Regulating Natural Resource Extraction through Quota: Grand vs Petty Corruption

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Abstract

This paper compares the effects of grand corruption versus petty corruption on economic surplus, environmental damage, and social welfare in the context of natural resource extraction. The extraction of natural resources by a profit-maximizing monopoly is modeled using a multi-stage game. There are three alternative scenarios. In the first scenario, the social planner is corruptible and the monopolist can bribe the social planner to influence the quota policy for extraction in his favor (Grand Corruption). In the second scenario, the social planner is honest but the monopolist can bribe local inspectors to overlook illegal extraction (Petty Corruption). In the third scenario, both the social planner and local inspectors are corruptible (Grand and Petty Corruption). Results demonstrate that when petty corruption-induced loss in the monopolist's revenue per unit of extraction is greater (lower) than grand corruption-induced distorted valuation of net marginal environmental damage, grand corruption leads to higher (lower) environmental damage, higher (lower) economic surplus, and lower (higher) social welfare compared to that under petty corruption. Moreover, if the

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above condition holds, then compared to only grand (petty) corruption, the presence of both grand and petty corruption leads to higher environmental damage, higher economic surplus, and lower social welfare.
KEYWORDS: Grand Corruption, Petty Corruption, Natural Resource Extraction, Environmental Damage, Social Welfare, Bribe

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1 Introduction

Corruption is a widely studied phenomenon in social sciences. While a universal definition for this complex and oftentimes culture-specific phenomenon remains contentious, economists usually define it as 'abuse of public office for private gain' (Bardhan 1997, Rose-Ackerman 2018, Bussell 2015, Cimova 2021). An act of corruption constitutes public officials undermining the responsibility they are entrusted with in exchange for illegal payments from a private agent (Rose-Ackerman 1997). Though the above definition is straightforward, it sheds little light on the different manifestations of corruption and their impact on economic and social outcomes. To this end, scholars across the board have offered multiple typologies of corruption (Bussell 2015, Cimova 2021, Amundsen 1999). In the economic literature, one such typology is grand corruption and petty corruption. Grand corruption is the abuse of power by politicians/policymakers to pass laws that are favorable to large private corporations in exchange for illicit monetary contributions. Petty corruption refers to bribes that are paid by private agents to public officials to sidestep existing rules and regulations (Rose-Ackerman 2018, Dahlström 2012,Amundsen 1999).

In the context of natural resources, large rents associated with extraction activities make mineral-rich countries a fertile ground for persistent corruption of both kinds (Kolstad and Søreide 2009). Singh and Harriss-White (2019) extensively document the criminal economies fueled by illegal large-scale mining [1] of coal in Jharkhand, where petty corruption permeates from the highest levels of government down to lower tiers of public administration. This enables large mining firms to engage in the illegal extraction of coal leading to displacement of the local populace and destruction of the environment. The 2010 Shri Justice M.B. Shah Commission of Inquiry for Illegal Mining of Iron Ore and Manganese in India uncovered rampant instances of illegal large-scale mining activities in Karnataka, Odisha, and Goa. Around 12,000 cases of illegal mining in Bellary, Karnataka were reported since 2000, with 77.5 million tonnes of high-grade iron ore extracted and exported primarily to China against a quota of 47 million tonnes from 2003-04 to 2009-10. The report has highlighted the existence of an intricate nexus between corrupt officials, self-serving politicians, and profit-maximizing private firms as one of the biggest factors behind the erosion of aforementioned minerals via LSM activities. Zhan (2017) notes several instances of illegal mining in China, where government officials often turn a blind eye to operations without proper permits. Mining reforms intended to address corruption in the Democratic Republic of Congo (DRC) have inadvertently provided bureaucratic officials with new avenues for patronage and corruption (Wakenge 2020). In Cambodia, public officials illegally grant mining licenses in environmentally protected areas (Beevers 2015).

While illegal mining driven by petty corruption draws significant public scrutiny due to its conspicuous nature, instances of large private corporations influencing the mining policy in exchange for kickbacks under grand corruption are shrouded

[1] Illegal large-scale mining (LSM) practices in mineral-rich countries encompass activities such as mining beyond designated lease areas, operating without proper licenses, and under-reporting total extraction to evade state royalties.

in secrecy. Apart from a select few countries in the Global North, such lobbying activities are unregulated, non-transparent, and illegal in the rest of the world (Gupta 2017). In India, documents obtained by The Reporter's Collective reveal that a prominent enterprise received exemptions under the 2015 Coal Mines Special Provision Act, allowing them with continued access to mining in coal blocks that were previously cancelled by the Supreme Court after the Coalgate scam in 2014 (Jalihal and Sambhav 2023). More recently, amendments to the Mine and Minerals Act now permit corporations with captive mines to commercially sell 50 % of excavated minerals annually (Aggarwal 2021; Hall 2021). Additionally, captive mines in reserve forests can now engage in commercial mining due to modifications in environmental clearance approvals under the Forest Conservation Act (Das 2023). An OCCRP report alleges aggressive lobbying by a major mining entity for these amendments (Deshmane 2023). Fritz (2007) highlights grand corruption in Mongolia's allocation of exploration licenses, fostering a grey market for trading these licenses among companies. In the Democratic Republic of Congo (DRC), Callaway (2018) discusses the state's diversion of mining rents through opaque contracting and subcontracting practices. In Ghana, Abdulai (2017) sheds light on the culture of clientelism among politicians, influencing the negotiation and allocation of mining licenses. Collusion between Indonesian officials and mining companies has resulted in the rezoning of protected areas for increased mining activities (Beevers 2015). The involvement of politicians and bureaucrats at the top echelons of the government ensures these illicit transactions do not see the light of day. At the same time, the over-extraction of minerals by large corporations is legitimized at the expense of the destruction of the environmental balance of densely forested, biodiversity-rich tribal belts that house the reserves of these minerals.

The present paper is an attempt to compare the effects of grand corruption and petty corruption on environmental damage, economic surplus, and social welfare in the context of natural resource extraction. A multi-stage game is used to model the extraction of a natural resource by a monopolist. A social planner announces a quota for the extraction of the resource and a local inspector is responsible for keeping illegal mining by the monopolist in check. In the presence of grand corruption, the monopolist can influence the extraction quota by offering a bribe schedule to the social planner. The bribe schedule is determined by the process of Nash Bargaining between the planner and the firm. In the presence of petty corruption, the monopolist can engage in illegal mining by offering an exogenously given bribe to the local inspector. In case the inspector is corrupt, the illegal transaction goes through. However, when the inspector is honest, illegally mined natural resources are seized and sold within the domestic economy by the social planner. Using backward induction and the concept of sub-game perfect equilibrium, we demonstrate the following results.

First, if petty corruption-induced loss in the monopolist's revenue per unit of extraction is greater (lower) than grand corruption-induced distorted valuation of net marginal environmental damage, then total extraction of natural resources is higher (lower) in the presence of grand corruption compared to petty corruption. Under grand corruption, the social planner optimizes a weighted sum of social welfare, which is defined as the net private benefit from extraction minus environmental damage from extraction net of spillover economic benefit from extraction, and the bribe it receives from the monopolist while deciding the quota, whereas, under petty corruption, the social planner maximizes its objective function that includes the net private benefit from legal and illegal extraction minus net environmental damage from legal and illegal extraction (environmental damage net of spillover economic benefit). Hence, in the former case, the social planner finds it optimal to announce an extraction quota that is higher than the welfare-maximizing level of extraction such that net marginal private benefit is equal to grand corruption-induced distorted valuation of net marginal environmental damage. In the latter case, an increase in extraction quota leads to a decline in total extraction (sum of legal and illegal extraction). Thus, the social planner finds it optimal to keep on increasing the extraction quota beyond the welfare-maximizing level of extraction till the point where net marginal private benefit is equal to the petty corruption-induced loss in the monopolist's revenue per unit of extraction such that the monopolist doesn't engage in illegal mining. As a result, if petty corruption-induced loss in the monopolist's revenue per unit of extraction is higher (lower) than grand corruption-induced distorted valuation of net marginal environmental damage, the optimal quota under petty corruption is lower (higher) than that under grand corruption. Second, consequently, environmental damage is more (less) pronounced under grand corruption. Third, since total extraction is higher (lower) under grand corruption, the total economic surplus is also higher (lower) under grand corruption compared to that under petty corruption. Fourth, the positive (negative) effect of lower (higher) environmental damage under petty corruption on social welfare dominates the loss (gain) in social welfare due to the lower (higher) economic surplus under petty corruption, compared to that under grand corruption. Thus, social welfare is higher (lower) under petty corruption compared to that under grand corruption.

Fifth, in the presence of both grand and petty corruption, if petty corruption-induced loss in the monopolist's revenue is lower (higher) than grand corruption-induced distorted valuation of net marginal environmental damage, then total extraction of natural resources is the same as in the case of only petty corruption (only grand corruption). Under both grand and petty corruption, the social planner optimizes a weighted sum of the social welfare function, which includes the net private benefit from extraction (both legal and illegal) and net environmental damage from extraction (both legal and illegal), and the bribe it receives from the monopolist. Additionally, in this scenario, at any extraction level lower than the extraction quota announced by the social planner under only petty corruption, bargaining between the social planner and the monopolist doesn't go through. Hence, if the petty corruption-induced loss in the monopolist's revenue is lower than the grand corruption-induced distorted valuation of net marginal environmental damage, setting the extraction quota at the equilibrium extraction quota under only grand corruption fetches the planner no bribe from the monopolist as the bargaining process breaks down. Moreover, setting the equilibrium extraction quota greater than that under only grand corruption makes the social planner worse off. Hence, it is optimal for the social planner to set the extraction quota at the equilibrium extraction quota announced under only petty corruption. However, when the petty corruption-induced loss in the monopolist's revenue per unit of extraction is higher than the grand corruption-induced distorted valuation of net marginal environmental damage, then bargaining goes through at the equilibrium extraction quota announced under only grand corruption. Hence, the social planner finds it optimal to set the equilibrium extraction quota equal to that under only grand corruption. Moreover, in both scenarios, illegal mining is completely eliminated.

Sixth, as a consequence of the fifth result, in the presence of both grand and petty corruption, if petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower (higher) than grand corruption-induced distorted valuation of net marginal environmental damage, then compared to the only grand (petty) corruption case, environmental damage and economic surplus are higher, and social welfare is lower. Compared to the only petty (grand) corruption cases, these outcomes do not change.

Our approach is different from the related literature in several key aspects. Harstad and Svensson (2011) offer a direct comparison between petty acts of bribery and lobbying by private firms that are required to comply with a regulation. However, the authors only consider the case of legal lobbying and do not categorize it as a form of corruption. In the present analysis, we focus on cases where lobbying is illegal and a private firm's attempts to influence the government's stance on the mining policy are acts of grand corruption. Moreover, the authors posit that firms would find it cost-effective to lobby for relaxation in 'bad regulations', and would not consider lobbying to remove 'good regulations'. In contrast, we specifically model the case where the monopolist bribes the social planner to increase the level of extraction quota, which is environmentally detrimental and leads to a loss in welfare and hence can be categorized as a 'good regulation'. The authors find that investment in the economy when firms lobby is higher than the case when the monopolist bribes a bureaucrat. While we do find cases where economic surplus is higher under grand corruption, social welfare suffers a decline on account of environmental damage due to higher extraction.

Datt (2016) addresses illegal mining in the form of under-reporting of extraction within a model of stratified federal corruption, wherein state-level politicians participate in under-reporting of extraction rather than distorting the extraction policy in exchange for bribes- unlike as in the case of grand corruption in the present paper. In another closely related paper, Ranjan (2018) examines illegal mining in a scenario where corrupt politicians grant illegal mining licenses to a private firm and reduces the penalty for damaging the environment in exchange for bribes, which is similar to the scenario under petty corruption in the present paper. This paper differs from these studies by modeling both petty corruption and grand corruption and carrying out a comparative analysis of the two alternative forms of corruption.

The rest of the paper is organized as follows: Section 2 presents a review of the associated literature. Section 3 presents the model and analysis. Section 4 offers concluding remarks and possible extensions. All the proofs are contained in Appendix A.

2 Literature Review

This paper contributes to two strands of literature: (a) grand and petty corruption, and (b) natural resource extraction in the presence of corruption.

First, theoretical research has traditionally analyzed petty corruption within the framework of principal-agent model. In their seminal work, Laffont and Tirole (1991) model collusion between a corruptible regulatory agency (or a bureaucrat official) and firms where a benevolent principal (or the government) faces informational asymmetry regarding the firm's cost and effort. The authors find that an optimal incentive scheme that compensates the agency against the bribes they receive from the firm can help minimize petty corruption. However, informational asymmetry between the firm and the regulatory agency, or the agency and the principal will cause petty corruption to persist in equilibrium (Burguet, Ganuza, and Garcia Montalvo 2016; Kofman and Lawarrée 1996). Moreover, a benevolent principal can choose to tolerate a positive level of petty corruption by balancing the cost of reducing corruption against its benefits (Lambsdorff 2017). Additionally, Lambert-Mogiliansky, Majumdar, and Radner (2008) find that in equilibrium, repeated interactions between bureaucrats and firms lead to the persistence of bribery and petty corruption.

The above studies assume the principal (or the government) to be benevolent. However, the principal-agent model is unable to capture the cases of grand corruption where the principal is self-interested and can be influenced by narrow agendas of a third party in return for kickbacks (Rothstein 2011; Lambsdorff 2017). Literature on lobbying models cases where special interest groups and the self-interested principal formulate laws that promote (Grossman and Helpman 1992; Grossman and Helpman 1996; Aidt 1998). Such models consist of special interest groups that offer monetary contributions to a corruptible and self-interested government through lobbying activities in order to influence policy in their favor. The government chooses a policy by taking into account the social welfare as well as the contribution it receives from these groups. Harstad and Svensson (2011) consider petty bribery and lobbying as substitutes. They posit that beyond a threshold level of capital accumulation, firms switch from bribing the bureaucracy to lobbying the government. On the other hand, Damania, Fredriksson, and Mani (2004) treat them as compliments. Taking the case of a polluting firm whose emissions are regulated through a pollution tax, they show that political instability intensifies lobbying by special interest groups thereby creating weak institutional structures, which in turn make corruption within the bureaucracy more pervasive. However, these studies do not examine the case when lobbying is illegal and constitute as acts of grand corruption. While Harstad and Svensson (2011) do compare capital accumulation under lobbying and petty bribery, the comparison of welfare implications of illegal acts of lobbying and petty bribery has largely been ignored in the literature.

Second, a majority of theoretical literature in the environment sector focus on the optimal design of policy instruments to combat corruption. Robinson, Torvik, and Verdier (2006) use a two-period probabilistic voting model to show that in the presence of an exogenous resource boom, politicians discount the future less as the value of staying in power increases and announce a more efficient path of resource extraction. However, the boom leads to increased inefficiency in the economy as politicians engage in clientelistic strategies to influence voting behavior. Taking the case of a polluting firm whose emissions are regulated through a pollution tax, Damania, Fredriksson, and Mani (2004) show that political instability intensifies lobbying by special interest groups thereby creating weak institutional structures, which in turn make corruption within the bureaucracy more pervasive. In an open economy dynamic framework, Barbier, Damania, and Léonard (2005) find that the presence of greater grand corruption leads to an increase in the cumulative level of resource conversion. Wilson and Damania (2005) note that in economies with weak institutions and low prosecution rates, high political competition can increase petty corruption and underreporting of emissions by polluting firms. Additionally, they observe that despite increased political competition, grand corruption may persist if politicians are sufficiently compensated by private entities. While these studies firmly establish that both grand and petty corruption persist despite the availability of policy instruments, they do not compare the implications of grand and petty corruption on outcomes such as welfare and the size of the shadow economy. Amacher, Ollikainen, and Koskela (2012) do compare optimal concession policy design in the context of illegal logging of timber under no corruption and petty corruption, however, they do not take grand corruption into account.

Datt (2016) looks at illegal mining in the presence of corruption. However, the author considers the case of the under-reporting of extracted mineral resources where instead of the local inspectors, state-level politicians are involved in petty corruption. Moreover, under-reporting and welfare outcomes are analyzed through the lens of a majoritarian bias within a national audit agency responsible for addressing such instances. On the other hand, our model studies and compares the impact of grand and petty corruption on over-extraction, environmental damage, economic surplus, and social welfare.

3 Model

Consider an economy with a social planner, a large profit-maximizing monopolist involved in the extraction of a non-renewable natural resource (e.g. coal), and local inspectors responsible for keeping illegal mining by the monopolist in check. The social planner, which may be corrupt, announces a level of quota e for the rate of extraction of the natural resource. The profit-maximizing monopolist can influence the announced quota level by offering $S(e)$ as a bribe to the social planner in the presence of '*grand corruption*'. It can also engage in illegal mining of the natural resource by offering a bribe at rate b per unit of illegal extraction x to the local inspector in the presence of '*petty corruption*'. The total stock of natural resource available for extraction is known to all. To compare and contrast the effects of grand corruption and petty corruption on social welfare and shadow economy in the context of natural resource extraction, we consider three scenarios: extraction under benchmark case of no corruption, extraction in the presence of grand corruption and extraction in the presence of petty corruption.

No Corruption

Let $p = p(e)$ denote the indirect market demand for the natural resource and $C = C(e)$ denote the cost of extraction of the natural resource faced by the monopolist, where e is the level of quota announced by the social planner.

The monopolist's profit is given by

$$\Pi_{UR}(e) = ep(e) - C(e) \tag{1}$$

The social planner takes into consideration the economic benefits from extraction as well as the environmental damage associated with it while deciding on the level of quota. Apart from higher profits for the monopolist, an increased rate of resource extraction also leads to higher consumer surplus and economy-wide multiplier effects on the total income. We henceforth refer to the combined increments in consumer surplus and economy-wide multiplier effects as spillover economic benefits of extraction and denote it by $\theta G(e)$. Here $\theta = 0$ corresponds to the case in which the entire extracted amount is exported and $\theta > 0$ represents the case when only a proportion of extracted minerals are exported. On the other hand, a hike in the quota level will give the monopolist an incentive to look for more sites for extraction thereby increasing the rate of deforestation, soil erosion as well as the destruction of biodiversity. The cost associated with the above environmental damage is represented by $D(e)$. The term $D(e) - \theta G(e)$ represents environmental damage net of spillover economic benefits from extraction, or net environmental damage from extraction. Here, we make the following assumption:

Assumption 1. *(a)* $G(0) = 0$, $G'(e) > 0$,$G''(e) < 0$, $D'(e) > 0$, *and* $D''(e) > 0$ $\forall e \geq 0$.

(b) $p'(e) < 0$, $p''(e) < 0$, $C'(e) > 0$, *and* $C''(e) > 0$, $\forall e \geq 0$. $p(0) > M$, *where* $M(> C'(0) + D'(0) - \theta G'(0))$ *is sufficiently large.*

(c) $D^{'}() > \theta G^{'}()$ *for all positive levels of extraction.*

Assumption 1(a) states that the spillover economic benefit function is concave and the environmental damage function is convex in the level of extraction. Assumption 1(b) is a standard regulatory assumption. Assumption 1(c) states that for all positive levels of extraction, marginal environmental damage net of marginal spillover economic benefit, or net marginal environmental damage is positive.

The social planner's objective function can be written as follows

$$W(e) = (e)p(e) - C(e) + \theta G(e) - D(e) \tag{2}$$

Let e^{UR} denote the equilibrium level of extraction undertaken by the monopolist when no regulation is imposed on mining by the social planner. Therefore, at $e = e^{UR}$, we have the following.[2]

$$\left.\frac{d\Pi_{UR}}{de}\right|_{e=e^{UR}} = \underbrace{p(e^{UR}) + e^{UR}p'(e^{UR})}_{\text{Marginal Private Benefit}} \quad - \quad \underbrace{C'(e^{UR})}_{\text{Marginal Private Cost}} \quad = 0 \tag{3}$$

In equilibrium, the unregulated monopolist extracts $e = e^{UR}$ such that the marginal private benefit of extraction is equal to the marginal private cost of extraction. Let e^{FB} denote the level of quota announced by the social planner under no corruption, or the first best level of quota. Hence, at $e = e^{FB}$,

$$\begin{aligned} \left.\frac{dW}{de}\right|_{e=e^{FB}} &= p(e^{FB}) + e^{FB}p'(e^{FB}) - C'(e^{FB}) - D'(e^{FB}) + \theta G'(e^{FB}) = 0 \\ \Rightarrow \underbrace{p(e^{FB}) + e^{FB}p'(e^{FB})}_{\text{Marginal Private Benefit}} \quad &= \quad \underbrace{C'(e^{FB})}_{\text{Marginal Private Cost}} \quad + \quad \underbrace{(D'(e^{FB}) + \theta G'(e^{FB}))}_{\text{Net Marginal Environmental Damage}} \end{aligned} \tag{4}$$

In equilibrium, the social planner announces $e = e^{FB}$ such that marginal private benefit equals marginal private cost plus net marginal environmental damage.

Lemma 1. *Given assumption 1, and* $\alpha = 1$, $e^{UR} > e^{FB}$ *i.e. the monopolist's profit-maximizing level of extraction rate is greater than the quota announced by the social planner in the absence of both grand and petty corruption.*

When there are no possibilities of corruption, the social planner internalizes environmental damage due to extraction as well as the spillover economic benefit of extraction while deciding the optimal level of quota. On the other hand, an unregulated monopolist only maximizes its profits and doesn't internalize environmental

[2] We mention here that, by assumption 1 the second-order condition is satisfied and the solution of the optimization problem is unique and interior, in each of the cases considered.

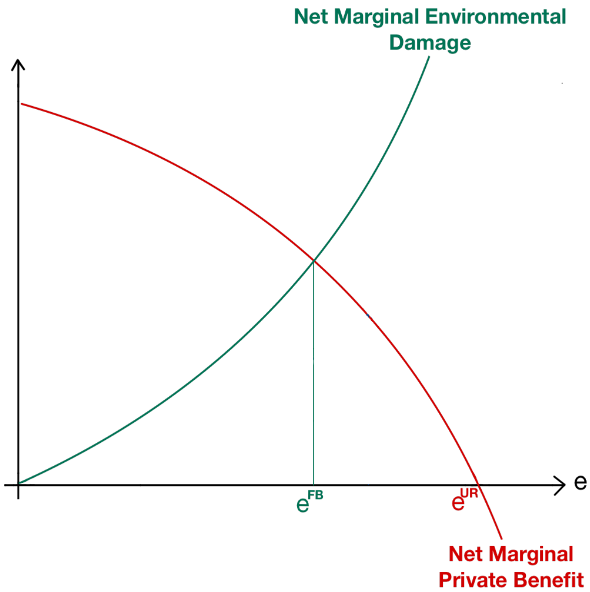

Figure 1: Benchmark Case - No Corruption

damage and spillover economic benefits from extraction. Since net marginal environmental damage from extraction is positive[3], the social planner's equilibrium choice of quota is strictly less than the privately optimal level of extraction. As a consequence, the monopolist has an incentive to over-extract when there is no corruption.

Grand Corruption

In the presence of grand corruption, the monopolist can sway the social planner's announced quota level by offering a bribe schedule $S(e)$ to the social planner. The bribe schedule is determined through Nash Bargaining between the planner and the monopolist. Here $\gamma \in [0, 1]$ is the planner's bargaining power and $(1-\gamma)$ is the monopolist's bargaining power. If bargaining fails, the planner gets 0, whereas the monopolist gets $\Pi(e^{FB})$. If bargaining is successful, the planer gets $S(e)$, whereas

[3]From Assumption 1(c)

the monopolist gets $\Pi(e) - S(e)$. The bargaining problem can be stated as:

$$\max_{S(e)} Z = [S(e) - 0]^{\gamma}[\Pi(e) - S(e) - \Pi(e^{FB})]^{(1-\gamma)} \tag{5}$$

Maximizing Z with respect to $S(e)$, the equilibrium value of bribe schedule is $S(e) = \gamma[\Pi(e) - \Pi(e^{FB})]$ and known to both the monopolist and the social planner. In line with Lopez and Mitra (2000), the social planner's objective function is given by

$$\begin{aligned} O_{GC} &= \alpha W(e) + (1-\alpha)S(e) \\ &= \alpha[(e)p(e) - C(e) + \theta G(e) - D(e)] + (1-\alpha)S(e) \end{aligned} \tag{6}$$

Here, $\alpha \in [0, 1]$ represents the importance the social planner attaches to the citizen's welfare and $(1-\alpha)$ represents the value it attaches to the bribe it receives from the monopolist. It can also be interpreted as the extent or degree of grand corruption in the economy. The stages of the game can now be stated as:

Stage 1: The social planner chooses extraction quota, e, to maximize the objective function $O_{GC}(e)$.

Stage 2: The monopolist carries out extraction activities. Payoffs are realized.

The equilibrium concept is Subgame Perfect Nash Equilibrium (SPNE) and backward induction is used to solve the game. In the second stage of the game, the monopolist produces e and earns $\Pi(e) - S(e)$.

In the first stage of the game, the social planner's objective function can be stated as

$$\begin{aligned} O_{GC} &= \alpha\Big(ep(e) - C(e) + \theta G(e) - D(e)\Big) + \gamma(1-\alpha)\Big(ep(e) - C(e) - e^{FB}p(e^{FB}) + C(e^{FB})\Big) \\ &= (\alpha + \gamma(1-\alpha))\left[\Big(ep(e) - C(e)\Big) - \left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)\Big(D(e) - \theta G(e)\Big) - K\right] \end{aligned} \tag{7}$$

where $K = \dfrac{\alpha(e^{FB}p(e^{FB}) - C(e^{FB}))}{\alpha + \gamma(1-\alpha)}$ is a constant. Note that

$$\frac{\alpha}{\alpha + \gamma(1-\alpha)} \begin{cases} = 1 & \text{if } \alpha = 1 \\ < 1 & \text{if } \alpha < 1 \end{cases} \tag{8}$$

This implies that the presence of grand corruption induces the social planner to distort the value of net environmental damage in its objective function downwards. The extent of distortion, δ is given by

$$\begin{aligned} \delta &= 1 - \frac{\alpha}{\alpha + \gamma(1-\alpha)} \\ &= \frac{\gamma(1-\alpha)}{\alpha + \gamma(1-\alpha)} \\ &= \frac{1}{1 + \frac{\alpha}{\gamma(1-\alpha)}} \end{aligned} \tag{9}$$

From (9), it is easy to see that as γ or the social planner's bargaining power increases, δ goes up. This happens because the size of the bribe the planner receives from the monopolist is an increasing function of γ. Also, a decrease in α or the importance the social planner attaches to social welfare relative to the bribe it receives from the monopolist results in an increase in the extent of distortion of the valuation of net environmental damage due to extraction in the social planner's objective function. The planner maximizes O_{GC}. Let e^{GC} be the equilibrium level of quota announced by the social planner in the presence of grand corruption. So, at $e = e^{GC}$,

$$\left.\frac{dO_{GC}}{de}\right|_{e=e^{GC}} = 0 \tag{10}$$

$$\Rightarrow \underbrace{[p(e^{GC}) + e^{GC}p'(e^{GC}) - C'(e^{GC})]}_{\text{Net Marginal Private Benefit}} = \left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right) \underbrace{[D'(e^{GC}) - \theta G'(e^{GC})]}_{\text{Net Marginal Environmental Damage}} \tag{11}$$

Hence, the social planner finds it optimal to set the extraction quota at $e = e^{GC}$ where net marginal private benefit from extraction is equal to grand corruption induced distorted valuation of net marginal environmental damage.

Also, the SOC for the above problem is

$$\begin{aligned}\frac{d^2 O_{GC}}{de^2} &= \alpha\Big[ep''(e) + 2p'(e) - C''(e) + \theta G''(e) - D''(e)\Big] \\ &+ \gamma(1-\alpha)\Big[ep''(e) + 2p'(e) - C''(e)\Big] < 0\end{aligned} \tag{12}$$

At $\alpha = 0$ i.e. when the social planner is completely corrupt, $O_{GC}(e) = S(e) = \gamma(\Pi_{GC}(e) - \Pi_{GC}(e^{FB}))$.

Lemma 2. *In the presence of grand corruption i.e. for all $\alpha \in [0, 1)$, the level of quota that maximizes the planner's objective function is always greater than the first best level of quota, or in other words, $e^{GC} > e^{FB}$.*

In the presence of grand corruption, the planner distorts downwards the value of net environmental damage in its objective function. As per the bargaining solution, in equilibrium, the bribe schedule is a proportion of the difference between the monopolist's profit at $e > e^{FB}$ and that at e^{FB} i.e. $S(e) = \gamma(\Pi(e) - \Pi(e^{FB})$. Consequentially, the corrupt planner gives higher weight to the monopolist's profit relative to net environmental damage in its objective function. Moreover, both $W(e)$ and $\Pi(e)$ are concave in e, because of which $O^{GC}(e)$ is also concave in e. Hence, the extraction level that maximizes a corrupt planner's objective function is always higher than the first best level of quota.

Lemma 3. *When the planner is completely corrupt i.e. at $\alpha = 0$, level of quota that maximizes its objective function is equal to the monopolist's profit-maximizing unregulated level of extraction, or in other words, $e^{UR} = e^{GC}$. When the planner attaches some importance to social welfare i.e. for all $\alpha \in (0, 1]$, the level of quota that maximizes the planner's objective function will always be less than the* *monopolist's profit-maximizing unregulated level of extraction, or in other words,* $e^{UR} > e^{GC}$.

When the planner is completely corrupt, he or she only cares about the monopolist's profit and will announce the quota level at the monopolist's profit-maximizing level of extraction. When the planner attaches some degree of importance to social welfare, net marginal environmental damage because of extraction is always positive. As a result, the quota announced by the planner will be less than the level of extraction that maximizes the monopolist's profits. The next lemma combines the results of the first three remarks to say the following

Lemma 4. *Combining Lemmas 1, 2 and 3, we can say the following:*

1. *If* $\alpha = 1$, $e^{FB} = e^{GC} < e^{UR}$
2. *If* $0 < \alpha < 1$, $e^{FB} < e^{GC} < e^{UR}$
3. *If* $\alpha = 0$, $e^{FB} < e^{GC} = e^{UR}$

The above lemma implies that for all values of $\alpha \in (0, 1]$ there exists an incentive for the monopolist to extract more than the announced level of quota unless the associated cost of non-compliance with the regulation is sufficiently high or the government cares only about its own private gain.

Lemma 5. *As the social planner becomes more corrupt, the equilibrium level of quota increases i.e.* $\left.\frac{de}{d\alpha}\right|_{e=e^{GC}} < 0$

As α goes down i.e. as the government becomes more corrupt and concerned about its own private gain, (i)$(e^* - e^{FB})$ increases or divergence of announced quota from first-best level of extraction increases, (ii) $(e^{UR} - e^*)$ decreases or announced level of quota becomes closer to the privately optimal level of extraction.

Expression for social loss due to corruption is given by

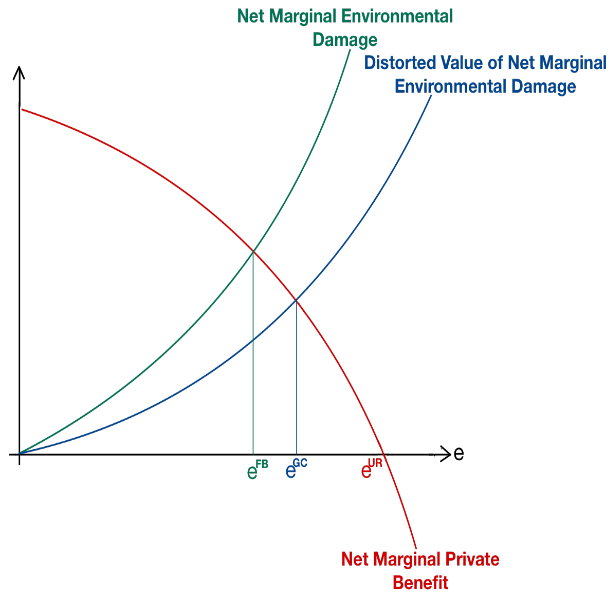

Figure 2: Extraction Quota - Grand Corruption

$$L = [W(e^{FB}) - W(e^{GC})] + \gamma\Pi(e^{GC}) \qquad (13)$$

where $W(e^{FB})$ represents social welfare when the planner is completely honest, $W(e^{GC})$ represents social welfare in the presence of grand corruption and $\gamma\Pi(e^{GC})$ is the amount of bribe that the monopolist pays the planner to influence quota on extraction of minerals. As we decrease α, e^* increases. Thus, social welfare at the equilibrium level of quota diverges from welfare at the first best quota level. This can be ascribed to the positive value of net marginal environmental damage from extraction. Moreover, the size of the bribe received by the government also goes up. These two effects lead to a significant rise in the size of social loss due to grand corruption.

Petty Corruption

In the presence of petty corruption, the monopolist can engage in illegal mining of natural resource by bribing local inspectors who are responsible for ensuring that the monopolist adheres to the extraction quota announced by a completely honest social planner. Let $\rho \in [0,1]$ denote the probability with which a local inspector is corrupt and accepts the bribe b per unit of illegal extraction denoted by $x(\geq 0)$. It can also be interpreted as a measure of the extent or degree of petty corruption prevalent in the economy. With probability $(1-\rho)$ the inspector is honest and penalizes the monopolist by seizing the entire amount x of the resource, which is then sold by the social planner in the domestic market. Here, note that the possibility of illegal mining arises only under the presence of petty corruption i.e. at $\rho = 0$, $x = 0$. In this case, we can write the market demand function as $p = p(e+x)$ and the monopolist's cost function as $C = C(e+x)$. Then the monopolist's expected profit is given by

$$E\Pi(e,x) = (e+\rho x)p(e+x) - C(e+x) - \rho bx \tag{14}$$

The social planner's objective function is given by

$$\begin{aligned} O_{PC}(e+x) &= (e+\rho x)p(e+x) - C(e+x) + \theta G(e+x) - D(e+x) + (1-\rho)xp(e+x) \\ &= (e+x)p(e+x) - C(e+x) + \theta G(e+x) - D(e+x) = W(e+x) \end{aligned} \tag{15}$$

Here, $(1-\rho)xp(e+x)$ represents the monetary value of the amount of illegal extraction seized by the honest inspectors, which the planner sells in the domestic market. Moreover, all the internal transfers between citizens get canceled out. As a result, transfer payments like bribe b will not be a part of gross welfare W. Stages of the game are as follows:

Stage 1: The social planner chooses quota, e, for the monopolist so that its objective function $O_{PC}(e+x)$ is maximized.

Stage 2: The monopolist chooses level of illegal mining x to maximize its expected profit $E\Pi(e+x)$ and carries out extraction activities. Payoffs are realized.

We solve the game by Backward Induction method and characterize the sub-game perfect equilibrium (SPNE).

Assumption 2. *ρ and b are such that $e^{FB}p'(e^{FB}) + \rho p(e^{FB}) - C'(e^{FB}) - \rho b > 0$*

Assumption 2 implies that the social planner cannot rule out the possibility of petty corruption by setting the level of extraction at the socially optimal level under no corruption, i.e. by setting $e = e^{FB}$. In the second stage of the game, the monopolist maximizes its expected profit which is defined in (14) by choosing the level of illegal extraction x. Considering that interior equilibrium exists, the first-order conditions can be written as follows.

$$\frac{\partial E\Pi_{PC}}{\partial x} = 0 \tag{16}$$

$$\Rightarrow \underbrace{(e+\rho x)p'(e+x) + \rho p(e+x)}_{\text{Marginal Expected Private Benefit}} = \underbrace{C'(e+x) + \rho b}_{\text{Marginal Private Cost plus Expected per unit Bribe}} \tag{17}$$

The monopolist finds it optimal to engage in illegal natural resource extraction till the point where the marginal expected private benefit is equal to the marginal private cost plus the expected per unit bribe. SOC for the above problem is

$$\frac{\partial^2 E\Pi_{PC}}{\partial x^2} = (e+\rho x)p''(e+x) + 2\rho p'(e+x) - C''(e+x) < 0 \tag{18}$$

Let $x = x(e)$ be the solution of (16). The following result characterizes the behavior of $x(e)$ with respect to the level of petty corruption in the economy i.e. ρ and the level of quota announced by the social planner i.e. e

Lemma 6. *(i) As the probability of the local inspector being corrupt increases,* *over-extraction by the monopolist also goes up or* $\dfrac{\partial x(e)}{\partial \rho} > 0$, *keeping* e *and* b *constant.*

(ii) *As the quota level decided by the planner increases, over-extraction by the monopolist goes down or* $\dfrac{\partial x(e)}{\partial e} < 0$, *keeping* ρ *and* b *constant. Further,* $\left|\dfrac{\partial x(e)}{\partial e}\right| > 1$.

(iii) *As the bribe rate charged by the corrupt inspector increases, over-extraction by the monopolist goes down or* $\dfrac{\partial x(e)}{\partial b} < 0$, *keeping* ρ *and* e *constant*

With an increase in the level of petty corruption, for given values of e and b, in equilibrium, illegal extraction $x(e)$ goes up. This is fairly intuitive as the probability of the local inspector being corrupt rises, monopolist finds it easier to get away with extracting and selling higher amounts of natural resource illegally. However, as the level of quota announced by the social planner increases keeping ρ and b constant, the monopolist finds it optimal to reduce illegal mining in equilibrium. One reason for this could be that the monopolist saves up on the extra cost of illegal sale. Moreover, the monopolist has a lower incentive to engage in illegal mining as the gap between the profit-maximizing unregulated level of extraction and the announced quota level closes. Similarly, keeping ρ and e constant, as the bribe rate increases, the monopolist finds it economical to reduce the level of illegal mining.

In the first stage, the social planner maximizes O_{PC} by choosing e such that $x(e) \geq 0$.

Differentiating (15) with respect to e, we have

$$\frac{dO_{PC}}{de} = \left(\frac{\partial(e+x(e))}{\partial e}\right)\Bigg[\underbrace{\{(e+x(e))p'(e+x(e)) + p(e+x(e)) - C'(e+x(e))\}}_{\text{Net Marginal Private Benefit from Total Extraction}} - \underbrace{\{D'(e+x(e)) - \theta G'(e+x(e))\}}_{\text{Net Marginal Environmental Damage from Total Extraction}}\Bigg] \tag{19}$$

Let e^{PC} be the equilibrium level of quota announced by the social planner in the presence of petty corruption. We can now state the following result

Lemma 7. *In the presence of petty corruption i.e.* $\rho \in (0,1)$ *such that assumption 2 holds, the equilibrium level of quota announced by the social planner is always greater than the first best level of quota i.e.* $e^{PC} > e^{FB}$. *Moreover, at* e^{PC}, *the monopolist doesn't undertake illegal mining i.e.* $x(e^{PC}) = 0$.

Assumption 2 and lemma 6(ii) together imply that it will never be the case that at $e = 0$, $x(0) \leq e^{FB}$. [4] Hence, the investigation is restricted to the case where $x(0) > e^{FB}$. At $e = 0$, $x(0) > e^{FB}$ implies that $\{x(0)p'(x(0)) + p(x(0)) - C'(x(0))\} - \{D'(x(0)) - \theta G'(x(0))\} < 0$ or $\left.\frac{dO_{PC}}{de}\right|_{e=0} > 0$.In other words, at $x(0)$, the net marginal private benefit from total extraction is lower than the net marginal environmental damage from total extraction. Moreover, lemma 6(ii) states that an increase in the extraction quota announced by the planner leads to a decline in total extraction (both legal and illegal extraction). It follows from this that $x(0) > e + x(e)$ for all $e > 0$. Consequently, an increase in e reduces total extraction which leads to an increase in net marginal private benefit from total extraction and a decrease in the net marginal environmental damage from total extraction [5]. Thus, the social planner finds it strictly optimal to increase the extraction quota from 0. At $e = e^{FB}$, from assumption 2, $x(e^{FB}) > 0$, or $e^{FB} + x(e^{FB}) > e^{FB}$,

[4] For a detailed explanation, the reader can refer to the proof contained in the Appendix

[5] Directly follows from Assumption 1

which implies that $\left.\frac{dO_{PC}}{de}\right|_{e=e^{FB}} > 0$. Intuitively, just like the case where $e = 0$, increasing the extraction quota such that $e^{PC} > e^{FB}$ will lead to a decrease in total extraction, which will further reduce the gap between net marginal private benefit from total extraction and net marginal environmental damage from total extraction. Hence, the social planner will find it optimal to set $e^{PC} > e^{FB}$.

Ideally, in equilibrium, the social planner will want to set the extraction quota $e^{PC} > e^{FB}$ such that net marginal private benefit from total extraction is equal to net marginal environmental damage, or $\frac{dO_{PC}}{de} = 0$. In this scenario, $\{(e^{PC} + x(e^{PC}))p'(e^{PC} + x(e^{PC}) + p(e^{PC} + x(e^{PC}) - C'(e^{PC} + x(e^{PC})\} - \{D'(e^{PC} + x(e^{PC}) - \theta G'(e^{PC} + x(e^{PC})\} = 0$, which implies that $e^{PC} + x(e^{PC}) = e^{FB}$. However, this condition will lead to $x(e^{PC}) < 0$, which is impossible. This implies, that O^{PC} is always an increasing function in e such that the constraint $x(e) \geq 0$ is satisfied. Therefore, the social planner will keep on increasing the extraction quota till $x(e)$ becomes 0. For $x(e) = 0$, $\left.\frac{\partial E\Pi}{\partial x}\right|_{x(e)=0} \leq 0$. Also, note that at $x(e) = 0$, O_{PC} reduces to the social welfare function W. Let $e = e^{PC}$ be such that

$$\left.\frac{\partial E\Pi}{\partial x}\right|_{x(e^{PC})=0} = 0 \tag{20}$$

Then for all $e > e^{PC}$, $W(e^{PC}) > W(e)$ since W is concave in e and is maximized at $e = e^{FB}$. Hence, the social planner will find it optimal to set $e = e^{PC}$ as the extraction quota. By construction, $x(e^{PC}) = 0$, or in equilibrium, the monopolist will not engage in the illegal extraction of the natural resource.

Lemma 8. *In the presence of petty corruption such that assumption 2 holds, the equilibrium level of quota announced by the social planner is always lower than the monopolist's profit-maximizing unregulated level of extraction, or* $e^{PC} < e^{UR}$.

At the monopolist's profit-maximizing unregulated level of extraction, the net marginal private benefit is equal to 0. Under petty corruption at $e = e^{PC}$ such that $x(e^{PC}) = 0$, we have

$$\left.\frac{\partial E\Pi}{\partial x}\right|_{x(e^{PC})=0} = e^{PC}p'(e^{PC}) + \rho p(e^{PC}) - C'(e^{PC}) - \rho b = 0 \tag{21}$$

$$\Rightarrow \underbrace{p(e^{PC}) + e^{PC}p'(e^{PC}) - C'(e^{PC})}_{\text{Net Marginal Private Benefit from Extraction}} = \underbrace{p(e^{PC}) - \rho(p(e^{PC}) - b)}_{\text{Petty Corruption induced Loss in Revenue per unit of Extraction}} \tag{22}$$

Here, the monopolist's net marginal private benefit from extraction at $e = e^{PC}$ is equal to the loss in the monopolist's revenue per unit of extraction induced by petty corruption at $e = e^{PC}$. Additionally, from (21), $p(e^{PC}) - b > 0$. This implies that $p(e^{PC}) - \rho(p(e^{PC}) - b) > 0$. Hence, the monopolist, if left unregulated, will increase the level of extraction from e^{PC} to e^{UR} in equilibrium so that net marginal private benefit becomes zero.

Grand Corruption vs Petty Corruption

Having compared the natural resource extraction quota of grand corruption and petty corruption with the benchmark cases of no corruption and unregulated monopoly, we now present a direct comparison between the extraction quota under grand corruption versus that under petty corruption. Let the conditions CI and CII represent the following respectively.

$$\textbf{Condition CI}: \quad \underbrace{p(e^{GC}) - \rho(p(e^{GC}) - b)}_{\text{Petty Corruption induced Loss in Revenue per unit of Extraction}} > \underbrace{\left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)[D'(e^{GC}) - \theta G'(e^{GC})]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}}$$

$$\textbf{Condition CII}: \quad \underbrace{p(e^{GC}) - \rho(p(e^{GC}) - b)}_{\text{Petty Corruption-induced Loss in Revenue per unit of Extraction}} < \underbrace{\left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)[D'(e^{GC}) - \theta G'(e^{GC})]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}}$$

Condition CI states that petty corruption-induced loss in revenue per unit of extraction is higher than grand corruption-induced distorted valuation of net marginal environmental damage, whereas condition CII states that petty corruption-induced loss in revenue per unit of extraction is lower than grand corruption-induced distorted valuation of net marginal environmental damage. Suppose that Assumption 1 and Assumption 2 hold. Now, we can state the following.

Proposition 1. *(i) If CI holds, then extraction quota under grand corruption is greater than that under petty corruption i.e. $e^{PC} < e^{GC}$.*

(ii) If CII holds, then extraction quota under grand corruption is lower than that under petty corruption i.e. $e^{PC} > e^{GC}$.

Let petty corruption-induced loss in the monopolist's revenue per unit of extraction exceed the grand corruption-induced distorted valuation of net marginal environmental damage. If the social planner announces e^{GC} as the extraction quota under petty corruption, then net marginal private benefit at e^{GC} will be lower than petty corruption-induced loss of the monopolist's revenue per unit of extraction i.e. $\left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0} < 0$. Given that $E\Pi$ at $x(e) = 0$ is concave in e, under petty corruption, the social planner is better off by increasing the extraction quota from e^{GC} to e^{PC} where net marginal private benefit is equal to petty corruption-induced loss in the monopolist's revenue per unit of extraction.

Now, let petty corruption-induced loss in the monopolist's revenue per unit of extraction be lower than the grand corruption-induced distorted valuation of net marginal environmental damage. If the social planner announces e^{GC} as the extraction quota under petty corruption, then net marginal private benefit at e^{GC} will be higher than petty corruption-induced loss of the monopolist's revenue per unit of extraction i.e. $\left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0} > 0$. Hence, under petty corruption, the social planner is better off by setting the optimal extraction quota at $e^{PC} > e^{GC}$ such that net marginal private benefit is equal to petty corruption-induced loss of the monopolist's revenue per unit of extraction.

Definition 1. *Economic Surplus from the extraction of natural resource is defined as*

$$ES(y) = yp(y) - C(y) + \theta G(y) \tag{23}$$

,where y represents total extraction.

Suppose that Assumption 1 and Assumption 2 hold. Comparing environmental damage, economic surplus, and social welfare under the two alternative scenarios, we have the following proposition

Proposition 2. *(i) If CI holds, then environmental damage and economic surplus are higher under grand corruption than that under petty corruption whereas social welfare is higher under petty corruption than that under grand corruption*

(ii) If CII holds, then environmental damage and economic surplus are higher under petty corruption than that under grand corruption whereas social wel-

fare is higher under grand corruption than that under petty corruption

When petty corruption-induced loss in the monopolist's revenue per unit of extraction is greater than grand corruption-induced distorted valuation of net marginal environmental damage, from proposition 1(i), $e^{PC} < e^{GC}$. It follows directly from here that environmental damage will be higher under grand corruption than that under petty corruption. Economic surplus from extraction includes the profit of the monopolist and the spillover economic benefit from extraction. Since the monopolist does not internalize the spillover economic benefit of extraction, the level of extraction y at which economic surplus is maximized will be higher than the monopolist's profit-maximizing unregulated level of extraction or e^{UR}. Hence, from proposition 1(i), economic surplus will be higher under grand corruption than that under petty corruption. On the other hand, social welfare is maximized at $e = e^{FB}$ and it is concave in e. Thus, from proposition 1(i), welfare under petty corruption is higher than that under grand corruption.

Similarly, using proposition 1(ii), it is easy to see that environmental damage and economic surplus are higher under petty corruption than that under grand corruption whereas social welfare is higher under grand corruption than that under petty corruption when petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower than grand corruption-induced distorted valuation of net marginal environmental damage.

Additionally, the shadow economy exists only under the presence of grand corruption and is represented by the amount of bribe the social planner receives from the monopolist. On the other hand in the presence of petty corruption, the social planner sets $e = e^{PC}$ such that $x(e^{PC}) = 0$. Hence, the shadow economy doesn't exist under petty corruption.

A decrease in α or the value that the social planner attaches to the social wel-

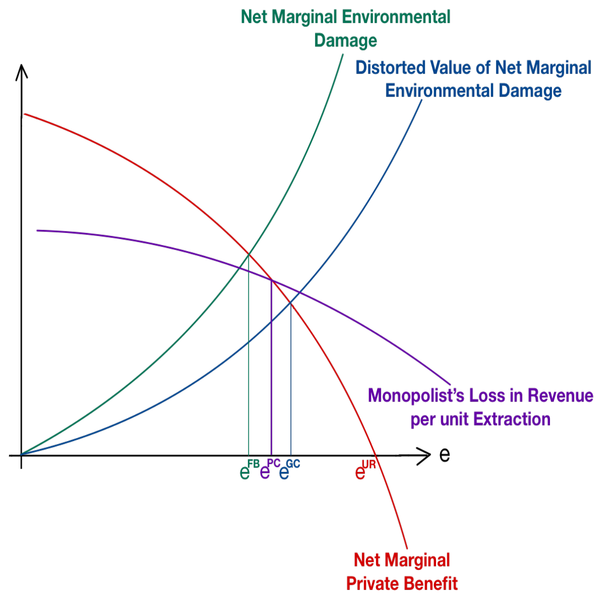

Figure 3: Comparison of e^{PC} and e^{GC} when CI holds

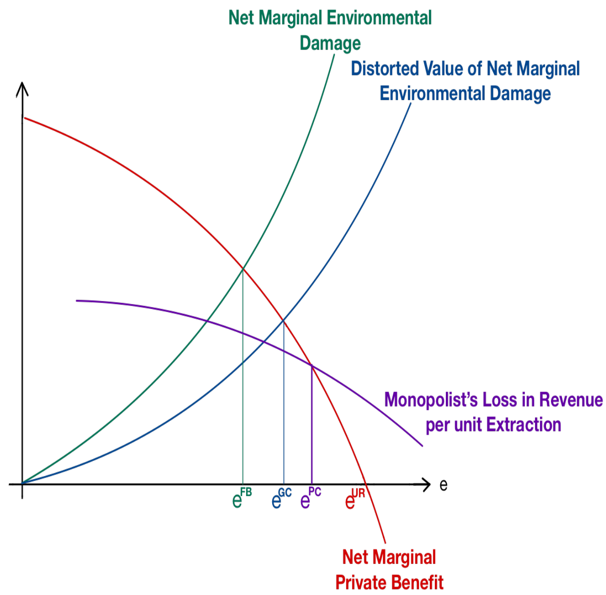

Figure 4: Comparison of e^{PC} and e^{GC} when CII holds

fare relative to the bribe it receives from the monopolist under grand corruption reduces the valuation of net marginal environmental damage within the planner's objective function. As a result, the likelihood of petty corruption-induced loss in the monopolist's revenue per unit of extraction being greater than the grand corruption-induced distorted valuation of net marginal environmental damage will be high. Therefore, the possibility of the extraction quota announced by the social planner under grand corruption being higher than that under petty corruption will be high as the intensity of grand corruption increases.

An increase in γ or the bargaining power of the social planner under grand corruption reduces the valuation of net marginal environmental damage within the planner's objective function. Hence, it is more likely that petty corruption-induced loss in the monopolist's revenue per unit extraction will be higher than grand corruption-induced distorted valuation of net marginal environmental damage. Thus, the possibility of optimal quota under grand corruption being greater than that under petty corruption is higher as the social planner's bargaining power goes up.

An increase in ρ or the probability of the local inspector being corrupt reduces the petty corruption-induced loss in the monopolist's revenue per unit of extraction. Hence, it is more likely that grand corruption-induced distorted valuation of net marginal environmental damage will be higher than petty corruption-induced loss in the monopolist's revenue per unit extraction. Thus, the possibility of the extraction quota announced by the social planner being higher under petty corruption than that under grand corruption will be high as the intensity of petty corruption increases.

An increase in b, or the per unit bribe that a corrupt local inspector charges increases the petty corruption-induced loss in the monopolist's revenue per unit of extraction. Hence, it is more likely that grand corruption-induced distorted valuation of net marginal environmental damage will be lower than petty corruption-induced loss in the monopolist's revenue per unit extraction. Thus, the possibility of the extraction quota announced by the social planner being lower under petty corruption than that under grand corruption will be high as bribe per unit of extraction under petty corruption increases.

Remark 1. *(i) In equilibrium, corruption occurs under grand corruption, but not under petty corruption.*

(ii) Tackling grand corruption is an effective way of ruling out incidences of petty corruption. However, this is achieved at the expense of over-extraction of natural resources and higher environmental damage compared to the first best level of extraction quota.

From a policy perspective, controlling corruption at the top, or the level of the policymaker, is an effective tool to rule out incidences of corruption at the lower levels of bureaucracy. This is in line with the literature on anti-corruption measures that aim to control administrative corruption. Hope (1985) states that in a *'soft state'* politicians lack discipline and leadership qualities. As a consequence, grand corruption among politicians creates an environment that is conducive to widespread petty corruption. Werner (1983) emphasizes the presence of a leader-follower spillover effect, where the acceptance of bribe within the bureaucracy is normalized by the politicians engaging in such corrupt activities themselves. Halim (2008) shows empirically that good and honest politicians, who are elected in a parliamentary democracy with an effective judiciary, can prove to be important checks against petty corruption. In a similar vein, Damania, Fredriksson, and Mani (2004) further bolster this argument by showing that a politically unstable regime with an ineffective judiciary leads to a higher incidence of grand corruption, which in turn increases the level of petty corruption in the economy. In our scenario, an honest social planner announces an extraction quota that eliminates petty corruption. However, it comes at the cost of higher environmental damage compared to the first best level of quota.

Both Grand and Petty Corruption

In the presence of both grand and petty corruption, the monopolist can engage in illegal mining by bribing the local inspector at the rate of b per unit of illegal extraction. It can also sway the extraction quota announced by the social planner in exchange for a bribe $S(e)$ which is determined through Nash Bargaining between the monopolist and the planner. Here, in case the bargaining fails, the monopolist gets $\Pi(e^{PC})$ whereas the planner gets 0. If the bargaining is successful, the planner gets $S(e)$, and the monopolist gets $E\Pi(e,x)$ such that

$$E\Pi(e,x) = \begin{cases} (e+\rho x)p(e+x) - C(e+x) - \rho bx & \text{if } x > 0 \\ ep(e) - C(e) & \text{if } x = 0 \end{cases} \tag{24}$$

The bargaining problem can be written as follows.

$$\max_{S(e)} Z = [S(e) - 0]^{\gamma}[E\Pi(e,x) - S(e) - E\Pi(e^{PC})]^{(1-\gamma)} \tag{25}$$

Solving (25), the equilibrium bribe schedule in the presence of both kinds of corruption is given by $S(e) = \gamma[E\Pi(e,x) - E\Pi(e^{PC})]$.

The social planner's objective function under the presence of both grand and petty corruption is given by

$$O_{BC} = \begin{cases} \alpha[(e+x)p(e+x) - C(e+x) + \theta G(e+x) - D(e+x)] & \\ \quad + \gamma(1-\alpha)[(e+\rho x)p(e+x) - C(e+x) - \rho bx - e^{PC}p(e^{PC}) + C(e^{PC})] & \text{if } x > 0 \\ & \\ \alpha[ep(e) - C(e) + \theta G(e) - D(e)] & \\ \quad + \gamma(1-\alpha)[ep(e) - C(e) - e^{PC}p(e^{PC}) + C(e^{PC})] & \text{if x} = 0 \end{cases} \tag{26}$$

Stages of the game are as follows:

Stage 1: The social planner chooses quota, e, for the monopolist so that its objective function $O_{BC}(e + x)$ is maximized.

Stage 2: The monopolist chooses level of illegal mining x to maximize its expected profit $E\Pi(e + x)$ and carries out extraction activities. Payoffs are realized.

We solve the game by Backward Induction method and characterize the SNPE. Analysis of the second stage remains the same as that presented in the only petty corruption case. In the first stage, for the bargaining to go through, it must be the case that $E\Pi(e, x) - E\Pi(e^{PC}) \geq 0$. Otherwise, bargaining will not take place and grand corruption will cease to exist. It is easy to see from Lemma 8 and equation (21) that for all $e \geq e^{PC}$, $E\Pi(e) \geq E\Pi(e^{PC})$. Hence, in this case, bargaining will take place. Now, we state the following result.

Lemma 9. *For all $e < e^{PC}$, bargaining between the social planner and the monopolist will not go through and grand corruption will not exist.*

Intuitively, we know that an increase in the extraction quota announced by the social planner leads to a decline in total extraction. As a consequence, for all $e < e^{PC}$, $e^{PC} < e + x(e) < x(0)$. Moreover, at $x(0)$, $\dfrac{d\Pi_{UR}}{de} > 0$, which implies that

$x(0) < e^{UR}$. [6] Additionally, for all $e < e^{UR}$, $\dfrac{dE\Pi}{de} > 0$, or $E\Pi$ is an increasing function of e. [7] Hence, for all $e < e^{PC}$, $E\Pi(e, x(e)) < E\Pi(e^{PC})$. In other words, bargaining will not take place and grand corruption will not exist. As a consequence, the social planner will maximize O_{BC} such that $e \geq e^{PC}$ is satisfied. Solving this problem gives rise to two scenarios as mentioned below.

Proposition 3. *If CII holds, then the social planner finds it optimal to eliminate petty corruption and set the extraction quota at $e = e^{PC}$. Moreover, $S(e^{PC}) = 0$ which implies that in equilibrium, grand corruption ceases to exist.*

We already know from Proposition 1(ii) that petty corruption-induced loss in the monopolist's revenue per unit of extraction being lower than grand corruption-induced distorted valuation of net marginal environmental damage implies that $e^{GC} < e^{PC}$. From Lemma 9, at e^{GC} bargaining will not go through. Additionally, for all $e \geq e^{PC}$, the only difference between O_{GC} and O_{BC} is the expression for $S(e)$. In the presence of only grand corruption, the threat point is $\Pi(e^{FB})$, which is a constant. In the presence of both grand and petty corruption, the threat point is $\Pi(e^{PC})$, which is also a constant. Hence, $\left.\dfrac{dO_{BC}}{de}\right|_{e \geq e^{PC}} = \dfrac{dO_{GC}}{de}$. Additionally, O_{GC} is concave in e and is maximized at $e = e^{GC}(< e^{PC})$. Consequentially, if the social planner becomes worse off by setting an extraction quota higher than e^{PC}. In other words, in equilibrium, it is optimal for the social planner to set the extraction quota at $e = e^{PC}$ and eliminate illegal mining. Intuitively, given the range of permissible levels of extraction quota, the social planner faces a higher level of distorted value of net marginal environmental damage compared to net marginal private benefit. Therefore, increasing the extraction quota beyond e^{PC} would make the social planner worse off.

[6]For details please refer to the proof of the Lemma 9 in the Appendix.

[7]For details please refer to the proof of the Lemma 9 in the Appendix.

Proposition 4. *If CI holds, then grand corruption will exist and it is optimal for the corrupt social planner to announce extraction quota at $e = e^{GC}$.*

When petty corruption-induced loss in the monopolist's revenue per unit of extraction is greater than grand corruption-induced distorted valuation of net marginal damage, from Proposition 1(i), $e^{PC} < e^{GC}$. This implies that at e^{GC}, bargaining goes through. As mentioned before, for all $e > e^{PC}$, $\frac{dO_{BC}}{de} = \frac{dO_{GC}}{de}$ and O_{GC} is maximized at $e = e^{GC} (> e^{PC})$. Therefore, in equilibrium, the social planner finds it optimal to set the extraction quota at $e = e^{GC}$ such that there is no illegal mining. Intuitively, given the range of permissible levels of extraction quota, a lower level of distorted value of net marginal environmental damage permits the social planner to equate it to the net marginal private benefit by setting the extraction quota at $e = e^{GC}$.

We note here that in both scenarios illegal mining is eliminated. Hence, despite the presence of corrupt local inspectors in the economy, the monopolist has no incentive to bribe them and engage in illegal mining. Moreover, at higher levels of distorted value of net marginal environmental damage the social planner receives no bribe from the monopolist, thereby doing away with the incidence of both grand and petty corruption despite there being a possibility for the monopolist to engage in both acts of corruption. On the contrary, at low levels of distorted value of net marginal environmental damage, the monopolist gives a part of its profits as a bribe to the social planner to influence the extraction quota. While there is no incidence of petty corruption, in this case, the incidence of grand corruption becomes rampant.

Remark 2. *A corrupt social planner will prefer an underestimation of the environmental damage function.*

We gather from the above analysis that a corrupt social planner would prefer to have lower values of net environmental damage and receive a bribe from the monopolist in exchange for increasing the extraction quota. Economic literature is replete with multiple methods of estimating environmental damage caused by the extraction of natural resources. However, there is an ongoing debate concerning the appropriate methodology that must be used for the estimation of environmental damage caused by mining activities. For instance, revealed preference methods such as travel cost method, hedonic pricing method, etc. help in capturing the use values of natural resources, whereas stated preference methods such as the contingent valuation method, choice experiment methods, benefit transfer method, etc. are used to determine use as well as non-use values of the resource (Sourokou, Vodouhe, and Yabi 2024; Abdullah, Markandya, and Nunes 2011; Birol, Karousakis, and Koundouri 2006; Barbier 1994). Additionally, there are significant variations in the estimates of the environmental damage furnished by these methods (Pirmana et al. 2021; Sourokou, Vodouhe, and Yabi 2024; Damigos 2006; Menegaki and Damigos 2020). A range of values is present in the literature for the social cost of carbon emissions which are estimated using integrated assessment models. A slight tweak in one of the parameters of these models generates an entirely different estimate (Metcalf and Stock 2017; Nordhaus 2014; Greenstone, Kopits, and Wolverton 2013; Howard and Sterner 2017). As a consequence, there is room for a corrupt social planner to pick a value that underestimates the environmental damage caused due to extraction activities which results in over-extraction of natural resources.

We now offer a comparison of environmental damage, economic surplus, and social welfare in the presence of both forms of corruption with that under no corruption, only petty corruption and only grand corruption in the following result.

Proposition 5. *(i) Compared to the first best level of extraction, in the presence of both grand corruption and petty corruption, environmental damage, and economic surplus are higher, whereas social welfare is lower.*

(ii) If CII holds, then compared to the only grand corruption case, in the presence of both grand and petty corruption, total extraction and economic surplus are higher, whereas social welfare is lower.

(ii) If CI holds, then compared to the only petty corruption case, in the presence of both grand corruption and petty corruption, total extraction, and economic surplus are higher, whereas social welfare is lower.

We know from Lemma 2 that $e^{GC} > e^{FB}$ and from Lemma 7 that$e^{PC} > e^{FB}$. This implies that irrespective of whether CI or CII is true, extraction quota under no corruption is always lower than the extraction quota in the presence of both grand and petty corruption. Hence, in this scenario environmental damage will always be higher compared to the benchmark case of no corruption. Since an unregulated monopolist doesn't internalize the spillover effects of resource extraction and only maximizes its profits, the extraction level that maximizes the economic surplus will always be higher than e^{UR}, which is greater than both e^{GC} (from Lemma 3) and e^{PC} (from Lemma 8). Thus economic surplus is higher under the presence of both grand and petty corruption compared to the benchmark case of no corruption. On the other hand, the social welfare function is maximized at e^{FB} which, as mentioned before, is lower than both e^{GC} and e^{PC}. This implies that irrespective of whether CI or CII is true, social welfare is always lower in the presence of both grand and petty corruption compared to the benchmark case of no corruption.

When petty corruption-induced loss in the monopolist's revenue is lower than the grand corruption-induced distorted value of net marginal environmental damage, from Proposition 3, the social planner sets the equilibrium extraction quota at

e^{PC}, and from Proposition 1, $e^{PC} > e^{GC}$. Hence, compared to the only grand corruption case, environmental damage is higher in the presence of both grand and petty corruption. Additionally, as mentioned before, extraction level that maximizes economic surplus is higher than e^{UR}, which is greater than e^{GC} and e^{PC}. Using Proposition 1, $e^{PC} > e^{GC}$, which implies that economic surplus in the presence of both grand and petty corruption compared to only grand corruption. However, social welfare is maximized at e^{FB}, which is lower than both e^{GC} and e^{PC}. This combined with Proposition 1 implies that social welfare lower in the presence of both grand and petty corruption compared to only grand corruption.

When petty corruption-induced loss in the monopolist's revenue is higher than the grand corruption-induced distorted valuation of net marginal environmental damage, from Proposition 4, the social planner sets the extraction quota at e^{GC} in the presence of both grand and petty corruption, and from Proposition 1, $e^{GC} > e^{PC}$. So, compared to the only petty corruption case, environmental damage is higher under the presence of both grand and petty corruption. Given that economic surplus is maximized at an extraction level higher than e^{UR}, using Lemma 3, Lemma 8 and Proposition 1, we have $e^{UR} > e^{GC} > e^{PC}$. Hence, compared to the only petty corruption case, economic surplus is higher under the presence of both grand and petty corruption. Social welfare, on the other hand, is maximized at e^{FB}, which is lower than e^{PC} and e^{GC}. Hence, using Proposition 1, in the presence of both grand and petty corruption, social welfare is lower compared to that under only petty corruption.

The Culture of Cut Money

In this scenario, like the previous section, the monopolist can engage in illegal mining by bribing the local inspector and sway the extraction quota by bribing the social planner at the same time. So, the monopolist's expected profit function $E\Pi(e, x)$ as well as the equilibrium bargaining solution for $S(e)$ will be the same as in the previous section. Henceforth, we refer to the bribe the social planner receives from the monopolist as *direct bribe*. However, unlike the previous case, over here, there is a bribe-sharing arrangement between the social planner and the corrupt local inspector under which the former receives a cut of the bribe earned by the latter from the monopolist. Henceforth, we refer to the bribe the social planner receives from the local inspector as *cut money*. The social planner's objective function can now be rewritten as:

$$O_{BC} = \begin{cases} \alpha[(e+x)p(e+x) - C(e+x) + \theta G(e+x) - D(e+x)] & \\ + (1-\alpha)[\gamma(E\Pi(e+x(e)) - E\Pi(e^{PC})) + \lambda\rho bx] & \text{if } x > 0 \\ & \\ \alpha[ep(e) - C(e) + \theta G(e) - D(e)] & \\ + \gamma(1-\alpha)[E\Pi(e) - E\Pi(e^{PC})] & \text{if x} = 0 \end{cases} \tag{27}$$

where $\lambda\rho bx$ represents the cut of the corrupt local inspector's bribe received by the social planner such that $\lambda \in [0, 1]$. The stages of the game are the same as stated in the previous section. We solve the game using backward induction and characterize the SPNE. Analysis of the second stage remains the same as presented in the previous section. Additionally, in the first stage, Lemma 9 will continue holding. This implies that for all $e < e^{PC}$, bargaining between the social planner and the monopolist will not go through. From the only petty corruption case, we know that for all $e \geq e^{PC}$, $x(e) = 0$. Hence, the social planner's objective function can be rewritten as:

$$O_{BC} = \begin{cases} O^{I}_{BC} = \alpha[(e+x)p(e+x) - C(e+x) \\ \qquad + \theta G(e+x) - D(e+x)] + (1-\alpha)\lambda\rho b x & \text{if } e < e^{PC} \\ \\ O^{II}_{BC} = \alpha[ep(e) - C(e) + \theta G(e) - D(e)] \\ \qquad + \gamma(1-\alpha)[ep(e) - C(e) - e^{PC}p(e^{PC}) + C(e^{PC})] & \text{if } e \geq e^{PC} \end{cases} \tag{28}$$

Let e^* maximize O^{I}_{BC}. This implies that at $e = e^*$, we have

$$\alpha\left(1 + \frac{\partial x}{\partial e}\right)\Bigg[(e^* + x(e^*))p'(e^* + x(e^*)) + p(e^* + x(e^*)) - C'(e^* + x(e^*)) \\ + \theta G'(e^* + x(e^*)) - D'(e^* + x(e^*))\Bigg] + (1-\alpha)\lambda\rho b\frac{\partial x}{\partial e} = 0 \tag{29}$$

The level of illegal mining at e^* is given by $x(e^*)$. Here, we make the following assumption:

Assumption 3. *(i) For given values of λ and ρ, $\underline{b} < b < \bar{b}$, where*

$$\bar{b} = -\frac{\alpha}{\lambda\rho(1-\alpha)}\left(\frac{\frac{\partial(e+x)}{\partial e}}{\frac{\partial x}{\partial e}}\right)\Bigg|_{e=0} W'(e = x(0))$$

and

$$\underline{b} = -\frac{\alpha}{\lambda\rho(1-\alpha)}\left(\frac{\frac{\partial(e+x)}{\partial e}}{\frac{\partial x}{\partial e}}\right)\Bigg|_{e=e^{PC}} W'(e = e^{PC})$$

(ii) $\dfrac{T_{e=e^{PC}}}{T_{e=0}} < \dfrac{W'(e = x(0))}{W'(e = e^{PC})}$, *where* $T_e = \dfrac{\frac{\partial(e+x)}{\partial e}}{\frac{\partial x}{\partial e}}$

The first part of the assumption ensures that e^* lies between 0 and e^{PC} if $\underline{b} < b < \bar{b}$. Also, it is evident that both $\underline{b}$ and $\bar{b}$ are positive[8]. The second part of the

[8]Since $W(e)$ is maximized at e^{FB} and $e^{FB} < e^{PC} < x(0)$, $W'(e^{PC}) < 0$ and $W'(x(0)) < 0$. Additionally, both $\dfrac{\partial(e+x)}{\partial e} < 0$ and $\dfrac{\partial x}{\partial e} < 0$

assumption ensures that $\underline{b} < \bar{b}$. Since $e^* < e^{PC}$, from Lemma 6(ii), $e^*+x(e^*) > e^{PC}$. The next result offers a comparison between $e^* + x(e^*)$ and e^{FB}.

Lemma 10. *Total extraction under the extraction quota that maximizes O^I_{BC} in the presence of both grand and petty corruption under the cut money culture is always greater than the extraction under the benchmark case of no corruption, or $e^* + x(e^*) > e^{FB}$.*

Extraction quota that maximizes O^I_{BC} can either be greater than or lower than the first best level of extraction quota. Consider the case where the former holds, or $e^* > e^{FB}$. Assumption 3 implies that $e^* < e^{PC}$. Also, we already know that for all e lower than e^{PC}, $x(e) > 0$ which implies that $x^{e^*} > 0$. Hence, in this case, total extraction under the extraction quota that maximizes O^I_{BC}, or $e^* + x(e^*)$is higher than the welfare maximizing level of extraction quota, ore^{FB}. Now, suppose that $e^* < e^{FB}$. From Lemma 6(ii), we know that an increase in the extraction quota leads to a decline in total extraction. Hence, increasing extraction quota from e^* to e^{FB} will result in a decline in total extraction, or $e^* + x(e^*) > e^{FB} + x(e^{FB})$. This along with Assumption 2 implies that, even when $e^* < e^{FB}$, total extraction under e^* will be higher than the welfare maximizing level of extraction quota, or $e^* + x(e^*) > e^{FB}$.

If CI holds, or when petty corruption-induced loss in the monopolist's revenue per unit of extraction is greater than grand corruption-induced distorted valuation of net marginal environmental damage, then according to Proposition 4, O^{II}_{BC} is maximized at e^{GC}. The social planner now chooses between e^* and e^{GC} by comparing value of O^I_{BC} at e^* and value of O^{II}_{BC} at e^{GC}. However, when CII is true, or when petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower than grand corruption-induced distorted valuation of net marginal environmental damage, then as per Proposition 3, O^{II}_{BC} is maximized at

e^{PC}. In this case, the social planner chooses between e^* and e^{PC} by comparing the value of O^I_{BC} at e^* with the value of O^{II}_{BC} at e^{PC}. We define the following conditions to aid us in these comparisons.

$$\textbf{Condition CIII}: \underbrace{\alpha[W(e^{PC}) - W(e^* + x(e^*))]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^{PC} \text{ over } e^*} > \underbrace{(1-\alpha)\lambda b\rho x(e^*)}_{\text{Social Planner's Valuation of Cut Money}}$$

$$\textbf{Condition CIV}: \underbrace{\alpha[W(e^{PC}) - W(e^* + x(e^*))]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^{PC} \text{ over } e^*} < \underbrace{(1-\alpha)\lambda b\rho x(e^*)}_{\text{Social Planner's Valuation of Cut Money}}$$

$$\textbf{Condition CV}: \underbrace{\alpha[W(e^* + x(e^*)) - W(e^{GC})]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^* \text{ over } e^{GC}} > \underbrace{(1-\alpha)[\gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})) - \lambda b\rho x(e^*)]}_{\text{Social Planner's Valuation of Direct Bribe net of Cut Money}}$$

$$\textbf{Condition CVI}: \underbrace{\alpha[W(e^* + x(e^*)) - W(e^{GC})]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^* \text{ over } e^{GC}} < \underbrace{(1-\alpha)[\gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})) - \lambda b\rho x(e^*)]}_{\text{Social Planner's Valuation of Direct Bribe net of Cut Money}}$$

Condition $CIII$ states that the social planner's valuation of welfare gain by choosing e^{PC} over e^* is greater than the social planner's valuation of cut money, whereas condition CVI states that the social planner's valuation of welfare gain by choosing e^{PC} over e^* is lower than the social planner's valuation of cut money. Condition CV states that the social planner's valuation of welfare gain by choosing e^* over e^{GC} is higher than the social planner's valuation of direct bribe net of cut money, whereas condition CVI states that the social planner's valuation of welfare gain by choosing e^* over e^{GC} is lower than the social planner's valuation of direct bribe net of cut money.

Now, we can state the following results.

Proposition 6. *Let CII be true.*

(i) If $CIII$ holds, then the social planner finds it optimal to set the equilibrium extraction quota at $e = e^{PC}$. Additionally, the monopolist doesn't engage in illegal mining.

(ii) If CIV holds, then the social planner finds it optimal to set the equilibrium extraction quota at $e = e^*$. The level of illegal mining in the economy is positive and is given by $x(e^*)$.

When petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower than grand corruption-induced distorted value of net marginal environmental damage, then from Proposition 1, $e^{PC} > e^{GC}$. Also, O^{II}_{BC} and O_{GC} such that $e \geq e^{PC}$ only differ in the expressions of $S(e)$. Under only grand corruption, the threat point for the Nash Bargaining game is profit at e^{FB}, whereas that under both grand and petty corruption with the cut money culture is profit at e^{PC}, both of which are constants. Since, $e^{GC} < e^{PC}$, it cannot be a solution to the problem of maximizing O^{II}_{BC}. Also, for all $e \geq e^{PC}$ $\dfrac{dO_{GC}}{de} = \dfrac{dO^{II}_{BC}}{de} < 0$ since both O_{GC} and O^{II}_{BC} are concave. This implies that for all $e > e^{PC}$, $O^{II}_{BC}(e) < O^{II}_{BC}(e^{PC})$. Thus, O^{II}_{BC} is maximized at e^{PC}. Given Assumption 3, O^{I}_{BC} is maximized at e^*. The social planner chooses between e^* and e^{PC} by comparing the values of $O^{I}_{BC}(e^* + x(e^*))$ and $O^{II}_{BC}(e^{PC})$. It is easy to see that when social planner's valuation of welfare gain by choosing e^{PC} over e^* is greater than the planner's valuation of cut money, then $O^{II}_{BC}(e^{PC}) > O^{I}_{BC}(e^* + x(e^*))$. Hence, the social planner is better off by setting the equilibrium extraction quota at $e = e^{PC}$. Moreover, $x(e^{PC}) = 0$ as the monopolist has no incentive to engage in illegal mining when the extraction quota is set at $e = e^{PC}$. On the other hand, when the planner's valuation of welfare gain from choosing e^{PC} over e^* is lower than its valuation of cut money, then $O^{II}_{BC}(e^{PC}) < O^{I}_{BC}(e^* + x(e^*))$. Hence, the social planner is better off by choosing e^*. At e^*, the monopolist finds it optimal to engage in positive level of illegal mining which is given by $x(e^*)$.

Proposition 7. *Let CI be true.*

(i) If CVI holds, then the social planner finds it optimal to set the equilibrium extraction quota at $e = e^{GC}$. Additionally, the monopolist doesn't engage in illegal mining.

(ii) If CV holds, then the social planner finds it optimal to set the equilibrium extraction quota at $e = e^*$. The level of illegal mining in the economy is positive and is given by $x(e^*)$.

When petty corruption-induced loss in the monopolist's revenue per unit of extraction is higher than grand corruption-induced distorted value of net marginal environmental damage, then from Proposition 1, $e^{GC} > e^{PC}$. As mentioned before, for all $e > e^{PC}$, $\frac{dO_{GC}}{de} = \frac{dO^{II}_{BC}}{de}$. Since O_{GC} is maximized at e^{GC}, this implies that O^{II}_{BC} is also maximized at e^{GC}. Given Assumption 3, O^{I}_{BC} is maximized at e^*. The social planner chooses between e^* and e^{GC} by comparing the values of $O^{I}_{BC}(e^* + x(e^*))$ and $O^{II}_{BC}(e^{GC})$. It is easy to see that when the social planner's valuation of welfare gain from choosing e^* over e^{GC} is lower than its valuation of direct bribe net of cut money, then $O^{II}_{BC}(e^{GC}) > O^{I}_{BC}(e^* + x(e^*))$. Hence, the social planner is better off by setting the equilibrium extraction quota at $e = e^{GC}$. Moreover, $x(e^{GC}) = 0$ as $e^{GC} > e^{PC}$ and the monopolist has no incentive to engage in illegal mining for all $e \geq e^{PC}$. On the other hand, the social planner's valuation of welfare gain from choosing e^* over e^{GC} is higher than its valuation of direct bribe net of cut money, then $O_{BC}^{II}(e^{GC}) < O_{BC}^{I}(e^* + x(e^*))$. Hence, the social planner is better off by choosing e^*. At e^*, the monopolist finds it optimal to engage in positive level of illegal mining which is given by $x(e^*)$.

Propositions 6 and 7 suggest that if the local inspector is able to offer sufficient compensation to the social planner, then the latter is willing to let go off the bribe it receives from the monopolist and tolerate petty corruption and illegal mining in the economy. Over here, incidence of grand corruption is replaced with rampant petty corruption, which suggests that tackling grand corruption at the top might not necessarily lead to elimination of petty corruption from the bottom under cut money culture in the presence of both grand and petty corruption.

The following result compares environmental damage, economic surplus and social welfare under the cut money culture with that under the benchmark case of no corruption.

Proposition 8. *Compared to the benchmark case of no corruption, in the presence of both grand and petty corruption with the cut money culture, environmental damage and economic surplus are higher, whereas social welfare is lower.*

We already know from Lemmas 10, 6(ii) and 7 that $e^* + x(e^*) > e^{PC} > e^{FB}$. Additionally, we also know that $e^{GC} > e^{FB}$ from Lemma 2. This implies that whichever extraction quota the social planner chooses in equilibrium, total extraction will always be greater than the first best level of extraction quota. As a consequence, compared to the benchmark case of no corruption, in the presence of both grand and petty corruption with cut money culture, environmental damage being higher follows directly from Assumption 1. Since the monopolist, when left unregulated, doesn't internalize the spillover economic benefits from extraction and only maximizes its profits, the economic surplus function is maximized at an extraction level higher than e^{UR} which is greater than e^{PC}, e^{GC} and $e^* + x(e^*)$. Hence, in this scenario, economic surplus is greater compared to the benchmark case. On the contrary, social welfare is maximized at $e = e^{FB}$ which is lower than e^{PC}, e^{GC} and $e^* + x(e^*)$. This implies that social welfare will be lower compared to the benchmark case.

Given the presence of both grand and petty corruption, we now offer a comparison of environmental damage, economic surplus and social welfare under the cut money culture with that under the no cut money culture. We define the following conditions for the same.

Condition CVII : $$\underbrace{[p(e^* + x(e^*)) + (e^* + x(e^*))p'(e^* + x(e^*)) - C'(e^* + x(e^*))]}_{\text{Net Marginal Private Benefit}} > \underbrace{\left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)[D'(e^* + x(e^*)) - \theta G'(e^* + x(e^*))]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}}$$

Condition CVIII : $$\underbrace{[p(e^* + x(e^*)) + (e^* + x(e^*))p'(e^* + x(e^*)) - C'(e^* + x(e^*))]}_{\text{Net Marginal Private Benefit}} < \underbrace{\left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)[D'(e^* + x(e^*)) - \theta G'(e^* + x(e^*))]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}}$$

Condition $CVII$ states that the net private benefit from extraction is higher than the grand corruption-induced distorted valuation of net marginal environmental damage, whereas condition $CVIII$ states that the net private benefit from extraction is lower than the grand corruption-induced distorted valuation of net marginal environmental damage.

Proposition 9. *Let CII be true.*

(i) If $CIII$ holds in the presence of both grand and petty corruption, then compared to the no cut money culture, environmental damage, economic surplus, and social welfare do not change under the cut money culture.

(ii) If CIV holds in the presence of both grand and petty corruption, then compared to the no cut money culture, environmental damage and economic surplus are higher, whereas social welfare is lower under the cut money culture.

Suppose, petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower than grand corruption-induced distorted valuation of net marginal environmental damage. Under the no cut money culture, from Proposition 1, the social planner sets the extraction quota at e^{PC} in equilibrium. Assuming that the social planner's valuation of welfare gain by choosing e^{PC} over e^* is greater than the social planner's valuation of cut money under the cut money culture, from Proposition 6, the planner sets e^{PC} as the extraction quota in equilibrium. Hence, in the presence of both grand and petty corruption, compared to the no cut money culture, environmental damage, economic surplus and social welfare do not change under cut money culture.

However, if the social planner's valuation of welfare gain by choosing e^{PC} over e^* is lower than the planner's valuation of cut money, then from Proposition 6, the social planner sets the extraction quota at e^* in equilibrium such that there is positive level of illegal mining in the economy given by $x(e^*)$. Combining this with Lemma 6, we have $e^* + x(e^*) > e^{PC}$. Hence, in the presence of both grand and petty corruption, compared to the no cut money culture, environmental damage is higher under the cut money culture. As mentioned before, the economic surplus function is maximized at an extraction level greater than e^{UR}, which in turn is greater than $e^* + x(e^*)$. Hence, compared to the no cut money culture, economic surplus is also higher under cut money culture. On the other hand, the social welfare function is maximized at e^{FB} which is lower than e^{PC}. This implies that compared to the no cut money culture, social welfare is lower under the cut money culture.

Proposition 10. *Let CI be true.*

(i) If CVI holds in the presence of both grand and petty corruption, then compared to the no cut money culture, environmental damage, economic surplus, and social welfare do not change under the cut money culture.

(ii) If CV holds in the presence of both grand and petty corruption, then compared to the no cut money culture,

(a) Given $CVII$, environmental damage and economic surplus are lower, whereas social welfare is higher under the cut money culture.

(b) Given $CVIII$, environmental damage and economic surplus are higher, whereas social welfare is lower under the cut money culture.

Suppose, petty corruption-induced loss in the monopolist's revenue per unit of extraction is higher than grand corruption-induced distorted valuation of net marginal environmental damage. Under the no cut money culture, from Proposition 1, the social planner sets the extraction quota at e^{GC} in equilibrium. Assuming that the social planner's valuation of welfare gain by choosing e^* over e^{GC} is lower than the social planner's valuation of direct bribe net of cut money, then under the cut money culture, the social planner sets the extraction quota at e^{GC}. Hence, in the presence of both grand and petty corruption, compared to the no cut money culture, environmental damage, economic surplus and social welfare do not change under the cut money culture.

Now, suppose that the social planner's valuation of welfare gain by choosing e^* over

e^{GC} is higher than the social planner's valuation of direct bribe net of cut money. In this case, if the net marginal private benefit from extraction is higher than the grand corruption-induced distorted valuation of net marginal environmental damage, then $e^* + x(e^*) < e^{GC}$. From here, it follows directly that in the presence of both grand and petty corruption, compared to the no cut money culture, environmental damage will be lower under the cut money culture. Additionally, the economic surplus function is maximized at an extraction level higher than e^{UR} which is greater than e^{FB}. Hence, economic surplus is also lower under the cut money culture compared to the no cut money culture. On the other hand, social welfare is maximized at e^{FB}, which is lower than $e^* + x(e^*)$. This implies that compared to the no cut money culture, social welfare is higher under the cut money culture. However, if the net marginal private benefit from extraction is lower than the grand corruption-induced distorted valuation of net marginal environmental damage, then $e^* + x(e^*) > e^{GC}$. As a consequence, in this scenario, compared to the no cut money culture, environmental damage and economic surplus will be higher, whereas social welfare will be lower under the cut money culture.

4 Conclusion

The study compares the impact of grand corruption and petty corruption on environmental damage, economic surplus, and social welfare in the context of natural resource extraction. Results reveal that if petty corruption-induced loss in monopolist's revenue per unit extraction is higher (lower) than grand corruption-induced distortion in valuation of net marginal environmental damage, then optimal extraction quota under grand corruption is higher (lower) than that under petty corruption. Consequently, environmental damage is more (less) pronounced whereas economic surplus is higher (lower) under grand corruption than that under petty corruption. The loss (gain) in welfare due to environmental damage dominates over the gain (loss) in welfare due to high (low) economic surplus under grand corruption compared to petty corruption. Hence, social welfare is lower (higher) under grand corruption than that under petty corruption. Moreover, if the above inequality holds, then compared to only grand (petty) corruption, the presence of both grand and petty corruption leads to higher environmental damage, higher economic surplus, and lower social welfare.

In this analysis, it is assumed that consumers do not distinguish between legally and illegally extracted minerals. Introducing such sensitivity into the model would create separate markets for legal and illegal extraction, potentially impacting the above results. Additionally, the bargaining power of the social planner is assumed to be constant. Endogenizing this parameter could yield further insights. These avenues for future research are worth exploring to enhance the depth and robustness of this analysis.

Appendix A: Proofs

Proof of Lemma 1. From (3) we know that $\left.\frac{d\Pi_{UR}}{de}\right|_{e=e^{UR}} = 0$. Evaluating (4) at $e = e^{UR}$ and by Assumption 1, we have

$$\left.\frac{dO_{FB}}{de}\right|_{e=e^{UR}} = \theta G^{'}(e^{UR}) - D^{'}(e^{UR}) < 0 \tag{30}$$

From (30) and (4), we have $e^{UR} > e^{FB}$ since O_{FB} is concave in e [9]. ■

Proof of Lemma 2. From (4),we have $e^{FB}p'(e^{FB})+p(e^{FB})-C'(e^{FB})+\theta G^{'}(e^{FB})-D^{'}(e^{FB}) = 0$. Also, from (10), we know that $\left.\frac{dO_{GC}}{de}\right|_{e=e^{GC}} = 0$. Evaluating $\frac{dO_{GC}}{de}$ at $e = e^{FB}$, we have

$$\begin{aligned}\left.\frac{dO_{GC}}{de}\right|_{e=e^{FB}} &= \alpha[e^{FB}p'(e^{FB}) + p(e^{FB}) - C'(e^{FB}) + \theta G^{'}(e^{FB}) - D^{'}(e^{FB})] \\ &+ \gamma(1-\alpha)(e^{FB}p'(e^{FB}) + p(e^{FB}) - C'(e^{FB}) \\ &= 0 + \gamma(1-\alpha)(D'(e^{FB}) - \theta G'(e^{FB}))\end{aligned}$$

From Assumption 1, we have $D'(e^{FB}) - \theta G'(e^{FB}) > 0$. Hence, $\left.\frac{dO_{GC}}{de}\right|_{e=e^{FB}} > 0$. Moreover, from (12), we know that O_{GC} is concave in e. Therefore, $e^{GC} > e^{FB}$ when $\alpha \in [0, 1)$ and $\rho = 0$. ■

Proof of Lemma 3. At $\alpha = 0$ and $\rho = 0$, $O^{GC} = \gamma(\Pi_{GC}(e) - \Pi_{GC}(eFB)) = \gamma(ep(e) - C(e) - e^{FB}p(e^{FB}) - C(e^{FB})) = \gamma(\Pi_{UR} - \Pi_{UR}(e^{FB}))$. So, the planner's objective function will be maximized at $e^{GC} = e^{UR}$.

At $\alpha \in (0, 1]$ and $\rho = 0$, from Assumption 1 and $\Pi'_{UR}(e^{UR}) = 0$, we have $\left.\frac{dO_{GC}}{de}\right|_{e=e^{UR}} = \theta G^{'}(e^{UR}) - D^{'}(e^{UR}) < 0$. But $\left.\frac{dO_{GC}}{de}\right|_{e=e^{GC}} = 0$ and O_{GC} is concave in e. Hence, $e^{UR} > e^{GC}$. ■

[9] Since e^{FB} is the global maximum of $O_{FB}(e)$, as per second order conditions $O''_{FB}(e) < 0$ for all e i.e. O_{FB} is concave in e.

Proof of Lemma 5. Using implicit function theorem (IFT) on Equation (10), we have:

$$\frac{de}{d\alpha}\bigg|_{e=e^{GC}} = \Big(\frac{1}{O''_{GC}(e^*)}\Big)\Big(\frac{\gamma \Pi'_{UR}(e^{GC})}{\alpha}\Big) \tag{31}$$

From remark 5 we know that for $\alpha \in (0,1]$, $\Pi'_{UR}(e^{GC}) > 0$. Also, the second order conditions for the planner's maximization problem must be satisfied at e^{GC} i.e. $O''_{GC}(e^{GC}) < 0$.This implies that $\frac{de}{d\alpha}\big|_{e=e^{GC}} < 0$. ■

Proof of Lemma 6. (i) Using implicit function theorem (IFT), we have

$$\frac{\partial x}{\partial \rho}\bigg|_{x=x(e)} = -\frac{p'(e+x)x + p(e+x) - b}{\frac{\partial^2 E\Pi}{\partial x^2}} > 0 \tag{32}$$

From (16), $p'(e+x)x + p(e+x) - b = (\frac{1}{\rho})(C'(e+x) - ep'(e+x)) > 0$. Also, by the monopolist's SOC we have $\frac{\partial^2 E\Pi}{\partial x^2} < 0$. Hence, $\frac{\partial x}{\partial \rho}\big|_{x=x(e)} > 0$ for any given e and b.

(ii) Again, using IFT we have

$$\frac{\partial x}{\partial e}\bigg|_{x=x(e)} = -\frac{(e+\rho x)p''(e+x) + (1+\rho)p'(e+x) - C''(e+x)}{(e+\rho x)p''(e+x) + 2\rho p'(e+x) - C''(e+x)} < 0 \tag{33}$$

Since $p'' < 0$, $p' < 0$, and $C'' > 0$, numerator in the RHS is negative. Therefore, $\frac{\partial x}{\partial e}\big|_{x=x(e)} < 0$ for any given ρ and b. Moreover, the magnitude of the numerator of (33) is greater than the denominator since $\rho < 1$. Hence, $\left(1 + \frac{\partial x}{\partial e}\big|_{x=x(e)}\right) < 0$ or $\left|\frac{\partial x}{\partial e}\big|_{x=x(e)}\right| > 1$.

(iii) Using IFT,

$$\frac{\partial x}{\partial b}\bigg|_{x=x(e)} = -\frac{-\rho}{\frac{\partial^2 E\Pi}{\partial x^2}} < 0 \tag{34}$$

Here, by the monopolist's SOC, $\frac{\partial^2 E\Pi}{\partial x^2} < 0$. This implies $\left.\frac{\partial x}{\partial b}\right|_{x=x(e)} < 0$ for any given ρ and e.

■

Proof of Lemma 7. From assumption 2, $e^{FB} + x(e^{FB}) > e^{FB}$. This implies that the social planner will not be able to rule out the possibility of petty corruption by setting $e = e^{FB}$. Differentiating (15) with respect to e, we have

$$\frac{dO_{PC}}{de} = \left(1 + \frac{\partial x}{\partial e}\right)\Big[(e + x(e))p'(e + x(e)) + p(e + x(e)) - C'(e + x(e)) + \theta G'(e + x(e)) - D'(e + x(e))\Big] \tag{35}$$

Suppose, at $e = 0$, $x(0) \leq e^{FB}$. Now, let the social planner increase e from 0 to e^{FB}. From lemma 6(ii), $\left(1 + \frac{\partial x}{\partial e}\right) < 0$. This implies that x will decrease by more than e^{FB}, or change in x is equal to $-(e^{FB} + \delta_1)$ where $\delta_1 > 0$. This implies that $x(e^{FB}) = x(0) - (e^{FB} + \delta_1) \leq -\delta_1 < 0$, which is in contradiction with Assumption 2.

Thus, $x(0) > e^{FB}$ always holds given Assumption 2. As a consequence, the following holds.

$$\left.\frac{dW}{de}\right|_{e=x(0)} = x(0)p'(x(0)) + p(x(0)) - C'(x(0)) + \theta G'(x(0)) - D'(x(0)) < 0 \tag{36}$$

Therefore, at $e = 0$,

$$\left.\frac{dO_{PC}}{de}\right|_{e=0} > 0 \tag{37}$$

It is evident from (37) that the social planner will increase e from 0. At $e = e^{FB}$, $e^{FB} + x(e^{FB}) > e^{FB}$ which implies that

$$\left.\frac{dO_{PC}}{de}\right|_{e=e^{FB}} > 0 \tag{38}$$

So, in equilibrium, the social planner will set the extraction quota e^{PC} greater than e^{FB}. Now, suppose, the social planner increases the extraction quota from e^{FB} to $\hat{e} > e^{FB}$ such that $\frac{dO_{PC}}{de} = 0$. Then it must be that $(\hat{e} + x(\hat{e}))p'(\hat{e} + x(\hat{e})) + p(\hat{e} + x(\hat{e})) - C'(\hat{e} + x(\hat{e})) + \theta G'(\hat{e} + x(\hat{e})) - D'(\hat{e} + x(\hat{e})) = 0$, or $\hat{e} + x(\hat{e}) = e^{FB}$ which implies that $x(\hat{e}) < 0$, a contradiction since $x(e) \geq 0$ for all $e > 0$. Therefore, O_{PC} is an increasing function in e given the constraint $x(e) \geq 0$. So, the social planner will keep on increasing e till $x(e) = 0$. When $x(e) = 0$, we have

$$\left.\frac{\partial E\Pi}{\partial x}\right|_{x(e)=0} = ep'(e) + \rho p(e) - C'(e) - \rho b \leq 0 \tag{39}$$

At $x(e) = 0$, the social planner's objective function O_{PC} reduces to the social welfare function W. Let $e = e^{PC}$ be such that

$$\left.\frac{\partial E\Pi}{\partial x}\right|_{x(e^{PC})=0} = e^{PC}p'(e^{PC}) + \rho p(e^{PC}) - C'(e^{PC}) - \rho b = 0 \tag{40}$$

For all $e > e^{PC}$, $W(e^{PC}) > W(e)$ since W is concave in e and maximized at $e = e^{FB}$. So, the social planner will find it optimal to set the extraction quota at $e = e^{PC}$. As a consequence, $x(e^{PC}) = 0$

■

Proof of Lemma 8. At $e = e^{UR}$,

$$\frac{d\Pi_{UR}}{de} = e^{UR}p'(e^{UR}) + p(e^{UR}) - C'(e^{UR}) = 0 \tag{41}$$

At $e = e^{PC}$,

$$\left.\frac{dE\Pi}{dx}\right|_{x(e^{PC})=0} = e^{PC}p'(e^{PC}) + \rho p(e^{PC}) - C'(e^{PC}) - \rho b = 0$$
$$\Rightarrow e^{PC}p'(e^{PC}) + p(e^{PC}) - C'(e^{PC}) = p(e^{PC}) - \rho(p(e^{PC}) - b) \tag{42}$$

Computing $\left.\frac{d\Pi_{UR}}{de}\right|_{e=e^{PC}}$ we have,

$$\left.\frac{d\Pi_{UR}}{de}\right|_{e=e^{PC}} = e^{PC}p'(e^{PC}) + p(e^{PC}) - C'(e^{PC}) = p(e^{PC}) - \rho(p(e^{PC}) - b) > 0 \tag{43}$$

Additionally, Π_{UR} is concave in e. Hence, $e^{PC} < e^{UR}$

■

Proof of Proposition 1. From (10) at $e = e^{GC}$

$$\left.\frac{dO_{GC}}{de}\right|_{e=e^{GC}} = 0 \tag{44}$$

$$\Rightarrow [e^{GC}p'(e^{GC}) + p(e^{GC}) - C'(e^{GC})] = \frac{\alpha}{\alpha + \gamma(1-\alpha)}[D'(e^{GC}) - \theta G'(e^{GC})]$$
$$\Rightarrow \left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0} = \frac{\alpha}{\alpha + \gamma(1-\alpha)}[D'(e^{GC}) - \theta G'(e^{GC})] - [p(e^{GC}) - \rho(p(e^{GC}) - b)] \tag{45}$$

Now, $\left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0} < 0$ if

$$p(e^{GC}) - \rho(p(e^{GC}) - b) > \frac{\alpha}{\alpha + \gamma(1-\alpha)}[D'(e^{GC}) - \theta G'(e^{GC})] \tag{46}$$

Additionally,

$$\frac{\partial}{\partial e}\left(\left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0}\right) = ep''(e) + (1+\rho)p'(e) - C''(e) < 0. \tag{47}$$

Hence, $e^{PC} < e^{GC}$ if (46) holds.

When

$$p(e^{GC}) - \rho(p(e^{GC}) - b) < \frac{\alpha}{\alpha + \gamma(1-\alpha)}[D'(e^{GC}) - \theta G'(e^{GC})] \tag{48}$$

then $\left.\frac{\partial E\Pi_{PC}}{\partial x}\right|_{x=0} > 0$. Hence, $e^{PC} > e^{GC}$ if (48) holds. ■

Proof of Proposition 2. (i) Let (46) hold. This implies $e^{PC} < e^{GC}$. Hence, it is immediate that environmental damage will be higher under petty corruption than that under grand corruption.

Now Let $y = y^*$ maximize ES with respect to y. Hence, at $y = y^*$, we have

$$\left.\frac{dES}{dy}\right|_{y=y^*} = y^* p(y^*) + p'(y^*) - C(y^*) + \theta G'(y^*) = 0 \tag{49}$$

Now, $\left.\frac{dES(y)}{dy}\right|_{y=e^{UR}} = e^{UR} p(e^{UR}) + p'(e^{UR}) - C(e^{UR}) + \theta G'(e^{UR})$. From equation (3), $\left.\frac{dES(y)}{dy}\right|_{y=e^{UR}} = \theta G'(e^{UR}) > 0$. Since $ES(y)$ is concave, $e^{UR} < y^*$. Thus Economic surplus under petty corruption will be higher than that under grand corruption.

Since social welfare is maximized at $e = e^{FB}$ and $e^{FB} < e^{PC} < e^{GC}$, it is immediate that social welfare under petty corruption will be higher

(ii) Let (48) hold. This implies $e^{PC} > e^{GC}$. The results mentioned in this part of the proposition are immediate from here.

■

Proof of Lemma 9. From Lemma 6(ii), Assumption 2 and equation (21), it is easy to see that for all $e < e^{PC}$, $x(e) > 0$ and $e^{PC} < e + x(e) < x(0)$. Additionally, at e^{UR},

$$\left.\frac{d\Pi_{UR}}{de}\right|_{e=e^{UR}} = e^{UR}p'(e^{UR}) + p(e^{UR}) - C'(e^{UR}) = 0 \tag{50}$$

and at $x = x(0)$,

$$\left.\frac{dE\Pi}{dx}\right|_{x=x(0)} = \rho p(x(0)) + \rho x(0)p'(x(0)) - C'(x(0)) - \rho b = 0 \tag{51}$$

Putting $e = x(0)$ in (50), we have

$$\begin{aligned}\left.\frac{d\Pi_{UR}}{de}\right|_{e=x(0)} &= p(x(0)) + x(0)p'(x(0)) - C'(x(0)) \\ &= \rho p(x(0)) + \rho x(0)p'(x(0)) - C'(e^{UR}) - \rho b + (1-\rho)[p(x(0)) + x(0)p'(x(0))] + \rho b \\ &= (1-\rho)[p(x(0)) + x(0)p'(x(0))] + \rho b > 0\end{aligned} \tag{52}$$

Since Π_{UR} is concave, from (52) it is evident that $x(0) < e^{UR}$. This implies that $e + x(e) < x(0) < e^{UR}$. Now, differentiating $E\Pi(e, x(e))$ with respect to e such that $x = x(e)$, we have

$$\begin{aligned}\frac{dE\Pi}{de} &= p(e+x) + (e+\rho x)p'(e+x) - C'(e+x) + \frac{\partial E\Pi}{\partial x}\frac{\partial x}{\partial e} \\ &= p(e+x) + (e+x)p'(e+x) - C'(e+x) - (1-\rho)xp'(e+x) \quad [\because \text{ at } x = x(e), \frac{\partial E\Pi}{\partial x} = 0]\end{aligned} \tag{53}$$

Given that $p'(e+x) < 0$, $-(1-\rho)xp'(e+x) > 0$. Additionally, since, $e+x(e) < e^{UR}$ and Π_{UR} is a concave function, hence, $p(e+x)+(e+x)p'(e+x)-C'(e+x) > 0$. As a result, $\frac{dE\Pi}{de} > 0$, or $E\Pi(e, x(e))$ is an increasing function of e. Consequentially, for all $e < e^{PC}$, $E\Pi(e, x(e)) < E\Pi(e^{PC})$ and the monopolist will not have enough profits to bribe the social planner. Thus, the bargaining doesn't go through.

■

Proof of Proposition 3. We know from Proposition 1(ii) that if petty corruption-induced loss in the monopolist's revenue per unit of extraction is lower than the grand corruption-induced distorted valuation of net marginal environmental damage, then $e^{PC} > e^{GC}$. Moreover, from Lemma 9, bargaining doesn't go through for any $e < e^{PC}$. For all $e \geq e^{PC}$, $S(e) \geq 0$ and the social planner's problem is to maximize O_{BC} such that the constraint $e \geq e^{PC}$ is maximized. The only difference between O_{GC} and O_{BC} (for $e \geq e^{PC}$) is the expression for $S(e)$. In the presence of only grand corruption, the threat point for the monopolist is $e^{FB}p(e^{FB}) - C(e^{FB})$, whereas in the presence of both grand and petty corruption, the threat point is $e^{PC}p(e^{PC}) - C(e^{PC})$. The point to be noted over here is that both the threat points are constants. Hence, $\left.\frac{dO_{BC}}{de}\right|_{e \geq e^{PC}} = \frac{dO_{GC}}{de}$. We already know that $\frac{dO_{GC}}{de} = 0$ at $e = e^{GC}(< e^{PC})$. Since, O_{GC} is concave in e, for all $e > e^{GC}$, $\frac{dO_{GC}}{de} < 0$. This implies for all $e > e^{PC}(> e^{GC})$, $\frac{dO_{BC}}{de} < 0$. As a consequence, for all $e > e^{PC}$, $O_{BC}(e^{PC}) > O_{BC}(e)$. Hence, the social planner is better off by setting the equilibrium extraction quota at $e = e^{PC}$. ■

Proof of Proposition 4. We know from Proposition 1(i) that if petty corruption-induced loss in the monopolist's revenue per unit of extraction is higher than the grand corruption-induced distorted valuation of net marginal environmental damage, then $e^{PC} < e^{GC}$. From Lemma 9, bargaining goes through at $e^{GC}(> e^{PC})$. As mentioned in the above proof, the threat point in the presence of only grand corruption and that in the presence of both grand and petty corruption are constants. Hence, $\left.\frac{dO_{BC}}{de}\right|_{e>e^{PC}} = \frac{dO_{GC}}{de}$. We already know that at e^{GC}, $\frac{dO_{GC}}{de} = 0$. This implies that $\left.\frac{dO_{BC}}{de}\right|_{e>e^{PC}} = 0$ at $e = e^{GC}$. Hence, the social planner finds it optimal to set the extraction quota at $e = e^{GC}$. ■

Proof of Proposition 5. (i) If CI holds, then from Proposition 4, the social planner sets the extraction quota at e^{GC}. We know from Lemma 2 that $e^{GC} > e^{FB}$. Hence, environmental damage will be higher compared to the benchmark case of no corruption. As shown in the Proof of Proposition 2, the $ES(y)$ function is maximized at $y^* > e^{UR}$. From Lemma 3, $e^{UR} > e^{GC}$. This implies that $\frac{dES}{dy} > 0$ for all $y < e^{UR}$ as $ES(y)$ is concave. Since $e^{UR} > e^{GC} > e^{FB}$, compared to the benchmark case of no corruption, economic surplus is higher in the presence of both grand and petty corruption. Social welfare function W is maximized at $e^{FB} < e^{GC}$. Since $W(e)$ is concave, compared to the benchmark case of no corruption, social welfare will be lower in the presence of both grand corruption and petty corruption.

If CII holds, then from Proposition 3, the social planner sets the extraction quota at e^{PC}. We know from Lemma 7 that $e^{PC} > e^{FB}$. It follows directly from here that environmental damage will be higher in the presence of both grand and petty corruption compared to the benchmark case of no corruption. Additionally, from Lemma 8, $e^{UR} > e^{PC}$. Hence, economic surplus will be higher in this scenario as well compared to the benchmark case of no corruption. Additionally, social welfare will be lower.

(ii) If CII holds, then from Proposition 3, the social planner sets e^{PC} as the equilibrium extraction quota. Additionally, from 1, $e^{PC} > e^{GC}$. In the presence of only grand corruption, the social planner sets the extraction quota at e^{GC}. Hence, it follows directly that compared to only grand corruption, environmental damage is higher in the presence of both grand and petty corruption. Since $y^* > e^{UR} > e^{PC} > e^{GC}$, and $ES(y)$ is concave and maximized at y^*, compared to only grand corruption, economic surplus will be higher in the presence of both grand and petty corruption. Additionally, $W(e)$ is maximized at e^{FB}, and concave. We already know from Lemma 2, Lemma 7, and Proposition 1 that $e^{PC} > e^{GC} > e^{FB}$. Hence, compared to only grand corruption, social welfare is lower in the presence of both grand and petty corruption.

(iii) If CI holds, then from Proposition 4, the social planner sets e^{GC} as the equilibrium extraction quota. Additionally, from 1, $e^{PC} < e^{GC}$. In the presence of only petty corruption, the social planner sets the extraction quota at e^{PC}. Hence, it follows directly that compared to only petty corruption, environmental damage is higher in the presence of both grand and petty corruption. Since $y^* > e^{UR} > e^{GC} > e^{PC}$, and $ES(y)$ is concave and maximized at y^*, compared to only petty corruption, economic surplus will be higher in the presence of both grand and petty corruption. Additionally, $W(e)$ is maximized at e^{FB}, and concave. We already know from Lemma 2, Lemma 7, and Proposition 1 that $e^{GC} > e^{PC} > e^{FB}$. Hence, compared to only petty corruption, social welfare is lower in the presence of both grand and petty corruption.

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Proof of Lemma 10. Extraction quota that maximizes O^I_{BC} can either be greater than or lower than the first best level of extraction quota. Consider the case where the former holds, or $e^* > e^{FB}$. From Assumption 3, $e^* < e^{PC}$, which implies that $x^{e^*} > 0$. Hence, in this case, $e^* + x(e^*) > e^{FB}$. Suppose that $e^* < e^{FB}$. From

Lemma 6(ii), $e^* + x(e^*) > e^{FB} + x(e^{FB})$, which implies that $e^* + x(e^*) > e^{FB}$ (given that Assumption 2 holds).

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Proof of Proposition 6. If CII is true, then from Proposition 1, $e^{PC} > e^{GC}$. Moreover, there is no difference between O^{II}_{BC} and O_{GC} apart from the expression of the direct bribe, or $S(e)$. In the presence of only grand corruption, $S(e) = \gamma[ep(e) - C(e) - e^{FB}p(e^{FB}) + C(e^{FB})]$, whereas in the presence of both and petty corruption with cut money culture, $S(e) = \gamma[ep(e) - C(e) - e^{PC}p(e^{PC}) + C(e^{PC})]$. Since, last two terms in both the expressions are constant, $\frac{dO_{GC}}{de} = \frac{dO^{II}_{BC}}{de}$. Now, at $e = e^{GC}$, $\frac{dO_{GC}}{de} = 0$, and at $e = e^{PC}$, $\frac{dO_{GC}}{de} = \frac{d)^{II}_{BC}}{de} < 0$ since O_{GC} and O^{II}_{BC} both are concave. Given that O^{II}_{BC} is defined for only $e \geq e^{PC}$, $e = e^{GC}$ is not a solution. Additionally, for all $e > e^{PC}$, $O^{II}_{BC}(e) < O^{II}_{BC}(e^{PC})$. Hence, O^{II}_{BC} is maximized at $e = e^{PC}$. As far as O^{I}_{BC} is concerned, by construction, it is maximized at e^* such that $0 < e^* < e^{PC}$. The social planner sets the equilibrium extraction quota by comparing $O^{I}_{BC}(e^* + x(e^*))$ with $O^{II}_{BC}(e^{PC})$. Subtracting $O^{II}_{BC}(e^{PC})$ from $O^{I}_{BC}(e^* + x(e^*))$, we have

$$\begin{aligned} O^{I}_{BC}(e^* + x(e^*)) - O^{II}_{BC}(e^{PC}) &= \alpha[W(e^* + x(e^*))] + (1-\alpha)\lambda b\rho x(e^*) - \alpha W(e^{PC}) \\ &= \alpha[W(e^* + x(e^*)) - W(e^{PC})] + (1-\alpha)\lambda b\rho x(e^*) \end{aligned} \tag{54}$$

(i) For the social planner to choose e^{PC} over e^*, $O^{I}_{BC}(e^*+x(e^*)) - O^{II}_{BC}(e^{PC}) < 0$, or

$$\underbrace{\alpha[W(e^{PC}) - W(e^* + x(e^*))]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^{PC} \text{ over } e^*} > \underbrace{(1-\alpha)\lambda b\rho x(e^*)}_{\text{Social Planner's Valuation of Cut Money}} \tag{55}$$

which is nothing but condition $CIII$. At e^{PC}, $x(e^{PC}) = 0$

(ii) For the social planner to choose e^* over e^{PC}, $O^I_{BC}(e^*+x(e^*))-O^{II}_{BC}(e^{PC}) > 0$, or

$$\underbrace{\alpha[W(e^{PC}) - W(e^* + x(e^*))]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^{PC} \text{ over } e^*} < \underbrace{(1-\alpha)\lambda b\rho x(e^*)}_{\text{Social Planner's Valuation of Cut Money}} \tag{56}$$

which is nothing but condition CIV. At e^*, $x(e^*) > 0$ since $e^* < e^{PC}$ given Assumption 3.

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Proof of Proposition 7. If CI is true, then from Proposition 1, $e^{GC} > e^{PC}$. Moreover, as mentioned in the previous proof, for all $e \geq e^{PC}$, $\frac{dO_{GC}}{de} = \frac{dO^{II}_{BC}}{de}$. We already know that at e^{GC}, $\frac{dO_{GC}}{de} = 0$. This implies that at e^{GC}, $\frac{dO^{II}_{BC}}{de} = 0$. Since O^{II}_{BC} is concave, it is maximized at $e = e^{GC}$. By construction, O^I_{BC} is maximized at e^*. The social planner chooses between e^{GC} and e^* by comparing $O^I_{BC}(e^* + x(e^*))$ with $O^{II}_{BC}(e^{GC})$. Subtracting $O^{II}_{BC}(e^{GC})$ from $O^I_{BC}(e^* + x(e^*))$, we have

$$\begin{aligned} O^I_{BC}(e^* + x(e^*)) - O^{II}_{BC}(e^{GC}) &= \alpha W(e^* + x(e^*)) + (1-\alpha)\lambda b\rho x(e^*) \\ &\quad - \alpha W(e^{GC}) + (1-\alpha)\gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})) \\ &= \alpha[W(e^* + x(e^*)) - W(e^{GC})] \\ &\quad + (1-\alpha)[\lambda b\rho x(e^*) - \gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})] \end{aligned} \tag{57}$$

(i) For the social planner to pick e^{GC} over e^* as the equilibrium extraction quota, $O^I_{BC}(e^* + x(e^*)) - O^{II}_{BC}(e^{GC}) < 0$, or

$$\underbrace{\alpha[W(e^* + x(e^*)) - W(e^{GC})]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^* \text{ over } e^{GC}} < \underbrace{(1-\alpha)[\gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})) - \lambda b\rho x(e^*)]}_{\text{Social Planner's Valuation of Direct Bribe net of Cut Money}} \tag{58}$$

which is nothing but condition CVI. Since $e^{GC} > e^{PC}$, this implies that $x(e^{GC}) = 0$

(ii) For the social planner to pick e^* over e^{GC} as the equilibrium extraction quota, $O^I_{BC}(e^* + x(e^*)) - O^{II}_{BC}(e^{GC}) > 0$, or

$$\underbrace{\alpha[W(e^* + x(e^*)) - W(e^{GC})]}_{\text{Social Planner's Valuation of Welfare Gain by choosing } e^* \text{ over } e^{GC}} > \underbrace{(1-\alpha)[\gamma(E\Pi(e^{GC}) - E\Pi(e^{PC})) - \lambda b\rho x(e^*)]}_{\text{Social Planner's Valuation of Direct Bribe net of Cut Money}} \tag{59}$$

which is nothing but condition CV. Since, $e^* < e^{PC}$, $x(e^*) > 0$.

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Proof of Proposition 8. When CI is true, the social planner chooses between e^* and e^{GC}. From Lemma 10, we know that $e^* + x(e^*) > e^{FB}$ and from Lemma 2, $e^{GC} > e^{FB}$. Hence, whichever choice the social planner ends up making, total extraction will always be higher than the welfare maximizing extraction quota. Therefore, compared to the benchmark case of no corruption, environmental damage is always higher in the presence of both grand and petty corruption with the cut money culture. The economic surplus function $ES(y)$ is maximized at $y^* > e^{UR}$. Additionally, from proof of Lemma 9, $e^* + x(e^*) < x(0) < e^{UR}$. Also, from Lemma 3, $e^{GC} < e^{UR}$. Since $ES(y)$ is concave, whichever choice the social planner makes, compared to the benchmark case of no corruption, economic surplus will always be higher in the presence of both grand and petty corruption with the cut money culture. The social welfare function is maximized at e^{FB} which is less than both $e^* + x(e^*)$ and e^{GC}. Whichever choice the social planner makes, compared to the benchmark case of no corruption, social welfare will always be lower in the presence of both grand and petty corruption with the cut money culture.

When CI is true, the social planner chooses between e^* and e^{PC}. From Lemma

10, we know that $e^* + x(e^*) > e^{FB}$ and from Lemma 7, $e^{PC} > e^{FB}$. Hence, whichever choice the social planner ends up making, total extraction will always be higher than the welfare maximizing extraction quota. Therefore, compared to the benchmark case of no corruption, environmental damage is always higher in the presence of both grand and petty corruption with the cut money culture. The economic surplus function $ES(y)$ is maximized at $y^* > e^{UR}$. Additionally, from proof of Lemma 9, $e^* + x(e^*) < x(0) < e^{UR}$. Also, from Lemma 8, $e^{PC} < e^{UR}$. Since $ES(y)$ is concave, whichever choice the social planner makes, compared to the benchmark case of no corruption, economic surplus will always be higher in the presence of both grand and petty corruption with the cut money culture. The social welfare function is maximized at e^{FB} which is less than both $e^* + x(e^*)$ and e^{PC}. Whichever choice the social planner makes, compared to the benchmark case of no corruption, social welfare will always be lower in the presence of both grand and petty corruption with the cut money culture. ∎

Proof of Proposition 9. If CII is true, then from Proposition 6, the social planner chooses between e^* and e^{PC} in the presence of both grand and petty corruption with the cut money culture. Also, from Proposition 3, the social planner chooses e^{PC} in the presence of both grand and petty corruption without the cut money culture.

(i) If $CIII$ holds, then from Proposition 6, the social planner chooses e^{PC} as the equilibrium extraction quota in the presence of both grand and petty corruption with the cut money culture. Hence, compared to the no cut money culture, environmental damage, economic surplus and social welfare do not change under the cut money culture.

(ii) If CIV holds, then from Propostion 6, the social planner chooses e^* as the equilibrium extraction quota in the presence of both grand and petty corruption with the cut money culture. From Lemma 6, $e^* + x(e^*) > e^{PC}$, which implies that environmental damage under cut money culture is higher than that under no cut money culture. The economic surplus function $ES(y)$ is maximized at $y^* > e^{UR}$. From the proof of Lemma 9, $e^{UR} > e^* + x(e^*) > e^{PC}$. Since $ES(y)$ is concave, compared to the no cut money culture, economic surplus is higher under the cut money culture. The social welfare function $W(e)$ is maximized at e^{FB}. Since $e^* + x(e^*) > e^{PC} > e^{FB}$, compared to the no cut money culture, social welfare will be lower under the cut money culture.

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Proof of Proposition 10. If CI is true, then from Proposition 7, in the presence of both grand and petty corruption with the cut money culture, the social planner chooses between e^* and e^{GC}. Also, from Proposition 4, in the presence of both grand and petty corruption without the cut money culture, the social planner chooses e^{GC}.

(i) If CVI holds, then from Proposition 7, the social planner chooses e^{GC} as the equilibrium extraction quota under the cut money culture. Hence compared to the no cut money culture, environmental damage, economic surplus and social welfare do not change under the cut money culture.

(ii) If CV holds, then from Proposition 7, the social planner chooses e^* as the equilibrium extraction quota under the cut money culture. Now computing $\frac{dO_{GC}}{de}$ at $e = e^* + x(e^*)$, we have

$$\left.\frac{dO_{GC}}{de}\right|_{e=e^*+x(e^*)} = \underbrace{[p(e^*+x(e^*)) + (e^*+x(e^*))p'(e^*+x(e^*)) - C'(e^*+x(e^*))]}_{\text{Net Marginal Private Benefit}} - \underbrace{\left(\frac{\alpha}{\alpha+\gamma(1-\alpha)}\right)[D'(e^*+x(e^*)) - \theta G'(e^*+x(e^*))]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}} \tag{60}$$

(a) For $e^* + x(e^*) < e^{GC}$, $\left.\frac{dO_{GC}}{de}\right|_{e=e^*+x(e^*)} > 0$, or

$$\underbrace{[p(e^*+x(e^*)) + (e^*+x(e^*))p'(e^*+x(e^*)) - C'(e^*+x(e^*))]}_{\text{Net Marginal Private Benefit}} > \underbrace{\left(\frac{\alpha}{\alpha+\gamma(1-\alpha)}\right)[D'(e^*+x(e^*)) - \theta G'(e^*+x(e^*))]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}} \tag{61}$$

which is nothing but condition $CVII$. This implies that environmental in this case, compared to the no cut money culture, environmental damage will be lower. As mentioned before, $ES(y)$ is maximized at $y^* > e^{UR} > e^{GC} > e^* + x(e^*)$. Since $ES(y)$ is concave, compared to the no cut money culture, economic surplus will be lower under the cut money culture. The social welfare function $W(e)$ is maximized at $e^{FB} < e^* + x(e^*) < e^{GC}$. Since $W(e)$ is concave, compared to the no cut money culture, social welfare will be higher under the cut money culture.

(b) For $e^* + x(e^*) > e^{GC}$, $\left.\dfrac{dO_{GC}}{de}\right|_{e=e^*+x(e^*)} < 0$, or

$$\underbrace{[p(e^* + x(e^*)) + (e^* + x(e^*))p'(e^* + x(e^*)) - C'(e^* + x(e^*))]}_{\text{Net Marginal Private Benefit}} <$$
$$\underbrace{\left(\frac{\alpha}{\alpha + \gamma(1-\alpha)}\right)[D'(e^* + x(e^*)) - \theta G'(e^* + x(e^*))]}_{\text{Grand Corruption-induced Distorted Valuation of Net Marginal Environmental Damage}} \tag{62}$$

which is nothing but condition $CVIII$. This implies that environmental in this case, compared to the no cut money culture, environmental damage will be higher. As mentioned before, $ES(y)$ is maximized at $y^* > e^{UR} > e^* + x(e^*) > e^{GC}$. Since $ES(y)$ is concave, compared to the no cut money culture, economic surplus will be higher under the cut money culture. The social welfare function $W(e)$ is maximized at $e^{FB} < e^{GC} < e^* + x(e^*)$. Since $W(e)$ is concave, compared to the no cut money culture, social welfare will be lower under the cut money culture.

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