future directions.

2 Methodology

Duggar and Duggar [9] sought to build a quantitative model that provides insight on the relation between organisational form and corruption. The authors developed an equation-based model of a theoretical organisation. We critique this model by developing an agent-based model with individual-level behaviours. In this paper we focus on a mapping of agent behaviours and simple learning mechanisms. The scenario is the working of an administrative bureaucratic organisation. Our abstract organisation's goal is to evaluate project proposals that are submitted to it, and decide which ones to implement. The organisation's theoretical goal is to generate as much 'societal profit' as possible: implement the projects that bring the most societal value, while costing the least resources.

The primary properties of an agent-based model are the agents (and their behaviour), and the environment in which they exist [24]. There are two types of **agents** present in our model: *bureaucrats* and *applicants*. Bureaucrats represent the administrative agents of the bureaucratic organisation, while applicants represent the enterprising citizens who submit project proposals to the agency.

The **environment** in which the agents exist aims to represent the hierarchic bureaucracy. Unlike Duggar and Duggar's fixed aggregation scheme, we model the bureaucracy as a directed acyclic graph, where the superior–subordinate relationships are represented by the edges. This allows for the simple pyramid shaped organisations investigated by Duggar and Duggar, but also for various other organisational structures. When the bureaucracy is pyramid-shaped, the lowest level is the largest (here, bureaucrats receive the minimum wage) with each level being strictly smaller (with the wages increasing on each level). For a fixed number of agents, the number by which the level sizes increase also defines the *steepness*: the steeper an organisation is, the more hierarchical it is.

2.1 Organisational Workflow

The model captures agents interactions as a sequence of rounds, each representing a workday. Each round, the following workflow operates, as depicted in Figure 2:

1. Applicants owning a project that is not yet in the bureaucracy **submit** their projects to the lowest level.
2. Each project is **evaluated** by the official currently handling it. These officials decide upon an initial verdict: pass or reject.
3. The applicants can **offer** an amount to the officials handling their project to change their mind. If this amount is high enough, and the official is willing to act corruptly, then **corruption happens**.
4. Each project that was rejected is **removed** from the hierarchy (and the applicant owning it receives a new project). Each official from a lower level than where the project was rejected is **fired**, since they are deemed to be corrupt and working against the organisations goals by forwarding an applicant with a project unworthy of implementation. This 'draconian' one-strike policy could of course be replaced by more nuanced firing policies as well. Following this, the empty positions of the bureaucracy are refilled with new officials.
5. Each project that passes the final official is **implemented**. The social welfare increases by the project's *value*: *cost*, and the applicant owning the project receives *cost*.

During the **evaluation** phase the official judges the project on whether it has a higher *value* than *cost*. However, officials are not perfect: each has a *fallibility rate*, uniformly sampled from $U(0, 0.5)$, which defines the chance that the official will simply make a mistake.

During the **corruption** phase, the officials make a decision to entertain the possibility of a bribe. The model captures conducive corruption; we do not treat coercive corruption in this paper. Each official has a *dishonesty* property, uniformly sampled from $U(0, 0.7)$ which serves as the parameter of the Bernoulli trial deciding whether the official is open to being bribed.

Once an official decides that he is open to being bribed, the official decides upon a threshold, influenced by his current wage, the number of superiors he

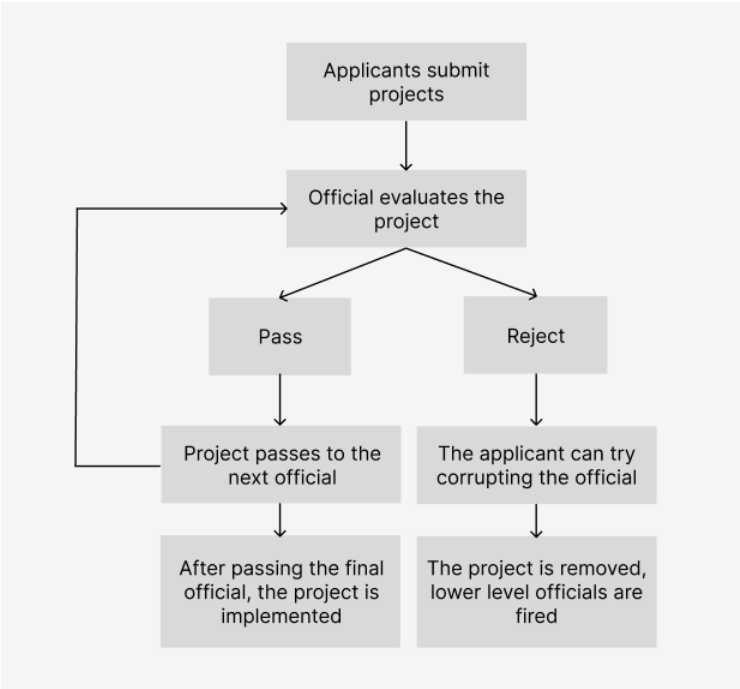

Fig. 2. Overview of the process each round (workday).

has, and his *bargaining score*, a property that can change due to experiences. The applicant then sends an offer, based on the applicant's expected reward (the *cost* of the project), the number of officials still left in the bureaucracy, and the applicant's own *bargaining score*. If this offer is higher than the official's bribery threshold, than they exchange the amount, and the official changes his verdict. Finally, both agents update their *bargaining score*s by their *learning rates*: an official will aim for a higher bribe next time, if he has been paid now, and a lower one if he would have been open to being bribed but the offer he received was too low; and vice versa for the applicant.

2.2 Experiment Setup

We study organisations with different number of applicants, as described in Section 3. The parameters are calibrated as follows. The minimum wage (the wage of the lowest ranking officials) is 1, and the wage doubles on every level of the hierarchy. The project's cost is sampled from $U(1000, 10000)$, while its value is sampled from $U(1000, 15000)$, representing how a government project can have vastly higher societal impact than the project's cost. During each experiment, the social welfare is recorded, as a measure of how well the organisation achieves its goal. As noted above, the welfare is calculated by summing the value of the

projects that the top-most official in the bureaucracy accepts and subtracting the sum of the costs of these projects.

Each experiment is run for 10000 rounds, which is long enough for a large amount of projects to go through all levels of the organisation. To ensure robustness, we ran each experiment 120 times, and our presented metrics are the average over the runs. Evaluating whether 120 is an appropriate number of runs for each experiment was done through windowed variance [21]. We reached a windowed variance less than 10^{-7} for measuring the percentage of corrupt acts amongst all acts, and at worst less than $4 * 10^{-4}$ windowed relative variance for societal wealth. This indicates that our findings are quite robust, and running them for 120 times is enough to control for chance.

After a trial implementation in NetLogo, the model was implemented using the Python Mesa library [18], using Python version 3.12.8, and Mesa version 3.1.3[2]. The model source will be made available for reproducibility.

3 Simulation Results

To examine the three research questions, we performed two sets of experiments.

3.1 Simple Pyramid Organisations and Steepness

First, to study how the level of corruption and the social utility might change with a difference in hierarchy, we conduct simulation experiments with the above ABM. We start with investigating the simple pyramid as an organisational structure. This is both the only form of organisation studied by Duggar and Duggar, and also amongst the most common forms of organisations, especially in the bureaucratic context [15, 31]. For a given amount of officials, the organisational pyramid can take on different values of 'steepness', depending on the distance from the top to the lowest level. At the extremes, we see the 'line' hierarchy, where officials have exactly one direct subordinate, and the 'flat' hierarchy, where each official is the direct subordinate of the leader of the bureaucracy.

Table 1 summarises the results. We observe the following: first, line structures (the most hierarchical 'pyramid') is leads consistently to the most corruption, and the least societal welfare. Second, we see that a lower level of corruption does not always lead to a higher societal welfare – as the small flat structure outperforms the small balanced structure welfare-wise, even though it has a higher percentage of corrupt acts. Third, we can observe that for the more hierarchical structures having a larger bureaucracy results both in a higher percentage of corrupt acts, and less social welfare generated - but for the flat structure, this is reversed, as it performs better with more officers.

3.2 Alternative Organisational Forms

Second, to demonstrate the flexibility of an agent-based modelling approach, we also simulate two alternative ways to structure an organisation: the matrix

[2] https://github.com/projectmesa/mesa

Table 1. The percentage of corrupt acts and societal welfare for different sizes and structures of organisations. The 'line' structure has 1 official per each level, while the flat structure has only 2 levels: 1 with 1 official, and another with all the others. The balanced structure differs for each size: the number of levels are 3, 4 and 7, while the number of officials a superior has directly below them are 5, 4 and 3 respectively.

Officials	Mean Percentage of Corrupt Acts		
	Line Structure	Balanced Structure	Flat Structure
Small (31)	0.03552	**0.03280**	0.04446
Medium (85)	0.06393	0.05970	**0.03545**
Large (1093)	0.06349	0.05515	**0.03546**
Officials	Mean Societal Welfare (in 1000 units)		
	Line Structure	Balanced Structure	Flat Structure
Small (31)	12	88,603	**117,358**
Medium (85)	0	49,431	**236,463**
Large (1093)	0	13,073	**236,462**

Table 2. The percentage of corrupt acts and societal welfare for alternative organisational structures. The specific structures are further described in the main text.

Officials	Mean Percentage of Corrupt Acts	
	Matrix/Grid Structure	Imbalanced Pyramid
Small (approx. 31)	0.05050	0.05049
Medium (approx. 85)	0.06120	0.05735
Large (approx. 1093)	0.06054	0.05991
Officials	Mean Societal Welfare (in 1000 units)	
	Line Structure	Imbalanced Pyramid
Small (approx. 31)	37,717	34,835
Medium (approx. 85)	10,891	9,835
Large (approx. 1093)	11	111

structure, and the imbalanced pyramid. The matrix organisational structure is prevalent organisational shape built on the idea of 'dual authority': each member of the hierarchy has two direct superiors [3, 19]. In the case of the imbalanced pyramid we model the common scenario when some branch of the organisation grows considerably larger than any other - in our case, we simulate this by a pyramid, where on each level the leftmost official has several (in the case of small and medium 3, in the case of large 4) direct subordinates, but every other official has only 1.

For both of these alternative organisational forms, we see similar tendencies as for the line and balanced structures of the simple pyramid organisation: adding more officials leads to both worse societal welfare, and more corruption. Both of these organisational structures seem to underperform both the balanced and the flat structures of the simple pyramid.

Our results show that more corrupt acts and better societal utility generation does not necessarily go hand in hand, implying that more hierarchical organisations increase the level of corruption and societal welfare in an unrelated manner, and not because one of them necessarily also increases the other value. This is in accordance with the 'functionalist account of hierarchy' [2]: according to it hierarchical organisations perform significantly better at routine tasks (where having alternative perspectives and ideas is not of use), and this gain can outweigh even the additional corruption imposed by a power imbalance between members; but lower corruption, everything else being equal, still leads to a better societal outcome. Connecting empirical (agent-based) simulation studies with the broader discourse in the literature on corruption is interesting to continue in the future.

4 Related Work

The phenomenon that hierarchy impacts corruption has long been accepted in the literature. As shown by artificial experiments done with crowd workers, people perceive more hierarchical organisations to be more conducive to corruption [13, 12]. Rosenblatt [25] argues that both hierarchical institutions, and a personal predisposition towards hierarchy leads to more corruption, basing it on previous empirical findings and social dominance theory. However, these studies do not propose a model that can be used to investigate the possible benefits and drawbacks of changing the hierarchical structures to a more egalitarian one.

Earlier corruption models created by classical (non-ABM) techniques have primarily addressed corruption as a rational behaviour. These modelling techniques included mathematical, game-theoretical, experimental analysis, principal-agent, and process models [11]. While these models had the traditional weaknesses of classical models, such as not being able to handle bounded rationality to a satisfying degree, important concepts have been explored in them. Most importantly, Duggar and Duggar [9]'s mathematical model discussed specifically the role the structure of a hierarchical (pyramid-shaped) organisation can play in corruption, and proposed the competitive-cooperative abstraction for organisational cultures. Our model comprises an ABM analogue of their work, with considerable extensions – including imperfect decision making (already mentioned in their model as a possible extension) and a simple form of learning. Other classical models which specifically study the impact of organisational structure and hierarchy on corruption include Bac [4]'s and Carrillo [7]'s models.

As well as theoretical characterisations, which are the interest of this paper, agent-based models have been built for specific domains of corruption: water service [5], maritime customs [27] or police corruption [10]. Other more general corruption models, and those dealing specifically with administrative corruption have also been proposed, as surveyed by Elnawawy et al. [11]. Hammond [16] and Zausinová et al. [33] created extensive models focusing on bureaucrat-citizen interactions, which showed how a corrupt (or honest) regime can appear endogenously. However, their models allow the bureaucrats to 'freely roam' and interact

with different agents without confining them to a hierarchical structure that is characteristic to bureaucracies [32].

5 Conclusion

A proposed policy towards reducing the negative effects of corruption in administrative bureaucracies is setting up the hierarchical structure of the organisation, in such a way that it discourages accepting bribes. To study the consequences of such a policy, this paper developed an initial agent-based model.

According to simulation experiments with the ABM, a less hierarchical organisational structure in an administrative bureaucracy tend to lead to less corrupt acts, and also a higher societal welfare. Thus the answer to research question Q1 is negative, more hierarchical bureaucracies lead to more corrupt acts committed, while for Q2 we find a less hierarchical bureaucracy does lead to more societal welfare. The somewhat surprising result to Q3 is that there is no apparent strong relationship between the number of corrupt acts and societal welfare generated, as we see situations where both of them increase together, but also situations where one increases and the other decreases.

Possible extensions to our work are plural, including replacement of the current method of enforcement (indiscriminate firing from the lower levels), with a possible new Inspector agent class. Second, uncovering the role of organisational culture [28], and exploring alternative sociological theories as part of the modelling process.

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