FACULTAD LATINOAMERICANA DE CIENCIAS SOCIALES
SEDE ECUADOR

PROGRAMA DE ECONOMÍA DEL DESARROLLO
CONVOCATORIA 2008 - 2010

TESIS PARA OBTENER EL TÍTULO DE MAESTRÍA EN CIENCIAS SOCIALES CON MENCIÓN EN ECONOMÍA DEL DESARROLLO

CORRUPTION NETWORKS: A SOCIAL NETWORK THEORY AND GAME THEORY APPROACH

Carlos Andrés Uribe Terán

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Resumen

Varios estudios demuestran que la corrupción no es únicamente un problema de negociación en el que un agente busca un objetivo en particular y un oficial exige un soborno para realizar su trabajo. Otras líneas de investigación analizan como las estructuras sociales pueden originar una sociedad corrupta. En este trabajo, combino la aproximación individualista de la teoría económica con el enfoque más social de otras ciencias sociales como la sociología, las ciencias políticas y la administración de empresas. Esto me permite estudiar la corrupción y el papel de las agencias de monitoreo cuando los actos corruptos se desarrollan bajo una estructura de redes sociales. El objetivo es comprobar que si la red es completa (i.e. no exhibe ninguna brecha), la coordinación entre agentes es más fluída y es más sencillo alcanzar objetivos corruptos. Además, cuando se incluye a las agencias de monitoreo, es fundamental que las instituciones y estas agencias complementen sus labores para prevenir el acto de corrupción de una manera más efectiva. Para ello, combino dos teorías sobre el comportamiento humano: la teoría de redes sociales y la teoría de juegos. Después de estudiar cuatro posibles escenarios, dos sin incluir las agencias de monitoreo y dos incluyéndolas, demuestro que la hipótesis planteada no puede ser descartada. Inclusive, si la penalidad que castiga el comportamiento corrupto es baja (o el costo administrativo de la justicia es alto) entonces los agentes preferirán involucrarse en actividades corruptas, sobre todo cuando la red es completa. Por el contrario, si la honestidad es altamente recompensada, los agentes tienen incentivos suficientes para no aceptar propuestas corruptas. La existencia de agencias de monitoreo, representadas como medios de comunicación libres, pueden desmotivar la corrupción desde el inicio.

Abstract

Many studies show that corruption is not only a bargaining problem between an agent that has an specific objective and an official that demand a bribe to do her job. Other lines of research analyzes how social structures are the origin of a corrupt society. In this work I combine the individualistic approach of economic theory with the social view of other social sciences such as sociology, political sciences and business administration to study corruption and the role of monitoring agencies when corruption takes place in a network structure. I will try to prove that if the social network is complete (i.e. it exhibits no gaps) then the coordination among agents is more fluent and it is easier to achieve corrupt objectives. On the other hand, institutions can generate incentives even if the network is complete. When monitoring agencies are included, it is important for institutions and monitoring agencies to complement each other to prevent more effectively the act of corruption. For this, I combine two theories on human behavior: social network theory and game theory. After studying four possible settings, two without monitoring agencies and two including them, I find that the hypothesis cannot be ruled out. Moreover, if the penalty for corrupt behavior is low (or the administrative cost of justice is high) then agents will prefer to get involved in corrupt activities, specially if the network is complete. On the other hand, if honesty is highly rewarded, agents have enough incentives to reject corrupt proposals. The existence of monitoring agencies represented as free press can discourage corruption from the beginning.

Introduction

Why corruption needs the formation of networks? Why strong institutions and independent monitoring agencies have crucial roles in preventing this kind of behavior? Economic theory have analyzed corruption as a problem in which two agents are involved and each one has their own private interests. Other social sciences have concentrated in analyzing corruption from a more social point of view (norms, culture, history). However, little effort has been made in studying corrupt behavior combining the economic approach with the social environment in which this behavior takes place. Moreover, the new political economy has generated an extensive body of literature that points out evidence about the importance of strong institutions and free press in preventing acts of corruption. Nevertheless, the role of checks and balances when corruption is based on a network structure have not been analyzed in dept.

Economic theory treats corruption as the existence of public officials who use their influences to accomplish private objectives. In general, this approach has not taken into account the social environment in which this behavior takes place. From this point of view, corruption can be seen as a framework of strategic interdependence where an agent have to pay a bribe to accomplish some objective and the official has the power to block the activities of the agent if she does not cooperate. The social characteristics in this kind of modeling are assumed to be exogenous. The relevant outcomes have helped economic theory to estimate the efficiency losses generated by corruption.

On the other hand, studies from other social sciences such as sociology, political science and even business administration have analyzed corrupt behavior from a social point of view. The main findings of these lines of research are that the existence of corruption is explained by the social characteristics of a given society. This means that unethical behavior is commonly found in societies that have weak institutions and monitoring agencies, flawed norms and a history of corrupt activities. Nonetheless, these studies hardly looks for explanations in the economic behavior of the agents involved.

Despite the independent efforts of pure economic theory and other social sciences, the new political economy have started to join ideas from the individualistic point of view of the economic side with the excessively social approach of other social sciences. This research considers that the social characteristics of a given society can influence deeply in the economic behavior of agents. It analyzes economic outcomes based on the social structure in which an specific activity takes place.

However, little research have combined the social structure criteria with the strategic interdependency framework in modeling corrupt behavior. The inclusion of social network theory in economic theory is a new line of research that few economic theorists are starting to explore. Furthermore, this approach can shed lights on policy design (regulations and incentives) to prevent corruption.

The purpose of this study is to analyze corrupt behavior under a social network theory and game theory approach and obtain conclusions on the importance of the system of checks and balances. For this, a first objective consist on modeling a complete and an incomplete corruption network in a setting without monitoring agencies. The second objective is to introduce monitoring agencies on each of the frameworks previously described.

In this study, I want to answer two questions: (i) why social networks are important for corrupt behavior? and (ii) How institutions and monitoring agencies can influence the decisions of the agents involved in corrupt activities.

The possible answers to these questions can be structured as a two part hypothesis. First, if the social network is complete (i.e. it exhibits no gaps) then the coordination among agents is more fluent and it is easier to achieve corrupt objectives. Second, institutions can generate incentives even if the network is complete. Furthermore, when monitoring agencies are included, it is important for institutions and monitoring agencies to complement each other to prevent more effectively the act of corruption.

To prove the hypothesis I introduce some concepts on the mathematical background of social network theory and basic definitions on game theory. Then, I try to join these two theories of social behavior under the assumption that the network structure determines the flows of information among agents and, due to this, the kind of game that has to be played (a game with complete information or a game with incomplete information) and the payoff functions when the agents belong to the network. Specifically, I will present four models. The first two models do not include a monitoring agency and analyze corruption when the network is complete and when it is incomplete. The second group of models study corruption under the same kind of network structures but monitoring agencies are incorporated.

Part I

Corruption and Networks: A Literature Review

Corruption has been subject of study in all social sciences. However, it still is a complex research topic, and existing literature is abundant and diverse. This study is centered in politic corruption understood under the concept developed by Caiden (1988) based on the definition elaborated by Nye (1967):

> [...] corruption is [a] behavior which deviates from the formal duties of a public role because of private-regarding (personal, close family, private clique) pecuniary or status gains; or violates rules against the exercise of certain types of private-regarding influence.

Hence, political corruption origins rests on the power differentials between public servants and common people, because of the effects of the decisions of the first over significant groups of the later. Furthermore, there is a direct link between the level of importance of the public servant's decisions and the benefits for the rest of persons derived of trying to influence the public servant behavior. This is why, according to Caiden, "[...] corruption seeks out key decision-makers and the most powerful officials" (Caiden 1988).

From this concept, the literature developed until now can be classified into three groups. The first group includes theoretic and empirical research that assess corruption from the traditional approach. This set of studies contains those which analyze the theory of corruption and evaluate the problem on applied basis, trying to find the determinants of this social phenomenon. Moreover, it includes research that breaks down the strategies used by governmental agencies and civil organisms to screen corruption acts and raise up the probability on which a public servant can be caught.

The second group, which constitutes the heart of this research, is related to the assessment of corruption from a systemic approach, i.e., contains those studies which analyze the role of social and economic relations among agents involved in corrupt doings. Finally, the third group is related with the analysis of specific corruption cases. This line of research takes previous theoretic and empirical work to contrast it against documented corruption cases that have taken place around the world. Although this classification is trying to be exhaustive, it does not include the universe of literature about the topic. On the contrary, it only consider the studies that have a direct link with the objectives of this study.

1 The traditional approach

Caiden (1988) builds a general theory of official corruption. For that matter, the author recognizes four kinds of corruption: low level, high level, politic, and bureaucratic. Furthermore, he emphasizes on the differences between endemic corruption, which is based on complex networks, sometimes at institutional levels; and isolated corruption, which is based on simple, bilateral relationships that much of the times result in contradictory effects.

In this line of work, although on a more specific ground, Shleifer & Vishny (1993) study corruption from an institutional approach and posit two hypothesis. First, they affirm that among the most important determinants of corruption, there are government structure, and political processes. Second, they asseverate that, because corruption implies a series of activities that must remain in secret, its costs tends to be important for development, and it generates market distortions that go beyond those created by tax systems.

With respect to the determinants of corruption, Djankov et al. (2003), and Besley & Prat (2006) show how property of the media affects corruption levels. Djankov et al. present an empirical study that finds a positive correlation between the proportion of media owned by the government and the level of corruption. Besley and Prat argument that, if there is the possibility for politicians to capture and silence the press, corruption levels will be higher. In the same line of research, Ahrend, Boukouras & Koufopoulos

2002, based on a data panel study, finds evidence that press freedom causes low corruption and no the other way around, i.e. that is corruption which affects press freedom.

However, it is worth to mention that Ahrend, Boukouras & Koufopoulos (2002) suffers of a failure commonly derived from the analysis grounded on the traditional approach. Although they show that press freedom causes low corruption, when the assessment is made from a systemic approach, counting with independent monitoring agencies increases the chances to detect corruption. This fact creates incentives for bureaucrats with enough power to try to influence monitoring agencies, creating a corruption network. These variables (such as the power invested in the official) are not considered by Besley & Prat (2006) or Djankov et al. (2003) either. Such studies assume that monitoring agencies are exogenous to the model, which creates endogeneity issues on empirical assessments and invalidates any attempt to obtain causal relations.

Brunetti & Weder (2003) show that press freedom constitute an important mean in fighting corruption. They build an empirical model based on a cross-country sample. Same as Besley & Prat (2006), they find that causality goes from higher levels of press freedom to lower levels of corruption. Brunetti and Weder classify corruption determinants in four groups: the role of external mechanisms inside bureaucracy, internal mechanisms and incentive mechanisms inside bureaucracy, independence of monitoring agencies, and indirect factors such as culture or income country level. Furthermore, the authors affirm that press freedom is a good mechanism to fight corruption not only because of its effectiveness to control bilateral corruption based on extortion, but because it also prevents the operation of collusive corrupt structures.

Inside the institutional approach, Treisman (2000) shows that current democracy levels have no effects on corruption. However, long time periods of a government structure build upon a democratic system significantly lowers this kind of behavior. In the same line of work, Persson, Tabellini & Trebbi (2003) find evidence based on a theoretical model and empirical contrast, that proportional elections are associated with higher corruption.

Maskin & Tirole (2004) show that there is a theoretical relation between types of politic organization and corruption. According to the authors, public positions subject to reelection has a negative effect over corruption, since this method lets the public monitor in a better way the behavior of its officials. However, the authors mention that there exists the possibility that, because of this mechanism, public servants concentrate their forces to get reelected, creating several barriers for the application and design of necessary, but *anti-popular,* policies.

Other line of research study corruption from a structural point of view. This is the case for Glaeser & Shleifer (2002). According to the authors, those countries on which its judiciary system are based on French civil law have stronger regulations, weaker property rights, governments which are more prone to corruption, and lower efficiency levels compared to those countries governed by common law.

2 Corruption Systems

When considering economic literature about corruption, introducing economic behavior in a social relations context is a relatively new approach, since social networks has been addressed mainly in Sociology and Business Administration. The advantage of approaching corruption from a social network theory point of view is that it is possible to include new variables that traditional approach have not taken account of. Moreover, combining social network theory with the traditional approach entitle us to solve inquiries such as those posted by Kingston (2008), who questions the completeness of the analysis when the study only considers the determinants of corruption (or even causal relations among variables), and not the way a specific anti-corruption policy solves the problem.

Nielsen (2003) justifies the use of a systemic approach when studying corruption, and he identifies twelve key elements in the operation of corrupt systems. According to the author, the first element consist in detecting the existence of a reciprocal sub-system with parasite and destructive win-win relations. The second element refers to extortion activities conducted by government officials and political parties, which are more serious problems compared to bribery. The third element recognizes the fact that corruption activities may be related to productive activities which helps to the sustainability of corruption networks. The forth element is about how unethical behavior conducted in previous periods by reform agents can be used against them, and obstruct the application of an anti-corruption policy.

The fifth element is related with the variety of relations that can exist among the members of a corruption network based on their qualities to enable and maintain social relations. The sixth element refers to norms that, despite coming from laws with high popular acceptance, include also high costs in terms of the creation of new opportunities for extortion or bribery. The seventh element recognizes the existence of links among political parties and the police, the office of the Attorney and other members of the judiciary, and some portions of the legislative. The eighth element is about the importance of analyzing the connections among political parties and the check and balances that guarantees the operation of a democratic system (La Porta et al. 2004).

The ninth element considers the large amounts of money needed by candidates for official positions to finance their campaigns, and how this kind of funding requires political favors in the future. The tenth element recognizes the fact that many corrupt businesses are offered to reforming agents who, in case of a negative response, are further threatened by a way of corruption in which the reforming agent always loses. The eleventh element is about how the principal-agent problem can emerge in relations among public sector participants. Finally, the twelfth element refers to rescue programs, both national and foreign, and the way they may "[...] maintain the corrupt system while forcing austerity measures on the middle and lower clases".

Although Brunetti & Weder (2003) analyze corruption from the traditional approach, they mention some characteristics of corrupt systems that become explicit with the use of social networks. For example, the authors recognize the existence of external controls for corruption, which are exercised by organizations outside the government administration. Furthermore, same as Nielsen (2003), they refer to checks and balances as one kind of external control in a working democratic system in which this role is played by the judiciary.

In the same line of research, Rauch & Evans (2000) argue that there is a direct link between the degree of nepotism inside an organization, and the probability of eliminating internal control through collisions among officials. These arguments implies that, when studying corruption, it is necessary to consider social relations existing inside an organization. This intuition is also contained in the study by Ades & Di Tella (1999). The authors affirm that monopoly power invested on public officials is the precondition for corruption.

Network theory also appears in the analysis of the role of monitoring agencies. In general, these agencies are exogenous in several models that capture the corrupt behavior. However, by means of network theory, it is possible to analyze what happens if this agencies are involved in the corruption network. Brunetti & Weder (2003) argues that, when media market is not competitive, the probability of some media belonging to the corrupt network raises, negating their role as monitoring agencies. This is what happened in Peru when Vladimiro Montesinos formed an extensive and well-planned corruption network. In this country, there is a limited number of mass media corporations (i.e. there exists a non-competitive media market), many of which where captured by Montesinos's network (McMillan & Zoido 2002).

Research made by Trevino (1986), Hunt & Vitell (1986) and Granovetter (1992) emphasizes on the importance of the social network approach when studying corruption when they recognize the fact that either individualistic perspective, nor the excessively social approach which considers that individual obey norms or cultural characteristics, are suitable approaches to try to explain and understand behavior in corrupt systems. This views complements previous studies accomplished by Hegarty & Sims (1978) or Cressey & Moore (1983), which shows that organizational factors such as rewards systems (Hegarty & Sims 1978), and norms, culture and behavior codes (Cressey & Moore 1983) can effectively reduce unethical behavior in organizational contexts.

Taking account of this facts, Brass, Butterfield & Skaggs (1998) argues that unethical behavior is a social phenomenon derived from relations among agents. This is why, based on social network theory, they build some propositions about the effects of types and structures of social relations over ethical behavior inside a system; and how the combination of types and structures of relations determine social contagion and conspiracy. When talking about types of relations, the authors classify them into three groups: according to its strength, multiplicity, asymmetries and status. When talking about structures, Brass, Butterfield and Skaggs refers to structural holes, centrality and density.

As for the strength of the relation, the authors borrow the concept proposed by Granovetter (1973), who considers that factors such as the frequency, reciprocity, emotional intensity, and intimacy of the relationship contribute to this measure. According to Brass, Butterfield and Skaggs, a weak tie implies that two agents meet only once, for a short time period, and with a high probability of never meeting each other again. This is why there exists little incentive for unethical behavior when relations among agents are weak. Lambsdorff (2002a) coincides with this intuition when he affirms that corruption network's operations requires high levels of trust among members. However, Brass, Butterfield and Skaggs emphasize that

> As frequency of interaction and trust increase, opportunities for unethical behavior increase, as do the possible payoffs. However, the cost of behaving unethically (the loss of a strong relationship) is much higher than in the case of a weak tie.

As for the multiplicity of relationships, the authors refers to how agents inside a network can be related in many ways (e.g. friendship, working relations, vicinity, etc.). According to Brass, Butterfield and Skaggs, relationships multiplicity increase the cost of unethical behavior, since many relations can be disrupted at once. However, as mentioned before, Lambsdorff (2002a) emphasizes on the role of trust in corruption networks operations. According to this author, when a social relation exists (aside from work relationships, for example) the probability of unethical behavior increases, subject to each agent's ethics and moral.

In regard to asymmetries, Brass, Butterfield and Skaggs assert that unethical behavior occurs more frequently when the relationship between agents is asymmetric. In this case, it is possible that the cost of breaking the relationship is higher for one of the agents involved. Something similar happens with status, which is related to relative power of one agent over the other.

Network structure also influences the appearing of unethical behavior. According to Brass, Butterfield and Skaggs, adding new members to the network incorporates to the analysis the concepts of surveillance and reputation. Surveillance is the possibility of being observed by other persons inside the organization, reducing the probability of being involved in unethical behavior. Reputation refers to how other members think of one specific agent inside the network. Based on this, a structural hole, defined as the absence of links between two agents (Burt 1995), increases the probability of unethical behavior, since it creates problems of incomplete information, which in turn eliminate all kind of surveillance or reputation control. Furthermore, when there is a unique agent who maintains links with all other agents in the network, information advantage of the first one makes unethical behavior arise more easily.

Centrality refers to one individual's capacity to reach each of the agents inside the network with the least number of direct and indirect connections. Direct connections increases the importance of maintaining some level of reputation, while indirect connections are related with surveillance. If there is an agent associated with a high measure of centrality, surveillance and the importance of reputation increases, hindering the appearance of unethical behavior. However, according to Lambsdorff (2002b), since corruption depends heavily on the degree of secrecy of its operations, reputation is vital for the provision of corrupt services, since conventional marketing methods are not at hand.

If the network is highly interconnected (i.e. a high density index), behavior surveillance increases along with the probability of loosing reputation. According to Scott (2000), the network's density is the proportion of the network's links in relation to the total number of possible connections.

Finally, the authors mention that conspiracies, defined as unethical behavior that requires cooperation of several agents pertaining to a particular network, are hard to detect if they are made trough weak links in a structural hole environment. According to the authors,

> Conspiracies or collusions are more likely to occur in sparsely connected, weak-tie networks. [...] the coordination needed may be provided by the central "structural hole" member who recruits co-conspirators, one at a time, through his or her extensive network of weak ties.

Lambsdorff (2002a) carry out an empirical research with a cross-country sample and shows that trust is a key element for the expansion of corruption. His results are robust to a variety of specifications and causality tests. His conclusions are based on the fact that corrupt agreements can not be enforced trough legal means. Furthermore, the author asserts that strong ties among agents and network economies are also favorable conditions which facilitates corrupt deals by means of including agents in trusty social networks.

In the same line of research, Lambsdorff (2002b) asseverate that, given that corruption must remain hidden from public, transaction costs differ from those that arise from legal transactions, since relation among agents does not end with the service provision, but remains in effect for a undetermined time period because of the threat of betray existing for all agents involved. According to this author, "[...] fighting against corruption should focus less on individual moral attitudes and more on methods to destabilize corrupt relationships".

Máiz (2003) present an empirical assessment that tries to explain the co-presence of corruption and political patronage in Latin America, and analyze its structural relations.

The objective of this research is to analyze if the connection between corruption and political patronage build incentives to convert corrupt transactions into stable, clientelistic networks.

Kingston (2008) combine the intuition of the analysis based on network theory with strategic relations existing among agents immerse in corrupt activities. For this, he builds a model based on *interlinked games* to show how informal relations among clients can help them to enforce agreements (or norms) to avoid paying bribes to a government official. According to the author, corruption culture is not exogenous, but it is an endogenous, path-dependent reflection of a strategy equilibrium. The author's analysis is based on the study of the *Briber's Dilemma*, in which an official have a fixed rent to offer to one of his "clients" and each one of them, in order to capture that rent, have incentives to pay a bribe to the official. However, all clients would experience a welfare improvement if nobody pays the bribe (Della Porta & Vannucci 1999), i.e. clients could collude and avoid corruption. On the other hand, Kingston (2007) argue that informal relations among officials and public can support the enforcement of corrupt transactions.

3 Study cases documented in the literature

Another important line of research concerning corruption is related with the study of specific cases. Klitgaard (1988) describes an example of collusive corruption in the Philippine's tax system. In this case, the private agent cooperates and always pays the bribe. According to Klitgaard, this kind of corrupt behavior is harder to detect since it is a win-win relation and every agent involved will do whatever necessary to keep it undercover.

Doig & Riley (1998) assert that corruption patterns depends on the specific context of each country. This is why, for policy to be effective, the design of anti-corruption strategies have to consider the social environment in which corruption occurs. The authors assess corruption and anti-corruption strategies in Botswana, Ecuador, Hong Kong, Tanzania, Mali, and Senegal. The point of departure for the study is the role of Structural Reform driven during the 90's by international financial organisms, in which one of the main objectives was to reduce official corruption.

Manzetti & Blake (1996) direct research in the same line, and assesses the effects of liberal reforms that took place in Latin America during the 90's. According to the sponsors of this policies, systematic reduction of State should end with the ability of politicians to engage in unethical behavior. The authors show that, if market reforms does not take place in an environment in which transparency prevails, this policies can be used as new means to achieve corrupt ends. In this study, they analyze the cases of Argentina, Brazil, and Venezuela build on the results of a theoretical agent-based-model.

Further in the same block of research, one of the most detailed study about how a political corruption network operate correspond to McMillan & Zoido (2002). This research presents deeply the operation of the corruption network headed by Vladimiro Montesinos, in Peru. A key element identified by this study has to do with the systemic functioning of this kind of politic corruption, since it was founded on the existing relationships among Montesinos, monitoring agencies, and the judicial system. The main objective of this network was to maintain the image of Alberto Fujimori's Government before the voters. Other case studies in the same line include: Maas (1997); Bremner & Thornton (1997); Kane (1989); Stille (1995), among others.

4 Games and Networks

In this section I present briefly the underling mathematical theory behind social networks. For this, I rely on the lecture notes written by Daron Acemoglu and Asu Ozdaglar for the course of Networks imparted in the Massachusetts Institute of Technology during the fall 2009 (Acemoglu & Ozdaglar 2009). Also, some ideas on the interaction between networks and game theory are taken from Kets (2008). In the first subsection I introduce the basic concepts of network theory and game theory. In the second subsection, I present the way in which networks can determine some of the components of games. Although there are many ways in which networks can determine games, I only present the one taken for the modeling of corruption under the approach presented in this study.

4.1 Basic concepts and definitions

Narrowly speaking, a network is a set of nodes and links. More formally, a network can be represented by a graph $\mathscr{G}$ that contains a set of nodes $N = \{0, \ldots, n\}$ and a matrix

$\ell = [\ell_{ij}]_{i,j \in N}$ that summarize the set of links between nodes $i, j \in N$. Definition (4.1) depicts this idea.

Definition 4.1. *A network* $\mathbb{N}$ *is a graph* $\mathscr{G}(N, \ell)$ *which consists of a set of nodes* $N = \{1, \ldots, n\}$ *and a matrix* $\ell = [\ell_{ij}]_{i,j \in N}$*, where* $\ell_{ij} \in \{0, 1\}$ *indicates if the relation among* i *and* j *exists. If* ℓ_{ij} *is not binary, then it also represents the intensity of interaction between nodes. In this case* $\mathscr{G}(N, \ell)$ *is called a* weighted graph.

The relations among nodes represented by matrix ℓ can be directed or undirected. If these relations are undirected it implies that ℓ is a symmetric matrix: if the connection between nodes i and j exists, then the exact same connection exists in the opposite direction.

In the context of social sciences, a network summarizes the existing relations among agents. This kind of networks are called *social networks.* In this case, the set of nodes is interpreted as a set of agents, and the links between them can represent a variety of relations; for example, power relations, friendship, flows of information, among others. The next definition gives the interpretation of the network components that will be used further in this research.

Definition 4.2. *Consider a network* $\mathbb{N}$ *represented by a graph* $\mathscr{G}(N, \ell)$*. All the elements of* N *are defined as agents or players. Furthermore, the connections among agents represented by the matrix* ℓ *are undirected relations which represent flows of information about the way each agent will behave under determined circumstances.*

The dynamics of information using networks is a state-of-the-art line of research among economists. An example of this investigation can be seen in Kets (2008) and Acemoglu, Bimpikis & Ozdaglar (2010).

These definitions on network theory its all that will be needed for the rest of the study. Furthermore, networks will determine the relationships and behavior of rational agents that pursue their own interests considering the actions of the other agents. This is why I introduce game theory to model this behavior; something already done by Kets (2008) and emphasized by Acemoglu & Ozdaglar (2009).

A game consists of a set of players, the rules, the possible outcomes and the payoffs. In the case of this particular study, the set of players is given by N. The following definitions and discussion on game theory relies heavily on Mas-Colell, Whinston & Green (1995).

There are basically two ways of representing the elements of a game. The strategic game representation presents games as a payoff matrix. Each column represents the possible actions of a player, and each row does the same for the other player. Inside the matrix are contained the payoffs that each agent will receive when the other player applies one particular action.

The extensive form representation of a game, on the other hand, captures

> [...] who moves when, what actions each player can take, what players know when they move, what the outcome is as a function of the actions taken by the players, an the players' payoffs from each possible outcome. (Mas-Colell, Whinston & Green 1995)

The extensive form representation practically gives all the necessary information to solve a game. There is one particular element that will be highly relevant in the discussion that follows: the extensive representation permits to know *what players know when they move.* This element generate two kinds of games; those with perfect information and those with imperfect information. It is said that a game is of perfect information when every player knows that every player knows that every player knows... all the relevant information. On the other hand, a game is said to have imperfect information when at least one player does not have information on the payoffs of other players, the possible action that they can take in an specific environment or the movements made before her turn to play.

So, basically, there are four groups of games: static games with perfect information, static games with imperfect information, dynamic games with perfect information and dynamic games with imperfect information. Each type of game have at least one equilibrium concept that solves it. I start by introducing some basic concepts on static games with perfect information.

A static game with perfect information is better represented by the normal form. Mathematically, the normal form is represented by an n-tuple or a collection that can be written as $\Gamma = \{I, \{S_i\}, \{u(\cdot)\}\}$, where I is the set of players, $\{S_i\}$ is the set of strategies for each player where each strategy can be pure or mixed,[1] A first approximation to solving this kind of games consist in finding optimal strategies for player i that are the

[1] A pure strategy *specifies a deterministic choice [for each player] at each of her information sets*. On the other hand, a mixed strategy is a randomized choice between two pure strategies (Mas-Colell, Whinston & Green 1995).

best strategy regardless of what the other player does (Mas-Colell, Whinston & Green 1995). This kind of strategies are called *strictly dominant strategies.*

Definition 4.3. *Consider game* Γ*. A strategy* $s_i \in S_i$ *is a strictly dominant strategy for player i if for all* $s_i' \neq s_i$ *it holds that*

$$u_i(s_i, s_{-i}) > u_i(s_i', s_{-i})$$

for all $s_{-i} \in S_{-i}$*.*

The intuition behind the definition implies that a strictly dominant strategy must bring the highest payoff for player i no matter the actions taken by the rest of players. Another way of modeling the behavior of a given player is that, if she is rational, then she will never play a dominated strategy. The next definition summarizes this concept.

Definition 4.4. *Consider game* Γ*. A strategy* $s_i \in S_i$ *is strictly dominated for player i if there exists another strategy* $s_i' \in S_i$ *such that for all* $s_{-i} \in S_{-i}$*,*

$$u_i(s_i', s_{-i}) > u_i(s_i, s_{-i}).$$

If the previous condition holds, then strategy s_i' *strictly dominates strategy* s_i*.*

If $u_i(s_i', s_{-i}) \geq u_i(s_i, s_{-i})$ then it is said that strategy s_i' weakly dominates strategy s_i. One possible algorithm to solve Γ consist in the iterated elimination of dominated strategies. However, a more general concept is that of a Nash equilibrium (Nash 1950).

Definition 4.5. *Consider game* Γ*. A strategy profile* $s = (s_1, \ldots, s_I)$ *is a Nash equilibrium if for every* $i = 1, \ldots, I$ *and for all* $s_i' \in S_i$*,*

$$u_i(s_i, s_{-i}) \geq u_i(s_i', s_{-i}).$$

Definition (4.5) can be rewritten so it can include the possibility that each player applies a randomized choice, i.e. a mixed strategy. The following definition states this equivalent condition.

Definition 4.6. *Consider game* Γ*. A mixed strategy profile* $\sigma = (\sigma_1, \ldots, \sigma_I)$ *is a Nash equilibrium if for every* $i = 1, \ldots, I$ *and for all* $\sigma_i' \in S_i$*,*

$$u_i(\sigma_i, \sigma_{-i}) \geq u_i(\sigma_i', \sigma_{-i}).$$

The previous concepts apply when the static game develops in a complete information setting. However, there are many non-trivial situations in which at least one agent does not have all the relevant information on the preferences of other players. In the games of incomplete information it is necessary to consider each player beliefs on the preferences of the rest of the players given their beliefs on the other players preferences and so on. However, Harsanyi (1967) simplifies this process by assuming that *each player's preferences are determined by the realization of a random variable* (Mas-Colell, Whinston & Green 1995). The realization of the random variable is known only by the player, but the probability distribution is common knowledge.

The approach proposed by Harsanyi (1967) consist in a first move made by Nature in which the realization of the random variable is made and this way each player *type* is determined. Also, the type of the player determines her payoff of applying an specific strategy. Given this elements, a game with incomplete information can be represented by a collection $\Gamma_\theta = \{I, \{S_i\}, \{u_i(\cdot)\}, \Theta, F(\cdot)\}$, where I is the set of players, $\{S_i\}$ is the set of strategies for each player i, $\{u_i(\cdot)\}$ is the set of payoff functions for every i, Θ is the set of all possible types and $F(\cdot)$ is the probability distribution over Θ. This way, the concept of a Bayesian Nash equilibrium is depicted in the following theorem, which uses Harsanyi (1967) approach.

Theorem 4.1. *Consider game Γ_θ. A profile of decision rules $(s_1(\cdot), \ldots, s_I(\cdot))$ is a Bayesian Nash equilibrium if and only if, for all i and all $\theta_i \in \Theta$ occurring with positive probability,*

$$\mathbb{E}_{\theta_{-i}}[u_i(s_i(\theta_i), s_{-i}(\theta_{-i}), \theta_i)|\theta_i] \geq \mathbb{E}_{\theta_{-i}}[u_i(s_i', s_{-i}(\theta_{-i}), \theta_i)|\theta_i]$$

for all $s_i' \in S_i$.

Intuitively, the previous theorem means that a profile of decision rules is a Bayesian Nash equilibrium when the expected payoff from applying this decisions is at least as high as the expected payoff of making any other possible decision.

Another relevant type of game includes dynamic games with complete information. The main difference with their static counterparts is that in a dynamic game players do not take their decisions simultaneously, but the game structure impose a sequence that specifies when each player plays and the available information that she has. The best way to represent such games is by means of the extensive form. Mathematically, a game in its extensive form Γ_E is a collection that includes a finite set of nodes, a set of actions and a set of players; a function that specifies the predecessor of an specific node, a function that assigns future nodes to each action taken, a collection of information sets which includes at least one node, a function that determines when a player moves and a collection of payoff functions for each player depending on the actions taken trough the game (for more details, see Mas-Colell, Whinston & Green (1995)). To solve a dynamic game it is necessary to consider at least three concepts: the backward induction algorithm, the definition of a perfect subgame and the concept of a subgame perfect Nash equilibrium.

Theorem 4.2 (Zermelo's Theorem)**.** *For all finite game of perfect information Γ_E, there exists a pure strategy Nash equilibrium that can be derived through backward induction. Furthermore, if no player has the same payoffs at any two terminal nodes, then there is a unique Nash equlibrium that can be obtained in this manner.*

Backward induction selects the best strategy of a player starting by the last set of nodes. The concept behind backward induction is that of sequential rationality, which states that a player will apply the strategy that maximizes her payoff given the strategies applied by the other players up to that point. Zermelo's Theorem also proves that every finite game of perfect information have at least one Nash equilibrium. For backward induction to work properly, it is necessary to identify perfect subgames.

Definition 4.7. *Consider game Γ_E. A subgame of Γ_E is a subset having the following properties:*

(i) It begins with an information set containing a single decision node, includes all the decision nodes that are successors of this node, and contains only these nodes.

(ii) If a decision node is included in a subgame and in an information set, the every other node included in the same information set is also included in the subgame.

The idea behind this definition is that each subgame of a given game can be treated as a *game in its own right* (Mas-Colell, Whinston & Green 1995). This means that each subgame has a Nash equilibrium. A strategy profile that is a Nash equilibrium in every subgame is a subgame perfect Nash equilibrium. The next definition states formally this concept.

Definition 4.8. *Consider game* Γ_E*. A strategy profile* $\sigma = (\sigma_1, \ldots, \sigma_I)$ *is a subgame perfect Nash equilibrium if it induces a Nash equilibrium in every subgame of* Γ_E*.*

With this basic definitions it is possible to join the concepts of network theory with those derived from game theory. This task is performed in the next subsection.

4.2 Joining Game Theory and Network Theory

There are many ways in which game theory can be influenced by network theory. In this study, the network structure is exogenous and determines the existence of flows of information among agents and their payoffs. In other words, when a network is such that all agents are connected with each other, then the flow of information between them is guaranteed and the strategic interdependency framework is that of complete information. On the contrary, when the network exhibits gaps (i.e. agents that are not connected to the rest of the network), then the flows of information are interrupted and the network structure implies a game with incomplete information.

Formally, the game (static or dynamic) will now depend on the network structure also; that is $\Gamma(\mathbb{N})$. Moreover, the network setting influences the payoffs of each player due to the costs related to the breaking of the links when players do not behave as planned. Therefore, each payoff will depend on the links implied by the network structure $u_i(s_i, s_{-i}, \ell)$. Obviously, if player i is not connected to the network, then her payoff function will not depend on ℓ. This discussion is summarized in the following definition.

Definition 4.9. *Consider an exogenously determined network* $\mathbb{N}$ *which is represented by a graph* $\mathscr{G}(N, \ell)$ *where* N *is the set of players and* ℓ *is a matrix that represents the links among players. If* $\mathbb{N}$ *is a fully-connected network, then the game structure defined by it is that of a game (static or dynamic) with complete information* Γ_C*. On the other hand, if* $\mathbb{N}$ *is a network such that* $\ell_{ij} = 0$ *for at least one of the nodes, then the implied game structure is that of a game (static or dynamic) with incomplete information* Γ_θ*.*

The relation between the payoff function and the network structure is stated in the next definition.

Definition 4.10. *Consider an exogenously determined network* $\mathbb{N}$ *which is represented by a graph* $\mathscr{G}(N,\ell)$. *If* $\ell_{ij}=1$ *then the payoff function of player* i *will depend on the status of the active link, that is* $u_i(s_i,s_{-i},\ell_{ij})$.

Note that ℓ_{ij} can be written as a function which depends on the strategy taken by player i. An example of this can be stated as follows: $\ell_{ij}=1$ if $s_i=1$ but $\ell_{ij}=0$ if $s_i=0$. This way the payoff function, although depends on the link between players, can be written solely as $u_i(s_i,s_{-i})$, as usual. This is done further in this work.

Part II

Modeling Corruption: An Alternative Approach

In this part I present an alternative approach for modeling corruption. For this matter, I combine both game theory and social network theory in such a way that the existing relations among agents are exogenous and the flows of information between them depends on the network structure.

To study the importance of networks in corrupt behavior, I will analyze different settings, each of which differ on the exogenous network structure and the existence of an outside-the-network monitoring agency. In the first section I assume the existence of three agents in which one of them has the power to propose an act of corruption. The first model in this section is based on a complete network, in the sense that every agent is connected with each other and the flows of information permits a game with complete and perfect information. The second model drops the perfect information assumption and take an incomplete network as point of departure.

The second section introduces the monitoring agency as an exogenous agent. The role of this agent is to create a probability of being captured on the act of corruption, despite the complete flow of information existing among the corrupt agents. For the sake of completeness, I study both of the settings proposed in the first section.

5 A World without Monitoring Agencies

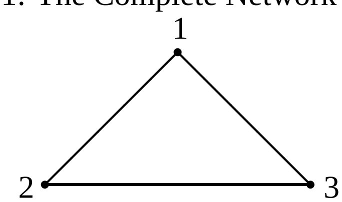
In this section I study two settings without monitoring agencies. In the first setting I will work with a complete network and, as a direct consequence from this, an extensive game with three agents and complete information due to the free flow of information.

In the second setting, one of the agents is not connected with the rest, generating gaps in the network. Because of this structure, the connected agents will have information about each other, but they will face information asymmetries on the type of player of the third agent. This naturally translates into a Bayesian Game.

5.1 A Complete Information Setting

In this first model I assume a network with three agents (nodes) given by the set $N = \{1,2,3\}$. Let ℓ_{ij} be the connection between any two agents in N such that $\ell_{ij} \in L$, where L is the set of links in the network (which is equivalent to matrix ℓ presented in the previous section). I set $\ell_{ij} = 1$ for all $i, j \in N$, so the resulting network will not exhibit any gap. This also guarantees the direct flow of information among agents (see figure 5.1).

Figure 5.1: The Complete Network



The network structure translates directly in an extensive game with complete information. The set of players is given by N. Let $I \subset N$ be a subset of players such that $2,3 \in I$. This subset includes the *peripheral* agents. This classification implies that agent 1 has a power relation over agents in I and is the one that can start an act of corruption.

Thus, the set of actions for player one is given by $s_1 = \{P, NP\}$, where P stands for *propose* an act of corruption and NP for *not to propose*. For mathematical purposes, s_1 will act as a *dummy* variable which takes the value of 1 if the agent choose to propose the act of corruption and 0 otherwise.

For agents $i \in I$, the set of actions is $s_i = \{A, D\}$, where s_1 is also a *dummy* variable. Action A implies that agent i accept the proposal of agent 1 and action D implies that she does not accept (or denounce) agent 1. I assume that justice is exogenous, so if an agent choose to tell on the others, they will certainly be captured.

If player 1 choose not to propose the act of corruption, the game ends and every agent gets a payoff of zero. On the other hand, if she makes the offer, agents in I have to decide simultaneously wether or not to accept her proposal. If both agents accept, player 1 gets a payoff of β_1 and players 2 and 3 get both β. If some agent choose to denounce and the other one accept, player 1 gets a penalty of $-m$, the same as the player who accept. On the contrary, the agent who denounces has to cover the administrative costs of justice η and the costs associated with the lost of relations with agent 1 and the agent who accepts γ_k. If both agents denounce, they assume the latter costs; however, since they agree they do not incur in any costs associated with the braking of the link with eachother. Formally, for player 1, her payoff function is given by

$$\Pi_1 = s_1 \left[\prod_{i \in I} s_i \beta_1 - (1 - \min s_i) m \right]. \tag{5.1}$$

In the same manner, the payoff functions for agents $i \in I$ are similar and can be written as

$$\Pi_i = s_1 \left\{ \prod_{i \in I} s_i \beta - s_i(1 - s_j)m - (1 - s_j)[\eta + (1 - s_i)\gamma_1 + (1 - s_i)s_j\gamma_j] \right\}, \tag{5.2}$$

for all $i, j \in I$. Note that agent 1 does not incur in any cost for the brake of a relation with agents in I. I make this so it can be explicitly noticed the unbalance of power existing among agents.

To summarize, the first game depending on the previous network ($\Gamma_1(\mathbb{N}_1)$) is defined as a collection such that

$$\Gamma_1(\mathbb{N}_1) = \{L, N, \{S_n\}, \Pi\}, \tag{5.3}$$

where $\Pi_1, \Pi_i \in \Pi$ is the set of payoffs and $\{S_n\}$ is the set for actions for each player. This game is depicted on figure (5.2) and it's corresponding payoffs are summarized on table (5.1).

Figure 5.2: The Game with Complete Information (Game 1)

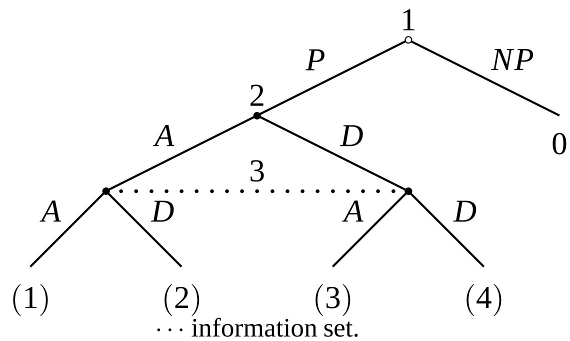


Table 5.1: Payoffs for Game 1

Player	(1)	(2)	(3)	(4)
1	β_1	$-m$	$-m$	$-m$
2	β	$-m$	$-(\eta+\gamma_1+\gamma_3)$	$-(\eta+\gamma_1)$
3	β	$-(\eta+\gamma_1+\gamma_2)$	$-m$	$-(\eta+\gamma_1)$

Game $\Gamma_1(\mathbb{N}_1)$ can be solved by backward induction using the concept of the subgame perfect Nash equilibrium. This result depends on the relation between the penalty imposed by justice m and the sum of the administrative cost of justice and the loss of the link with agent 1. Let me assume first an institutional framework in which the cost of the penalty is not high enough, so each agent always will prefer to accept.

Proposition 5.1 (Weak institutions)**.** *Consider the game* $\Gamma_1(\mathbb{N}_1)$. *Let* $\Gamma_1^{'}(\mathbb{N}_1)$ *be the first perfect subgame in which agents* 2 *and* 3 *have to decide simultaneously whether or not to accept player* 1*'s proposal. If* $m < \eta + \gamma_1$ *then the Nash Equilibrium in* $\Gamma_1^{'}(\mathbb{N}_1)$ *implies that both agents accept and agent* 1 *will make the proposal. This strategy profile is the subgame perfect Nash equilibrium for* $\Gamma_1(\mathbb{N}_1)$.

Note that the assumption that $m < \eta + \gamma_1$ is very restrictive. This implies that the institutional context in this society is so weak that the legal costs of committing a felony are smaller that the associated costs with ending corrupt behavior. However, this is far from being the general case. There exists social structures in which corrupt behavior is heavily penalized and agents think twice before engaging in this kind of activities. Let x_i represent the probability that agent $i \in I$ accepts the proposal. Also, let $\varsigma = \prod_{i \in I} x_i$ denote the joint probability of accepting for both agents in I. The next proposition shows what happens when the institutional context is a strong one.

Proposition 5.2 (Strong institutions)**.** *Consider the game $\Gamma_1(\mathbb{N}_1)$ and the perfect subgame $\Gamma_1'(\mathbb{N}_1)$. If $m \geq \eta + \gamma_1$ the subgame perfect Nash equilibrium in mixed strategies is:*

(i) In the perfect subgame $\Gamma_1'(\mathbb{N}_1)$, agent $i \in I$ will accept the proposal if and only if

$$x_j \geq \frac{m - (\eta + \gamma_1)}{\beta + m + \gamma_j}. \tag{5.4}$$

(ii) In the same way, agent 1 will make the proposal if and only if

$$\varsigma \geq \frac{m}{\beta + m}. \tag{5.5}$$

Thus there exists three possible subgame perfect Nash equilibria: two in pure strategies and one in mixed strategies.

The results in this section shows the importance of networks for corrupt behavior. The links in the network permit that all the agents have enough information on each other, so all of them can be sure that the other will cooperate. Also, as highlighted by Lambsdorff (2002b) and Nielsen (2003), the fact that corruption works in a network introduces costs related with the breaking of the links among agents.

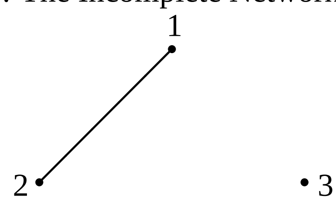
However, these results depends on the institutional framework of a given society and the way checks and balances act as a restriction for corrupt behavior (see for example Brunetti & Weder (2003) of La Porta et al. (2004)). In a weak institutional framework and due to the long term relationship that corruption implies (Lambsdorff 2002b), the costs related with the breaking of the links among agents can be so high that corrupt agents will prefer to pay a penalty in case of being captured instead of loosing the relation with the rest of agents. On the other hand, if institutions are strong enough, corrupt behavior can still occur but the high penalties act as incentives for agents to denounce. Strong institutions reduce the probability that a corruption network will work properly.

5.2 The Effect of Information Asymmetries

When someone thinks about corruption, the next thought is about risk. In the previous section I presented a model with the *optimal* environment for corrupt activities. In this section I drop the assumption about perfect information. As before, I will work with a network composed by three nodes or agents. The set of nodes is given by $N = \{1,2,3\}$ and the subset of peripheral agents is $I = \{2,3\}$.

The difference with the network presented in the previous section lies on the links structure. Let ℓ_{ik} be the connection among any two agents in N. I assume that $\ell_{k3} = 0$ for all $k \neq 3 \in N$, that is, both agents 1 and 2 does not have knowledge on the the third agent; they only know that they need her cooperation for the act of corruption to succeed. This network structure is depicted in figure (5.3).

Figure 5.3: The Incomplete Network



Because of the lack of connections with agent 3, the flows of information with this agent is interrupted and the setting calls for a modeling strategy based on imperfect information. For this I take Bayesian Games. Let N be the set of players. The information asymmetry is that players 1 and 2 do not know if player 3 will cooperate with the act of corruption. Define θ_3 as the *type* for agent 3. If $\theta_3 = 1$ then agent 3 will incur in the administrative cost of justice if she decides to denounce. On the contrary, if $\theta_3 = 0$ then agent 3 will receive a reward for her honesty.

Using Harsanyi approach to solve Bayesian games (Harsanyi 1967), this imperfect information environment can be translated into an incomplete information setting. For this, I assume that both agents 1 and 2 have some beliefs about the type of agent 3, which are the same due to the flow of information between them. This beliefs are represented by means of a Bernoulli probability distribution where the density function is given by

$$f(\theta_3, \rho) = \rho^{\theta_3}(1-\rho)^{1-\theta_3}.$$

In other words, agents 1 and 2 assign a probability ρ for $\theta_3 = 1$ and a probability of $1-\rho$ for $\theta_3 = 0$. The set of actions for agent 1 is $s_1 = \{P, NP\}$ and for agents in I is $s_i = \{A, D\}$ and work just as they did in the previous model. In a similar manner, I maintain the assumption that justice is exogenous and monitoring agencies do not exist. The payoff function for player 1 is

$$\Pi_1(s_1, s_2, s_3(\theta_3), \theta_3) = s_1\left[s_2 s_3(\theta_3)\beta_1 - \left(1 - \min\{s_2, s_3(\theta_3)\}\right)m\right]. \tag{5.6}$$

For player 2, her payoff function can be written as

$$\begin{aligned} \Pi_2(s_1, s_2, s_3(\theta_3), \theta_3) &= s_1\left\{s_2 s_3(\theta_3)\beta - s_2\left(1 - s_3(\theta_3)\right)m \right. \\ &- \left. (1-s_2)\left[\eta + (1-s_2)\gamma_1\right]\right\}. \end{aligned} \tag{5.7}$$

In the case of player 3, the difference in her payoff depending on her type is that, if $\theta_3 = 1$ then the decision to denounce will cost her the administrative costs of justice η. On the other hand, if $\theta_3 = 0$ she still has to bare this costs, but also she can get a benefit α. Note that because of her lack of connections, agent 3 does not have to assume any costs in the case of the braking of links. Thus, her payoff function is

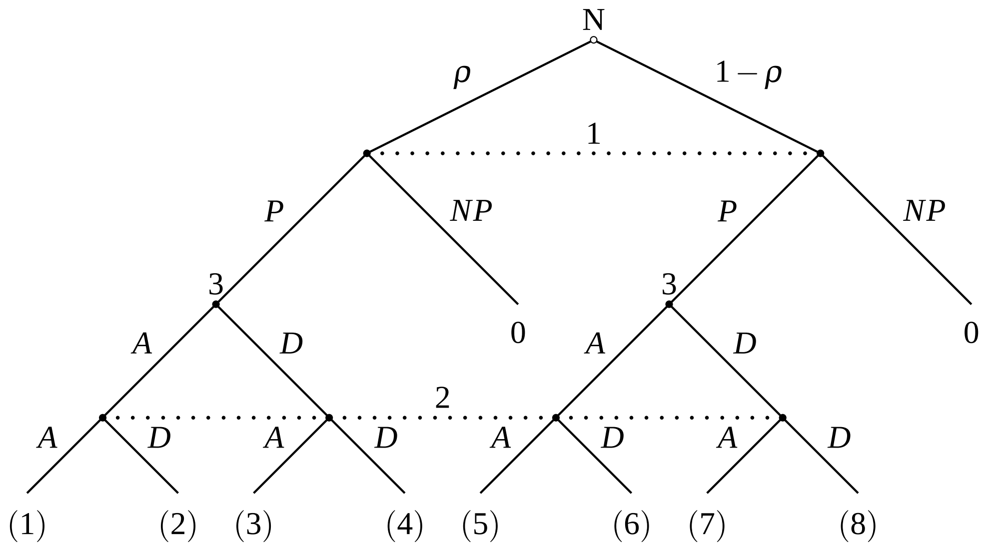
$$\begin{aligned} \Pi_3(s_1, s_2, s_3(\theta_3), \theta_3) &= s_1\left\{s_2 s_3(\theta_3)\beta - s_3(\theta_3)(1-s_2)m \right. \\ &+ \left. \left(1 - s_3(\theta_3)\right)\left[(1-\theta_3)(\alpha - \eta)\right]\right\}. \end{aligned} \tag{5.8}$$

All this components of the game can be summarized as follows. Let $\Gamma_2(\mathbb{N}_2)$ be the Bayesian game described previously. Also, define Θ as the set of types for player 3, $f(\rho, \theta_3)$ the probability distribution for the beliefs of agents 2 and 3 about the type of agent 3, and $\Pi(\theta_3)$ as the set of payoff functions for all players, then $\Gamma_2(\mathbb{N}_2)$ is a collection such that

$$\Gamma_2(\mathbb{N}_2) = \left\{L, N, \Theta, f(\rho, \theta_3), \{S_n\}, \Pi(\theta_3)\right\}. \tag{5.9}$$

The structure of the game is depicted in figure (5.4) and the corresponding payoffs derived from the previous functions are summarized in table (5.2).

Figure 5.4: The Game with Incomplete Information (Game 2)



··· information set.

Table 5.2: Payoffs for Game 2

Player	(1)	(2)	(3)	(4)
1	β_1	$-m$	$-m$	$-m$
2	β	$-(\eta+\gamma_1)$	$-m$	$-(\eta+\gamma_1)$
3	β	$-m$	$-\eta$	$-\eta$
Player	(5)	(6)	(7)	(8)
1	β_1	$-m$	$-m$	$-m$
2	β	$-(\eta+\gamma_1)$	$-m$	$-(\eta+\gamma_1)$
3	β	$-m$	$\alpha-\eta$	$\alpha-\eta$

To solve this game it is necessary to use the concept of a Bayesian Nash Equilibrium. Before doing so, it will be useful to state player 3's possible strategies given that player 1 makes the proposal and player 2 accepts it. These strategies are:

s_3^a: A if $\theta_3 = 1$ and A if $\theta_3 = 0$.

s_3^b: D if $\theta_3 = 1$ and D if $\theta_3 = 0$.

s_3^c: A if $\theta_3 = 1$ and D if $\theta_3 = 0$.

s_3^d: D if $\theta_3 = 1$ and A if $\theta_3 = 0$.

There is enough intuitive arguments to assume that strategy (d) may be a dominated strategy: it would be strange that agent 3 will denounce the proposal given that she is corrupt and will accept it given that she is honest. However, I must rule out this behavior formally. As I will show further, this depends on a key relationship between the benefit from denouncing α and the opportunity costs associated with this action $\beta + \eta$ for agent 3. Proposition (5.3) formalizes the intuition to rule out s_3^d as a possible component of the Bayesian Nash optimal strategy profile.

Proposition 5.3. *Consider game* $\Gamma_2(\mathbb{N}_2)$. *Suppose that agent* 1 *choose to make the proposal and agent* 2 *accepts it. If* $\alpha > \beta + \eta$ *then* s_3^d *will be a dominated strategy for agent* 3*.*

The previous proposition permits me to rule out strategy s_3^d if $\alpha > \beta + \eta$. However, it is important to keep in mind this relation as it will be determinant in the results that I will present next. The purpose of the following paragraphs is to study the conditions that have to hold for different options of possible Bayesian Nash equilibria. The first relevant strategy profile that I will evaluate is the one in which agent 1 choose to make the proposal, agent 2 accepts it and agent 3 also accepts it no matter what her type is (i.e. she applies strategy s_3^a). The following proposition gives the conditions that have to hold for this strategy profile to be a Bayesian Nash equilibrium.

Proposition 5.4 (Corrupt equilibrium)**.** *Consider game* $\Gamma_2(\mathbb{N}_2)$. *If* $\rho \geq 1$, *then in the Bayesian Nash equilibrium agent* 1 *will make the proposal, agent* 2 *will accept it and agent* 3 *will apply strategy* s_3^a*.*

The proof of proposition (5.4) (see appendix) shows once again the relevance of the relation between the benefit derived from denouncing and the opportunity costs related with passing on corruption. If the benefit from denouncing is less than the opportunity cost, then agent 3 will always prefer to accept the corrupt proposal, despite her type, against the strategy that implies that she will denounce the act of corruption every time.

The next possible equilibrium that is worth analyzing is the one in which agent 1 makes the proposal given that agent 2 will accept it but agent 3 decides to make the denounce no matter her type. However, there is an important fact that have to be taken into account. Due to the independence of the judiciary, all that is needed to apply the penalty is that at least one of the agents in I decides to tell on the others. In this setting, I am assuming that agent 1 choose to make the proposal despite the fact that agent 3 is denouncing in every case. This implies that the expected payoff for agent 1 derived from the strategy profile that is a candidate will be $-m$. On the other hand, if she chooses to abstain from making the proposal given the actions of the other players, her expected payoff will be 0. Thus, this profile cannot be a Bayesian Nash equilibrium. The following proposition summarizes this result.

Proposition 5.5. *Consider game* $\Gamma_2(\mathbb{N}_2)$. *Suppose that* $m > \eta + \gamma_1$, $\alpha \geq \beta + \eta$ *and* $\rho = 0$. *Then, the strategy profile in which agent* 1 *makes the proposal, agent* 2 *accepts it and agent* 3 *denounce despite her type can be ruled out as a possible Bayesian Nash equilibrium.*

Once again the result in the previous proposition shows a relation between the cost imposed by institutions m and the opportunity cost of passing on corruption $\eta + \gamma_1$. As in the case of the complete information framework, the assumption that the society have very weak institutions is a strong constraint. Furthermore, note that if institutions are strong and the opposite relation holds (i.e. $m > \eta + \gamma_1$) then agent 2 will also denounce corruption given that agent 1 makes the proposal and agent 3 denounce it every time. This constitute additional evidence to rule out this strategy profile as a possible Bayesian Nash Equilibrium. Moreover, the relation between the benefit from being honest and the opportunity cost of passing on corruption takes relevance. If the benefit derived from honesty is not high enough, then agent 3 will choose strategy s_3^a over strategy s_3^b. Furthermore, if this condition does not hold, agent 3 will even behave in a counter intuitive manner, accepting when she is honest and denouncing when she is corrupt.

As I showed in the previous results, this possible equilibrium is not likely, basically because, as I discussed before, the strategy of making the proposal given that agent 3 denounce it despite her type and agent 2 accepts it is a dominated strategy. This fact is stated in the following proposition.

Proposition 5.6 (Honest equilibrium)**.** *Consider game* $\Gamma_2(\mathbb{N}_2)$. *Suppose that* $\alpha \geq \beta + \eta$, $\rho = 0$ *and* $m > \eta + \gamma_1$. *Then, in the Bayesian Nash equilibrium agent* 3 *will denounce independently of her type, agent* 2 *will also denounce given the decision of agent* 3, *and agent* 1 *will abstain from making the proposal.*

Finally, I study the conditions that have to hold so a profile strategy in which agent 1 makes the proposal, agent 2 accepts it and agent 3 accepts it if she is corrupt and denounce it if she is honest constitutes a Bayesian Nash equilibrium. These conditions are depicted in the following proposition.

Proposition 5.7 (Conditional equilibrium)**.** *Consider game* $\Gamma_2(\mathbb{N}_2)$. *Suppose that the following conditions holds:*

$$\rho \geq \frac{m}{\beta_1 + m}, \tag{5.10}$$

$$\rho \geq \frac{m - (\eta + \gamma_1)}{\beta + m} \quad \textit{and} \tag{5.11}$$

$$\rho \geq \frac{1}{\beta + \eta}. \tag{5.12}$$

Then, in the Bayesian Nash Equilibrium agent 1 *will make the proposal, agent* 2 *will accept it (if* $m < \eta + \gamma_1$*, agent* 2 *will always accept) and agent* 3 *will embrace corruption when* $\theta_3 = 1$ *and reject it when* $\theta_3 = 0$*.*

Note that the condition (5.10) is charged with useful intuition. If the benefit from corruption increases, then this condition becomes less restrictive. On the contrary, if the penalty becomes higher, the condition will never hold. To see why this is so, if $m \to \infty$, then the right-hand-side of (5.10) tends to infinity.

Moreover, if the penalty imposed by the judiciary is not high enough, then the costs associated with passing on corruption for agent 2 will be so high that she will always accept to commit the felony. If corruption is heavily punished, this will reduce the probability that the corrupt act comes to an end. Another interesting finding arise when analyzing how the restriction imposed by condition (5.11) varies when there is changes in the value of m. Let $\hat{\rho} = [m - (\eta + \gamma_1)]/(\beta + m)$ denote this critical value. Taking the derivative of $\hat{\rho}$ with respect to m yields

$$\frac{\partial \hat{\rho}}{\partial m} = \frac{\beta - (\eta + \gamma_1)}{(\beta + m)^2}. \tag{5.13}$$

If $\beta > \eta + \gamma_1$, then $\partial \hat{\rho}/\partial m > 0$. This implies that, if the benefit from corruption is higher than the opportunity cost related to passing on corruption, an increase in m will make condition (5.11) even more restrictive. On the other hand, if $\beta \leq \eta + \gamma_1$, $\partial \hat{\rho}/\partial m < 0$ which implies that an increase in the penalty m given that the benefit from corruption is less than opportunity cost of passing on corruption, will relax the constraint imposed by (5.11). In other words, if the costs associated with denouncing and the cost of loosing the relation with agent 1 exceeds the payment from corruption, an increase in the penalty requires that the critical value of ρ for agent 2 to accept corruption will be smaller.

A relevant question is: what happens if $\alpha > \beta + \eta$ does not hold? In this case, I need an additional condition to guarantee the optimality of option s_3^c for agent 3. This condition is

$$\rho \geq \frac{1}{2} \frac{\beta + \eta - \alpha}{\beta + \eta - \frac{1}{2}\alpha}. \tag{5.14}$$

However, when this expression is added, there is not a clear cut condition that can seed lights on which expression (5.12 or 5.14) is the most restrictive. Note that this result shows once again the importance of the benefit derived from being honest for agent 3.

The results presented in this section give evidence about the importance of the completeness of the network for corrupt behavior. From a social point of view, when the network is incomplete and the flow of information among agents is not guaranteed, the coordination needed for unethical activities becomes more complex. This translates in the fact that the lack of information opens the door to the possibility that agent 1 can even abstain from making such proposal when at least one agent have an incentive to denounce. This incentives can be studied from two sides: the institutional and the economic.

From the institutional side, the previous propositions show that the independence of the judiciary system is not enough. It is needed that the legal penalty related with corrupt behavior be sufficiently high to a point in which it exceeds the costs related with denouncing, specifically, the administrative cost of justice and the cost of breaking the link with the powerful agent. This also implies that, for an efficient judiciary, the administrative costs of justice must be low. Furthermore, it is shown that, to prevent corrupt behavior, it is necessary that honesty is highly rewarded.

The economic analysis of corrupt behavior under the approach proposed in this research shows the importance of cost-benefit analysis for the decisions of agents, principally, those contained in set I. For agent 2 note that if the penalty exceeds the opportunity cost of passing of corruption measured as the sum of the administrative cost of justice and the cost of breaking the link with agent 1, then this will be enough incentive for agent 2 to avoid corrupt behavior. On the other hand, for agent 3 if the benefit from being honest is less than the costs of passing on corruption measured as the sum of the possible corrupt benefit and the administrative cost of justice, then she can be tempted by corruption and engage in corrupt activities, even when she is honest.

6 Introducing Monitoring Agencies

According to La Porta et al. (2004), monitoring agencies are part of the check and balances of a democratic system. Among other roles that these institutions play in an economic and political system, research made by Ahrend, Boukouras & Koufopoulos (2002), Besley & Prat (2006), Brunetti & Weder (2003) or Djankov et al. (2003), shows that a free press is crucial in the fight against corruption. In this section I introduce monitoring agencies (represented by press) to the environments modeled up to now. Before presenting the specific models, I will expose the main assumptions on the behavior of the press and the judicial system. This assumptions will apply to both of the models presented in the forthcoming subsections.

6.1 Basic Assumptions

The modeling of the behavior of a monitoring agency in a corrupt environment is out of the scope of this study. This is why I will assume that this agencies, represented by press, are exogenous to the system. To guarantee that this institutions will not take part of an act of corruption, I assume that every press agency is part of a competitive market, which implies that there exists a sufficiently large number of monitors. If one media firm pass on the publication of a story on an act of corruption, there will immediately appear another agency with the same access to the information and it will publish the news.

One straightforward implication of the last part of the previous paragraph is that, if a monitoring agency gets information about a story on corruption, then this information will become available for the publication by the rest of agencies. The implicit assumption behind this assertion is that media firms are connected with a complete network among all the media market members, which implies that there will exists free flows of information between them.

As before, the judicial system is exogenous. If the media does not find out about the act of corruption, then one of the members of the corrupt network will have to denounce so the judicial system can apply the corresponding penalties. However, if the media get information on the act of corruption, they will immediately publish the story and, once the judicial system becomes aware of the problem, they will make the legal investigation and apply the penalty.

The existence of monitoring agencies with the characteristics just described, create the exogenous risk of being caught in an act of corruption, despite the cooperation of all agents involved. This risk is measured by a probability of detection φ. Let $\delta = 1$ if the media gets information on corrupt behavior and publish the story and $\delta = 0$ if they do not get this information. Then, φ will follow a Bernoulli distribution represented by

$$g(\varphi, \delta) = \varphi^{\delta}(1-\varphi)^{1-\delta}.$$

6.2 The Full-linked Version

Consider the network $\mathbb{N}_1$ presented in the previous section with three agents contained in set N and with subset I with $2, 3 \in I$. The complete set of connections among agents in $\mathbb{N}_1$ ensures the free flow of information between them. Based on this, I take the game structure summarized in $\Gamma_1(\mathbb{N}_1)$ and introduce the monitoring agencies as described above.

The innovation in $\Gamma_1(\mathbb{N}_1)$ is located in the agent's payoffs. Let me assume that agent 1 make the proposal and both agents in I accept it. In $\Gamma_1(\mathbb{N}_1)$, agent 1 would get a payoff of β_1. However, because of the existence of the monitoring agency, there is the plausible risk that the act of corruption would be detected and, thus, the payoff becomes an expected payoff: with probability $(1-\varphi)$ agent 1 will get the payment from corruption β_1 in case the monitoring agency does not get the story. On the other hand, if the media gets information on corruption, they will publish the story and, with probability φ, agent 1 will have to pay the penalty $-m$ applied by justice because of corrupt behavior. The rest of payoff remain the same. Table (6.2) shows the payoffs for each agent attached to the game depicted in figure (5.2), which for expositional poruses, is presented again in figure (6.1).

Figure 6.1: The Game with Complete Information (Game 1')

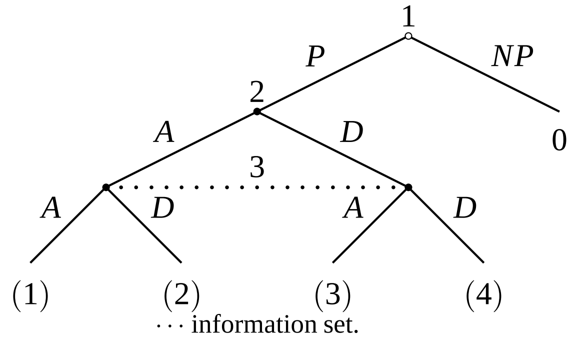


Table 6.1: Payoffs for Game 1'

Player	(1)	(2)	(3)	(4)
1	$(1-\varphi)\beta_1 - \varphi m$	$-m$	$-m$	$-m$
2	$(1-\varphi)\beta - \varphi m$	$-m$	$-(\eta+\gamma_1+\gamma_3)$	$-(\eta+\gamma_1)$
3	$(1-\varphi)\beta - \varphi m$	$-(\eta+\gamma_1+\gamma_2)$	$-m$	$-(\eta+\gamma_1)$

From this payoffs, the payoff functions for each agent are listed in the next group of equations:

$$\Pi_1 = s_1\left\{\prod_{i\in I} s_i[(1-\varphi)\beta_1 - \varphi m] - (1-\min s_i)m\right\}, \tag{6.1}$$

$$\begin{aligned}\Pi_i &= s_1\left\{\prod_{i\in I} s_i[(1-\varphi)\beta - \varphi m] - s_i(1-s_j)m\right.\\ &- \left.(1-s_j)[\eta + (1-s_i)\gamma_1 + (1-s_i)s_j\gamma_j]\right\},\end{aligned} \tag{6.2}$$

for all $i, j \in I$. Now, recall that the set of players for this game is N, which are connected by a set of links, L. Furthermore, the set of actions for each player in N are $\{S_n\}$ for all $n \in N$ an the set of payoffs is Π' with $\Pi'_n \in \Pi'$ for all $n \in N$. Taking this inputs and considering the probability distribution given that $g(\varphi,\delta)$, which measures the possibility that the act of corruption can be detected by the monitoring agencies, the game described above can be summarized as a collection such that

$$\Gamma_{1'}(\mathbb{N}_1) = \{L, N, \{S_i\}, \Pi', g(\varphi, \delta)\}. \tag{6.3}$$

When monitoring agencies are included, multiple equilibria arise naturally. Given that the press is exogenous to the model, it is possible to solve game $\Gamma_{1'}(\mathbb{N}_1)$ by means of the subgame perfect Nash equilibrium. To keep this process general, I use mixed strategies from the beginning and I proceed with the algorithm of backward induction.

For a moment, let me think that there exists strong institutions, so $m \geq \eta + \gamma_1$ always hold. Let x_j denote the probability assigned by agent i to agent j accepting the proposal and ε represent the joint probability that both agents in I accepts agent 1's proposal (i.e. $\varepsilon = \prod_i x_i$). The following proposition states the conditions for the subgame perfect Nash equilibrium.

Proposition 6.1. *Consider game $\Gamma_{1'}(\mathbb{N}_1)$ and its first perfect subgame $\Gamma'_{1'}(\mathbb{N}_1)$. Also, suppose that $m \geq \eta + \gamma_1$. The subgame perfect Nash equilibrium states that agent* 1 *will make the proposal if and only if*

$$\varepsilon \geq \frac{m}{(1-\varphi)(\beta + m)}, \tag{6.4}$$

and agents $i \in I$ will accept it if and only if

$$x_j \geq \frac{m - (\eta + \gamma_1)}{(1-\varphi)(\beta + m) + \varphi_j}. \tag{6.5}$$

As the previous proposition shows, if $m \geq \eta + \gamma_1$ (a condition that appeared in the previous section), then the first perfect subgame of $\Gamma_{1'}(\mathbb{N}_1)$ exhibits three Nash equilibria. One in which both agents accept, the second in which both agents denounce and the third one in mixed strategies in which each agent accepts if condition (6.5) holds. Note the similarity of this result with that of proposition (5.2). If institutions are weak then the penalty may be so low (or the administrative cost of justice so high) that agents will prefer to accept to avoid the costs of justice and the costs of breaking their links with agent 1. Furthermore, the existence of the monitoring agencies does not solve the problem generated by institutions. To see this, note that if $m < \eta + \gamma_1$, by the concept of the Nash equilibrium, agent i will choose to accept if and only if

$$(1-\varphi)\beta - \varphi m \geq -(\eta + \gamma_1 + \gamma_j).$$

Solving this condition for φ yields

$$\varphi \leq \frac{\beta + \eta + \gamma_1 + \gamma_j}{\beta + m}. \tag{6.6}$$

However, given that $m < \eta + \gamma_1$ the previous condition always hold so, despite press, agents will still assume the risk and choose to accept every time. On the other hand, if institutions and the media work together, the results change dramatically. To verify this intuition, take $m \geq \eta + \gamma_1$ and let $\hat{x}_j = [m - (\eta + \gamma_1)]/[(1-\varphi)(\beta + m) + \varphi_j]$ denote the critical value for x_j. If agents perceive that is *almost* certain that the media is on them and they will publish the story about corruption, then

$$\lim_{\varphi \to 1} \hat{x}_j = \frac{m - (\eta + \gamma_1)}{\varphi_j}, \tag{6.7}$$

where $\hat{x}_j < \lim_{\varphi \to 1} \hat{x}_j$. This implies that, if institutions are strong and the monitoring agencies are informed and free to publish the stories, then condition (6.5) becomes more restrictive, preventing (or increasing the risk) of getting involved in corrupt activities.

Despite the decision of agents $i \in I$ when $m < \eta + \gamma_1$, the existence of a monitoring agency has an effect on agent 1's decision, even when institutions are weak. To see this, if $m < \eta + \gamma_1$ holds and given that agents $i \in I$ accept her proposal, agent 1 will propose if and only if $(1-\varphi)\beta - \varphi m \geq 0$. Solving this expression for φ I get

$$\varphi \leq \frac{m}{\beta + m}. \tag{6.8}$$

This condition implies that, contrary to the results for agents $i \in I$, in the case of agent 1 the existence of monitoring agencies can make him think twice before making a corrupt proposal. Furthermore, if the penalty increases, then the critical value for making the proposal will become more restrictive.

Next, let me study what happens with agent 1 when strong institutions work together with monitoring agencies. For this, let me assume again that $m \geq \eta + \gamma_1$. Let $\hat{\varepsilon} = m/[(1-\varphi)(\beta + m)]$ denote the critical value of condition (6.4). If $\varphi = 0$, condition (6.4) reflects the situation without monitoring agencies. However, if $\varphi \to 1$ (i.e. it is *almost* certain that agents will face informed press), condition (6.4) will never hold and agent 1 will abstain from making the proposal. Formally

$$\lim_{\varphi \to 1} \hat{\varepsilon} = \lim_{\varphi \to 1} \frac{m}{(1-\varphi)(\beta + m)} = \infty, \tag{6.9}$$

that is, when institutions and monitoring agencies work hand by hand, the system of checks and balances in the society can be enough to prevent corruption from ever happening. On the other hand, if the media is captured or it does not work as a competitive market, corruption can find an open door.

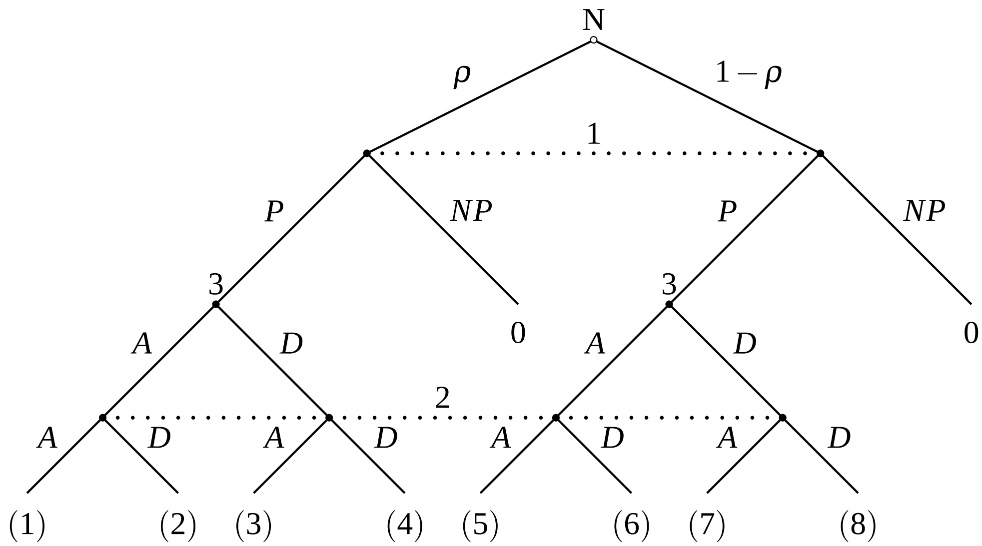
6.3 An Incomplete Network

In the last subsection I analyzed what happens when there is a corrupt network with complete information and a monitoring agency is introduced. Now, I relax the complete information assumption. Thus, consider once again the network structure summarized in $\mathbb{N}_2$, with $N = \{1, 2, 3\}$ denoting the set of nodes (or agents) and the corresponding subset of peripheral agents I with $1, 2 \in I$. Remember that, for this network, the only existing link is the one between agents 1 and 2.

This network environment invoke the game structure depicted in figure (5.4), which, for expositional purposes, I reproduce again in figure (6.2). Similar to game $1'$, the difference between game 2 and the one presented in this subsection lies on the payoffs for each agents, which in this case are linear combinations between the result when the monitoring agency does not have information on the act of corruption (with probability $(1-\varphi)$) and when the media publishes the story (with probability φ). Let $\Gamma_2'(\mathbb{N}_2)$ represent this new game. The set of players is given by N and, following Harsanyi (1967), there are two types for agent 3: $\theta_3 = 1$ if the agent is corrupt, which occur with a probability of ρ, and $\theta_3 = 0$ if the agent is not corrupt, which occurs with probability $1-\rho$. The set of actions for agent 1 is $s_1 = \{P, NP\}$ and for agents in I is $s_i = \{A, D\}$. The new set of payoffs for $\Gamma_2'(\mathbb{N}_2)$ is summarized in table (6.2).

For player 1, the payoffs in table (6.2) can be represented as a payoff function, which is given by

Figure 6.2: The Game with Incomplete Information (Game 2')



$\cdots$ information set.

Table 6.2: Payoffs for Game 2'

Player	(1)	(2)	(3)	(4)
1	$(1-\varphi)\beta_1-\varphi m$	$-m$	$-m$	$-m$
2	$(1-\varphi)\beta-\varphi m$	$-(\eta+\gamma_1)$	$-m$	$-(\eta+\gamma_1)$
3	$(1-\varphi)\beta-\varphi m$	$-m$	$-\eta$	$-\eta$
Player	(5)	(6)	(7)	(8)
1	$(1-\varphi)\beta_1-\varphi m$	$-m$	$-m$	$-m$
2	$(1-\varphi)\beta-\varphi m$	$-(\eta+\gamma_1)$	$-m$	$-(\eta+\gamma_1)$
3	$(1-\varphi)\beta-\varphi m$	$-m$	$\alpha-\eta$	$\alpha-\eta$

$$\begin{aligned}\Pi_1(s_1,s_2,s_3(\theta_3),\theta_3,\varphi) &= s_1\big\{s_2 s_3(\theta_3)[(1-\varphi)\beta_1-\varphi m] \\ &- \big(1-\min\{s_2,s_3(\theta_3)\}\big)m\big]. \end{aligned} \tag{6.10}$$

In the same scheme, the payoff function for agent 2 is

$$\begin{aligned}\Pi_2(s_1,s_2,s_3(\theta_3),\theta_3,\varphi) &= s_1\big\{s_2 s_3(\theta_3)[(1-\varphi)\beta-\varphi m]-s_2\big(1-s_3(\theta_3)\big)m \\ &- (1-s_2)\big[\eta+(1-s_2)\gamma_1\big]\big\}. \end{aligned} \tag{6.11}$$

Finally, the payoff function for player 3 can be written as

$$\begin{aligned}\Pi_3(s_1,s_2,s_3(\theta_3),\theta_3,\varphi) &= s_1\big\{s_2s_3(\theta_3)[(1-\varphi)\beta-\varphi m]-s_3(\theta_3)(1-s_2)m \\ &+ \big(1-s_3(\theta_3)\big)\big[(1-\theta_3)(\alpha-\eta)\big]\big\}. \end{aligned} \tag{6.12}$$

Define $\Pi'(\theta_3,\varphi)$ as the new set containing the payoff functions just depicted. Also, remember that Θ is the set of types for player 3, $f(\rho,\theta_3)$ the probability distribution for the beliefs of agents 2 and 3 about the type of agent 3 and $g(\varphi,\delta)$ is the probability distribution that defines if the monitoring agency has information on corruption. Therefore, $\Gamma_{2'}(\mathbb{N}_2)$ is a collection such that

$$\Gamma_{2'}(\mathbb{N}_2)=\big\{L,N,\Theta,f(\rho,\theta_3),g(\varphi,\delta),\{S_n\},\Pi'(\theta_3,\varphi)\big\}. \tag{6.13}$$

To follow more easily the following thoughts, it is worth to remember agent 3 possible strategies given the decisions of agents 1 and 2:

s_3^a: A if $\theta_3=1$ and A if $\theta_3=0$.

s_3^b: D if $\theta_3=1$ and D if $\theta_3=0$.

s_3^c: A if $\theta_3=1$ and D if $\theta_3=0$.

s_3^d: D if $\theta_3=1$ and A if $\theta_3=0$.

Before analyzing the relevant possible Bayesian Nash equilibria, it is important to remember two results that I obtained in the setting of incomplete information and without monitoring agencies. The first one corresponds to proposition (5.3), which I present again for expositional purposes as proposition (6.2).

Proposition 6.2. *Consider game $\Gamma_2(\mathbb{N}_2)$. Suppose that agent 1 choose to make the proposal and agent 2 accepts it. If $\alpha>\beta+\eta$ then s_3^d will be a dominated strategy for agent 3.*

If the conditions in the previous proposition holds, then it is possible to rule out any strategy profile that contains strategy s_3^d as a possible candidate for a Bayesian Nash equilibrium. When monitoring agencies are introduced, the condition for s_3^d to be a dominated strategy is less restrictive. Formally, all that is needed is that

$$\alpha \geq (1-\varphi)\beta - \varphi m + \eta . \tag{6.14}$$

As φ increases, the restriction will become less restrictive. Something similar happens when I analyze a strategy profile in which agent 1 makes the proposal, agent 2 accepts it and agent 3 make a denounce despite her type. By proposition (5.5), I already know that in the non monitoring agencies setting, if some conditions hold, then this strategy profile can also be ruled out as a possible equilibrium. Proposition (5.5) is stated again in proposition (6.3).

Proposition 6.3. *Consider game $\Gamma_2(\mathbb{N}_2)$. Suppose that $m > \eta + \gamma_1$, $\alpha \geq \beta + \eta$ and $\rho = 0$. Then, the strategy profile in which agent 1 makes the proposal, agent 2 accepts it and agent 3 denounce despite her type can be ruled out as a possible Bayesian Nash Equilibrium.*

As before, when monitoring agencies are introduced, the restriction on α becomes less restrictive. Given this facts, it is not interesting to study strategies profiles in which agent 3 chooses strategies s_3^b or s_3^d given that the results obtained in the previous section will not change in a significant manner. Considering this, I propose to study two possible optimal strategy profiles. The first one, in which agent 1 chooses to make the proposal, agent 2 accepts it and agent 3 accepts independently of her type. And, the second one, in which agent 1 chooses to make the proposal, agent 2 accepts it and agent 3 accepts if she is corrupt ($\theta_3 = 1$) and denounce if she is honest ($\theta_3 = 0$).

Let me start by assessing the conditions that have to hold for the first candidate to be a Bayesian Nash equilibrium. The next proposition states the corresponding conditions.

Proposition 6.4. *Consider game $\Gamma_{2'}(\mathbb{N}_2)$. Assume that $m \geq \eta + \gamma_1$. Then, in the Bayesian Nash equilibrium agent 1 makes the proposal, agent 2 accepts it and agent*

3 *also accepts it when* $\theta_3 = 1$ *and when* $\theta_3 = 0$ *if and only if*

$$\begin{aligned}
\varphi &\leq \frac{\beta_1}{\beta_1 + m}, && (6.15)\\
\varphi &\leq \frac{\beta + \eta + \gamma_1}{\beta + m}, && (6.16)\\
\rho &\geq 1 + \frac{\varphi m - [\eta + (1-\varphi)\beta]}{\alpha}, \quad \textit{and} && (6.17)\\
\alpha &\leq (1-\varphi)\beta - \varphi m + \eta. && (6.18)
\end{aligned}$$

The result in this proposition shows again the importance of the coordination that must exists between the institutions and the monitoring agencies. To see this, note that as the legal penalty from corruption gets larger, condition (6.15) becomes more restrictive. If $m \to \infty$, then the critical value of this condition tends to zero. This implies that agent 1 will only make the proposal if she is certain that monitoring agencies cannot intervene. On the contrary, if the payment from corruption is high, the condition becomes less restrictive. Furthermore, if $\beta_1 \to \infty$, then the critical value will also tend to infinity, and agent 1 will always make the proposal.

What happens if institutions are weak and $m < \eta + \gamma_1$? If this is so, then $(\beta + \eta + \gamma_1)/(\beta + m) > 1$, which implies that condition (6.16) will always hold. Once again, the importance of checks and balances working together gains relevance.

To analyze condition (6.17), let $\hat{\rho} = 1 + \{\varphi m - [\eta + (1-\varphi)\beta]\}/\alpha$. When the probability that monitoring agencies are not informed on corruption is low, condition (6.17) becomes less restrictive. Furthermore, it is possible to see that

$$\lim_{\varphi \to 0} \hat{\rho} = 1 - \frac{\eta + \beta}{\alpha}. \tag{6.19}$$

The previous equation implies that when the probability that the media is informed tends to zero, then the situation is similar to the setting where monitoring agencies are not included. Moreover, given that $\alpha \leq (1-\varphi)\beta - \varphi m + \eta$, it is straightforward to see that $\alpha \leq \beta + \eta$ and, if φ tends to zero, the condition for agent 3 to accept every time will always hold.

On the other hand, if the media is informed and the probability of intervention is almost certain, agent 3 will not choose to accept, even when she is corrupt. To see this, take $\hat{\rho}$ and calculate the limit of this expression when φ tends to one. Doing this

$$\lim_{\varphi \to 0} \hat{\rho} = 1 + \frac{m}{\alpha}. \tag{6.20}$$

The limit of $\hat{\rho}$ when φ tends to one is a number bigger than one, which implies that condition (6.17) will never hold and agent 3 will denounce despite her type. In this case, it is possible to see the importance of monitoring agencies: even if honesty is not highly rewarded (due to the condition on α), the existence of an informed and free press create an incentive to denounce, even if the agent is corrupt.

Now, I will focus on the analysis of the second strategy profile candidate for a Bayesian Nash equilibrium. In this case, the equilibrium that I want to assess implies that agent 1 makes the proposal, agent 2 accepts it and agent 3 accepts if $\theta_3 = 1$ and denounce if $\theta_3 = 0$. The next proposition states the conditions for the Bayesian Nash equilibrium.

Proposition 6.5. *Consider game $\Gamma_{2'}(\mathbb{N}_2)$. Then, in the Bayesian Nash equilibrium agent* 1 *will make a proposal, agent* 2 *will accept it and agent* 3 *will also accept it if $\theta_3 = 1$ and will denounce if $\theta_3 = 0$ if and only if*

$$\begin{aligned} \rho &\geq \frac{m}{(1-\varphi)\beta_1 - \varphi m + m}, && (6.21) \\ \rho &\geq \frac{m - (\eta + \gamma_1)}{(1-\varphi)(\beta + m)} \quad \textit{and} && (6.22) \\ \alpha &\geq (1-\varphi)\beta - \varphi m + \eta. && (6.23) \end{aligned}$$

When monitoring agencies are included in an information asymmetry setting, they can have a determinant role in preventing corruption. If the probability of intervention is close to zero, then the situation is similar to the one in which there are not any media. On the other hand, let $\hat{\rho} = m/[(1-\varphi)\beta_1 - \varphi m + m]$. When the probability of media intervention is close to one, then agent 1 will abstain of making the proposal even if its acceptation is guaranteed. To see this, note that

$$\lim_{\varphi \to 1} \hat{\rho} = \infty, \tag{6.24}$$

which implies that condition (6.21) will never hold.

Something similar occurs with agent 2. To assess the implications of condition (6.22), let me first analyze what happens when the probability that agents are facing an informed media is very low. For this, note that when φ tends to zero, then the critical value in (6.22) tends to

$$\frac{m-(\eta+\gamma_1)}{\beta+m}.$$

This expression shows, once again, the importance of institutions when the media is not present, something I assess in previous sections. On the other hand, when the media is present and it is informed, the probability of publishing corruption is very high. As φ gets closer to one, condition (6.22) becomes more restrictive. Furthermore, when φ tends to one, the critical value in (6.22) tends to infinity, which implies that the previous proposition will never hold and agent 2 will not accept agent 1's proposal.

Finally, note that the existence of monitoring agencies will make condition (6.23) less restrictive. Also, note that if institutions are strong (i.e. the penalty is high and the administrative costs of justice are low) and the press being involved is almost certain (i.e. when φ tends to one), then the critical value for α can even be negative, which implies that condition (6.23) will always hold.

Concluding Remarks

In this research I wanted to analyze why corruption needs the formation of networks. Also, my purpose was to study the roles of institutions and monitoring agencies in preventing this king of behavior. Specifically, I address two questions: (i) why social networks are important for corrupt behavior? and (ii) How institutions and monitoring agencies can influence the decisions of the agents involved in corrupt activities.

The hypothesis for this study is that (i) if the social network does not exhibit any gap, then the coordination among agents is more fluent and it is easier to achieve corrupt objectives; and (ii) institutions can create incentives even if the network is complete. Furthermore, when monitoring agencies are included, it is important for institutions and monitoring agencies to complement each other to prevent more effectively the act of corruption.

To prove the hypothesis I combined social network theory with game theory and I present four scenarios. In the first group I work separately with two networks, one complete and one incomplete. In this setting monitoring agencies were not introduced. In the second group, the same two networks are analyzed, but in this case I considered the existence of an exogenous monitoring agency represented by free media that works inside a competitive market.

In the literature about corruption it is possible to find three relevant lines of research. The first line treats corruption from an individualistic point of view. According to this research, corruption is basically a bargaining problem closely related with a problem of private incentives.

The second line of research is based on the idea that the foundations of corruption lies on the characteristics of a given society. If a social group is characterized by weak institutions, flawed norms, culture and history, then corruption will emerge.

The third line of research tries to combine the previous findings. In these studies, the authors recognize that private interests among with the social environment can be determinant factors in the appearance of corruption.

Inside the last body of theory, many authors have made some propositions about how social networks can influence unethical behavior. A basic result in which almost all the literature from sociology and business administration find common ground is that when networks exhibit structural holes, then corruption (or unethical behavior) will emerge more easily.

However, other authors, from a more economic point of view, state that, when the social network is solid, it is easier to coordinate corrupt behavior due to the costs implied in breaking the links among agents.

After analyzing the first scenario, the results give evidence in favor of the economic hypothesis. I find that the links in the network permits that all agents have enough information on each other to know if they will cooperate or not with the act of corruption.

However, not only the network structure is what matters. If the institutional framework is weak (low penalties or high administrative costs of justice) and because of the long term relationship implied by corruption (costs related with the breaking of the links between agents), the opportunity costs of passing on a corrupt proposal can be so high that agents will prefer to pay a penalty in case of being captured instead of loosing the relation with the rest of agents and incur in the costs of denouncing. This implies that to accept is a dominant strategy.

On the other hand, if institutions are strong (high penalties and low administrative costs), there is a possibility that corrupt behavior can still appear, but the high penalties and the low costs from denouncing can act as incentives for agents to denounce.

The second scenario gives evidence on the importance of complete social networks for corrupt behavior. When the network exhibit gaps and the flow of information among agents is not guaranteed, the possibility for corruption to succeed is significantly lower. Moreover, if the agent who makes the proposal have doubts on how corrupt is one of the agents, this can be enough reason for her to abstain of ever making the proposal.

From the institutional point of view, a high penalty and low costs of justice are still needed even if the corruption network exhibits gaps. Furthermore, honesty must be highly rewarded to incentive agents to denounce corrupt behavior.

From an economic side, the results shows once again the way agents make cost-benefit analysis before making their decisions.

The introduction of monitoring agencies shows the importance of the complementarity of check and balances in a given society. In some cases, when the network is complete and the belief that the media will know about corruption is imminent, agents will abstain of making the corrupt proposal. However, there are cases in which the work of the media must be complemented by strong institutions. That is, even if the media has the story and they are ready to publish it, low penalties and high administrative costs can be enough for corruption to appear.

These results, and in addition, the importance of the reward on honesty, gives the same evidence when the network is incomplete. There exists cases in which, even the existence of an informed media cannot guarantee that corruption will not happen because of the weakness of institutions.

The findings in this study can be considered for policy design. The theoretical evidence shows that it is important that justice apply high penalties for corrupt behavior and that the access to the judiciary is guaranteed for all by reducing the associated administrative costs.

On the other hand, there has to be enough incentives for the existence of monitoring agencies. The Government should guarantee press freedom and the justice should see the media as an ally in the fight against corruption.

One strong assumption considered in this work is the independence of the judicial system. The agents inside a corrupt network knows about the this risk and try to find counterparts inside the judiciary. An endogenous judiciary is a topic for further research.

Another assumption that is worth considering in future studies is related with the exogenous formation of the network. The links that each agent search for is also an endogenous decision and should be considered.

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Appendix

In this appendix I present the proofs for each one of the propositions stated in the study.

A World without Monitoring Agencies

A Complete Information Setting

Proof for proposition 5.1. First consider the simultaneous game of the first perfect subgame in $\Gamma_1(\mathbb{N}_1)$. Suppose that agent 3 decides to accept the proposal. Then $\beta > -(\eta + \gamma_1 + \gamma_3)$ will always hold for agent 2 and to accept will be an optimal strategy. Now, assume that agent 3 choose to denounce. Given that $m < \eta + \gamma_1$, to accept will also be an optimal strategy for agent 2. This implies that to accept is a dominant strategy for agent 2. Due to the symmetry of the game, the same logic applies to the decision of agent 3, so to accept is a Nash Equilibrium.

Finally, note that if both agents choose to accept, by backward induction agent 1 will have to decide if she propose the act (with a payoff of β) or not to propose it (with a payoff of 0). Because $\beta > 0$, then agent 1 will make the proposal. Therefore, to accept if player 1 makes the proposal and player j accepts is an optimal strategy for player i and to make the proposal if both agents in I accept is the optimal strategy profile implied by the definition of the subgame perfect Nash equilibrium. ■

Proof for proposition 5.2. The proof is straightforward using the concept of the subgame perfect Nash equilibrium in mixed strategies. First consider the perfect subgame $\Gamma_1^{'}(\mathbb{N}_1)$. Following the previous concept, agent i will assign a probability x_j to agent j choosing *accept* in this subgame. Then, according to the definition of a Nash Equilibrium in mixed strategies, agent i will also accept if and only if

$$x_j\beta-(1-x_j)m \geq -x_j(\eta+\gamma_1+\gamma_j)-(1-x_j)(\eta+\gamma_1).$$

Whit some simple algebraic manipulation it can be shown that this expression is equivalent to condition (5.4). The fact that $m \geq \eta+\gamma_1$ guarantees that the right-hand-side of (5.4) is not negative. For the result in the second incise of the previous proposition, note that agent 1 will also assign probabilities to the actions taken by agents in I. Following once again the concept of the subgame perfect Nash equilibrium in mixed strategies and with the proper algebra, agent 1 will make the proposal if and only if

$$\varsigma\beta-(1-\varsigma)m \geq 0,$$

which is equivalent to condition (5.5). The multiple equilibria arise from analyzing the previous conditions when the *at least as big* constraint is not accomplished. ■

The Effect of Information Asymmetries

Proof for proposition 5.3. To show that proposition 5.3 holds I have to prove that the expected payoff of s_3^d is lower that the expected payoff of choosing any other possible strategy. To do so, first note that the expected payoff of s_3^d is

$$\mathbb{E}[\Pi_3|s_3^d,\cdot]=(1-\rho)\beta-\rho\eta.$$

On the other hand, the expected payoffs of choosing any other strategy are:

$$\begin{aligned}
\mathbb{E}[\Pi_3|s_3^a,\cdot] &= \beta, \\
\mathbb{E}[\Pi_3|s_3^b,\cdot] &= (1-\rho)\alpha-\eta, \quad \text{and} \\
\mathbb{E}[\Pi_3|s_3^c,\cdot] &= \rho\beta+(1-\rho)(\alpha-\eta).
\end{aligned}$$

To begin, I start by comparing $\mathbb{E}[\Pi_3|s_3^a,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^d,\cdot]$. Note that $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^d,\cdot]$ if $\rho \geq 0$, which implies, by the definition of a probability, that this will always hold. Next, compare $\mathbb{E}[\Pi_3|s_3^b,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^d,\cdot]$. In this case $\mathbb{E}[\Pi_3|s_3^b,\cdot] \geq \mathbb{E}[\Pi_3|s_3^d,\cdot]$

will hold if and only if

$$\alpha \geq \beta + \eta.$$

Finally, for $\mathbb{E}[\Pi_3|s_3^c, \cdot] \geq \mathbb{E}[\Pi_3|s_3^d, \cdot]$ it has to be truth that

$$\rho \geq \frac{1}{2}\frac{\beta + \eta - \alpha}{\beta + \eta - \frac{1}{2}\alpha}.$$

If $\alpha > \beta + \eta$, then the right-hand-side of the previous condition will be negative and ρ will always be bigger, since it is a probability. To complete the proof, note that $\alpha > \beta + \eta$ is the most restrictive condition. ■

Proof for proposition 5.4. Let me start the proof showing that the decision of players 1 and 2 does not depend on the condition stated on the previous proposition, so the only necessary and sufficient condition for agent 1 to make the proposal and for agent 2 to accept it every time is that agent 3 accepts the proposal no matter her type.

For agent 1, given that player 2 accepts her proposal and agent 3 will accept despite her type, all that is needed is to apply the definition of the Bayesian Nash equilibrium. If player 1 choose to make the proposal, her expected payoff is β. On the other hand, if she refuse to make the proposal, her expected payoff is 0 given that both agents will always accept. Since $\beta > 0$, to propose given that all $i \in I$ will accept is the optimal strategy for player 1.

For agent 2 the logic is similar. Given that agent 1 makes the proposal and agent 3 accepts it independently from her type, the expected payoff for agent 2 from accepting is β and her expected payoff from denouncing is $-(\eta + \gamma_1)$. Since $\beta > 0$, the first expected payoff will always exceed the expected payoff from denouncing. This condition guarantees the optimality of the strategy.

For agent 3 to accept despite her type it has to be truth that the expected payoff from applying strategy s_3^a is higher to the expected payoff derived from any other possible strategy for agent 3. Considering this, first take the expected payoff from s_3^a and compare it to the expected payoff from applying s_3^b. If

$$\rho \geq 1 - \frac{\beta + \eta}{\alpha}, \tag{6.25}$$

then it is true that $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^b,\cdot]$. Furthermore, if $\alpha < \beta + \eta$ this condition will always hold. Next, compare the expected payoff from s_3^a with the expected payoff from s_3^c. The fact that $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^c,\cdot]$ implies that

$$\beta \geq \rho\beta + (1-\rho)(\alpha - \eta).$$

Solving the previous inequality for ρ yields

$$\rho \geq 1,$$

which implies that agent 3 will always accept if she is certain that she is corrupt ($\theta_3 = 0$), i.e. that $\rho = 1$. Now, compare $\mathbb{E}[\Pi_3|s_3^a,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^d,\cdot]$. The first expected payoff will always be higher than the second one since

$$\beta \geq (1-\rho)\beta - \rho\eta$$

implies that $\rho \geq 0$, which is always true because of the definition of a probability. Finally, note that $\rho \geq 1$ is the most restrictive condition. ■

Proof for proposition 5.5. Given that $\alpha \geq \beta + \eta$ and $\rho = 0$ holds, then agent 3 will choose to denounce corruption when $\theta_3 = 1$ and when $\theta_3 = 0$. First, let me show that if agent 3 choose to denounce despite her type, then for agent 1 to make the proposal for player 2 to accept it cannot be a Bayesian Nash Equilibrium. Suppose that agent 1 making the proposal and agent 2 accepting it are part of the Bayesian Nash Equilibrium. Then

(ii) For agent 1, the concept of the Bayesian Nash Equilibrium implies that $\mathbb{E}[\Pi_1|s_1 = P,\cdot] \geq \mathbb{E}[\Pi_1|s_1 = NP,\cdot]$ holds. However, given that $\alpha \geq \beta + \eta$ and $\rho = 0$, at least agent 3 will choose to denounce and the condition will never hold (if at least one player in I choose to denounce, $\mathbb{E}[\Pi_1|s_1 = P,\cdot] = -m$ and $\mathbb{E}[\Pi_1|s_1 = NP\cdot] = 0$, which implies that abstaining from the making the proposal is a dominant strategy). This is the first contradiction.

(i) For agent 2 it has to hold that $\mathbb{E}[\Pi_2|s_2 = A,\cdot] \geq \mathbb{E}[\Pi_2|s_2 = D,\cdot]$. If $m > \eta + \gamma_1$, then this condition will never hold and I have arrived to the second contradiction. To show this, note that given that agent 1 makes the proposal and agent 3 denounce the act of corruption despite her type, the expected payoff from accepting for agent 2 is $-m$ while her expected payoff from denouncing is $-(\eta+\gamma_1)$. Applying the definition of a Bayesian Nash Equilibrium, agent 2 will accept the proposal if and only if $m \leq \eta+\gamma$.

Now, for agent 3 to denounce despite her type, all that is needed is to show that $\rho = 0$ and $\alpha \geq \beta+\eta$ are the strongest conditions that have to hold to guarantee that the expected payoff from applying (b) is higher than the expected payoff from applying any other strategy given the decisions made by other agents. First, compare $\mathbb{E}[\Pi_3|s_3^b,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^a,\cdot]$. This means that $(1-\rho)\alpha-\eta \geq \beta$. Solving this equation for ρ yields

$$\rho \leq 1-\frac{\beta+\eta}{\alpha}.$$

If $\alpha < \beta+\eta$, the previous condition never holds, and agent 3 will prefer s_3^a. Now compare $\mathbb{E}[\Pi_3|s_3^b,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^c,\cdot]$. According to the definition of the Bayesian Nash Equilibrium, if s_3^b is preferred to s_3^c given the other players decisions, it has to be true that $(1-\rho)\alpha-\eta \geq \rho\beta+(1-\rho)(\alpha-\eta)$. Solving this expression for ρ I get

$$\rho \leq 0,$$

which, by the definition of probability, only holds when $\rho = 0$. Finally, compare $\mathbb{E}[\Pi_3|s_3^b,\cdot]$ with $\mathbb{E}[\Pi_3|s_3^d,\cdot]$. Following the same arguments based on the Bayesian Nash Equilibrium, if $\mathbb{E}[\Pi_3|s_3^b,\cdot] \geq \mathbb{E}[\Pi_3|s_3^d,\cdot]$ then

$$\alpha \geq \beta+\eta$$

has to hold. If this does not happen, then agent 3 will choose strategy s_3^d. To complete the proof, note that the second and the third conditions are the most restrictive. ■

Proof for proposition 5.6. The proof of this proposition is straightforward. By proposition (5.5) I know that $m > \eta+\gamma_1$ is sufficient to guarantee that agent 2 will denounce if agent 3 denounce every time and agent 1 abstain herself from making the proposal. Moreover, $\alpha \geq \beta+\eta$ and $\rho = 0$ assures that agent 3 will choose to denounce despite her type. Note that, because of the payoff structure, proposition (5.5) holds even when agent 2 choose to denounce and agent 1 abstains from making the proposal. Finally, remember that given these conditions, to abstain from making the proposal is a dominant strategy for player 1. This completes the proof. ■

Proof for proposition 5.7. This proof only requires the application of the Bayesian Nash Equilibrium. According to this concept, given the other players actions, agent 1 will choose to make the proposal if and only if $\mathbb{E}[\Pi_1|s_1 = P, \cdot] \geq \mathbb{E}[\Pi_1|s_1 = NP \cdot]$; that is, if and only if

$$\rho\beta_1 - (1-\rho)m \geq 0.$$

Solving the previous equation for ρ yields condition (5.10). For agent 2, given the strategies of agents 1 and 3, she will accept agent 1's proposal if and only if $\mathbb{E}[\Pi_2|s_2 = A, \cdot] \geq \mathbb{E}[\Pi_2|s_2 = D \cdot]$; that is, if and only if

$$\rho\beta - (1-\rho)m \geq -(\eta + \gamma_1).$$

Solving this equation for ρ yields the result. Finally, note that if $m < \eta + \gamma_1$, then the right-hand-side of condition (5.11) will be negative, so this expression always will be true.

As for agent 3, the condition that $\alpha > \beta + \eta$ guarantees that strategy s_3^d is a dominated strategy (recall proposition (5.3)), so I can rule out this option for the rest of the proof. Now, note that if option s_3^c is an optimal strategy, it has to be true that $\mathbb{E}[\Pi_3|s_3^c, \cdot] \geq \mathbb{E}[\Pi_3|s_3^a \cdot]$. This happens if

$$\rho \leq 1,$$

which, by the definition of probability, always holds. In the same manner, for option s_3^c to be part of agent 3's optimal strategy, $\mathbb{E}[\Pi_3|s_3^c, \cdot] \geq \mathbb{E}[\Pi_3|s_3^b \cdot]$ has to hold. This is true when

$$\rho \geq \frac{1}{\beta + \eta}.$$

Finally, note that the last condition is the most restrictive. This completes the proof. ■

Introducing Monitoring Agencies

The Full-linked Version

Proof for proposition 6.1. By the definition of the subgame perfect Nash equilibrium and the concept of backward induction, agent i will accept agent 1 proposal if and only if the linear combination of her payoffs for accepting is at least as high as the linear combination of her payoffs for denouncing. Formally,

$$x_j[(1-\varphi)\beta-\varphi m]-(1-x_j)m \geq -x_j(\eta+\gamma_1+\gamma_j)-(1-x_j)(\eta+\gamma_1).$$

Solving this equation for x_j gives (6.5) and, due to the symmetry of the game, this condition has to hold for all $i \in I$. Finally, $m \geq \eta+\gamma_1$ is imposed to guarantee that the critical value for x_j is nonnegative.

For agent 1, note that given that $m \geq \eta+\gamma_1$, by the definition of the subgame perfect Nash equilibrium, she makes the proposal if and only if

$$\varepsilon[(1-\varphi)\beta_1-\varphi m]-(1-\varepsilon)m \geq 0.$$

Solving this inequality for ε yields condition (6.4). ■

An Incomplete Network

Proof for proposition 6.4. By the definition of the Bayesian Nash equilibrium, agent 1 will make the proposal if and only if her expected payoff of doing it (given the strategies of other agents) is at least as high as her expected payoff from abstaining. Formally,

$$(1-\varphi)\beta_1-\varphi m \geq 0.$$

Solving this inequality for φ yields condition (6.15).

Given the strategies of agents 1 and 3, according to the definition of the Bayesian Nash equilibrium, agent 2 will accept agent 1's proposal if and only if

$$(1-\varphi)\beta-\varphi m \geq -(\eta+\gamma_1).$$

Simple algebraic manipulation shows that this expression is equivalent to condition (6.16).

For agent 3, let me start by assessing condition (6.17). Following the definition of a Bayesian Nash equilibrium, for accepting despite her type to be an optimal strategy, it has to be true that $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^b,\cdot]$. This implies that

$$(1-\varphi)\beta - \varphi m \geq (1-\rho)\alpha - \eta$$

has to hold. Solving this condition for ρ yields condition (6.17). Following the same concept, $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^c,\cdot]$ must also hold. This implies that

$$(1-\varphi)\beta - \varphi m \geq \rho[(1-\varphi)\beta - \varphi m] + (1-\rho)(\alpha - \eta).$$

Algebraic manipulation shows that the result in this case does not depend on the value of ρ. Due to this fact, the last expression can be solved for α, and this ends as condition (6.21). Finally, note that option s_3^d is a dominated strategy by s_3^a given the other players strategies. To see this, simply note that for condition $\mathbb{E}[\Pi_3|s_3^a,\cdot] \geq \mathbb{E}[\Pi_3|s_3^d,\cdot]$ to be true is that $\rho \geq 0$, which, by the definition of probability, always holds. ■

Proof for proposition 6.5. Following the definition of the Bayesian Nash equilibrium, given the rest of the agents strategies, agent 1 will choose to make the proposal if and only if $\mathbb{E}[\Pi_1|s_1 = P,\cdot] \geq \mathbb{E}[\Pi_1|s_1 = NP,\cdot]$. That is, if and only if

$$\rho[(1-\varphi)\beta_1 - \varphi m] - (1-\rho)m \geq 0.$$

Solving this inequality for ρ yields condition (6.21).

Applying again the definition of the Bayesian Nash equilibrium, agent 2 will accept the proposal given that agent 1 makes it and agent 3 accepts it if $\theta_3 = 1$ and denounces if $\theta_3 = 0$ if and only if

$$\rho[(1-\varphi)\beta - \varphi m] - (1-\rho)m \geq -(\eta + \gamma_1).$$

Some simple algebra shows that this condition is equivalent to (6.22).

For agent 3, all that is needed is to show that strategy s_3^c is preferred to any other strategy. Take first strategy s_3^a. For s_3^c to be optimal, $\mathbb{E}[\Pi_3|s_3^c,\cdot] \geq \mathbb{E}[\Pi_3|s_3^c,\cdot]$ has to hold.

That is

$$\rho[(1-\varphi)\beta - \varphi m] + (1-\rho)(\alpha - \eta) \geq (1-\varphi)\beta - \varphi m.$$

Some algebraic manipulation shows that the last expression can be solved so it does not depend on ρ. Solving this for α yields condition (6.23).

Next, note that for $\mathbb{E}[\Pi_3|s_3^c,\cdot] \geq \mathbb{E}[\Pi_3|s_3^a,\cdot]$ to be true, the only condition needed is that $\rho \geq 0$ which, by the definition of probability, always holds. Finally, by proposition (6.2) and given condition (6.23), strategy s_3^d can be ruled out because it is a dominated strategy. $\blacksquare$