Does Introduction of Bureaucratic Competition Reduce Corruption in Public Service Delivery?

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Abstract

The paper theoretically explores the impact of introducing bureaucratic competition on corruption. For this purpose it considers three alternative measures of corruption such as corruption incidence (CI), relative corruption incidence (CRI) and corruption rents (CR) in three different types of economies namely corruption-tolerant economies (where bribery is extortion based), corruption-reliant economies (where bribery is collusion based) and an economy where both extortion based and collusion based bribery are possible. As it compares both intensive margin (i.e. the magnitude of bribe) and extensive margin (i.e. the number of bribe incident) of corruption with and without bureaucratic competition, it turns out that as traditionally perceived the introduction of bureaucratic corruption does not necessarily reduce corruption in an economy. The outcome depends on the type of the economy that has been studied, the measure of corruption being used and the initial level of corruption in the economy. Among the counterintuitive results, we find that in a corruption tolerant economy and in an economy where both types of bribery is present, going by the CI measure, corruption is always higher under competitive regime compared to monopoly regime. The same holds true if the CR measure is used in a corruption tolerant economy with sufficiently high share of corrupt officials. If CRI measure is applied, in a reliant economy corruption is more in competitive regime; in an economy where both types of bribery is present the same holds true under certain conditions.

***JEL Classification*:** D73, K42.

***Keywords*:** Corruption, competition, bureaucracy, red tape, measures of corruption, extortion, collusion.

1. Introduction

It is well known in economic theory that competition improves the functioning of the private sector. However whether the same holds true for the public sector, especially in delivery of public goods/services, is an interesting research question. As far as the corrupt bureaucracies are concerned, the conventional theories suggest, if competition is introduced among bureaucrats for delivery of public goods and services, corruption falls (Becker and Stigler (1974), Rose Ackerman (1978), Shleifer and Vishny (1993)). The competing bureaucrats, who supply substitute products, would gradually lower their bribe demands and eventually corruption would disappear. But the recent theory (Drugov (2010)) points out that the change in intensive margin of bribes is not the only outcome of bureaucratic competition as the conventional theory suggests. The extensive margin can also change as the number of bribe transactions may itself get affected by such competition. The paper shows that once the change in extensive margin is taken into account alongside the change in the intensive margin, according to some of the measures of corruption, the conventional wisdom about the impact of introducing competition[1]. in a corrupt bureaucracy may change: corruption may in fact rise in some economies.

The paper adapts Drugov (2010) framework to compare two alternative bureaucratic regimes: monopoly and competition. As the bureaucracy moves from monopoly to competitive regime we argue that the bribe rate definitely falls as suggested by the conventional theory, but the lower bribe rate also implies lower deterrent power of bribes in discouraging occurrence of bribe transactions. As the cost of participation in bribe transactions fall, the number of bribe transactions increases. Thus a change in intensive margin induces a change in extensive margin as well. Drugov (2010) uses his model for welfare comparison under the two regimes and concludes that in presence of corruption the welfare of an economy may not necessarily improve on introduction of bureaucratic competition But he does not compare the level of corruption under the two regimes, as we do it in this paper. Here we try to fill this gap.

[1] In contrast Ahlin and Bose (2006) consider a partially honest bureaucracy where bureaucratic competition for sure leads to greater inefficiencies through delay and misallocation. Earlier while exploring the effect of product market competition on bribe rate Bliss and Di Tella (1997) considered the determination of extensive margin at the equilibrium.

In addressing the research question posed above the next step would be to define a measure of corruption. Here we follow Mendez and Sepulveda (2009). They define three alternative measures of corruption: Incidence of Corruption (CI), Relative Corruption Incidence (CRI) and Corruption Rents (CR) in two different types of economies: corruption-tolerant economies (where bribery is extortion based), corruption-reliant economies (where bribery is collusion based). We also introduce an economy with pervasive corruption (where both extortion based and collusion based bribery coexist). While the CI measures the number of times a bribe transaction is observed; the CRI measures the ratio of bribe transactions relative to the total number of transactions; the CR measures the total amount of rents collected by dishonest public officials from bribe transactions. While the corruption tolerant economy is the one where firms are extorted to pay bribes, the corruption reliant economy is the one where bribes are Pareto improving side contracts and collusive in nature. In this paper we use the measures defined by Mendez and Sepulveda to compare a monopoly regime of bureaucracy with a competitive regime of bureaucracy in terms of corruption[2]. Mendez and Sepulveda restrict their attention only in tolerant and reliant economies. We also discuss the case of an economy, which we call an economy with pervasive corruption, where both the extortion and collusive bribery is present. We thought it is essential as in most of the economies where corruption is present both these types of bribery coexist.

The current paper in effect marries Drugov's model of bureaucratic competition with the measures of corruption used by Mendez and Sepulveda to derive its conclusions. In Drugov (2010) a firm can either use an old polluting technology for production which generates negative externality to the society in the form of pollution, or they can invest in a clean technology. As per legislation, only the firms investing in the clean technology are qualified to produce. The investment in clean technology is costly. There are both honest and corrupt bureaucrats in the system, the identity of whom is not disclosed to the firms unless they meet an official. The honest bureaucrats grant licenses only to qualified firms and do not charge a bribe, but the corrupt bureaucrats will grant license to any firm in exchange for a bribe. Mendez and Sepulveda (2009) study a search theoretic model in a

[2]Foster, Horowitz and Mendez (2013) provide axiomatic foundation of these measures.The papers like Cadot (1987), Mookherjee and Png (1995), Bliss and Di Tella (1997), Guriev (2004), Barron and Olken (2009) use one of these measures of corruption.

similar set up where firms are replaced by agents who undertake some investment projects to become entrepreneurs. Similar to Drugov's model these agents need the project to be certified by the government and that requires some regulations to be followed which is costly. Just as the licences are administered by some officials, the certification is provided some officials who can be honest or corrupt. An honest official will certify only if regulations have been followed whereas a corrupt official will certify any project in exchange for a bribe. The bribe is determined through Nash Bargaining in both the models. Mendez and Sepulveda then compare the corruption levels across the corruption tolerant and reliant economies, using CI, CRI and CR for two specific types of parametric changes: change in the number of honest officials and a change in the compliance cost. Drugov's model shows how the bribery decisions change when the economy moves from monopoly to competition. Under monopoly regime, a single bureaucrat administers the license and the firms do not have choice to avoid her. Thus having full authority to refuse an applicant, corrupt official charges the same amount of bribe to both qualified and unqualified firms. In both the regimes, the firms can reapply for the license in the next period if they are refused in the first period. However, while under monopoly regime the firms have to reapply to the same official, under competitive regime firms have choice: they can randomly choose an official to reapply in the next period[3]. The reapplication is costly. However it increases the bargaining power of the firms with the corrupt officials and reduces the bribe amount: the qualified and the unqualified firms pay different bribe amounts. Under monopoly regime, the firms choose from two different strategies: they can either be qualified from period one itself or they can initially remain unqualified and decide to invest later once the official they meet turns out to be honest. However under competitive regime, firms can have three different strategies; (i) Never invest, (ii) Invest in period one and (iii) Invest once an honest official is met. Following Drugov (2010) we consider all of the above strategies under both the regimes and characterize the profile of bribes. As we compare both the intensive margin (i.e. the magnitude of bribe) and the extensive margin (i.e. the number of bribe incident) under the regimes with and without bureaucratic competition, we find that as traditionally

[3] Drugov (2010) reports existence of such competition in bureaucracy in case of passport delivery in US, distribution of driving licenses in Russia. Indian state of Gujarat has introduced competition in delivery of driving licenses in recent times. The case of 'zero FIR' in India by the Advisory (No. 15011/35/2013 – SC/ST–W) under government of India, is another example of competitive bureaucracy as a First Information Report can be lodged at any police station of the country, not necessarily at the police station where the crime has taken place add references.

perceived we cannot necessarily conclude that introduction of bureaucratic competition reduce corruption in an economy. The outcome depends on the type of the economy that has been studied, the measure of corruption being used and the initial level of corruption in the economy. While some of the results we derive are consistent with the traditional corruption literature, however some of them are counterintuitive. Among the counterintuitive results, we find that in a corruption tolerant economy and in an economy where both types of bribery is present, going by the CI measure, corruption is always higher under competitive regime compared to monopoly regime. The same holds true if the CR measure is used in a corruption tolerant economy with sufficiently high share of corrupt officials. If CRI measure is applied, in a reliant economy corruption is more in competitive regime; in an economy where both types of bribery is present the same holds true under certain conditions.

In the cross country comparison of corruption (Svensson (2005), Shabbir and Anwar (2007)) usually the less developed economies are more or less identified either with the corruption tolerant economies (since the majority of corruption incidence is of extortion) or with the economies with pervasive corruption, while the developed economies are identified with the corruption reliant economies (since the majority of corruption incidence is of collusion). The results obtained in the paper, as mentioned above, suggests that the introduction of bureaucratic competition is likely to invite more corruption in developing economies; going by certain measures like CRI it is likely to increase in the developed economies as well. The results would also apply to certain government departments depending on whether extortion or collusion prevails in them. Therefore some of the results go completely against the usual policy rhetoric. If control of corruption is the sole objective of introducing competition in a bureaucracy, the current paper sounds a caution.

The next section presents the model and derives the results. The section following concludes.

2. The Model

There is a continuum of firms who need a license to produce and the license is provided by some government officials. The firms can use either a new and clean technology or an old polluting one. As per legislation, firms investing in the clean technology are eligible for a license and are thus *qualified* and firms using the old technology are not eligible for the license and are thus *unqualified*. We use the superscripts q and u to denote qualified and unqualified firms, respectively. A firm becomes qualified by investing in clean technology at a cost C. The ith firm will invest in the clean technology if $C \leq R_i$ where R_i denotes revenue of the ith firm. The *PDF* of the firms' revenue is denoted by $g(R_i)$. If a firm produces in spite of being unqualified, it generates a negative externality to the society in the form of pollution.

The government officials are supposed to grant licenses only to qualified firms. The share of honest official is h and these officials give license only to firms who are qualified without charging a bribe. The rest (with share $(1-h)$) is corrupt. A corrupt official will give license to any firm, regardless of their eligibility, in exchange for a bribe. This introduces possibilities of both extortion (qualified firms paying bribe) and collusion (unqualified firms getting the license in exchange for a bribe) in the model.

Following Drugov (2010) we consider two different types of bureaucratic regime: monopoly and competition. Under the monopoly regime, there is a single official and so each firm applies to the same official for a license. Under competitive regime, there are multiple officials and each firm can choose to apply randomly to an official and if refused, it can reapply to the same official or a separate official chosen at random. Firms are only aware of the probabilities of the type of official; identities of both the parties are revealed once the interaction takes place. We assume both the firms and the corrupt officials are risk neutral. In both the regimes, corrupt officials ask for a bribe b the amount of which is determined through Nash Bargaining: the assumption of risk neutrality implies that the firm and the official equally split the surplus in the bribe negotiation. Since under monopoly regime, a single bureaucrat administers the delivery of license, she has full authority to refuse an applicant and thus will charge the highest bribe amount. Under competition since multiple bureaucrats administer the delivery of licenses, firms have outside option. The possibility of reapplication in bribe negotiations increases the bargaining power of the firms against the corrupt officials. This leads to a lower bribe charged under competitive regime compared to monopoly regime. However, if there is cost of reapplication bargaining power of the firms fall. We use the subscripts c and m in relevant variables to denote competition and monopoly regimes respectively.

The timeline of the game between the firms and the officials are as follows. Initially all the firms are unqualified. At the beginning of period 1, a firm decides whether to invest or not to invest. A firm, which invests once, remains qualified forever. In period 2 the firm then applies to an official for a license. The possibility of bribery occurs. If the firm gets the license, it produces and earns profit π and quits the game, otherwise it reapplies in the next period. Under monopoly, the firms will reapply to the same official and in competition the firm can reapply to the same official or a different official chosen at random. There is an infinite horizon and a common discount factor $\delta \in (0, 1)$ among the firms which is used as the costs of their reapplication: the payoff of the firm reduces by δ in each subsequent period compared to the previous one. The bribes collected by the corrupt officials are considered as pure transfers. Let us now consider the two regimes in detail.

2.1 Monopoly Regime

Under the monopoly regime while applying for the license the firms cannot switch from one official to another. The monopoly official, if corrupt, collects bribe from both qualified and unqualified firms. The amount of bribe is determined through Nash Bargaining. Let the bribe for qualified and unqualified firms in monopoly regime is denoted by b_m^q and b_m^u respectively.

Observation1: [*Drugov* (2010)] $b_m^q = b_m^u = b_m = \frac{1}{2} R_i$.

Notice any firm in monopoly, if required to pay a bribe, pays half of the bribe surplus R_i as bribe. Anticipating this, a firm under monopoly regime can adopt two different strategies. It can either choose to be unqualified at period 1 or can wait till period 2 and become qualified once an honest official is met. The expected profit of a firm that chooses to be qualified at period 1 is:

$$\pi_m^q = hR_i + (1-h)\frac{1}{2}R_i - C. \tag{1}$$

Initially if the firm decides to remain unqualified, the only way it gets the license in this regime is that it meets a corrupt official and pays bribe for the license. Otherwise, the official it meets is an honest one. Then it knows that for receiving the license it has no other alternative than investing in clean technology and reapplying to the same official in the next period. Therefore the expected profit of the initially unqualified firm is given by:

$$\pi_m^u = \delta h(R_i - \mathrm{C}) + (1-h)\frac{1}{2}R_i. \tag{2}$$

A firm with its revenue R_i decides to be qualified in period 1 itself if and only if $\pi_m^q - \pi_m^u \geq 0$. Substituting from (1) and (2) that implies: $Ri \geq R_1^m$ where $R_1^m = \frac{C(1-\delta h)}{h(1-\delta)}$. On the other hand an unqualified firm under monopoly regime produces if and only if $\pi_m^u \geq 0$. Substituting from (2) for π_m^u , $\pi_m^u \geq 0$ implies $R_i \geq R_2^m$ where $R_2^m = \frac{2\delta hC}{h(2\delta-1)+1}$.

Observation 2: $R_1^m > R_2^m$.

Proof: See the appendix.

Observation 2 shows that the qualified firms investing in period one itself must have higher revenue compared to firms who remain initially unqualified. This happens because investment is costly and only the firms with sufficiently high revenue undertake such investment in period 1.

We shall now summarize the monopoly regime equilibrium as:

If $R_2^m > 0$ a firm having its revenue in [0, R_2^m), does not enter the industry. A firm in [R_2^m, R_1^m) remains unqualified initially, but invests and becomes qualified if the official it meets while applying turns out as honest; and a firm in [$R_1^m, \propto$), invests and becomes qualified in period one itself. All firms in [$R_2^m, \propto$) pay bribe of amount $\frac{1}{2}R_i$ if met with a corrupt official.

2.2 Competitive Regime

In the competitive regime, once denied, a firm may subsequently access another official for the license. So now it has an outside option. In this situation if an unqualified firm meets an honest official and gets denied of the license, it may decide to remain unqualified and reapply to some other official chosen randomly in the next period. It may continue doing so till it meets a corrupt official. Similarly a qualified firm that meets a corrupt official rather than submitting itself to the bribe demand may decide to reapply in the next period. Since firms under competitive regime have outside option, they have greater bargaining power against a corrupt official in bribe negotiation. Now each firm has three mutually exclusive strategies: (1) invest in period one (to be qualified); (2) never invest (to remain unqualified); and (3) invest (to be qualified) once an honest official is met in period 2. Which one of these will be chosen? To find an answer let us consider these strategies separately in detail.

Strategy 1: Invest in period one

In this case, a firm invests and becomes qualified in period one itself. Subsequently if the firm meets an honest official definitely gets the license without paying a bribe. However it may also meet a corrupt official and then faces a demand for bribe. In such a situation, given the outside option, it can refuse to pay the bribe and reapply in the subsequent periods until it meets an honest official. However this increases the reapplication costs. Therefore a qualified firm who wishes to avoid these costs will agree to pay bribe b_c^q to the corrupt official whom it may meet in period 2 itself and will obtain the license. So in competitive regime as well, there exists a case of extortion. The expected profit of a qualified firm becomes:

$$\pi_c^q = hRi + (1-h)\left(R_i - b_c^q\right) - C. \tag{3}$$

Strategy 2: Never invest

A firm following this strategy decides never to invest and remains unqualified forever. So its only source of license is a corrupt official. If in period 2, such a firm meets an honest official, it will go on reapplying in the next period, until it finds a corrupt official. Once it meets a corrupt official, it pays the bribe b_c^u to get the license. The expected profit of an unqualified firm thus becomes:

$$\pi_c^u = \delta h \pi_c^u + (1-h)(R_i - b_c^u)\ . \tag{4}$$

Strategy 3: Invest once an honest official is met

If a firm that is initially unqualified meets an honest official in period two, it will not get the license. However, in this case, the firm will invest in the clean technology and reapply next period to the same honest official so that it gets the license without a bribe for sure. If the firm in period two meets a corrupt official, it pays the bribe b_c^{uq} and gets the license. Note that this behaviour of the firm is identical as that of a firm under monopoly regime, which remains initially unqualified and meets an honest official in period 2. The expected profit of a firm adopting this strategy is thus:

$$\pi_c^{uq} = \delta h(Ri - C) + (1-h)\left(R_i - b_c^{uq}\right). \qquad (5)$$

Observation 3: [*Drugov* (2010)]

(i)$b_c^q = \frac{R_i(1-\delta)}{2-\delta+\delta h}$, $b_c^u = \frac{R_i(1-\delta)}{2-\delta-\delta h}$and $b_c^{uq} = \frac{R_i-\delta^2 h(Ri-C)-\delta R_i(1-h)}{2-\delta+\delta h}$;

(ii) b_c^q

$b_c^q < b_c^{uq} < b_c^u < b_m$.

In each case the bargaining surplus is equally divided between the firm and the corrupt official in determination of bribe.

The bribe amount depends on relative bargaining strength of the parties involved which in turn is determined by their disagreement payoffs. Note here it is the disagreement payoff of the firms that changes depending on the regime type and their own period one investment strategy. Under monopoly regime the bargaining power of a firm in the bribery game is lower than that in the competitive regime because it cannot dispense with the official. Under competitive regime, however, once refused the firms have outside option of applying to a second official. A firm which follows the strategy of never investing has the least and a firm which invests in period one itself has the greatest bargaining power against a corrupt official in this regime. The firm which follows the strategy of 'invest once an honest official is met' has its bargaining power between these two extremes.

Substituting the values of b_c^q , $b_c^{uq}$and b_c^u in equations (3), (4) and (5) respectively we calculate the values of the profit function π_c^q, π_c^u and π_c^{uq}. It turns out that for all values of $R_i \geq 0$, $\pi_c^u \geq 0$. So unlike the monopoly regime, where if $R_2^m > 0$ firms having their revenue in [0, R_2^m) do not enter the economy, here all the firms enter irrespective of their revenue potential. A firm invests in period 1 itself if and only if $\pi_c^q - \pi_c^{uq} \geq 0$ implying $R_i \geq R_1^c$ where $R_1^c = \frac{C[(2-\delta(1+h)]}{2h(1-\delta)} > 0$. Thus R_1^c is the revenue threshold, below which a firm under competitive regime will not invest in period 1. Similarly if $\pi_c^{uq} - \pi_c^u \geq 0$ a firm under competitive regime remains initially unqualified and invests once it meets an honest official. Note this happens for all firms having $R_i \geq R_2^c$ where $R_2^c = \frac{C(2-\delta-\delta h)}{(1+h)(1-\delta)} > 0$.

Observation 4: $R_1^c > R_2^c$.

Proof: See the appendix.

Observation 4, like observation 2, shows that since investment is costly, firms investing in period one under competitive regime has higher revenue compared to the rest.

Using the discussion above and observation 4 we shall now summarize the features of competitive regime equilibrium:

Under competitive regime all the firms with $R_i \geq 0$ produce. A firm having its revenue in [0, R_2^c) never invests in clean technology. A firm in $[R_2^c, R_1^c)$ invests and becomes qualified if honest official is met, and a firm in $[R_1^c, \propto)$ invests to be qualified in period one itself. All firms in $[0, \propto)$ pay bribe if met with a corrupt official. However, qualified and unqualified firms under competitive regime pay different bribe amounts depending on their period one investment strategy.

2.3 Comparison of the Regimes

Observation 5: $R_1^m > R_1^c$.

Proof: See the appendix.

Observation 6: $R_2^m < R_2^c$.

Proof: See the appendix.

Using observations 2, 4, 5 and 6 in figure 1 below we compare the revenue thresholds under the two regimes:

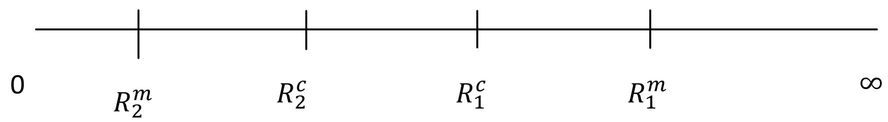

Figure 1: Comparison of revenue thresholds in monopoly and competitive regimes

Although from observation 3 it follows that under competitive regime the qualified firms pays lower amount of bribe compared to monopoly regime, since $R_1^m > R_1^c$, figure 1 shows that the number of firms paying such extortion money is more under the former regime. Similarly if $R_2^m > 0$ an inefficient firm having its revenue in [0, R_2^m) who do not enter into production under monopoly regime, enters under the competitive regime and remains unqualified forever. All the firms having their revenue in [0, R_2^c) get the license through collusive bribe with the corrupt officials. Compared to the monopoly regime in competitive regime for the firms who invest to get qualified after meeting an honest official the range of potential revenue shrinks from [R_2^m, R_1^m) to [R_2^c, R_1^c); the bribe paid also falls. So as we move from monopoly regime to competitive regime of bureaucracy both the intensive margin and the extensive margin of the corruption equilibrium change.

Now we compare the extent of corruption under the two regimes.

For this purpose following Mendez and Sepulveda (2009) we use three alternative measures as follows:

Corruption Incidence (CI): measures the number of licenses administered through bribes.

Relative Corruption Incidence (CRI): measures the ratio of licenses involving a bribe to the total number of licenses administered.

Total Corruption Rents (CR): measures the total amount of rents collected by dishonest public officials in the form of bribes.

We compare these measures for three different types of economies defined below:

Corruption Tolerant Economy (T): an economy where qualified firms are extorted to pay bribes.

Corruption Reliant Economy (R): an economy where unqualified firms pay collusive bribes.

Economy with Pervasive Corruption (P): an economy where both extortion and collusive bribery are present.

Using the model developed above, the corruption in a tolerant economy under competitive regime is measured in three alternative ways as:

$$CI_c^T = (1-h)\int_{R_1^c}^{\infty} g(R_i)dR_i; \tag{6}$$

$$CRI_c^T = \frac{(1-h)\int_{R_1^c}^{\infty} g(R_i)dR_i}{\int_{R_1^c}^{\infty} g(R_i)dR_i} = (1-h); \tag{7}$$

and

$$CR_c^T = (1-h)\int_{R_1^c}^{\infty} b_c^q g(R_i)dR_i. \tag{8}$$

The corruption in a tolerant economy under monopoly regime is similarly measured in three alternative ways as:

$$CI_m^T = (1-h)\int_{R_1^m}^{\infty} g(R_i)dR_i; \tag{9}$$

$$CRI_m^T = \frac{(1-h)\int_{R_1^m}^{\infty} g(R_i)dR_i}{\int_{R_1^m}^{\infty} g(R_i)dR_i} = (1-h); \tag{10}$$

and

$$CR_m^T = (1-h)\int_{R_1^m}^{\infty} b_m g(R_i)dR_i. \tag{11}$$

Proceeding similarly, the corruption in a reliant economy under competitive regime is measured in three alternative ways as:

$$CI_c^R = (1-\mathrm{h})\int_0^{R_2^C} g(R_i)dR_i + (1-\mathrm{h})\int_{R_2^c}^{R_1^C} g(Ri)dR_i = (1-\mathrm{h})\int_0^{R_1^C} g(R_i)dR_i\ ; \tag{12}$$

$$CRI_c^R = \frac{(1-h)\int_0^{R_2^c} g(R_i)dR_i + (1-h)\int_{R_2^c}^{R_1^c} g(R_i)dR_i}{(1-h)\int_0^{R_2^c} g(R_i)dR_i + \int_{R_2^c}^{R_1^c} g(R_i)dR_i}; \quad (13)$$

and

$$CR_c^R = (1-h)[\int_0^{R_2^c} b_c^u\, g(R_i)dR_i + \int_{R_2^c}^{R_1^c} b_c^{uq}\, g(R_i)dR_i]\,. \quad (14)$$

The corruption in a reliant economy under monopoly regime is similarly measured in three alternative ways as:

$$CI_m^R = (1-\mathrm{h})\int_{R_2^m}^{R_1^m} g(R_i)dR_i\,; \quad (15)$$

$$CRI_m^R = \frac{(1-h)\int_{R_2^m}^{R_1^m} g(R_i)dR_i}{\int_{R_2^m}^{R_1^m} g(R_i)dR_i} = (1-h)\,; \quad (16)$$

and

$$CR_m^R = (1-h)[\int_{R_2^m}^{R_1^m} b_m\; g(R_i)dR_i]\,. \quad (17)$$

The corruption in an economy where corruption is pervasive under competitive regime is measured in three alternative ways as:

$$CI_c^P = (1-h)\int_0^{\infty} g(R_i)\,dR_i; \quad (18)$$

$$CRI_c^P = \frac{(1-h)\int_0^{\infty} g(R_i)dR_i}{(1-h)\int_0^{R_2^c} g(R_i)dR_i + \int_{R_2^c}^{\infty} g(R_i)dR_i}; \quad (19)$$

and

$$CR_c^P = (1-h)[\int_0^{R_2^c} b_c^u g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c} b_c^{uq} g(R_i)\,dR_i + \int_{R_1^c}^{\infty} b_c^q g(R_i)\,dR_i]. \quad (20)$$

The corruption in an economy where corruption is pervasive under monopoly regime is similarly measured in three alternative ways as:

$$CI_m^P = (1-h)\int_{R_2^m}^{\infty} g(R_i)\,dR_i\,; \quad (21)$$

$$CRI_m^P = \frac{(1-h)\int_{R_2^m}^{\infty} g(R_i)dR_i}{(1-h)\int_{R_2^m}^{R_1^m} g(R_i)dR_i + \int_{R_1^m}^{\infty} g(R_i)dR_i}; \quad (22)$$

and

$$CR_m^P = (1-h)\int_{R_2^m}^{\infty} b_m g(R_i)\, dR_i. \tag{23}$$

We shall now compare measures of corruption across the two regimes viz. competition and monopoly to check whether introducing bureaucratic competition actually reduces corruption. First we do it for tolerant economies.

Proposition 1: *In a tolerant economy, according to the CI measure, corruption under the competitive regime is higher compared to the monopoly regime i.e.* $CI_c^T > CI_m^T$.

Proof: See the appendix

Since in competition if faced with a bribe demand firms have outside option of applying to another bureaucrat, firms investing in period one have higher bargaining power against the corrupt officials and the bribe falls: therefore competitive regime provides more ex ante incentive to invest in period one. The expansion of extensive margin due to introduction of bureaucratic competition increases the frequency of bribery and intuitively explains proposition 1.

Proposition 2: *In a tolerant economy, according to CRI measure, corruption in both competitive and monopoly regime is identical i.e.* $CRI_m^T = CRI_c^T$.

Proof: See the appendix

Note a tolerant economy consists of qualified firms who are extorted and only the corrupt officials extort. So out of the total number of licenses issued in either regime the number of extortion incidents remains fixed at the proportion of corrupt officials in the bureaucracy in $(1-h)$.

Proposition 3: *In a tolerant economy, according to CR measure, as* $h \to 1, CR_c^T < CR_m^T$ *and as* $h \to 0, CR_c^T > CR_m^T$.

Proof: See the appendix

Let us explain the intuition behind Proposition 3. First suppose $h \to 1$ and extortion is unlikely to occur. Therefore, in both the regimes, more firms get qualified in period 1 itself i.e. both $[R_1^m, \propto), [R_1^c, \propto)$ expand and tend to be the same at the limit. The extensive margin for both regimes tends to be same. Since, b_m is independent of h and b_c^q is decreasing in h, $CR_c^T - CR_m^T < 0$.

Now suppose h decreases and tends to 0. In this case, the chances of extortion increase. Therefore both $[R_1^m, \propto), [R_1^c, \propto)$ shrinks but $(R_1^m - R_1^c)$ expands. Hence, firms' investing in period one decrease in both the regimes but the decrease is more in the monopoly regime. So the extensive margin in competition exceeds that of monopoly. Moreover with h tending to 0, the outside option for qualified firms in competition is now lower than before and the qualified firms now have little bargaining power. Thus as h tends to zero, the competitive bribe (b_c^q) increases and moves closer to the monopoly bribe: the intensive margin tends to be same in both the regimes. So based on the difference in extensive margin of the two regimes, rent collected in the form of bribes is relatively higher in competitive regime compared to monopoly regime and hence the statement of the proposition follows.

Now we compare the corruption measures under the two regimes for a reliant economy.

Proposition 4: *In a reliant economy, according to CI measure, corruption under monopoly regime is higher compared to competitive regime i.e.* $CI_m^R > CI_c^R$.

Proof: See the appendix

The absolute frequency of collusive bribery in competitive and monopoly regime is given by $(1-h)\int_0^{R_1^c} g(R_i)dR_i$ and $(1-h)\int_{R_2^m}^{R_1^m} g(R_i)dR_i$ respectively. As $h \rightarrow 1$, the bureaucrats are mostly honest and clearly the frequency of collusive bribery goes to zero in both the regimes. It comes to the comparison of $[0, R_1^c)$ and $[R_2^m, R_1^m)$. If $R_2^m = 0$, all the firms produce even in monopoly regime. Since $R_1^m > R_1^c$ from observation 5, it is obvious that the frequency falls as competition is introduced in the bureaucracy. If $R_2^m > 0$, since $(R_1^m - R_2^m - R_1^c) > 0$, the same result holds. What happens if $h \rightarrow 0$? The intuition is the following. Since $\frac{\partial R_1^m}{\partial h} < 0, \frac{\partial R_1^c}{\partial h} < 0, \frac{\partial R_2^m}{\partial h} > 0$, as $h \rightarrow 0$, $[0, R_1^c)$ and $[R_2^m, R_1^m)$ expands as h falls. This implies that there is a surge in the number of unqualified firms in both regimes. In a reliant economy as h tends to zero, unqualified firms have a higher chance of getting a license through a bribe in both regimes. Thus these firms no longer have incentive to be qualified in period 1. However unlike monopoly due to the availability of outside option in competitive regime, unqualified firms still have a relatively higher chance of going through costly reapplication compared to monopoly. Since a chance of this costly reapplication is minimized in monopoly, the pool of unqualified firms becomes larger in monopoly compared to competition and hence the frequency of corruption is higher under monopoly.

Proposition 5: *In a reliant economy, according to CRI measure, corruption level in competitive regime exceeds corruption level in monopoly regime i.e.* $CRI_m^R < CRI_c^R$.

Proof: See the appendix

Intuitively, in competition since the firms have outside option, unlike monopoly firms have a higher incentive to enter the industry. Moreover in a reliant economy, the probability with which an unqualified firm gets a license through collusive bribery is higher in competition compared to in monopoly.

Proposition 6: *In a reliant economy, according to CR measure, corruption under the monopoly regime is higher compared to the competitive regime i.e.* $CR_m^R > CR_c^R$.

Proof: See the appendix

The extensive margin of collusive bribery in monopoly regime is $[R_2^m, R_1^m)$ and in competitive regime it is $[0, R_1^c)$. If $R_2^m = 0$, since $R_1^m > R_1^c$ from observation 5, the extensive margin under monopoly regime would be greater than the extensive margin under competitive regime. Since bribe rate is also higher in the monopoly regime, as competition is introduced corruption rent falls. If $R_2^m > 0$, the extensive margin of the monopoly shrinks. Now the firms having their revenue in $[0, R_2^m)$ do not enter the industry in monopoly regime. However, they would enter the industry in the competitive regime as firms forever remaining unqualified and in order to obtain the license would pay bribe b_c^u to the corrupt officials. On the other hand the firms having their revenue in $[R_1^c, R_1^m)$ pays collusive bribe only under the monopoly regime. Under competitive regime they would invest to be qualified and would not be paying the collusive bribe. The rest of the firms will be paying bribes under both the regimes. Since $R_1^m - R_1^c - R_2^m > 0$, clearly the number of firms that will be paying collusive bribe under the monopoly regime will be greater than the number of firms paying the same under the competitive regime. Since the bribe rate is also higher under the monopoly regime, the corruption rent will be higher in the monopoly regime than in competitive regime. The introduction of competition in the bureaucracy would reduce corruption rent.

Now we compare the corruption measures under the two regimes for an economy where corruption is pervasive.

Proposition 7: *In an economy with pervasive corruption, according to CI measure, corruption under competitive regime is not lower than that in monopoly regime i.e.* $CI_c \geq CI_m$.

Proof: See the appendix

If $R_2^m = 0$, in the monopoly regime similar to the competitive regime all firms enter the market. In both the regimes firms pay bribe either through extortion or collusion if a corrupt official is met and the extensive margin essentially gets determined by the number of corrupt officials. Therefore the CI measure becomes the same in both the regimes. On the other hand, if $R_2^m > 0$, while no firm having their $R_i < R_2^m$ enters the market in monopoly regime, all the firms enter in a competitive regime. Since the presence of option of applying to another official broadens the extensive margin of both qualified and unqualified firms in the competition regime compared to the monopoly regime, corruption increases by the CI measure in the competition regime.

Proposition 8: *In an economy with pervasive corruption, according to the CR measure, corruption under the competitive regime is lower than that under monopoly regime i.e.* ${CR_c}^P < {CR_m}^P$.

Proof: See the appendix

If $R_2^m = 0$, all the firms enter the market in monopoly the extensive margin under the monopoly regime becomes identical to that under the competitive regime. Since monopoly bribe for both extortion and collusion exceeds that of competition, the corruption rent in monopoly is higher than the rent in competition. If $R_2^m > 0$, then no firms with $R_i < R_2^m$ enters the market in monopoly compared to competition where all firms enter the market. Hence the extensive margin under the monopoly regime shrinks compared to the competitive regime. However compared to number of firms who invest in period one in competition, more number of firms engaging in collusive bribery under monopoly and this holds true since $R_1^m - R_1^c - R_2^m > 0$.Since collusive bribe amount in monopoly is higher than that in competition, rent collected would be higher in monopoly. Considering extortion, the same result holds as although more number of firms invests in period one under competitive regime, $(R_1^m > R_1^c)$ since monopoly bribe for extortion is higher than competitive bribe for extortion, the total corruption rent in monopoly will be higher than that in competition.

Proposition 9: *In an economy where both collusive bribery and extortion are present, according to the CRI measure, if* $\delta > \frac{1}{2}$, $CRI_c{}^P - CRI_m{}^P < 0$. *If* $\delta < \frac{1}{2}$, $CRI_c{}^P - CRI_m{}^P >=< 0 \; if \; and \; only \; if \; AB <=> 1$

$$where\ A = \left[\frac{\int_{R_2^m}^{\infty} g(R_i)dR_i}{\int_0^{\infty} g(R_i)dR_i}\right] and\ B = \left[\frac{\int_0^{\infty} g(R_i)dR_i - h\int_0^{R_2^c} g(R_i)dR_i}{\int_{R_2^m}^{\infty} g(R_i)dR_i - h\int_{R_2^m}^{R_1^m} g(R_i)dR_i}\right].$$

Proof: See the appendix

If $\delta > \frac{1}{2}$, $R_2^m = 0$ and all firms enter the market in both the monopoly and the competitive regime. From Proposition 7 we already know that the extensive margin of extortion and collusion based corruption taken together remains the same under both the regimes. But since the honest officials never issue a licence to an unqualified firm the total number of licenses issued is lower under the monopoly regime compared to the competition regime. Therefore by CRI measure corruption in the monopoly regime is higher than that in the competitive regime.

If $\delta < \frac{1}{2}$ $R_2^m > 0$ some firms do not enter the market in monopoly. Thus the total number of licenses administered in monopoly will be less than that under competition. Note as $R_2^m > 0$, the extensive margin of firms engaging in collusive bribery in monopoly, given by $[R_2^m, R_1^m)$ is less than that under competition, given by $[0, R_1^c)$ since $R_1^c > R_1^m$. Also, the extensive margin of extortion in monopoly given by $[R_1^m, \infty)$ is less than that under competition, given by $[R_1^c, \infty)$ since $R_1^m > R_1^c$. Thus the extensive margin of pervasive corruption under monopoly shrinks compared to that under competition. Given these difference in extensive margin, the share of licenses through pervasive corruption is relatively less under monopoly regime, and as per the CRI measure pervasive corruption under competitive regime will exceed corruption under monopoly regime.

3. Conclusions

Introducing competition in a bureaucracy allows consumers to have an outside option of reapplying to another official in delivery of public goods/services if they want. At the policy level the introduction of competition in bureaucracy has long been thought as an antidote to bureaucratic corruption. The paper analyses this issue in a theoretical model following Drugov (2010) where firms interact with officials to obtain pollution certificate in order to be eligible for production. While an honest official does not demand bribe and issues licences only to qualified firms, a corrupt official collects bribe from both qualified and unqualified firms for issuing licenses. As competition is introduced in the bureaucracy the bribe rate falls as now the firms have option of walking out of the bribe negotiation, more firms choose to remain unqualified as they expect to eventually meet a corrupt official to obtain the license. The paper tries to measure the impact of introducing bureaucratic competition on corruption using three different measures of corruption such as corruption incidence, relative corruption incidence and corruption rents in three different types of economies namely corruption-tolerant economies (where the bribes are extortion based), corruption-reliant economies (where the bribes are collusion based) and an economy where corruption is pervasive with the coexistence of both types of bribes. As both intensive margin (i.e. the magnitude of bribe) and extensive margin (i.e. the number of bribe incident) are compared under the two regimes of with and without bureaucratic competition, it finds that as traditionally perceived we cannot necessarily conclude that introduction of bureaucratic competition reduces corruption in an economy. The outcome depends on the type of the economy that has been studied, the measure of corruption being used and the initial level of corruption in the economy. In particular, we find that in a corruption tolerant economy and in an economy with pervasive corruption going by the corruption incidence measure, corruption is always higher under competitive regime compared to monopoly regime. The same holds true if the corruption rents measure is used in tolerant economies with sufficiently high share of corrupt officials. If relative corruption incidence measure is applied, corruption is more under competitive regime in a reliant economy. The same would be the outcome in an economy with pervasive corruption under certain conditions.

The results derived in the paper have policy implications for both less developed economies and developed economies of the world, as well as individual government departments in these economies. The distinction we have drawn here between a corruption tolerant economy and a corruption reliant economy can be interpreted on the basis of extortion and collusion. A corruption tolerant economy is the one where firms are victims of extortion and a corruption reliant economy is the one where firms engage in mutually gainful collusion by "buying" the license from the officials. In the cross country comparison of corruption usually the less developed economies are more or less identified with the corruption tolerant economies (since the majority of corruption incidence is of extortion) and the economies with pervasive corruption, while the developed economies are identified with the corruption reliant economies (since the majority of corruption incidence is of collusion). The results obtained in the paper, as mentioned above, suggests that the introduction of bureaucratic competition is likely to invite more corruption in developing economies; going by certain measures like relative corruption incidence it is likely to increase in the developed economies as well. The results would also apply to certain government departments depending on whether extortion or collusion prevails in them. Therefore the results go completely against the usual policy rhetoric. If control of corruption is the sole objective of introducing competition in a bureaucracy, the current paper sounds a caution.

This work can be extended as well. We have analysed here what happens to corruption on introduction of bureaucratic competition in corruption tolerant and corruption reliant economies. The scope of the present work can be broadened by analysing the consequent effect on welfare of these economies. It would also be interesting to check whether the behaviour of firms and officials change if a punishment strategy is introduced and how would the reactions of firms alter if the type of officials is known to them beforehand. These remain as our future work.

Appendix

Proof of Observation 2:

Note, $R_1^m - R_2^m = \frac{C(1-h)(1+\delta h)}{h(1-\delta)(1-h+2\delta h)}$. (A.1)

Since $\delta < 1$and $h < 1$, from (A.1) $R_1^m - R_2^m > 0$. □

Proof of Observation 4:

Note $R_1^c - R_2^c$ = $\frac{C(1-h)[2-\delta(1+h)]}{2h(1-\delta)(1+h)}$. (A.2)

Since, $\delta < 1, 2 - \delta(1+h)$> 0 and both the numerator and denominator of L.H.S of (A.2) is positive. Therefore $R_1^c - R_2^c > 0$

Hence the statement of the observation follows. □

Proof of Observation 5: Let us consider,

$R_1^m - R_1^c = \frac{\delta C(1-h)}{2h(1-\delta)}$. (A.3)

Since $0 < h < 1, \delta < 1$, L.H.S. of (A.3) is positive. Therefore, $R_1^m - R_1^c > 0$

Hence the statement of the observation follows. □

Proof of Observation 6: Let us consider,

$R_2^m - R_2^c = \frac{2\delta h C(1+h)(1-\delta) - C(2-\delta-\delta h)[h(2\delta-1)+1]}{[h(2\delta-1)+1](1+h)(1-\delta)}$. (A.4)

<u>Case 1</u>

Suppose $h < \frac{1}{1-2\delta}$. Then $[h(2\delta - 1) + 1] > 0$. Since $\delta < 1$ $[h(2\delta - 1) + 1](1 + h)(1 - \delta) > 0$

Let us now consider the numerator of RHS of (A.4) which can be written as:

$X(h) = -C[\delta\{h(2-h) - 1\} + 2(1-h)]$.

As $\frac{2(1-h)}{1-h(2-h)} > 2 > \delta \Rightarrow \delta\{h(2-h) - 1\} + 2(1-h) > 0$ Thus $X(h) < 0$

Since$0 < h < 1, \frac{2(1-h)}{1-h(2-h)} > 2 > \delta, X(h) < 0$ for all values of h in $(0, 1)$. Therefore the statement of the observation follows.

Case 2

Suppose $h > \frac{1}{1-2\delta}$. Then $[h(2\delta - 1) + 1] < 0.$ Since$\delta < 1$ $[h(2\delta - 1) + 1](1 + h)(1 - \delta) < 0$. But now since $(2 - \delta(1 + h)) > 0$ the numerator of RHS of (A.4) is positive. Therefore the RHS of (A.4) is negative and the statement of the observation follows. □

Proof of Proposition 1: From equations (6) and (9) we obtain:

$$CI_c^T - CI_m^T = (1 - h)[\int_{R_1^c}^{\infty} g(R_i)dR_i - \int_{R_1^m}^{\infty} g(R_i)dR_i]. \quad \text{(A.5)}$$

Since from observation 6 we know $R_1^m > R_1^c$, the RHS of equation (A.8)is positive. Therefore, the statement of the proposition follows. □

Proof of Proposition 2: From (7) and (10) we obtain:

$$CRI_c^T - CRI_m^T = 0.$$

Therefore, the statement of the proposition follows. □

Proof of Proposition 3: From equations (8) and (11) we obtain:

$$CR_c^T - CR_m^T = (1 - h)[\int_{R_1^c}^{\infty} b_c^q\, g(R_i)dR_i - \int_{R_1^m}^{\infty} b_m\, g(R_i)dR_i\ ]. \quad \text{(A.6)}$$

As
$h \to$
$1, R_1^c \to C, R_1^m \to C$ and $(R_1^m - R_1^c) \to 0.$ Also from obervation 3 $b_c^q <$
b_m. Therefore $CR_c^T - CR_m^T < 0$ and

Similarly, as $h \to 0, R_1^c \to \infty, R_1^m \to \infty$ and $(R_1^m - R_1^c) \to \infty,$ but $since\ b_c^q \to b_m\ as\ h \to 0,$ $CR_c^T - CR_m^T > 0.$

Therefore, the statement of the proposition follows. □

Proof of Proposition 4: From equations (12) and (15) we obtain:

$$CI_c^R - CI_m^R = (1 - h)[\int_0^{R_1^c} g(R_i)dR_i - \int_{R_2^m}^{R_1^m} g(R_i)dR_i\ ] \quad \text{(A.7)}$$

Case 1 $\delta > \frac{1}{2}$

If $\delta > \frac{1}{2}$, it is $h > \frac{1}{1-2\delta}$ for all values of $h \in (0,1)$ and $R_2^m = 0$. From observation 5 we know, $R_1^m > R_1^c$. Therefore as $h \rightarrow 1$ from (A.7) as $h \rightarrow 0$, $(CI_c^R - CI_m^R) < 0$ and as $h \rightarrow 1$ it follows that $(CI_c^R - CI_m^R) \rightarrow 0$

Case 2 $\delta < \frac{1}{2}$

Now $(1-2\delta) > 0$ and $h < \frac{1}{1-2\delta}$ for all values of $h \in (0,1)$. Since $h < \frac{1}{1-2\delta}$ $R_2^m > 0$.

Let us define $R_1^m - R_2^m = \frac{C(1-h)(1+\delta h)}{h(1-\delta)(1+2\delta h-h)}$ as Y.

Therefore, $-R_1^c = \frac{C[2(1-h)(1+\delta h)-(2-\delta-\delta h)(1-h+2\delta h)]}{2h(1-\delta)(1+2\delta h-h)]}$. (A.8)

Note as $\delta < \frac{1}{2}$ and $0 < h < 1$ the denominator of (A.8) is positive. The numerator is also positive if $h < \frac{1}{3-2\delta}$ holds, which is always true in this case. Therefore $Y - R_1^c > 0$ for all values of $h \in (0,1)$. From (A.7) as $h \rightarrow 0$, $(CI_c^R - CI_m^R) < 0$ and as $h \rightarrow 1$, $(CI_c^R - CI_m^R) \rightarrow 0$.

Therefore the statement of the proposition follows. □

Proof of Proposition 5: From equations (13) and (16) we obtain:

$$CRI_m^R - CRI_c^R = (1-h) - \frac{(1-h)\int_0^{R_2^C} g(R_i)dR_i + (1-h)\int_{R_2^C}^{R_1^C} g(R_i)dR_i}{(1-h)\int_0^{R_2^C} g(Ri)dRi + \int_{R_2^C}^{R_1^C} g(Ri)dRi} \quad (A.9)$$

$$= (1-h)[1 - \frac{\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)dR_i}{(1-h)\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)dR_i}].$$

Since $\frac{\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)dR_i}{(1-h)\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)R_i} > 1$, $\left[1 - \frac{\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)dR_i}{(1-h)\int_0^{R_2^C} g(R_i)dR_i + \int_{R_2^C}^{R_1^C} g(R_i)dR_i}\right] < 0$.

Since $0 < h < 1$ the statement of the proposition follows. □

Proof of Proposition 6: From equations (14) and (17) we obtain:

$$CR_c^R - CR_m^R = (1-h)[\int_0^{R_2^C} b_c^u g(R_i)dR_i + \int_{R_2^C}^{R_1^C} b_c^{uq} g(R_i)dR_i - \int_{R_2^m}^{R_1^m} b_m g(R_i)dR_i]. \quad (A.10)$$

Or,

$CR_c^R - CR_m^R =$

$(1-h)[\int_0^{R_1^c}(b_c^u - b_m)g(R_i)dR_i + \int_{R_2^c}^{R_1^m}(b_c^{uq} - b_m)g(R_i)dR_i - \int_{R_2^m}^{R_2^c} b_m g(R_i)dR_i$

Case 1 $\delta > \frac{1}{2}$

If $\delta > \frac{1}{2}$, it is $h > \frac{1}{1-2\delta}$ for all values of $h \in (0,1)$ and $R_2^m = 0$. But since From observation 3 we know that $b_c^q < b_c^{uq} < b_c^u < b_m$. Also from observations 2, 4, 5 and 6 it follows that $R_1^m > R_1^c > R_2^c > R_2^m = 0$. Therefore:

$[\int_0^{R_2^c} b_c^u g(R_i)dR_i + \int_{R_2^c}^{R_1^c} b_c^{uq} g(R_i)dR_i - \int_{R_2^m}^{R_1^m} b_m g(R_i)dR_i < 0$ and as $h \to 0$, the RHS of equation (A.10) tends to a negative number.

As $h \to 1$ $(CR_c^R - CR_m^R) \to 0$.

Case 2 $\delta < \frac{1}{2}$

Now it is $(1-2\delta) > 0$, and $h < \frac{1}{1-2\delta}$ for all values of $h \in (0,1)$. Since $h < \frac{1}{1-2\delta}$ $R_2^m > 0$.

But since $b_c^q < b_c^{uq} < b_c^u < b_m$ and $R_1^m > R_1^c > R_2^c > R_2^m > 0$ hold even in this case,

$(1-h)\left[\int_0^{R_1^c}(b_c^u - b_m)g(R_i)dR_i + \int_{R_2^c}^{R_1^m}(b_c^{uq} - b_m)g(R_i)dR_i - \int_{R_2^m}^{R_2^c} b_m g(R_i)dR_i\right] < 0$ and as $h \to 0$, the RHS of equation (A.10) tends to a negative number.

A $h \to 1$ $(CR_c^R - CR_m^R) \to 0$.

Therefore the statement of the proposition follows. □

Proof of Proposition 7: From equations (18) and (21) we obtain:

$$CI_c{}^P - CI_m{}^P = (1-h)[\int_0^{\infty} g(R_i)\, dR_i - \int_{R_2^m}^{\infty} g(R_i)\, dR_i] \quad \text{(A.18)}$$

From observation 6 we know:

If $\delta > \frac{1}{2} \Rightarrow h > \frac{1}{1-2\delta} \Rightarrow R_2^m = 0, CI_c - CI_m = 0$

If $\delta < \frac{1}{2}, \Rightarrow\ h < \frac{1}{1-2\delta} \Rightarrow R_2^m > 0, CI_c - CI_m > 0$

Therefore, the statement of the proposition follows. □

Proof of Proposition 8: From equations (20) and (23) we obtain:

$$CR_c{}^P - CR_m{}^P = (1-h)\left[\int_0^{R_2^c} b_c^u g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c} b_c^{uq} g(R_i)\,dR_i + \int_{R_1^c}^{\infty} b_c^q g(R_i)\,dR_i - \int_{R_2^m}^{\infty} b_m g(R_i)\,dR_i\right]. \tag{A.19}$$

If $\delta > \frac{1}{2}, R_2^m = 0$ and $CR_c - CR_m$ can be written as:

$$CR_c{}^P - CR_m{}^P = (1-h)[\int_0^{R_2^c}(b_c^u - b_m)g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c}(b_c^{uq} - b_m)g(R_i)\,dR_i + \int_{R_1^c}^{\infty}(b_c^q - b_m)g(R_i)\,dR_i$$

Since $b_m > b_c^u > b_c^{uq} > b_c^q$, it follows that $(b_c^u - b_m) < 0, (b_c^{uq} - b_m) < 0$ and $(b_c^q - b_m) < 0$ respectively. Hence $CR_c{}^P - CR_m{}^P < 0$.

If $\delta < \frac{1}{2},\ R_2^m > 0$ and $CR_c - CR_m$ can be written as:

$$CR_c{}^P - CR_m{}^P = (1-h)\left[\int_0^{R_2^c} b_c^u g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c} b_c^{uq} g(R_i)\,dR_i + \int_{R_1^c}^{\infty} b_c^q g(R_i)\,dR_i\right] - \left[\int_{R_2^m}^{R_2^c} b_m g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c} b_m g(R_i)\,dR_i + \int_{R_1^c}^{\infty} b_m g(R_i)\,dR_i\right]$$

$$= (1-h)[\int_0^{R_2^c}[(b_c^u - b_m]g(R_i)\,dR_i + \int_{R_2^c}^{R_1^c}(b_c^{uq} - b_m)g(R_i)\,dR_i + \int_{R_1^c}^{\infty}(b_c^q - b_m)g(R_i)\,dR_i$$

Since $b_m > b_c^u > b_c^{uq} > b_c^q, (b_c^u - b_m) < 0, (b_c^q - b_m) < 0, (b_c^{uq} - b_m)$

Hence$CR_c{}^P - CR_m{}^P < 0$.

Therefore, the statement of the proposition follows. □

Proof of Proposition 9: From equations (19) and (22) we obtain:

$$CRI_c{}^P - CRI_m{}^P = \frac{(1-h)\int_0^{\infty} g(R_i)dR_i}{(1-h)\int_0^{R_2^c} g(R_i)dR_i + \int_{R_2^c}^{\infty} g(R_i)dR_i} - \frac{(1-h)\int_{R_2^m}^{\infty} g(R_i)dR_i}{(1-h)\int_{R_2^m}^{R_1^m} g(R_i)dR_i + \int_{R_1^m}^{\infty} g(R_i)dR_i} \tag{A.20}$$

From observation 6 we know:

If $\delta > \frac{1}{2}, h > \frac{1}{1-2\delta}$ $R_2^m = 0$; $\delta < \frac{1}{2}, h < \frac{1}{1-2\delta}$ $R_2^m > 0$. If $\delta > \frac{1}{2}, R_2^m = 0$.

If $\delta > \frac{1}{2}, h > \frac{1}{1-2\delta}$ $R_2^m = 0$ and ${CRI_c}^P - {CRI_m}^P$ can be written as:

$$ {CRI_c}^P - {CRI_m}^P = \frac{(1-h)\int_0^\infty g(R_i)dR_i}{\int_0^\infty g(R_i)dR_i - h\int_0^{R_2^c} g(R_i)dR_i} - \frac{(1-h)\int_0^\infty g(R_i)dR_i}{\int_0^\infty g(R_i)dR_i - h\int_0^{R_1^m} g(R_i)dR_i} \quad \text{(A.21)} $$

On the RHS of equation (A.21), since $R_2^c < R_1^m$,

$\int_0^\infty g(R_i)\,dR_i - h\int_0^{R_2^c} g(R_i)dR_i > \int_0^\infty g(R_i)\,dR_i - h\int_0^{R_1^m} g(R_i)dR_i$.

Thus, ${CRI_c}^P - {CRI_m}^P < 0$.

If $\delta < \frac{1}{2}, h < \frac{1}{1-2\delta}$ $R_2^m > 0$ and ${CRI_c}^P - {CRI_m}^P$ can be written as:

$$ {CRI_c}^P - {CRI_m}^P = \frac{(1-h)\int_0^\infty g(R_i)dR_i}{\int_0^\infty g(R_i)dR_i - h\int_0^{R_2^c} g(R_i)dR_i}[1 - AB] $$

where$A = \frac{\int_{R_2^m}^\infty g(R_i)dR_i}{\int_0^\infty g(R_i)dR_i}$ and $B = \frac{\int_0^\infty g(R_i)dR_i - h\int_0^{R_2^c} g(R_i)dR_i}{\int_{R_2^m}^\infty g(R_i)dR_i - h\int_{R_2^m}^{R_1^m} g(R_i)dR_i}$.

Note $A < 1$. Since $R_1^m - R_2^m - R_1^c > 0$and $R_1^c > R_2^c$, it must be true that $R_1^m - R_2^m - R_2^c > 0$ and thus $B > 1$.

$\Rightarrow CRI_c - CRI_m >=< 0$ if and only if $AB <=> 1$

Therefore, the statement of the proposition follows. □

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