WP-2023-009

Corruption-Proof Minimum Regulation for ‘Zero Emission’: Status Incentives – Bane or Boon?

Preksha Jain and Rupayan Pal

Indira Gandhi Institute of Development Research, Mumbai
September 2023

Corruption-Proof Minimum Regulation for ‘Zero Emission’: Status Incentives – Bane or Boon?

Preksha Jain and Rupayan Pal

Email(corresponding author): rupayan@igidr.ac.in

Abstract

This paper explores the possibility of designing environmental regulation that ensures ‘zero emission’, by promoting non-polluting ‘green’ technology adoption by firms, without creating new rooms for corruption. It demonstrates that it is feasible to implement the ‘target equilibrium’, in which there is ‘no emission and no corruption’, through environmental regulation alone. It also characterizes the ‘target equilibrium’ implementing ‘minimum environmental regulation’, which corresponds to the least possible subsidy expenditure and the lowest possible tax burden on firms, in alternative scenarios. More interestingly, it shows that, in the presence of corruption possibilities, introduction of reputation enhancing non-monetary incentives for ‘green’ technology adoption makes it harder to implement the ‘target equilibrium’. It underscores that usefulness of status incentives to nudge firms’ behaviour for environmental protection is rather limited. These are robust results.

Keywords: Zero Emission; Corruption; Minimum Environmental Regulation; Non-monetary Status Incentive; Brown Tax; Green Technology Subsidy

JEL Code: Q58; H23; Q52; D73

Acknowledgements:

We are thankful to Indraneel Dasgupta and Maitreesh Ghatak for their comments and suggestions, and to Prasenjit Banerjee for sharing some related literature. An earlier version was circulated as “The environment and corruption: monetary vs. non-monetary incentives and the first best”.

Corruption-Proof Minimum Regulation for ‘Zero Emission’: Status Incentives – Bane or Boon?

Preksha Jain and Rupayan Pal*

Indira Gandhi Institute of Development Research (IGIDR), India

Abstract: This paper explores the possibility of designing environmental regulation that ensures ‘zero emission’, by promoting non-polluting ‘green’ technology adoption by firms, without creating new rooms for corruption. It demonstrates that it is feasible to implement the ‘target equilibrium’, in which there is ‘no emission and no corruption’, through environmental regulation alone. It also characterizes the ‘target equilibrium’ implementing ‘minimum environmental regulation’, which corresponds to the least possible subsidy expenditure and the lowest possible tax burden on firms, in alternative scenarios. More interestingly, it shows that, in the presence of corruption possibilities, introduction of reputation enhancing non-monetary incentives for ‘green’ technology adoption makes it harder to implement the ‘target equilibrium’. It underscores that usefulness of status incentives to nudge firms’ behaviour for environmental protection is rather limited. These are robust results.

Keywords: Zero Emission; Corruption; Minimum Environmental Regulation; Non-monetary Status Incentive; Brown Tax; Green Technology Subsidy

JEL Classifications: Q58; H23; Q52; D73

Corresponding Author and Address: Rupayan Pal, Indira Gandhi Institute of Development Research (IGIDR), Film City Road, Santosh Nagar, Goregaon (E), Mumbai 400065, India. Phone: +91-22-69096545.Email: (Pal) rupayan@igidr.ac.in; rupayanpal@gmail.com. (Jain) preksha3011@gmail.com.

Acknowledgements: We are thankful to Indraneel Dasgupta and Maitreesh Ghatak for their comments and suggestions, and to Prasenjit Banerjee for sharing some related literature. An earlier version was circulated as “The environment and corruption: monetary vs. non-monetary incentives and the first best”.

Declarations of interest: None

1. Introduction

Climate change and corruption are two of the biggest threats to the planet and its inhabitants. The Intergovernmental Panel on Climate Change (IPCC) has warned that the increasing trend of global warming must be reined in below the 1.5^0C mark, else it would be calamitous for the world. IPCC has also asserted that "limiting warming to 1.5^0C implies reaching net-zero CO_2 emissions globally around 2050 and concurrent deep reductions in non-CO_2 forcers" (IPCC, 2018).[1] On the other hand, corruption, i.e., abuse of entrusted power for private gain, is highly contagious in nature. It tends to intensify over time and hinders socio-economic prosperity through various channels: by eroding moral values and social trust, curbing health and educational outcomes, reducing productive investment and institutional quality, increasing socio-economic inequality, promoting conflict and political instability, exacerbating environmental crisis, so on and so forth.[2] It implies that corruption inflicts colossal costs to societies, the environment and economies. Unfortunately, corruption is prevalent in most (if not all) countries in the world, albeit in varying degrees of severity. Clearly, there is need to design appropriate regulatory mechanism to attain the target of net zero emission and to eradicate corruption.

It is well argued that there are two-way effects between regulation and corruption: corruption reduces effectiveness of regulations, and regulations often create rooms for corruption (Gordon and Hafer, 2005; Damania et al, 2004; Acemoglu and Verdier, 2000; Kaller et al, 2018; Feng and Liao, 2016;). Thus, while designing regulation to attain the target of net zero emission, it is necessary, not only to take into account the presence of corruption, but also to ensure that the proposed regulation does not widen the scope for corruption. This is particularly important because of the following reasons. First, in most countries tasks to design environmental regulations and corruption control mechanisms are entrusted upon different government departments, and there is often lack of inter-departmental coordination. Second, corruption is a deep-rooted problem and in the short run one can expect a rather limited change in corruption scenario at the best, even if a well-designed corruption control mechanism is implemented in its true spirit. For example, Sweden, which is considered to be one of the least corrupt democracies today, took more than fifty years to make significant progress in corruption reduction, despite implementing a 'big bang' type reform to curtail corruption

[1] IPCC (2022) reconfirms these estimates.

[2] See, for example, Schram (2022), Demant and Tosato (2018), Sui et al (2018), López-Valcárcel et al (2017), Innes and Mitra (2013), Aidt (2009), Bardhan (1997) and Wolfensohn (1996).

(Rothstein, 2011). Therefore, it seems to be necessary to examine the feasibility to attain the target of net zero emission through environmental regulation alone, without creating new rooms for corruption, which is the focus of this paper.

Traditionally, studies on regulation and incentives assume that economic agents are purely self-interested and primarily focus on designing incentive schemes in monetary terms to promote socially desirable actions. Recently, a growing stream of literature allows for non-standard behavioral preferences of economic agents. It is argued that economic agents may have social preferences, and they may care about relative status/reputation in the society, albeit in varying degrees (Benabou and Tirole, 2006; Levitt and List, 2007; Charness and Rabin, 2002; Tran and Zeckhauser, 2012; Bruhin et al, 2019; Breza and Chandrasekhar, 2019). Further, status enhancing non-monetary incentives, such as medals, certification, felicitation, etc. for doing the 'right' thing, are argued to be useful instruments to attain the desired outcome at a lower cost (Besley and Ghatak, 2008; Kosfeld and Neckermann, 2011; Banerjee et al. 2021). The usefulness of non-monetary status incentive stems from its scarcity value (Besley and Ghatak, 2008). Several experimental studies have also highlighted the effectiveness of non-monetary incentives in many different scenarios.[3] However, these studies have sidestepped the issue of corruption. The question is, is non-monetary incentive effective to induce agents to 'take pro-environmental actions and to refrain from engaging in corrupt practice'?

Consider a scenario in which there is a set of firms, and each firm can choose its production technology from the available pool of equally efficient technologies, which includes a polluting 'brown' technology and a non-polluting 'green' technology. However, the cost of green technology adoption is such that, although firms have intrinsic valuation for the environment, no firm has an incentive to adopt it in absence of any regulatory intervention. There is a benevolent social planner, whose aim is to induce each firm to adopt the green technology. The set of regulatory instruments available to the social planner is assumed to include the following. (i) A direct tax on polluting firms (henceforth, brown firms), which is referred to as 'brown tax'. (ii) A subsidy to the supplier(s) of the green technology that reduces

---

[3] See, for example, Shogren et al (2010), Duflo et al (2011), Bradler et al (2016), Erkal et al (2018) and Lefebvre and Stenger (2020).
In 2017, the Maharashtra Pollution Control Board (MPCB) launched a new Star Rating Programme to control air pollution from industries. Under this scheme, rating of the industries happens based on the density of fine particulate pollution coming from their smokestacks. The best performing industries are given five stars while the worse are given one star and this information is made public. Similar schemes are present in different regions as well. To name a few, like the United States Toxic Release Inventory (TRI), the Program for Pollution Control Evaluation and Rating (PROPER) in Indonesia, AKOBEN in Ghana and the India Centre for Science and Environment Green Rating Programme in India.

the cost of green technology adoption, which is referred to as 'green technology subsidy'. Note that the green technology subsidy is essentially an indirect subsidy to non-polluting firms (henceforth, green firms). (iii) A non-monetary status incentive in the form of green certification for green firms only. Recipients of the green certificate gets honor, while non-recipients are stigmatized in the society. Honor (stigma) is decreasing (increasing) in the number of green certificate recipients, and the distance between a recipient's honor and a non-recipient's stigma determines a firm's reputation in the society *a la* Benabou and Tirole (2006). Firms are assumed to be heterogeneous in terms of their valuation for reputation, while in all other respects they are identical to each other. For simplicity, it is assumed that only a subset of firms is concerned about reputation, while others do not.

A firm's technology choice is its private information. However, for effective implementation of the regulation, it is necessary to identify each firm's type – green or brown. To overcome this problem, the social planner undertakes firm-level inspection by officials. Post technology choice, each firm is inspected by an official, who correctly identifies the technology in use and is supposed to report truthfully. However, inspecting officials may utilize their informational advantages to seek/accept bribe: a brown firm may bribe to misreport its type, and a green firm may bribe to avoid the possibility of being misreported. Inspecting officials are heterogeneous in terms of their privately known intrinsic cost of being corrupt, the distribution of which is common knowledge. There is an exogenously determined corruption control mechanism in place, which includes a random audit system and a penalty structure, and on which the social planner cannot exert any influence.[4] The corruption control mechanism is such that it can induce only a fraction of inspecting officials, whose intrinsic cost of being corrupt is sufficiently high, to act honestly. So, the social planner faces a two-fold problem. She needs to design the regulatory mechanism such that it induces each firm to adopt the green technology and no firm finds it incentive compatible to bribe.

Considering a four-stage sequential move game corresponding to the above-mentioned scenario, this paper demonstrates the following. It is feasible to achieve the target of 'zero emission and no corruption' through environmental regulation alone, which involves either (i) only a brown tax or (ii) a combination of a brown tax and a green technology subsidy, depending on whether the cost of green technology adoption is sufficiently low or not. It also characterizes the 'lowest-subsidy minimum-tax' regulation that implements the 'target

[4] A separate department/agency, viz. Corruption Control Bureau, determines the random audit mechanism and penalty structure.

equilibrium' in which there is 'zero emission and no corruption'. More interestingly, this paper shows that the presence of social reputation enhancing non-monetary incentive for green technology adoption makes it harder, by putting an extra burden on the government exchequer, to achieve the target. This is in sharp contrast to the findings of existing studies that focuses on behavioral incentives. Intuitions behind these results are as follows.

First consider that each firm offers an exogenously fixed amount of bribe *a la* Amir and Burr (2015), firms (i.e., bribers) initiate corrupt transactions *a la* Bayer (2005), and there is no non-monetary incentive. Since the two alternative technologies are equally efficient and the green technology is costly, the brown tax needs to be greater than a critical level (henceforth, 'critical greening level') for the green technology adoption to be incentive compatible. On the other hand, a higher brown tax makes 'hiding by bribing' more profitable for brown firms, since by pretending to be green it can evade a larger tax liability. Further, a higher brown tax also results in a greater incentive of green firms to bribe, since in that case a green firm can avoid a larger amount of tax liability by avoiding being mis-reported as brown. Thus, to induce each firm to refrain from bribing, the brown tax must be sufficiently low. The highest possible brown tax that induces each firm not to bribe is referred to as 'no-bribe brown tax'. It is easy to observe that an increase in the cost of green technology adoption leads to an increase the 'critical greening level' of brown tax, while the 'no-bribe brown tax' remains unchanged. Now, it is feasible to implement the 'target equilibrium' by imposing a brown tax alone, if and only if the 'critical greening level' of brown tax is less than the 'no-bribe brown tax'. This is possible only if the cost of green technology adoption is sufficiently low. Otherwise, if the cost of green technology adoption is not sufficiently low, a technology subsidy is necessary to make the 'critical greening level' of brown tax to be less than the 'no-bribe brown tax'.

Next, suppose that the social planner offers the non-monetary incentive along with the tax-subsidy scheme. In this scenario, a reputation concerned firm obtains a higher (lower) payoff, if it receives (fails to receive) the green certificate. It implies that reputation concerned firms have greater incentives to adopt the green technology as well as to bribe, compared to those in absence of the non-monetary incentive. Therefore, in the presence of non-monetary incentives the highest possible brown tax that can be set without providing incentives to bribe is less than the 'no-bribe brown tax'. On the other hand, while the minimum brown tax necessary to induce reputation concerned firms to adopt the green technology is less than that in absence of non-monetary incentive, the corresponding brown tax necessary to induce green technology adoption by non-reputation concerned firms does not depend on whether there is non-monetary incentive or not. As a result, to induce each firm to be green, the brown tax must be greater than the 'critical greening level' brown tax. It follows that, to implement the 'target equilibrium' in the presence of non-monetary incentives, the upper limit of the cost of green technology must be less than corresponding upper limit in absence of non-monetary incentive. That is, the presence of non-monetary incentive reduces the scope of the 'target equilibrium' implementation only through a brown tax. Moreover, if the cost of green technology adoption is higher than the upper limit under non-monetary incentive, (i) a lower brown tax is necessary to counter reputation concerned firms' reputational payoff from bribing, and (ii) a lower brown tax calls for a higher green technology subsidy to induce green technology adoption by non-reputation concerned firms. Clearly, when the direct corruption control mechanism is not effective to nullify corruption possibilities, implementation of the 'target equilibrium' in the presence of non-monetary incentive requires setting a lower brown tax and a higher green technology subsidy compared to those in case of only tax-subsidy regulation, unless the cost of green technology adoption is very low. This result completements Charness et al. (2014)'s findings from an experimental study on implications of performance-linked status incentives within organization, which suggest that non-monetary incentive schemes may aggravate the problem of corruption.

The underlying mechanism remains the same in case corrupt transactions are initiated by inspecting officials (i.e., bribees), except that firms do not face any risk of being penalized by offering bribe to an official who is not interested in taking bribe, unlike as in case firms initiate corrupt transaction. As a result, ceteris paribus, firms' expected gain from bribing is higher under bribee-initiated corrupt transactions compared to that under briber-initiated corrupt transactions. It calls for a lower brown tax to dissuade firms from bribing under bribee-initiated corrupt transactions, which in turn makes it necessary to set a higher technology subsidy to promote green technology adoption. This is because, a lower brown tax increases the effective relative cost of green technology adoption. The presence of non-monetary incentive requires to further reduce the brown tax and increase the green technology subsidy to implement the 'target equilibrium'.

In an alternative scenario in which bribe amount is endogenously determined through bargaining between firm-official pairs, the possibility of corruption can be completely ruled out if it is feasible to ensure that a firm's maximum willingness to pay as bribe is less than the minimum acceptable bribe amount of the official with the lowest intrinsic cost of being corrupt. This paper shows that it is indeed feasible to satisfy this necessary and sufficient condition for no corruption by setting the brown tax appropriately. The reason is, firm's maximum willingness to pay as bribe is increasing in the brown tax, while official's minimum acceptable bribe amount does not depend on it. Given this, the subsidy amount to the green technology seller needs to be adjusted to satisfy firm's incentive compatibility condition for green technology adoption. Implications of non-monetary incentives in the case remains the same as before.

This paper makes two important contributions. First, it offers new insights in designing environmental regulation under corruption. While there is a two-way relationship between corruption and the environment, it shows that it is possible to achieve the target of zero emission without creating new rooms for corruption through environmental regulation alone. Second, to the best of our knowledge, this is one of the first studies to demonstrate that non-monetary status incentives can backfire in the presence of corruption possibilities by developing a theoretical framework. It highlights that the role of status incentives in the context of environmental regulation is rather limited since most countries suffer from the problem of corruption, albeit in varying degrees.

The rest of the paper is organized as follows. Section 2 presents the benchmark model and characterizes the 'lowest-subsidy minimum-tax' regulation that implements the 'target equilibrium' in absence of non-monetary incentives. Section 3 analyses the role of non-monetary incentive under corruption by allowing for heterogeneity in terms of firms' concern for social reputation. Implications of alternative norms for corruption and endogenous determination of bribe rate through bargaining are presented in Section 4. Section 5 concludes. Proofs and technical details are presented in the Appendix.

2. The Benchmark Model: No Status Incentive

Suppose that there are two different technologies, 'green' and 'brown', available to produce a good. Both technologies are equally efficient in the sense that production through either of the two technologies involve zero marginal cost of production. However, these two technologies differ from each other in terms of their implications to the environment. The 'green' technology is environment friendly, whereas production through the 'brown' technology emits pollutants. Further, adoption of the 'green' technology is costlier compared to the 'brown' technology. A firm must incur cost $c(> 0)$ to adopt the 'green' technology, while adoption cost of the 'brown' technology is normalized to be equal to zero.[5]

There are n risk neutral firms in the industry. Each firm chooses its technology type – green or brown (henceforth, a 'green' technology adopting firm will be referred to as a 'green firm', and a 'brown' technology adopting firm as a 'brown firm'). A firm's technology choice is its private information, and, thus, its true type is not publicly observable. Each firm produces $y\ (> c)$ amount the good and sells at a price equal to one, regardless of whether it is green or brown. A brown firm emits $e(> 0)$ units of pollutants, while the green firm does not emit any.

A firm suffers from intrinsic cost $v_E e$ if it emits e units, where $v_E(> 0)$ is a firm's intrinsic valuation for the environment. By being green, a firm can avoid such cost. Therefore, a firm's effective cost of green technology adoption is $v_T c - v_E e$, where v_T is a firm's intrinsic valuation for money. We assume that $v_E e < v_T c$, i.e., in absence of any regulatory intervention, firms do not have any incentive to adopt the green technology.

Marginal environmental damage due to emission is assumed to be sufficiently high and, thus, it is necessary to ensure zero emission by firms. This is consistent with the argument that countries must commit to ensure 'net zero' emission to avoid climate catastrophe and ensure sustainability.[6] The benevolent social planner, thus, aims to induce each firm to adopt the green technology through regulatory intervention. We first consider that the regulatory intervention involves (i) a tax $t\ (\geq 0)$ on brown firms and (ii) a subsidy ζs to green technology seller(s), which effectively reduces each firm's cost of green technology adoption from c to $(c - s)$; $0 \leq s \leq c, \zeta \geq 1$.[7] For any given n, a higher value of the parameter ζ indicates that the technology subsidy scheme is less effective.

For effective regulatory intervention, it is necessary for the social planner to identify each firm's type – green or brown, which are publicly unobservable. To mitigate the information asymmetry the social planner appoints officials, who can correctly identify firm's type upon inspection, by offering exogenously determined wage w.[8] However, officials may

---

[5] This is the same as considering that each firm's existing production technology is brown and each of them can upgrade to green technology by incurring cost c.

[6] IPCC (2018 & 2022). See also https://climateactiontracker.org/methodology/net-zero-targets/#:~:text=As%20of%20March%202022%2C%2033,target%20(ECIU%2C%202021)

[7] We abstract away from the details of the technology market for simplicity. Note that reduced tariff to facilitate green technology transfer, incentives to expand capacity, production-linked-subsidy to green technology producers, etc. are commonly observed phenomenon.

[8] It is a common practice in many countries, including India, to offer fixed salaries to government employees. Moreover, employees in the same rank, but works in different departments, get the same salary. That is, wage-parity is maintained across different departments. Further, wages and salaries are revised only with a long gap (5 to 10 years) in between two revisions. For example, in India, since 1947, only seven pay-commissions have been set up by the Central Government

exploit the information advantage and report a firm as green only in exchange of bribe b, regardless of the firm's true type. Brown firms may bribe to pass on as green and evade tax, while green firms may bribe to avoid being misreported.

There is an exogenously determined random audit mechanism in place to control corruption. Given the efficiency of the random audit mechanism, a corrupt official gets off safely with probability ρ $(0 < \rho < 1)$, while the probability of getting caught is $1 - \rho$. Once caught, the official loses all his income $(w + b)$ and the firm needs to pay fine $f(> 0)$.[9] Further, detection of corrupt dealings by audit agency reveals involved firms' true technology choices and tax liabilities are settled accordingly.[10]

We assume that officials are heterogeneous with respect to their (psychological) intrinsic cost, h, of being corrupt. h is continuously distributed with positive density $z(h)$ and cumulative distribution $Z(h)$ over the interval $[\underline{h}, \bar{h}] \subset \mathbb{R}$. An official's type is his private information. However, the distribution of h is common knowledge. The incentive compatibility condition (ICC) of an h-type official to accept bribe b can be written as follows.

$$\rho(w + b) - h > w \Leftrightarrow h < \rho(w + b) - w = \hat{h}(b) \Leftrightarrow b > \underline{b}(h) = \frac{h + (1 - \rho)w}{\rho}$$

Clearly, (a) if $\hat{h}(b) \leq \underline{h} \Leftrightarrow b \leq \frac{\underline{h}+(1-\rho)w}{\rho} = \underline{b}(\underline{h})$, no official will engage in corruption, and (b) if $\hat{h}(b) \geq \bar{h} \Leftrightarrow b \geq \frac{\bar{h}+(1-\rho)w}{\rho} = \underline{b}(\bar{h})$, no official will act honestly. It follows that, if $b \in (\underline{b}(\underline{h}),\ \underline{b}(\bar{h}))$, an official will act honestly with probability $\lambda = 1 - F(\hat{h}(b))$ and he will engage in corruption with probability $1 - \lambda = F(\hat{h}(b))$; $\lambda \in (0, 1)$.

We begin with the scenario in which officials do not ask for bribe upfront. Owners of firms, who are uncertain about the type of the official, need to decide whether to offer a bribe or not, i.e., bribers initiate corrupt transactions a la Bayer (2005). The bribe amount b is exogenously fixed a la Amir and Burr (2015), and it is such that $b \in (b^0(\underline{h}),\ b^0(\bar{h}))$.[11] Thus, in absence of bribe payment, firms perceive that it will be truthfully reported with probability

(https://web.archive.org/web/20140815234718/http://7cpc.india.gov.in/about_us.html). It implies that the social planner, who has been entrusted with the task to promote green technology adoption, often enjoys a very limited degrees of flexibility in setting wages for the inspecting officials employed.

[9] That is, corrupt officials are subject to limited liability constraint. We do not impose any limited liability constraint on firms. Thus, the departure from a frictionless world is due to existence of externality, noisy detection technology and limited liability of officials. While this setup is simplistic, it helps to identify the problem of pollution control in a corrupt society in a clearer manner.

[10] By 'corrupt dealings' we mean illegal transfer of money from firms to officials.

11 We extend the analyse to allow for (a) endogenous determination of bribe amount through bargaining and (b) bribee initiated corrupt transaction in Section 4.

λ, while with probability $1-\lambda$ it will be reported as brown. On the other hand, if a firm offers bribe, (a) with probability λ the official will reject the offer, report truthfully, and the firm will have to pay fine f for offering bribe; and (b) with probability $1-\lambda$ the official will accept the bribe and report the firm as green. This is true regardless of the firm's true type.[12]

As argued before, corruption inflicts colossal cost to the society, economy and the environment. Thus, in the present context, we consider that the social planner is tasked with inducing firms to adopt the green technology and at the same time she needs to ensure that corruption does not take place.

We also consider that the opportunity cost of government expenditure is very high, and, at the same time, a higher brown tax is politically less viable. Therefore, the social planner's objective is to achieve zero emission without inviting corruption by designing a tax-subsidy scheme, such that (a) the government expenditure on green technology subsidy is at its lowest possible level and (b) given the green technology subsidy, the corresponding brown tax is at its minimum necessary level (henceforth, '*lowest-subsidy minimum-tax*').

Definition 1 (The Target Equilibrium)*: An equilibrium outcome is the target equilibrium outcome, if in that equilibrium no firm bribes and all firms adopt the green technology, i.e., if that equilibrium ensures 'zero emission and no corruption'.*

Since corruption control mechanisms can bring only limited success in the short run, as discussed before, it seems to be important to examine the feasibility to implement the target equilibrium through environmental regulation alone, keeping possible direct instruments to control corruption (e.g., audit efficiency and penalties) as exogenously given.

We consider that there is a four-stage sequential move game as follows.

Stage 1: The social planner decides the brown tax $t\ (\geq 0)$ and the amount of subsidy $\zeta s(\geq 0)$ to green technology seller(s) with the objective to implement the target equilibrium, such that ζs and t satisfy the 'lowest-subsidy minimum-tax' criterion.

Stage 2: Each firm, simultaneously and independently, decides its type of production technology – green or brown.

Stage 3: Each firm is inspected by an official, who correctly identifies the firm's type. Following the inspection, each firm decides whether to offer bribe b to the official or

[12] We assume that, in case a truly green firm is reported as brown for not bribing, the firm may appeal for a redressal service. However, it involves a sufficiently long waiting period, costly procedures, and uncertain outcome, which discourages firms to appeal for redressal. While this assumption may appear to be simplistic, it conforms with the ground reality in many developing countries. In contrast, if inspecting officials report that a firm attempted to bribe, fine (f) gets imposed on that firm.

not. If a firm offers bribe b, regardless of its true type, it is reported as green with probability $1-\lambda$, and with probability λ it pays fine f and the official reports its true type. On the other hand, if a firm does not offer bribe, it is reported as brown with probability $1-\lambda$ and its true type is reported with probability λ. If a firm is reported as brown, it pays tax t.

Stage 4: Random audit takes place. If a corrupt transaction is detected, both parties involved in that transaction are penalized: the official loses all his income $w+b$, and the firm pays fine f (fine f plus tax t) if it is truly green (brown). Payoffs are realized.

We solve the game via backward induction method.

Let us first consider that the planner does not offer any subsidy, i.e., $s=0$. Note that the last stage (i.e., Stage 4) is trivial. In Stage 3, each firm compares its payoff with and without bribing and accordingly decides whether to bribe the official or not. Let $\pi_{B,B}$ and $\pi_{B,NB}$ ($\pi_{G,B}$ and $\pi_{G,NB}$) denote, respectively, expected payoffs of a brown (green) firm when it bribes and when it does not bribe. Then, we have the following.

$$\pi_{B,B} = (v_T y - v_E e - v_T t - v_T f)\lambda + (v_T y - v_E e - v_T b)(1-\lambda)\rho + (v_T y - v_E e - v_T t - v_T b - v_T f)(1-\lambda)(1-\rho) \quad (1)$$

$$\pi_{B,NB} = v_T y - v_E e - v_T t \quad (2)$$

$$\pi_{G,B} = (v_T y - v_T c - v_T f)\lambda + (v_T y - v_T c - v_T b)(1-\lambda)\rho + (v_T y - v_T c - v_T b - v_T f)(1-\lambda)(1-\rho) \quad (3)$$

$$\pi_{G,NB} = (v_T y - v_T c)\lambda + (v_T y - v_T c - v_T t)(1-\lambda)\rho + (v_T y - v_T c)(1-\lambda)(1-\rho). \quad (4)$$

We consider that a firm will offer bribe if its expected payoff from bribing is strictly greater than that from not bribing. Therefore, ICCs of brown and green firms to bribe are as in (5) and (6), respectively.

ICCs to Bribe

Brown Firm: $\pi_{B,B} > \pi_{B,NB} \Leftrightarrow t > \frac{b(1-\lambda)+f\lambda+f(1-\lambda)(1-\rho)}{\rho(1-\lambda)} = \underline{t^C}$ (5)

Green Firm: $\pi_{G,B} > \pi_{G,NB} \Leftrightarrow t > \frac{b(1-\lambda)+f\lambda+f(1-\lambda)(1-\rho)}{\rho(1-\lambda)} = \underline{t^C}$ (6)

From (5) and (6), it is evident that a firm's Stage 3 equilibrium strategy, regardless of its type – green or brown, is "bribe the official", if $t > \underline{t^C}$; otherwise, if $t \le \underline{t^C}$, "do not offer bribe".[13] Next, in Stage 2 each firm decides the type of technology to adopt. Given the expectation regarding Stage 3 outcome (bribe or not bribe), a firm's ICC to choose the green technology can be written as follows.

ICCs to Choose Green Technology

Bribe: $\pi_{G,B} \geq \pi_{B,B} \Leftrightarrow t \geq \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))} = \underline{t}^G(c)$ (7)

No Bribe: $\pi_{G,NB} \geq \pi_{B,NB} \Leftrightarrow t \geq \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))} = \underline{t}^G(c)$ (8)

Clearly, if $t \geq \underline{t}^C$, a firm's expected payoff from choosing the green technology is at least as much as that from choosing the brown technology, regardless of that firm's anticipated decision to be made in the subsequent stage of the game. That is, each firm's ICC to adopt the green (brown) technology is always satisfied, if $t \geq \underline{t}^G(c)$ ($t < \underline{t}^G(c)$).

From (5)-(6) and (7)-(8) it follows that, given the audit efficiency and penalties for being corrupt, a higher brown tax makes green production more attractive, but it also makes bribing more attractive (see Appendix for details). Clearly, the government faces a trade-off between environmental protection and corruption reduction while intervening through the policy instrument 'brown tax'.

Now, note that $\underline{t}^C \geq (<) \underline{t}^G(c) \Leftrightarrow c \leq (>) \underline{c}$, where

$$\underline{c} = \frac{\left(1-\rho(1-\lambda)\right)}{\rho(1-\lambda)}[b(1-\lambda) + f\lambda + f(1-\lambda)(1-\rho)] + \frac{v_E}{v_T}e > 0. \quad (9)$$

It follows that, if $c \leq \underline{c}$, any $t \in \left[\underline{t}^G(c), \underline{t}^C\right]$ would guarantee that each firm produces green and none bribes. Clearly, $t = \underline{t}^G(c)$ is the lowest possible brown tax which implements the target equilibrium.

If $c > \underline{c}$, we have $\underline{t}^C < \underline{t}^G(c)$, implying that there does not exist any brown tax t such that both $t \leq \underline{t}^C$ and $t \geq \underline{t}^G(c)$ are true. In this case there is complete trade-off between environment and corruption. To induce firms to produce via green technology $t \geq \underline{t}^G(c)$ must hold. But, if $t \geq \underline{t}^G(c)$, each firm will bribe. If $t \leq \underline{t}^C$, then no firm bribes, but no firm adopts the green technology either. If $\underline{t}^C < t < \underline{t}^G(c)$, each firm adopts the brown technology and bribes. Thus, if $c > \underline{c}$, there does not exist any brown tax (t) that can implement the target equilibrium. Therefore, the following proposition is immediate.

[13] We assume that, whenever firms are indifferent between alternative strategies, they choose the one that is better for the society.

Proposition 1: ***(a)*** *When the cost of green technology adoption is less than or equal to a critical level ($\underline{c}$), the government can implement the target equilibrium by setting the brown tax equal to* $t^*=\underline{t^G}(c)$, *and there does not exist any brown tax* $t < \underline{t^G}(c)$ *that alone implements the target equilibrium; where* $\underline{c}$ *and* $\underline{t^G}(c)$ *are as in (9) and (8), respectively.*

(b) *When the cost of green technology adoption is greater than a critical level ($\underline{c}$), the government cannot implement the target equilibrium using a tax policy alone.*

We now turn to examine the feasibility of implementing the target equilibrium by introducing green technology subsidy along with brown tax, when $c > \underline{c}$.

We know $\frac{\partial \underline{t^G}}{\partial c} > 0$ and $\frac{\partial \underline{t^C}}{\partial c} = 0$. Therefore, $\frac{\partial(\underline{t^G} - \underline{t^C})}{\partial c} > 0$. Clearly, if green technology subsidy is such that $s = s^* = c - \underline{c}$, then $\underline{t^G}\left(\underline{c}\right) = \underline{t^C}$. It follows that, when $c > \underline{c}$, the target equilibrium can be implemented by a combination of a brown tax and a green technology subsidy, and the corresponding 'lowest-subsidy minimum-tax' policy sets by $t = t^* = \underline{t^C}$ and $\zeta s = \zeta s^* = \zeta(c - \underline{c})$.

Proposition 2: *When the cost of green technology adoption is greater than* $\underline{c}$ *, the brown tax* $t^*=\underline{t^C} = \underline{t^G}\left(\underline{c}\right)$ *along with the green technology subsidy* $\zeta s^* = \left(c - \underline{c}\right)\zeta$ *implements the target equilibrium, where* $\underline{t^G}\left(\underline{c}\right) = \frac{\underline{c} - v_E e}{v_T\left(1-\rho(1-\lambda)\right)}$ *and* $\underline{c}$ *is given by (9).* ($t^* = \underline{t^C} = \underline{t^G}\left(\underline{c}\right)$, $\zeta s^* = \left(c - \underline{c}\right)\zeta$) *is the 'lowest-subsidy minimum-tax' policy.*

Proof: Follows directly from the above discussions.

Remarks: Note that the technology subsidy is offered directly to green technology seller(s). Instead, if reportedly green firms are directly subsidized, truly brown firms will have an additional incentive to bribe the official to hide their identity, while truly green firms may not get subsidy benefits unless they bribe. In the later scenario, firms' ICCs will be distorted and the two critical values of the brown tax, $\underline{t^C}$ and $\underline{t^G}$, will be changed to $\underline{t^C}(s) = \underline{t^C} - s$ and $\underline{t^G}(s) = \underline{t^G} - s$, respectively. Since $c > \underline{c} \Leftrightarrow \underline{t^C}(s) < \underline{t^G}(s)$, the target equilibrium cannot be implemented by such a tax-subsidy scheme, unlike as under direct subsidy to technology seller(s).

3. Status Incentives and Firms' Concern for Social Reputation

Suppose that the government makes use of status incentive, such as a green certification award for green firms, along with a brown tax and a green technology subsidy. For firms, such non-monetary incentive helps to gain social reputation. Green certified firms get honour, while others are stigmatized in the society.

We consider that firms are heterogeneous with respect to their valuation for reputation, which is denoted by $\theta \in \{0,1\}$. Assume that $\beta \in (0,1)$ proportion of firms care about their reputation ($\theta = 1$), while $1 - \beta$ proportion of firms do not care about reputation ($\theta = 0$).

Suppose that $x \in [0, n]$ number of firms out of total $n(> 0)$ firms receive the green certification and are perceived to be green by fellow members of the society. Remaining $n - x$ firms do not get the green certification and, thus, are perceived as brown firms. Each of these x green certified firms get honor, while other $n - x$ firms are stigmatized. Then, reputational payoff of a green certified firm, $R(\cdot)$, is as follows.

$$R(x) = [H(x) - S(n - x)],$$

where $H(x)$ denotes the honor of a green certified firm and $S(n - x)$ denotes the stigma of a brown certified firm. Furthermore,

(a) $H(x) > 0$ and $H'(\cdot) < 0 \;\forall\, x \in [0, n]$, and

(b) $S(n - x) < 0$ and $\frac{\partial S(n-x)}{\partial x} = \frac{\partial S(n-x)}{\partial (n-x)}(-1) = -S'(\cdot) > 0 \;\forall\, x \in [0, n]$.

Clearly, when more firms are awarded the green certification, the honour value of green certification drops and at the same time the stigma of being a brown firm increases (e.g., see Benabou and Tirole 2006, p. 1665-1667). The net reputational payoff of green certifications, $R(x)$, is the distance between the gain in honor value and the stigma avoided. It follows that $R(x) > 0 \forall x \in [0, n]$.

Now, note that $\frac{\partial R(x)}{\partial x} = \frac{\partial H(x)}{\partial x} - \frac{\partial S(n-x)}{\partial (n-x)}\left(\frac{\partial (n-x)}{\partial x}\right) = \frac{\partial H(x)}{\partial x} + \frac{\partial S(n-x)}{\partial (n-x)}$. Clearly, $R' < 0 \Leftrightarrow -H' > S'$. Thus, net reputational value of green certification falls (increases) as a greater number of firms gets green certification, i.e., $R' < 0$ ($R' > 0$), if the decrease in honour is more (less) than the increase in stigma.[14] Reputational payoff of a firm depends only on (a) whether it is a green certified firm or not and (b) total number of green certified firms.[15] If a brown firm gets green certified by bribing and it retains the certificate in post-audit scenario, it is perceived

---

[14]Examples of honour and stigma functions that satisfy the set of desired properties are as follows. $H(x) = b - \psi x$ and $S(n - x) = \alpha(n - x) - K$, where $b, \psi, \alpha, K > 0, b > \psi n$ and $K > \alpha n$. Clearly, if $\psi < \alpha$, $R' > 0$. Otherwise, if $\psi > \alpha$, $R' < 0$.

[15]A firm's reputation for environmental performance is assumed to be independent of its corruption history. Note that, while corruption information on penalties imposed on firms for bribing may be accessible, such information often does not attract media attention and, thus, often remains largely unobservable by people. In contrast, firms often proactively publicise their awards and certifications.

as green. On the other hand, if a green firm fails to obtain the green certificate, people perceive it as brown.[16]

Stages of the game and all other things remain the same as in Section 2.

Now, in Stage 3 firms' decision of whether to bribe the official depends on their relative payoffs. Let $\pi^R_{G,B}(\theta)$, $\pi^R_{G,NB}(\theta)$, $\pi^R_{B,B}(\theta)$ and $\pi^R_{B,NB}(\theta)$, respectively, denote expected payoffs of a (i) green firm in case it bribes, (ii) green firm when it does not bribe, (iii) brown firm in case it bribes and (iv) brown firm when it does not bribe, given the firm's valuation for social reputation θ. We can express these expected payoffs as follows.

$$\begin{aligned}\pi^R_{G,B}(\theta) = {} & [v_T y + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - v_T c - v_T f]\lambda + \\ & [v_T y + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - v_T c - v_T b](1-\lambda)\rho + \\ & [v_T y + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - v_T c - v_T b - v_T f](1-\lambda)(1-\rho) \qquad (10)\end{aligned}$$

$$\begin{aligned}\pi^R_{G,NB}(\theta) = {} & [v_T y + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - v_T c]\lambda \\ & + \left[v_T y - v_T t - \theta\left\{H\big(E(x)\big) - S\big(E(n-x)\big)\right\} - v_T c\right](1-\lambda)\rho \\ & + [v_T y + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - v_T c](1-\lambda)(1-\rho) \qquad (11)\end{aligned}$$

$$\begin{aligned}\pi^R_{B,B}(\theta) = {} & \left[v_T y - v_E e - v_T t - \theta\left\{H\big(E(x)\big) - S\big(E(n-x)\big)\right\} - f\right]\lambda + \\ & [v_T y - v_E e + \theta\{H(E(x)+1) - S(E(n-x)-1)\} - b](1-\lambda)\rho + \\ & \left[v_T y - v_E e - v_T t - \theta\left\{H\big(E(x)\big) - S\big(E(n-x)\big)\right\} - b - f\right](1-\lambda)(1-\rho) \qquad (12)\end{aligned}$$

$$\pi^R_{B,NB}(\theta) = v_T y - v_E e - v_T t - \theta\left\{H\big(E(x)\big) - S\big(E(n-x)\big)\right\} \qquad (13)$$

In above equations, x is the number of other firms, excluding itself, who get the green certification out of n firms. Since firms are uncertain about x, they form expectations. If a green firm is caught bribing, it retains its green certificate and, thus, net reputational payoff gets

[16] We assume that the citizens are naive and infer about the greenness of firms only based on the certification, which remains their only source of information. In such a scenario, the consideration of green certification having full credibility seems to be valid. Alternatively, one may consider a scenario in which citizens, who confer honour and stigma on firms, may be able to use the information regarding corrupt practices between firms and officials to assess the credibility of the green certification. Then given the probabilities of an official to be corrupt and the probability of penalizing them once caught, there are different probabilities with which honour and stigma is conferred upon firms. For example, when the firms get a green certification, they get honour with probability $\lambda + (1-\lambda)(1-\rho)$ and stigma with probability $(1-\lambda)\rho$. However, when the firms do not get the certification and are termed as brown, they still get honor with probability $(1-\lambda)\rho$ and stigma with $\lambda + (1-\lambda)(1-\rho)$. This is because citizens are aware that with probability $(1-\lambda)\rho$ truly green firms were falsely denied certification by corrupt officials who didn't get caught. Then the number of perceived true green firms is given by $\tilde{x} = [\lambda + (1-\lambda)(1-\rho)]x + [(1-\lambda)\rho](n-x)$. Accordingly, net reputational payoff is $R(\tilde{x}) = \gamma\big[[\lambda + (1-\lambda)(1-\rho)]H(\tilde{x}) - (1-\lambda)\rho S(n-\tilde{x})\big]$. We are interested in the scenario where the certification has some credibility. For this we need that once the firms get the certification, the probability of getting honor is strictly higher than the probability of getting stigma, that is, $\lambda + (1-\lambda)(1-\rho) > (1-\lambda)\rho \Rightarrow (1-\lambda)\rho < 0.5$. Thus, if corruption is not too widespread and the audit mechanism is efficient to the extent that the corrupt officials get caught with higher probability, then the certification holds credibility, and qualitative results of this paper go through. However, if corruption is too rampant and corrupt officials get off easily, then the certification will lose its credibility. Hence, when citizens are not naive, we need to assume that $(1-\lambda)\rho < 0.5$.

added in its payoff (equation (10)). However, if a green firm does not bribe and fails to get the green certificate, it gets stigmatized, which results in a negative reputational payoff (the second term in the right-hand-side of equation (11)). On the other hand, if a brown firm goes free after bribing, it gets the green certificate and, thus, the net reputational payoff gets added in its payoff with bribing with probability$(1-\lambda)\rho$ ((equation 12)). However, if the brown firm does not bribe, it does not get the green certificate and, thus, receives a disutility as reflected in equation (13).

Note that $1-\beta$ proportion of firms do not care about reputation, i.e. $\theta = 0$. Therefore, for these $1-\beta$ proportion of firms we have $\pi^R_{B,B}(\theta = 0) = \pi_{B,B}$, $\pi^R_{B,NB}(\theta = 0) = \pi_{B,NB}$, $\pi^R_{G,B}(\theta = 0) = \pi_{G,B}$ and $\pi^R_{G,NB}(\theta = 0) = \pi_{G,NB}$, which are same as in equations (1), (2), (3) and (4), respectively, in Section 2.

On the other hand, for β proportion of firms, who care about reputation, $\theta = 1$. Let $\pi^R_{B,B}(\theta = 1) = \pi^R_{B,B}$, $\pi^R_{B,NB}(\theta = 1) = \pi^R_{B,NB}$, $\pi^R_{G,B}(\theta = 1) = \pi^R_{G,B}$ and $\pi^R_{G,NB}(\theta = 1) = \pi^R_{B,NB}$, which we get from equations (12), (13), (10) and (11), respectively, by substituting $\theta = 1$.

Now, given the technology choice, in Stage 3 the ICC of a reputation-concerned firm $(\theta = 1)$ to bribe is as follows.

Reputation-concerned Brown Firm's IC to Bribe:

$$\pi^R_{B,B} > \pi^R_{B,NB} \Leftrightarrow t > \underline{t^C} - \frac{(P+Q)}{\mathrm{v_T}} = \underline{t^{RC}}, \tag{14}$$

Reputation-Concerned Green Firm's IC to Bribe:

$$\pi^R_{G,B} > \pi^R_{G,NB} \Leftrightarrow t > \underline{t^C} - \frac{(P+Q)}{\mathrm{v_T}} = \underline{t^{RC}}, \tag{15}$$

where $\underline{t^C} = \frac{b(1-\lambda)+f\lambda+f(1-\lambda)(1-\rho)}{\rho(1-\lambda)}$ as in (5) and (6), $P = H\big(E(x)\big) - S\big(E(n-x)\big) > 0$, and $Q = H(E(x)+1) - S\big(E(n-x-1)\big) > 0$. Clearly, $\underline{t^C} > \underline{t^{RC}}$. On the other hand, if a firm does not care about social reputation $(\theta = 0)$, its ICC to bribe in Stage 3, given its technology choice, remains the same as in Section 2 (conditions (5) and (6)).

From (5), (6), (14) and (15), it follows that a firm's ICC to bribe does not depend on its technology choice, green or brown, regardless of its reputation-concern. However, in the presence of non-monetary incentives, a firm's concern for reputation provides an additional incentive to bribe – a reputation-concerned firm bribes, not only to avoid the brown tax, but also to acquire the green certificate to gain reputation. Thus, we get $\underline{t^C} > \underline{t^{RC}}$, which implies the following. In the equilibrium, β proportion of firms that care about reputation $(\theta = 1)$ bribe for a larger range of brown tax compared to the other $1-\beta$ proportion of firms that do not care about reputation ($\theta = 0$).

Now, in Stage 2 ICC to adopt green technology by non-reputation-concerned ($\theta = 0$) firms remain the same as in Section 2 (condition (7), in case the firm anticipates bribing will be incentive compatible in Stage 3; otherwise, condition (8)). On the other hand, reputation-concerned ($\theta = 1$) firms' ICCs to adopt the green technology can be written as follows.

Reputation-concerned Firm's ICC to Adopt Green Technology:

Bribe: $\pi^R_{G,B} \geq \pi^R_{B,B} \Leftrightarrow t \geq \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))} - \frac{(P+Q)}{v_T} = \underline{t^G}(c) - \frac{(P+Q)}{v_T} = \underline{t^{RG}}(c)$; (16)

No Bribe: $\pi^R_{G,NB} \geq \pi^R_{B,NB} \Leftrightarrow t \geq \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))} - \frac{(P+Q)}{v_T} = \underline{t^G}(c) - \frac{(P+Q)}{v_T} = \underline{t^{RG}}(c)$; (17)

where $\underline{t^G}(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$ as in conditions (7)-(8), $P = H(E(x)) - S(E(n-x)) > 0$, and $Q = H(E(x)+1) - S(E(n-x-1)) > 0$ as in conditions (14)-(15). Clearly, $\underline{t^{RG}}(c) < \underline{t^G}(c)$.

It is intuitive to observe, from conditions (7)-(8) and (16)-(17), that a less stringent environmental regulation ($\underline{t^{RG}}(c) < t < \underline{t^G}(c)$) coupled with non-monetary incentives for green production can induce reputation-concerned firms to produce green, compared to what is necessary ($\underline{t^{RG}}(c) < \underline{t^G}(c) \leq t$) to induce non-reputation-concerned firms to choose green technology. Overall, a reputation-concerned firm is more likely, not only to adopt green technology, but also to bribe in the presence of non-monetary incentives.

Now, from conditions (5)-(8) and (14)-(17) it follows that (a) none of the firms bribe, if brown tax $t \leq Min\{\underline{t^{RC}}, \underline{t^C}\} = \underline{t^{RC}}$, and (b) all firms choose the green technology, if brown tax $t \geq Max\{\underline{t^{RG}}(c), \underline{t^G}(c)\} = \underline{t^G}(c)$. Therefore, if $\underline{t^G}(c) \leq \underline{t^{RC}}$ holds true and brown tax t is such that $\underline{t^G}(c) \leq t \leq \underline{t^{RC}}$ is satisfied, in the equilibrium all firms will be green and none will bribe, i.e. the equilibrium will be the target equilibrium.

Proposition 3: *Suppose that some firms care about social reputation, while others do not. Then, in the presence of non-monetary incentive the following is true. The target equilibrium can be implemented through the combination of the* brown *tax t^{R*}on each brown firm and the green technology subsidy ζs^{R*}, which is the lowest-subsidy minimum-tax policy; where $t^{R*}$and $s^{R*}$are as follows.*

(a) $t^{R*} = \underline{t^G}(c)$ and $s^{R*} = 0$, if $c \leq \hat{c} = \underline{c} - \Delta$;

(b) $t^{R*} = \underline{t^G}(\hat{c})$ and $s^{R*} = c - \hat{c}$, if $c > \hat{c} = \underline{c} - \Delta$;

where $\underline{c}$ *and* $\underline{t}^G(c)$ *are given by (9) and (8), respectively,* $\Delta = 2\gamma\left[H\left(n\left(1-\rho(1-\lambda)\right)\right) - S\left(n\rho(1-\lambda)\right)\right]\frac{(1-\rho(1-\lambda))}{v_T} > 0$*, and* $\underline{t}^G(\hat{c}) = \frac{v_T\hat{c}-v_E e}{v_T\left(1-\rho(1-\lambda)\right)}$.

Proof: See Appendix

Proposition 3 implies that in the presence of non-monetary incentives and firm heterogeneity it may not be possible to implement the target equilibrium outcome only by imposing a brown tax on each brown firm unless the cost of green technology adoption is less than $\underline{c} - \Delta$, unlike as in absence of non-monetary incentives. Further, rates of brown tax and green technology subsidy, which ensures the target equilibrium outcome in absence of non-monetary incentives, is ineffective to do so in the presence of non-monetary incentives, unless $c \leq \underline{c} - \Delta$. Comparing the target equilibrium implementing optimal policies in alternative scenarios, we obtain the following**.**

Proposition 4: [Excess burden of non-monetary incentive] *In the presence of corruption, implementation of the target equilibrium outcome through a combination of monetary and non-monetary incentives calls for higher expenditure on green technology subsidy and a lower brown tax compared to that under monetary incentives alone, unless the cost of green technology adoption is sufficiently less: (a)* $s^{R*} > s^* \geq 0$ *and* $t^{R*} < t^*$*, if* $c > \hat{c} = \underline{c} - \Delta$*; and (b)* $s^{R*} = s^* = 0$ *and* $t^{R*} = t^*$*, if* $c \leq \hat{c} = \underline{c} - \Delta$.

Proof: See Appendix..

From Proposition 4 it follows that presence of non-monetary incentives put an extra burden on government exchequer compared to pure monetary incentives, unless the cost of green technology adoption is sufficiently small ($c \leq \underline{c} - \Delta$). The intuition is as follows. Non-monetary incentive opens the possibility to gain reputation, which gives additional incentives to reputation-concerned firms to bribe as well as to adopt the green technology. As a result, if a brown tax induces a non-reputation-concerned firm to adopt the green technology, it also induces reputation-concerned firms to do the same; but the reverse is not true. Now, if the cost of green technology adoption is sufficiently small, the minimum brown tax that induces non-reputation-concerned firms to adopt the green technology is small enough to discourage reputation-concerned firms to bribe. Therefore, in that case, the target equilibrium implementing brown tax remains the same regardless of the incentive scheme. However, if the cost of green technology adoption is not sufficiently small, presence of non-monetary incentives calls for a lower brown tax to refrain reputation-concerned firms from bribing. Since a lower brown tax reduces each firm's incentive to adopt the green technology, it needs to be coupled with a higher green technology subsidy to induce each firm to be green.

4. Alternative Scenarios

So far, we have considered briber-initiated corruption and exogenous bribe rate. In this section we extend the analysis by relaxing these assumptions.

4.1 Bribee-Initiated Corrupt Transaction

Suppose that officials initiate corrupt transactions as in Bayer (2005), ceteris paribus. Then, an h-type official will ask for bribe if and only if $b > \underline{b}(h) \Leftrightarrow h < \rho(w+b) - w = \hat{h}(b)$. So, given exogenously fixed b, in Stage 3 only officials with $h \in \left[\underline{h}, \hat{h}(b)\right)$ demand bribe, others do not. In this scenario, firms do not face the risk of being penalized for offering bribe to an official, who is not interested in b, unlike as under briber-initiated corruption. It implies that firms' have greater incentives to bribe now. Thus, to nullify the possibility of corruption, it is necessary to impose a lower brown tax. On the other hand, a decrease brown tax increases the relative cost of green technology adoption $(c - t)$, which reduces firm's incentives to be green. Therefore, in this case the scope of the target equilibrium implementation by imposing only a brown tax is less than that under briber-initiated corrupt transaction. Furthermore, unless the cost of green technology adoption is less than a critical level, to counter the negative effect of a lower brown tax on firms' incentives to be green, it is necessary to offer a higher green technology subsidy compared to that under briber-initiated corrupt transaction. This is true regardless of whether non-monetary incentive exists or not. However, since non-monetary incentive makes both bribing and green technology adoption more attractive, qualitative results of Proposition 4 go through under briber-initiated corrupt transaction as well. See Appendix for details.

4.2 Endogenous Bribe Rate

Suppose that in Stage 3 bribe rate b is endogenously determined through independent bargaining between official-firm pairs. Bargaining powers of an official and a firm are, respectively, γ and $1-\gamma$; $\gamma \in [0,1]$. Note that an h-type official's minimum acceptable bribe rate is $\underline{b}(h) = \frac{h+(1-\rho)w}{\rho}$ (> 0), $\frac{\partial \underline{b}(h)}{\partial h} > 0$, $h \in \left[\underline{h}, \overline{h}\right]$. Let $\overline{b}$ (≥ 0) be a firm's maximum willingness to pay as bribe. Suppose that γ, $\underline{b}(h)$ and $\overline{b}$ are common knowledge. Then, if $\underline{b}(h) < \overline{b}$, the generalized Nash bargaining problem between an official-firm pair can be written as $\max_{b\in[\underline{b},\overline{b}]}\left[\left(b-\underline{b}(h)\right)^{\gamma}\left(\overline{b}-b\right)^{1-\gamma}\right]$. Solving this problem, we get the bargained bribe rate $b^0(h) = \gamma\,\overline{b}\, + (1-\gamma)\underline{b}(h) \in [\underline{b}(h),\ \overline{b}]$.

Note that, when each official's type (i.e., h) is common knowledge, a h-type official will not demand any bribe if $\overline{b} < \underline{b}(h)$. However, an official's type is his private information, and he can utilize this information advantage to distort the bargaining outcome in his favour. Nonetheless. it is feasible to ensure that corruption does not take place in the equilibrium if and only if it is feasible to ensure that $\overline{b} < \underline{b}(h)$ holds true for all $h \in [\underline{h}, \overline{h}]$. While it turns out that an official's minimum acceptable bribe is independent of tax and subsidy amounts, norm of corruption (briber-initiated of bribe-initiated) and type of incentive scheme, a firm's maximum willingness to pay as bribe $(\overline{b})$ is always decreasing in brown tax (t). In fact, it can be checked that the planner can always ensure that $\overline{b} < \underline{b}\ (\underline{h})$ is satisfied by choosing the brown tax appropriately. On the other hand, in Stage 2 a firm's ICC for choosing the green technology under endogenous bribe remains the same as that under exogenously given bribe rate, since at this stage firms cannot update their beliefs regarding the official's type and the ICC condition for going green does not depend on the bribe amount. As a result, qualitative results of this analysis hold true even when bribe is endogenously determined via bargaining, regardless of who initiates corrupt transactions. See Appendix for details.

5. Conclusion

We have developed a theoretical model to analyse implications of environmental regulation in the presence of corruption, with a special focus on efficacies of non-monetary incentives. We have demonstrated that it is feasible to implement the 'target equilibrium', in which there is zero emission and no corruption, through environmental regulation alone. We have characterized the 'lowest-subsidy minimum-tax' criterion satisfying environmental regulation, which implements the 'target equilibrium'. Interestingly, we have also demonstrated that, in the presence of corruption possibilities, introduction of non-monetary incentive, such as social reputation enhancing green certification, makes it harder for the social planner to implement the 'target equilibrium'. This result is in sharp contrast to conventional wisdom that non-monetary incentives are useful to better motivate agents and improve efficiency at a lower cost.[17] It seems to suggest that non-monetary status incentives to nudge behaviour of economic agents, who are motivated by social preferences, should be used cautiously as this could increase the spending of public fund with less environmental protection, since corruption exists in most (if not all) countries in the world.

References

1. Acemoglu, D., & Verdier, T. (2000). The choice between market failures and corruption. *American Economic Review*, 90(1): 194-211.
2. Aidt, T. S. (2009). Corruption, institutions, and economic development. *Oxford Review of Economic Policy (25)2*: pp. 271–291.
3. Amir, R., & Burr, C. (2015). Corruption and socially optimal entry. *Journal of Public Economics*, *123*: 30-41.
4. Banerjee, P., Pal, R., Wossink, A., & Asher, J. (2021) Heterogeneity in farmers' social preferences and the design of green payment schemes, *Environmental and Resource Economics*, 78(2): 201-226.
5. Bardhan, P. (1997). Corruption and development: a review of issues. *Journal of Economic Literature, 35(3)*: 1320–1346.
6. Bayer, G. (2005). The role of intermediaries in corruption. *Public Choice*, 122(3/4): 277-298.
7. Bénabou, R., & Tirole, J. (2006). Incentives and prosocial behavior. *American Economic Review*, *96*(5): 1652-1678.
8. Besley, T., & Ghatak, M. (2005). Competition and incentives with motivated agents. *American Economic Review*, *95*(3): 616-636.
9. Besley, T., & Ghatak, M. (2008). Status incentives. *American Economic Review*, *98*(2): 206-211.
10. Bradler, C., Dur, R., Neckermann, S., & Non, A. (2016). Employee recognition and performance: A field experiment. *Management Science*, *62*(11): 3085-3099.
11. Breza, E., & Chandrasekhar, A. G. (2019). Social networks, reputation, and commitment: Evidence from a savings monitors experiment. *Econometrica*, *87*(1): 175-216.

[17] See Besley and Ghatak (2008 & 2005), Shogren et al (2010), Kosfeld and Neckermann (2011), Bradler et al (2016), Erkal et al (2018), Lefebvre and Stenger (2020), Banerjee et al (2021), and Carlsson et al (2021), to name a few.

12. Bruhin, A., Fehr, E. & Schunk D. (2019). The many faces of human sociality: Uncovering the distribution and stability of social preferences, *Journal of the European Economic Association*, 17(4): 1025–1069.
13. Carlsson, F., Gravert, C., Johansson-Stenman, O. & Kurz, V. (2021). The use of green nudges as an environmental policy instrument. *Review of Environmental Economics and Policy*, *15*(2): 216-237.
14. Charness, G. & Rabin, M. (2002). Understanding social preferences with simple tests. *Quarterly Journal of Economics,* 117(3): 817–869.
15. Charness, G., Masclet, D., & Villeval, M. C. (2014). The dark side of competition for status. *Management Science*, *60*(1): 38-55.
16. Damania, R., Fredriksson, P. G., & Mani, M. (2004). The persistence of corruption and regulatory compliance failures: theory and evidence. *Public choice*, *121*(3): 363-390.
17. Dimant, E. & Tosato, G. (2018). Causes and effects of corruption: What has past decade's empirical research taught us? A survey. *Journal of Economic Surveys, 32(2)*: 335-356.
18. Duflo, E., Kremer, M., & Robinson, J. (2011). Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya. *American Economic Review*, 101 (6): 2350-90.
19. Erkal, N., Gangadharan, L. & Koh, B.H. (2018). Monetary and non-monetary incentives in real-effort tournaments. *European Economic Review*, *101:* 528-545.
20. Feng, L., & Liao, W. (2016). Legislation, plans, and policies for prevention and control of air pollution in China: achievements, challenges, and improvements. *Journal of Cleaner Production*, *112*:1549-1558.
21. Gordon, S. C. & Hafer, C. (2005). Flexing muscle: Corporate political expenditures as signals to the bureaucracy. *American Political Science Review*, *99*(2): 245-261.
22. IPCC. (2018) *Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 616 pp. doi: 10.1017/9781009157940.
23. IPCC. (2022) Climate Change 2022: *Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K.

Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

24. Innes, R. & Mitra, A. (2013), Is dishonesty contagious? *Economic Inquiry, 51(1)*: 722-734.
25. Kaller, A., Bielen, S., & Marneffe, W. (2018). The impact of regulatory quality and corruption on residential electricity prices in the context of electricity market reforms. *Energy Policy*, *123:* 514-524.
26. Kosfeld, M. & Neckermann, S. (2011). Getting more work for nothing? Symbolic awards and worker performance. *American Economic Journal: Microeconomics*, *3*(3): 86-99.
27. Lefebvre, M., & Stenger, A. (2020). Short- & long-term effects of monetary and non-monetary incentives to cooperate in public good games: An experiment. *PLoS ONE, 15(1)*.
28. Levitt, S. D. & List, J. A. (2007) What do laboratory experiments measuring social preferences reveal about the real world? *Journal of Economic Perspectives*, 21 (2): 153-174.
29. López-Valcárcel, B. G., Jiménez, J. L., & Perdiguero, J. (2017) Danger: Local corruption is contagious!, *Journal of Policy Modeling*, *39(5)*: 790-808,
30. Rothstein, B. (2011) Anti-corruption: the indirect 'big bang' approach, *Review of International Political Economy*, 18(2): 228-250.
31. Schram, A., Zheng, J. D., & Zhuravleva, T. (2022). Corruption: A cross-country comparison of contagion and conformism. *Journal of Economic Behavior & Organization, 193:* 497-518.
32. Shogren, J. F., Parkhurst, G. M., & Banerjee, P. (2010). Two cheers and a qualm for behavioral environmental economics. *Environmental and Resource Economics*, *46*(2): 235-247.
33. Sui, B., Feng, GF. & Chang, CP. (2018). The pioneer evidence of contagious corruption. *Quality and Quantity* 52: 945–968.
34. Tran, A. & Zeckhauser, R. (2012). Rank as an inherent incentive: Evidence from a field experiment. *Journal of Public Economics*, *96*(9-10):645-650.
35. Wolfensohn, J. D. (1996). *People and development: address to the Board of Governors, Washington, DC, October 1, 1996 (English).* Presidential speech Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/243871468141893629/People-and-development-address-to-the-Board-of-Governors-Washington-DC-October-1-1996 (last accessed on July 31, 2023)

Appendix to "Corruption-Proof Minimum Regulation for 'Zero Emission': Status Incentives – Bane or Boon?"

A.1. Comparative Statics Analysis

From (5)-(6) and (7)-(8) we get $\left.\begin{array}{l} t > \underline{t^C} \Leftrightarrow \rho > \frac{b(1-\lambda)+f}{(1-\lambda)(v_T t+f)} = \underline{\rho^C} \quad \text{and} \\ t \geq \underline{t^G}(c) \Leftrightarrow \rho \leq \left[1 - \frac{v_T c - v_E e}{t v_T}\right]\frac{1}{(1-\lambda)} = \underline{\rho^G}\,. \end{array}\right\}$. It follows that

$\frac{\partial \underline{\rho^C}}{\partial t} < 0$ and $\frac{\partial \underline{\rho^G}}{\partial t} > 0$, *since* $\lambda \in (0,1), b > 0, f > 0, v_T > 0$ and $t > 0$, Clearly, for any given efficiency of the audit system $(1-\rho)$ and fine rates, a higher brown tax (t) makes both the inequalities $\rho > \underline{\rho^C}$ and $\rho \leq \underline{\rho^G}$ to be more likely to be satisfied. If the planner imposes a higher brown tax, not only the incentive compatibility conditions to choose the green technology are more likely to be satisfied, but also firms are more likely to find it optimal to bribe.

A2. Proof of Proposition 3

By construction, there are total n firms, out of which β proportion of firms are reputation concerned $(i.e. \theta = 1)$ and remaining $1-\beta$ proportion of firms do not care about reputation$(i.e. \theta = 0)$.

A non-reputation concerned (i.e. $\theta = 0$) firm's optimal decisions in Stage 3 and Stage 2 are, respectively, as follows.

(a) Do not offer bribe, if $t \leq \underline{t^C} = \frac{1}{(1-\lambda)\rho}[b(1-\lambda) + f\lambda + f(1-\lambda)(1-\rho)]$, from conditions (5) and (6).

(b) Opt for the green technology, if $t \geq \underline{t^G}(c) = \frac{v_T c - v_E e}{(1-\rho(1-\lambda))v_T}$, from conditions (7) and (8).

A reputation concerned (i.e. $\theta = 1$) firm's optimal decisions in Stage 3 and Stage 2 are, respectively, as follows.

(a) Do not offer bribe, if $t \leq \underline{t^C} - \frac{(P+Q)}{v_T}$, where $P = H(E(x)) - S(E(n-x)) > 0, Q = H(E(x)+1) - S(E(n-x-1)) > 0$ and x is the actual number of firms getting the green certification, from conditions (14) and (15).

(b) Opt for the green technology, if $t \geq \underline{t^G}(c) - \frac{(P+Q)}{v_T}$, from conditions (16) and (17).

It is evident that $\underline{t^{RC}} < \underline{t^{C}}$, $\underline{t^{RG}}(c) < \underline{t^{G}}(c)$, $\frac{\partial \underline{t^{RG}}(c)}{\partial c} = \frac{\partial \underline{t^{G}}(c)}{\partial c} > 0$ and $\frac{\partial \underline{t^{RC}}}{\partial c} = \frac{\partial \underline{t^{C}}}{\partial c} = 0$.

Next, note that the target equilibrium outcome calls for 'no firm bribes and all firms choose the green technology' (by Definition 1).

From the above discussion it follows that (a) none of the firms bribe, if tax on brown firm $t \leq Min\{\underline{t^{RC}}, \underline{t^{C}}\} = \underline{t^{RC}}$, and (b) all firms choose the green technology, if tax on brown firm $t \geq Max\{\underline{t^{RG}}(c), \underline{t^{G}}(c)\} = \underline{t^{G}}(c)$. Therefore, if $\underline{t^{G}}(c) \leq \underline{t^{RC}}$ holds true and tax on brown firm t is such that $\underline{t^{G}}(c) \leq t \leq \underline{t^{RC}}$ is satisfied, the equilibrium outcome will be the first best.

Now,

$\underline{t^{G}}(c) \leq \underline{t^{C}} \Leftrightarrow c \leq \frac{(1-\rho(1-\lambda))}{\rho(1-\lambda)} [b(1-\lambda) + f\lambda + f(1-\lambda)(1-\rho)] + \frac{v_E}{v_T} e = \underline{c}$, and

$\underline{t^{G}}(c) \leq \underline{t^{RC}} \Leftrightarrow \underline{t^{G}}(c) \leq \underline{t^{C}} - \frac{(P+Q)}{v_T} \Leftrightarrow c \leq \underline{c} - \frac{(P+Q)}{v_T}\big(1-\rho(1-\lambda)\big) < \underline{c}$; since $P, Q > 0$.

Therefore, if $c \leq \underline{c} - \frac{(P+Q)}{v_T}\big(1-\rho(1-\lambda)\big)$, $\forall\, t \in [\underline{t^{G}}(c),\ \underline{t^{RC}}]$ the equilibrium outcome will be the target equilibrium outcome.

Note that $\rho(1-\lambda)$ is the probability that 'the official is corrupt and the act of corruption remains undetected'. So, if a green firm does not offer any bribe, then that green firm gets the award of green certification with probability $\big(1-\rho(1-\lambda)\big)$. Implying that, if all firms have chosen the green technology and no firm bribes, the expected number of firms getting the award of green certification is $n\big(1-\rho(1-\lambda)\big)$. Therefore, in the target equilibrium the net reputational payoff of each firm is given by $R = \gamma\left[H\left(n\big(1-\rho(1-\lambda)\big)\right) - S\left(n - n\big(1-\rho(1-\lambda)\big)\right)\right] > 0$ (by construction). Now, note that $(-P)$ is the reputational payoff of firm in case that firm does not get the green certification and Q is the reputational payoff of a firm in case that firm gets the green certification. In any equilibrium we must have $P = Q$, and in the first best equilibrium we must have $P = Q = R = \gamma\left[H\left(n\big(1-\rho(1-\lambda)\big)\right) - S\left(n - n\big(1-\rho(1-\lambda)\big)\right)\right] > 0$. Therefore, in the target equilibrium, $\frac{(P+Q)}{v_T}\big(1-\rho(1-\lambda)\big) = 2\gamma\left[H\left(n\big(1-\rho(1-\lambda)\big)\right) - S\big(n\rho(1-\lambda)\big)\right]\frac{(1-\rho(1-\lambda))}{v_T} = \Delta > 0$. It follows that, if $c \leq \underline{c} - \Delta = \hat{c}$, the target equilibrium can be implemented by any $t \in [\underline{t^{G}}(c),\ \underline{t^{RC}}]$, without offering any subsidy to the green technology seller. However, since $t = \underline{t^{G}}(c)$ corresponds to the minimum penalty on each brown firm, we propose that the social planner will choose $t = \underline{t^G}(c) = t^{R*}$and $s^{R*} = 0$, which ensures the target equilibrium outcome.

Now, if $c > \underline{c} - \Delta = \hat{c}$ and $s = 0$, $\nexists$ any t which induces all firms to be green and not to offer any bribe, since the necessary condition to ensure the target equilibrium $\underline{t^G}(c - 0) \leq \underline{t^{RC}}$ is not satisfied. For the necessary condition to be satisfied, the cost of green technology adoption must be reduced to at least to $\hat{c} = \underline{c} - \Delta$, i.e. at the minimum we must have $s = c - \hat{c}$; since $\frac{\partial \underline{t^G}(c)}{\partial c} > 0$, $\frac{\partial \underline{t^{RC}}}{\partial c} = 0$ and $\underline{t^G}(\hat{c}) = \frac{v_T \hat{c} - v_E e}{v_T(1-\rho(1-\lambda))} = \underline{t^{RC}}$. Implying that, if $c > \underline{c} - \Delta = \hat{c}$, the target outcome outcome can be implemented by setting $s = c - \hat{c} = s^{R*} > 0$ and $t = \underline{t^G}(\hat{c}) = t^{R*} > 0$.

Note that, if $c > \underline{c} - \Delta = \hat{c}$, the tax-subsidy scheme $(t^{R*} = \underline{t^G}(\hat{c}),\ \ s^{R*} = c - \hat{c})$ involves the minimum expenditure on subsidy necessary to ensure the target equilibrium outcome. This is because, in this case the target equilibrium outcome can be implemented by a tax subsidy pair (t, s) provided that $t \in [\underline{t^G}(c - s),\ \underline{t^{RC}}]$ and $s \geq c - \hat{c}$. ■

A3. Proof of Proposition 4

First consider that $c > \underline{c}$. Then, $s^{R*} = c - (\underline{c} - \Delta) = (c - \underline{c}) + \Delta$ and $s^* = (c - \underline{c})$, by Proposition 3 and Proposition 2. Clearly $s^{R*} > s^*$, since $\Delta > 0$. Further, in this case $t^{R*} = \underline{t^G}(\hat{c})$ and $t^* = \underline{t^G}(\underline{c})$, by Proposition 3 and Proposition 2. We have $\hat{c} = \underline{c} - \Delta < \underline{c}$ and $\frac{\partial \underline{t^G}(c)}{\partial c} > 0 \ \forall\, c$. It follows that $t^{R*} < t^*$. Next, consider that $\underline{c} - \Delta < c < \underline{c}$, then $s^{R*} = c - (\underline{c} - \Delta) > 0 = s^*$, by Proposition 3 and Proposition 2. Also, $t^{R*} = \underline{t^G}(\hat{c})$ and $t^* = \underline{t^G}(c)$. Since $\hat{c} = \underline{c} - \Delta < c$ and $\frac{\partial \underline{t^G}(c)}{\partial c} > 0 \ \forall\, c$, we have $t^{R*} < t^*$. Finally, If $c \leq (\underline{c} - \Delta)$, it is evident from Proposition 3 and Proposition 2 that $s^{R*} = s^* = 0$ and $t^{R*} = t^* = \underline{t^G}(c)$. ■

A.4: Analysis of Bribee Initiated Corrupt Transaction

No Non-monetary Incentives

First consider the scenario in which there is no non-monetary incentive and firms are identical. Note that firms are not subject to any risk of being penalized by offering bribe to an honest official, which is synonymous to the case of no penalty for bribing an honest official. It implies that firms' expected payoffs from bribing will be higher in this case than in the case of briber (i.e. firm) initiated corruption, while expected payoffs from not bribing will remain the same, regardless of firms' technology choices. Thus, in Stage 3, firms' incentive compatibility conditions to bribe will now be different.

To illustrate it further, in the present scenario, if in Stage 3 the official demands bribe to a firm, the firm becomes certain that the official is corrupt ($\lambda = 0$) and thus its incentive compatibility condition to accept the demand and pay bribe b implies the following, regardless of whether the firm is green or brown.

$$t > \frac{b + f(1-\rho)}{\rho} = t_b \qquad (Ap.1)$$

Condition (Ap. 1) can be obtained by substituting $\lambda = 0$ in conditions (5) and (6). It is evident that $t_b < \underline{t^C}$. That is, if bribee initiates the corrupt transaction, corruption will take place even for a lower brown tax compared to that in the case of briber initiated corrupt transactions. Now, for any given tax rate t, incentive compatibility conditions for adopting the green technology will remain the same as before (conditions (7) and (8)), since at the technology choice stage (Stage 2) a firm does not know whether he will meet an honest official or a corrupt official in Stage 3. Thus, in the present scenario, the target equilibrium outcome can be ensured only by a brown tax, if and only if, $\underline{t^G}(c) \leq t_b$ and $t \in \left[\underline{t^G}(c), t_b\right]$. It is easy to check that $\underline{t^G}(c) \leq t_b \Leftrightarrow c \leq \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e = c_b$ and $c_b < \underline{c}$. Thus, following same arguments as before, the 'lowest-subsidy minimum-tax' regulation that ensures the target equilibrium outcome in the case of bribee initiated corruption is as in Lemma 1.

Lemma 1: *Suppose that corrupt transactions, if any, are initiated by bribees and the bribe rate is exogenously given. Then, in absence of non-monetary incentives, the 'lowest-subsidy minimum-tax' policy to implement the target equilibrium outcome sets the brown tax t^{*O} and the green technology subsidy s^{*O} as follows.*

(i) $t^{*O} = \underline{t^G}(c)$ *and* $s^{*O} = 0$, *if* $c \leq c_b$; *otherwise*

(ii) $t^{*O} = \underline{t^G}(c_b)$ *and* $s^{*O} = c - c_b$, *if* $c > c_b$; *where*

$c_b = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e$ *and* $\underline{t^G}(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$.

Proof: Condition (Ap. 1) implies that firms will accept the bribe demand from official and bribe, if and only if $t > t_b = \frac{b + f^G(1-\rho)}{\rho}$. That is, firms will not pay any bribe, if $t \leq t_b$. It follows that to implement the target equilibrium outcome we must have $t \leq t_b$. Next, from incentive compatibility conditions (7) and (8), all firms will choose the green technology, if $t \geq \underline{t}^G(c)=\frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$. Therefore, the target equilibrium outcome is implementable, if $\underline{t}^G(c) \leq t_b$ and $t \in [\underline{t}^G(c), t_b]$. Now, $\underline{t}^G(c) \leq t_b \Leftrightarrow c \leq \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e = c_b$. It implies that, if $c \leq c_b$, any $t \in [\underline{t}^G(c), t_b]$ implements the target outcome. Clearly, if $c \leq c_b$, $t = \underline{t}^G(c)$ and $s = 0$ implements the target equilibrium, which is the 'lowest- subsidy minimum-tax' regulation that implements the target equilibrium outcome. Finally, note that $c > c_b \Leftrightarrow \underline{t}^G(c) > t_b$. Therefore, if $c > c_b$ and $s = 0$, there does not exist any tax t that ensures the target equilibrium outcome. In this case, if $s \geq c - c_b$, then $\underline{t}^G(c - s) \leq t_b$ holds. It implies that "$s = c - c_b$ and $\underline{t}^G(c_b)$" the 'lowest- subsidy minimum-tax' regulation that implements the target equilibrium outcome. ■

Now, comparing Lemma 1 with Proposition 1 and Proposition 2, we get the following.

Lemma 2: $s^{*O} > s^* \geq 0$ and $t^{*O} < t^*$, if $c > c_b$. Otherwise, if $c \leq c_b$, $s^{*O} = s^* = 0$ and $t^{*O} = t^*$.

Proof: We have $c_b = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e$, $\underline{c} = \frac{(1-\rho(1-\lambda))}{\rho(1-\lambda)}[b(1-\lambda) + f\lambda + f(1-\lambda)(1-\rho)] + \frac{v_E}{v_T}e$ and $\underline{t}^G(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$. Thus, $\underline{c} - c_b = \frac{(1-\rho(1-\lambda))}{\rho(1-\lambda)}f\lambda > 0$ and $\frac{\partial \underline{t}^G(c)}{\partial c} > 0$. Now, from Lemma 1, Proposition 1 and Proposition 2 we have the following, since $c_b < \underline{c}$ and $\frac{\partial \underline{t}^G(c)}{\partial c} > 0$.

(i) If $0 < c \leq c_b$, $s^{*O} = s^* = 0$ and $0 < t^{*O} = t^* = \underline{t}^G(c)$.

(ii) If $c_b < c \leq \underline{c}$, $s^{*O} = c - c_b > 0 = s^*$ and $0 < t^{*O} = \underline{t}^G(c_b) < \underline{t}^G(c) = t^*$.

(iii) If $\underline{c} < c$, $s^{*O} = c - c_b > c - \underline{c} = s^* > 0$ and $0 < t^{*O} = \underline{t}^G(c_b) < \underline{t}^G(\underline{c}) = t^*$. ■

Therefore, it is more difficult to ensure the target equilibrium outcome when corrupt transactions are initiated by bribee compared to the scenario in which briber initiates corrupt transactions, unless the extra cost of green technology is less than a critical level. This is because, firms do not face the risk of being penalized for offering bribe to an honestly behaved official under bribee initiated corrupt transactions.

Non-monetary Incentives

Let us now consider that the government offers non-monetary status incentive in the form of green certification to adopt the green technology in addition to the tax-subsidy policy, as in Section 3. Note that firms are heterogeneous in terms of their valuations for social reputation. While $\beta \in (0, 1)$ proportion of firms care about social reputation ($\theta = 1$), remaining $1-\beta$ proportion of firms do not care about it ($\theta = 0$). In such a scenario, a reputation concerned firm's incentive compatibility condition to 'accept bribe demand from a corrupt official and pay bribe b' in Stage 3, regardless of the technology choice, is satisfied if and only if condition (Ap. 2) is satisfied, which is obtained from conditions (14) and (15) by substituting $\lambda = 0$.

$$t > \frac{b + f(1-\rho)}{\rho} - \frac{(P+Q)}{\mathrm{v_T}} = t_b - \frac{(P+Q)}{\mathrm{v_T}} = t_b^R, \qquad (Ap.2)$$

where $= H\big(E(x)\big) - S\big(E(n-x)\big) > 0$, and $Q = H(E(x)+1) - S\big(E(n-x-1)\big) > 0$. On the other hand, incentive compatibility conditions of non-reputation concerned firms to accept bribe demand from corrupt officials are satisfied if and only if condition (Ap. 1) is satisfied. The reasons are same as discussed in the case of no non-monetary incentives. It is evident that $t_b^R < t_b$. Thus, to ensure that none of the n firms bribe in the equilibrium, regardless of their valuation for social reputation, we must have $t \leq t_b^R$.

It is easy to observe that, in Stage 2, firms incentive compatibility conditions to adopt the green technology under bribee initiated corrupt transactions remain same as those under briber initiated corrupt transactions, as in absence of no non-monetary incentives. This is because, firms do not know the type of the official, honest or corrupt, while choosing the technology in Stage 2, regardless of whether corrupt transactions in Stage 3 will be initiated by bribee or briber. Thus, following the analysis of Section 3, we can say that each firm will choose the green technology in Stage 2 if and only if $t \geq \frac{v_T c - \mathrm{v_E} e}{v_T(1-\rho(1-\lambda))} = \underline{t^G}(c)$ is satisfied, regardless of whether a firm is reputation concerned or non-reputation concerned. Overall, it follows that the target equilibrium outcome can be achieved, if and only if $\underline{t^G}(c) \leq t_b^R$ and $t \in [\underline{t^G}(c), t_b^R]$. Now, $\underline{t^G}(c) \leq t_b^R \Leftrightarrow c \leq c_b - \big(1-\rho(1-\lambda)\big)\frac{(P+Q)}{v_T}$, where $c_b = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{\mathrm{v_E}}{v_T}\mathrm{e}$. Therefore, we have the following.

Lemma 3: *Suppose that corrupt transactions, if any, are initiated by bribees. Then, in the presence of non-monetary incentives, the 'lowest-subsidy minimum-tax' policy that implements the terget equilibrium outcome is as follows.*

(i) $t^{*OR} = \underline{t}^G(c)$ and $s^{*OR} = 0$, if $c \leq c_b^R$; otherwise

(ii) $t^{*OR} = \underline{t}^G(c_b^R)$ and $s^{*OR} = c - c_b^R$, if $c > c_b^R$; where

$c_b^R = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e - \Delta = c_b - \Delta$, $\Delta = 2\gamma\left[H\left(n\left(1-\rho(1-\lambda)\right)\right) - S\left(n\rho(1-\lambda)\right)\right]\frac{(1-\rho(1-\lambda))}{v_T} > 0$ and $\underline{t}^G(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$. *$t^{*OR}$ and s^{*OR} denote, respectively, the lowest possible brown tax on each brown firm and the lowest green technology subsidy in the presence of non-monetary incentive, when corrupt transactions are initiated by officials.*

Proof: We know, the target equilibrium outcome can be achieved, if and only if $\underline{t}^G(c) \leq t_b^R$ and $t \in [\underline{t}^G(c), t_b^R]$. Also, $\underline{t}^G(c) \leq t_b^R \Leftrightarrow c \leq c_b - \left(1-\rho(1-\lambda)\right)\frac{(P+Q)}{v_T}$, where $c_b = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e$. Now, in the target equilibrium, we have $\frac{(P+Q)}{v_T}\left(1-\rho(1-\lambda)\right) = 2\gamma\left[H\left(n\left(1-\rho(1-\lambda)\right)\right) - S\left(n\rho(1-\lambda)\right)\right]\frac{(1-\rho(1-\lambda))}{v_T} = \Delta > 0$ (see Proof of Proposition 3). Therefore, we can state the following.

(i) If $c \leq c_b^R = c_b - \Delta$, any (t, s) combination such that $t \in [\underline{t}^G(c), t_b^R]$ and $s \geq 0$ implements the target equilibrium outcome. Clearly, '$s = 0$ and $t = \underline{t}^G(c)$' is the '*lowest- subsidy minimum-tax*' that implements the target equilibrium.

(ii) If $c > c_b^R = c_b - \Delta$, the minimum technology subsidy necessary to ensure that $\underline{t}^G(c - s) \leq t_b^R$ holds true is given by $s = c - c_b + \left(1-\rho(1-\lambda)\right)\frac{(P+Q)}{v_T}$. Therefore, '*lowest- subsidy minimum-tax*' that implements the target equilibrium is given by '$s = c - c_b + \Delta = c - c_b^R$ and $t = \underline{t}^G(c - s) = \underline{t}^G(c_b^R)$'. ■

From Proposition 3, Lemma 1 and Lemma 3, we get the following.

Lemma 4: (a) $s^{*OR} > s^{R*} \geq 0$ and $0 < t^{*OR} < t^{R*}$, if $c > c_b^R$. Otherwise, if $c \leq c_b^R$, $0 < t^{*OR} = t^{R*}$ and $s^{*OR} = s^{R*} = 0$.

(b) $s^{*OR} > s^{*O} \geq 0$ and $0 < t^{*OR} < t^{*O}$, if $c > c_b^R$. Otherwise, if $c \leq c_b^R$, $0 < t^{*OR} = t^{*O}$ and $s^{*OR} = s^{*O} = 0$.

Proof: We have the following. $c_b^R = c_b - \Delta$, $c_b = \frac{(1-\rho(1-\lambda))}{\rho}[b + f(1-\rho)] + \frac{v_E}{v_T}e > 0$, $\hat{c} = \underline{c} - \Delta$, $\underline{c} = \frac{(1-\rho(1-\lambda))}{\rho(1-\lambda)}[b(1-\lambda) + f\lambda + f(1-\lambda)(1-\rho)] + \frac{v_E}{v_T}e > 0$, $\Delta = 2\gamma\Big[H\Big(n\big(1 -$

$\rho(1-\lambda))\big) - S\big(n\rho(1-\lambda)\big)\Big]\frac{(1-\rho(1-\lambda))}{v_T} > 0$. Clearly, $c_b^R < c_b < \underline{c}$ and $\hat{c} < \underline{c}$. It follows that $c_b^R < \hat{c}$, since $c_b < \underline{c}$.

Now, from Lemma 3 and Proposition 3 we get the following, since $c_b^R < \hat{c}$.

(i) If $c \leq c_b^R$, $s^{*OR} = s^{R*} = 0$ and $0 < t^{*OR} = t^{R*} = \underline{t}^G(c)$

(ii) If $c_b^R < c \leq \hat{c}$, (a) $s^{*OR} = c - c_b^R > 0 = s^{R*}$ and (b) $0 < t^{*OR} = \underline{t}^G(c_b^R) < \underline{t}^G(c) = t^{R*}$, since $\frac{\partial \underline{t}^G(c)}{\partial c} < 0$ and $c_b^R < c$.

(iii) If $c > \hat{c}$, (a) $s^{*OR} = c - c_b^R > c - \hat{c} = s^{R*}$ and (b) $0 < t^{*OR} = \underline{t}^G(c_b^R) < \underline{t}^G(\hat{c}) = t^{R*}$, since $\frac{\partial \underline{t}^G(c)}{\partial c} < 0$.

Next, form Lemma 2 and Lemma 4 we get the following, since $c_b^R < c_b$.

(i) If $c \leq c_b^R$, $s^{*OR} = s^{*O} = 0$ and $0 < t^{*OR} = t^{*O} = \underline{t}^G(c)$

(ii) If $c_b^R < c \leq c_b$, (a) $s^{*OR} = c - c_b^R > 0 = s^{*O}$ and (b) $0 < t^{*OR} = \underline{t}^G(c_b^R) < \underline{t}^G(c) = t^{*O}$, since $\frac{\partial \underline{t}^G(c)}{\partial c} < 0$ and $c_b^R < c$.

(iii) If $c > c_b$, (a) $s^{*OR} = c - c_b^R = c - c_b + \Delta = s^{*O} + \Delta > s^{*O} > 0$, since $\Delta > 0$; and (b) $0 < t^{*OR} = \underline{t}^G(c_b^R) < \underline{t}^G(c_b) = t^{*O}$, since $\frac{\partial \underline{t}^G(c)}{\partial c} < 0$. ■

From Lemma 4(a) it is evident that, in the presence of non-monetary incentives, the scope to achieve the target equilibrium outcome only by imposing a brown tax under bribee initiated corrupt transactions is less than that under briber-initiated corruption. Further, bribee initiated corruption calls for a higher green technology subsidy and a lower brown tax, unless the extra cost of adopting the green technology is less than a critical level. The intuition is same as in the case of no non-monetary incentive. From Lemma 4(a) and Lemma 2, it follows that implications of bribee initiated corruption on required 'lowest-subsidy and minimum-tax policy' to implement the target equilibrium outcome in the presence of non-monetary incentives are similar to those in absence of non-monetary incentives.

Lemma 4(b) and Proposition 4 together implies that qualitative effects of introduction of non-monetary incentives on the 'lowest-subsidy and minimum-tax' policy required to achieve the target outcome in the equilibrium in the case of bribee initiated corruption are the same as those in the case of briber-initiated corruption. Thus, Proposition 4 remains valid regardless of whether corrupt transactions are initiated by firms or corrupt officials.

Proposition 5:

(a) Implementation of the target outcome in the equilibrium requires a higher green technology subsidy and a lower brown tax in the scenario in which corrupt transactions are initiated by bribee compared to those in the scenario of briber initiated corrupt transactions, unless the extra cost of green technology is less than a critical level. This is true both in the presence and in absence of non-monetary incentive. However, the critical level of extra cost of green technology is lower in the presence of non-monetary incentives compared to that in absence of non-monetary incentives.

(b) In a corrupt society, the target outcome can be achieved in the equilibrium at a lower cost through appropriately designed tax-subsidy policy alone compared to that when the tax-subsidy policy is coupled with non-monetary incentives, regardless of whether corrupt transactions are initiated by bribees or bribers.

Proof: Follows directly from Proposition 4, Lemma 2 and Lemma 4. ■

A5. Endogenous Bribe Rate

We know that officials are risk neutral and a type-h official's minimum acceptable bribe rate is $\underline{b}(h) = \frac{h+(1-\rho)w}{\rho}$ (> 0), $\frac{\partial \underline{b}(h)}{\partial h} > 0$, $h \in [\underline{h}, \overline{h}]$. $\underline{b}(h)$ does not depend on tax-subsidy policy or on the norm regarding corrupt transaction – bribee initiated of briber initiated or on whether non-monetary incentives are in place or not. Further,

Given the tax rate and technology choice, let b^j and b^{Oj} denote a type-j firm's maximum willingness to pay as bribe (i) in case briber initiates corrupt transactions and (ii) in case bribee (i.e. official) initiates corrupt transactions, respectively, in absence of non-monetary incentives; where $j \in \{G, B\}$, $j = G$ indicates 'green' and $j = B$ indicates 'brown'. Similarly, in the presence of non-monetary incentives, type-j firm's maximum willingness to pay as bribe are denoted by b^{jR} and b^{OjR} (i) in case briber initiates corrupt transactions and (ii) in case bribee initiates corrupt transactions, respectively.

Note that in case bribee initiates corrupt transactions, if a firm faces a bribe demand at Stage 2, firms become certain that the official is interested in bribe. Then, the firm does not face any risk of being subject to penalty f, at Stage 2 (as in Section 4). Further, a firm's maximum willingness to pay as bribe is such that the firm is indifferent between paying that amount as bribe and not paying any bribe. Therefore, by using equations (1)-(4) and (10)-(13), we get b^j, b^{Oj}, b^{jR} and b^{OjR} as given by following equations; where $P = H\big(E(x)\big) - S\big(E(n-x)\big) > 0$, $Q = H(E(x)+1) - S\big(E(n-x-1)\big) > 0$ and $j = G, B$.

Type-j Firm's Maximum willingness to pay as bribe:

(i) <u>No non-monetary incentive</u>

(a) Briber initiated corrupt transactions

$$\pi_{j,B}\big|_{b=b^j} = \pi_{j,NB}\big|_{b=b^j} \Leftrightarrow b^j = t\rho - f(1-\rho) - \frac{f\lambda}{(1-\lambda)} \qquad (Ap.3)$$

(b) Bribee initiated corrupt transactions

$$\pi_{j,B}\big|_{\lambda=0,b=b^{Oj}} = \pi_{j,NB}\big|_{\lambda=0,b=b^{Oj}} \Leftrightarrow b^{Oj} = t\rho - (1-\rho) \qquad (Ap.4)$$

(ii) <u>Non-monetary incentives</u>

(a) Briber initiated corrupt transactions

$$\pi_{j,B}^{R}\big|_{b=b^{jR}} = \pi_{j,NB}^{R}\big|_{b=b^{jR}} \Leftrightarrow b^{jR} = t\rho - f(1-\rho) - \frac{f\lambda}{(1-\lambda)} + \frac{(P+Q)}{\mathrm{v_T}} \qquad (Ap.5)$$

(b) Bribee initiated corrupt transactions

$$\pi_{j,B}^{R}\big|_{\lambda=0,b=b^{OjR}} = \pi_{j,NB}^{R}\big|_{\lambda=0,b=b^{OjR}} \Leftrightarrow b^{OjR} = t\rho - f(1-\rho) + \frac{(P+Q)}{\mathrm{v_T}} \qquad (Ap.6)$$

Clearly, a firm's maximum willingness to pay as bribe does not depend on technology choice, ceteris paribus: $b^G = b^B, b^{GR} = b^{BR}$, $b^{OG} = b^{OB}$, and $b^{OGR} = b^{OBR}$. However, it depends on (a) the type of policy intervention (only monetary or both monetary and non-monetary) and magnitude of tax on brown firm t and (b) the prevailing norm regarding corruption (bribee initiated or briber initiated).

For any given brown tax t, a firm's maximum willingness to pay as bribe is less in the case of briber initiated corrupt transactions than that in the case of bribee initiated corrupt transactions, regardless of whether the firm is green or brown and whether there is any non-monetary incentive or not: $b^j < b^{Oj}$ and $b^{jR} < b^{OjR}$, $j = G, B$. This is because firms do not face the risk of offering bribe to and get penalized by the official himself, which results in higher expected payoff of firms from paying the bribe amount, in the former case. Also, for any given brown tax t, a firm's maximum willingness to pay as bribe is more in the presence of non-monetary incentive than that in case there is no non-monetary incentive, regardless of whether the firm is green or brown and whether corrupt transactions are initiated by bribee or briber: $b^{jR} > b^j$ and $b^{OjR} > b^{Oj}$, $j = G, B$. The reason is, in the former case, the green firm is willing to pay higher bribe to get the reward of being green, while the brown firm is willing to pay higher bribe to buy social reputation. It follows that $b^j < b^{jR} < b^{OjR}$ and $b^j < b^{Oj} < b^{OjR}$.

Since $\frac{\partial b^j}{\partial t} = \frac{\partial b^{Oj}}{\partial t} = \frac{\partial b^{jR}}{\partial t} = \frac{\partial b^{OjR}}{\partial t} = \rho > 0,\ j = G, B$, a firm's maximum willingness to pay as bribe can be reduced by setting a lower tax on brown firm. Now, to ensure that no corrupt transaction takes place, $\overline{b} < \underline{b}(h)$ must hold true, where $\overline{b} \in \{b^j, b^{jR}, b^{Oj}, b^{OjR}\}$.. Therefore, we have the following.

i) In absence of non-monetary incentives, brown tax t ensures that no corrupt transaction takes place, if

$$t < \begin{cases} \frac{1}{\rho}\left[\underline{b} + f(1-\rho) + \frac{f\lambda}{(1-\lambda)}\right] = \underline{t^C_{endo}}, & \text{if briber initiates corrupt transactions;} \\ \frac{1}{\rho}\left[\underline{b} + f(1-\rho)\right] = t_{b,endo}, & \text{if bribee initiates corrupt transactions;} \end{cases}$$

ii) In the presence of non-monetary incentives, brown tax t ensures that no corrupt transaction takes place, if

$$t < \begin{cases} \frac{1}{\rho}\left[\underline{b} + f(1-\rho) + \frac{f\lambda}{(1-\lambda)} - \frac{(P+Q)}{v_T}\right] = \underline{t^{CR}_{endo}}, & \text{if briber initiates corrupt transactions;} \\ \frac{1}{\rho}\left[\underline{b} + f(1-\rho) - \frac{(P+Q)}{v_T}\right] = t^R_{b,endo}, & \text{if bribee initiates corrupt transactions;} \end{cases}$$

Clearly, $t^R_{b,endo} < t_{b,endo} < \underline{t^C_{endo}}$ and $t^R_{b,endo} < \underline{t^{CR}_{endo}} < \underline{t^C_{endo}}$.

In Stage 2, i.e., at the technology choice stage, firms' incentive compatibility conditions for choosing the green technology under endogenous bribe rate remains the same as that under exogenously given bribe rate. This is because, at Stage 2 firms cannot update their beliefs regarding the official's type and incentive compatibility conditions for choosing the green technology does not depend on the bribe rate. Therefore, at Stage 2, each firm will find it optimal to choose the green technology, if $t \geq \underline{t^G}(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$, regardless of whether (a) corrupt transactions are initiated by bribee or by briber, (b) there is non-monetary incentive or not, and (c) bribe rate is endogenous or exogenous. Further, it is easy to check that, if we consider $b = \underline{b}$ in (5), (14), (Ap.1) and (Ap.2), we get $\underline{t^C_{endo}} = \underline{t^C}$ (as in (5)), $t_{b,endo} = t_b$ (as in (Ap.1)), $\underline{t^{CR}_{endo}} = \underline{t^{CR}}$ (as in (13)) and $t^R_{b,endo} = t^R_b$ (as in (Ap.2)).

Overall, it follows that the quantitative results of the analysis under exogenous bribe rate also remain unchanged in the case of endogenous bribe rate, if the exogenously given bribe rate is equal to the minimum acceptable bribe rate to a $\underline{h}$-type official ($b = \underline{b}(\underline{h})$). However, when $b > \underline{b}(\underline{h})$, it is fairly straightforward to observe that $\underline{t_{endo}^{C}} < \underline{t^{C}}$, $t_{b,endo} < t_b$, $\underline{t_{endo}^{CR}} < \underline{t^{CR}}$ and $t_{b,endo}^{R} < t_b^{R}$. It implies that, in the later case, implementation of the first best equilibrium outcome under endogenous bribe rate (a) only through a brown tax is feasible for a lower range of the cost of green technology adoption compared to that under exogenous bribe rate, (b) calls for a lower brown tax and higher green technology subsidy, when only a brown tax is not sufficient to ensure the first best outcome, compared to that under exogenous bribe rate. This is true, regardless of (a) whether corrupt transactions are initiated by bribee or by briber and (b) whether there is non-monetary incentive or not. Nevertheless, Proposition 4 and Proposition 5 remains valid always regardless of whether bribe rate is exogenously given or endogenously determined in the model.

Remarks: In this paper it is considered that, if $\overline{b} < \underline{b}(h)$, (a) in the case of briber initiated corrupt transactions, the firm offers bribe $b \leq \overline{b}$, but the h-type official does not accept it and reports the firm as brown regardless of the true type of the firm, and (b) in the case of bribee initiated corrupt transactions, the h-type official asks for bribe if $b \geq \underline{b}\ (h)$, but the firm does not accept the bribe demand and gets reported as brown regardless of whether the firm is truly brown or green. That is, while $\overline{b} < \underline{b}\ (h)$ ensures that no corrupt transaction takes place, it does not rule out the possibility of misreporting of firm's true type, green or brown, by corrupt officials.

An alternative possible scenario is as follows. an official asks for bribes only in case he can expect to get that, i.e., only in case his minimum acceptable bribe rate is less than or equal to the firm's maximum willingness to pay ($\underline{b}(h) \leq \overline{b}$); otherwise, the h-type official behaves as an honest official, i.e. he does not ask for any bribe and reports firms technology choice truthfully. In such a scenario, if the norm is such that bribee initiates corrupt transactions, (a) the required brown tax t to ensure that no corrupt transaction takes place will remain unchanged and (b) at the technology choice stage (Stage 2) firms can correctly anticipate that there will not be any bribe demand or misreporting by any official, if brown tax is such that $\overline{b} < \underline{b}\ (\underline{h})$ holds true. It implies that, in the alternative scenario with bribee initiated corrupt transactions, if t is such that $\overline{b}(t) < \underline{b}\ (\underline{h})$ is satisfied, the relevant incentive compatibility condition of firms to choose the green technology will be modified to $v_T y - v_T c \geq v_T y - v_E e - v_T t \Leftrightarrow t \geq \frac{v_T c - v_E e}{v_T} = \underline{t^{g}}(c)$, since this case is equivalent to the case of $\lambda = 1$. Now, since $\underline{t^{g}}(c) < \underline{t^{G}}(c) = \frac{v_T c - v_E e}{v_T(1-\rho(1-\lambda))}$, both $\overline{b}(t) < \underline{b}$ and $t \geq \underline{t^{g}}(c)$ will be satisfied for a lower range of c

compared to that in the earlier scenario (in which corrupt official always misreports unless bribe is paid). It follows that, *under bribee initiated corrupt transactions in the alternative scenario* (a) *the scope for implementation of the target equilibrium outcome through the tax instrument alone is less and (b) the 'lowest-subsidy minimum-tax' policy to implement the target equilibrium outcome calls for a lower brown tax a higher green technology subsidy compared to that in the earlier scenario. This is true, regardless of whether there is any monetary incentive or not. Further, implications of non-monetary incentives on the required 'lowest-subsidy minimum-tax' policy remains the same in both the scenarios. Interestingly, in the alternative scenario, implementation of the target equilibrium outcome under bribee initiated corrupt transactions also guarantees that there will not be any misreporting in the equilibrium.*

■■■