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On the (In)Effectiveness of Some Commonly Proposed Anti-Corruption Reforms

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Abstract: Using a theoretical model of two-candidate political competition under probabilistic voting, I study the effectiveness of the following anti-corruption reforms: (i) higher wages for politicians, (ii) higher penalties for political corruption, and (iii) constitutional constraints on the tax rates and the public good levels. In the setup I study, the competing candidates may differ in their popularity, (non-verifiable) ability, and corruptibility. I find that the reforms are more likely to be effective when the candidates are (almost) identical. When the candidates differ significantly from each other, each reform may increase equilibrium level of corruption or reduce voters' welfare.

JEL classification: D72; H30; H83; K42
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1 Introduction

It is not clear what the best way is to reduce political corruption. In this paper, I study the effectiveness of three anti-corruption reforms: (i) higher salaries for politicians, (ii) higher penalties for corruption, and (iii) constitutional constraints that limit the size of the government. I find that none of these reforms is always effective; under certain conditions each reform reduces voters' welfare or increases corruption.

I study the effectiveness of these reforms in a setup in which two career politicians compete with each other. For this I use an extended and generalized version of the duopoly model of political agency provided by Polo (1998).[1] The career politicians in the model can differ in terms of their (non-verifiable) ability to produce the public good, popularity, or corruptibility. Each candidate proposes a tax rate and a public good level before the voting takes place; then, implements this policy when elected. The voters care about both the fiscal policy and other issues such as ideology and candidate characteristics. Their preferences on these issues are subject to random shocks: the voting is probabilistic. Each politician's objective is to maximize his expected rents: the legal rents (ego rents and the wage), and, if he decides to steal, the illegal rents. In the model a corrupt politician may get caught. Then, there are two different types of penalties for corruption. The constant penalty is independent of the amount stolen, and the variable penalty is proportional to the amount stolen. Although there are penalties and although it would reduce the probability that he wins the election, a corrupt politician may still choose to propose an inefficiently high tax rate or an inefficiently low public good level and steal the difference between tax revenues and actual public good costs. A politician's incentives to steal increase in his ability (or, popularity) advantage over his rival; in the extend of randomness in voting behavior; and in the rival's level of corruption (strategic complementarity). I also consider the possibility that some politicians are honest.

To evaluate the effectiveness of the reforms I calculate comparative statics focusing on the equilibria in which at least one candidate steals. A salary increase always reduces the amount a candidate steals in equilibrium. Yet, since the taxpayers eventually finance the wage bill, the reform is effective only when a one dollar increase in the wage reduces the expected equilibrium level of corruption by more than one dollar. I find that this is the case when the candidates are identical and when there are no legal penalties for corruption.

When the variable penalty on illegal rents is low, a wage increase is not that effective. Because, then, a corrupt candidate who gets caught certainly loses his wage, but, he (effectively) keeps part of his illegal rents. If only one candidate is corrupt, then the wage increase is even less likely to be welfare increasing. There are two reasons for this. First, the higher wage paid to the honest candidate is a waste from the voters' point of view (he would not steal even without the wage increase). Second, in this case the reform does not have a strategic effect. The strategic effect exists

[1] See Evrenk (2008a) for a detailed discussion of the model and its equilibria.

when both candidates steal; then, each candidate's level of corruption are strategic complements. That is, a wage increase does reduce a candidate's level of corruption not only because it makes the office more attractive, but also because it reduces the other candidate's level of corruption. When the rival is honest, this effect is absent.

If the legal penalties are not severe enough to eradicate corruption completely, they may increase it. The intuition is that, then, an increase in the penalties reduce the expected rents from the office. A small increase in the constant penalty (almost) always raises corruption and reduces voters' welfare. An increase in variable penalty reduces equilibrium level of corruption and increases voters' welfare only when the net expected legal rents (legal rents minus the constant penalty) is positive. Thus, a higher variable penalty increases the effectiveness of the salary reform and a higher salary increases the effectiveness of the penalty.

Brennan and Buchanan (1980, Ch. 10) discuss the effect of constitutional constraints on tax rates using a monopoly model of government for whom theft constitutes the sole source of rents. In a setting with political competition and multiple sources of rents, I find that there exists an effective tax constraint when the competing candidates are *ex ante* identical. When candidates have different levels of ability, however, the constraint may reduce voters' welfare. To see why, note that, in equilibrium, an honest candidate who is able but unpopular can propose a tax rate higher than the rate proposed by a dishonest, less able, but more popular candidate. Then, a tax rate constraint that binds only for the honest candidate increases equilibrium level of corruption and reduces voters' welfare. A significantly low tax rate constraint would bind for both candidates, but as it would enforce a public good level that is too low compared to social optimum, it may reduce not only political corruption but also the voters' welfare.

I also show that a tax rate limit enforcing a small government is not the only welfare-increasing fiscal restraint; a constitutional constraint that enforces a *large* public good level can also be welfare increasing. Further, when the candidates have the same ability, the first-best fiscal policy can be implemented only by a constitution that imposes a binding upper bound on tax rate and a binding lower bound on public good level.

Using an extended and generalized version of the incumbency model of political agency, recently Besley and Smart (2007 p.764), too, study the effects of a tax limitation on voter welfare. Their model could be further extended to study the effectiveness of the other reforms that I study here. It should be noted, however, that the incumbency model and the duopoly model emphasize different types of agency problems. In their model the agency problem is due to imperfect information; in the duopoly model it is due to imperfect competition. So, when the reforms work or fail in each model, it is usually for different reasons.

In their model, a voter decides between the current incumbent and a challenger. She cannot observe their types (honest or corrupt); she only knows the proportion of each type. She tries to infer the current incumbent's type by also looking into his performance in the previous period (there are only two periods). An honest politician would impose a high (low) tax rate when the cost of the public good is high (low). The voter, however, cannot observe this cost parameter either. If, based on the first period behavior of the incumbent, the voter decides that he is corrupt, then she votes for the challenger. In his first period, a corrupt incumbent may steal everything, then he will certainly be voted out (a separating equilibrium). Another possibility is that he imposes a high tax rate when the cost of the public good is low, then steal the difference (a pooling equilibrium). When she observes a high tax rate, the voter re-elects the incumbent. Following his re-election, then, the corrupt incumbent steals all he can in the second period.

Besley and Smart (2007, Proposition 3) shows that in this setup a tax-rate constraint may reduce the voter's welfare because of a selection effect. That is, by limiting the amount that a corrupt candidate can steal, the constraint may increase the corrupt incumbent's incentives to pool (that is, steal less in the first period). Then, the voter is more likely to be deceived, increasing the probability of rampant corruption in the second period.

The selection effect is absent in the duopoly model of political agency. In the duopoly model, the voters look at the policies proposed by each candidate, because these policies are relevant; the competing candidates are well known career politicians; their election promises are credible. In the incumbency model the voter disregards the policies that candidates propose in election. Further, in the incumbency model, there is no ability difference between the candidates. Due to the ability differences in the duopoly model, an honest candidate may choose a higher tax rate than a corrupt one does in equilibrium, see Example 1 below. This, as I discuss in Section 3.3., explains how the tax-rate constraint may reduce voters' welfare in the duopoly model.

2 The Model

Consider a continuum of voters of measure one. Voter i has income Y_i and $F(Y_i)$ denotes the cumulative density of Y_i. The average income is normalized to one, $\int Y_i dF(Y_i) = 1$. Each voter pays an income tax at flat rate t and spends the rest of his income on a private good sold at unit price, $c_i = (1-t)Y_i$. Collected taxes are available to be used by the elected leader to produce a public good, g. Each voter's preferences over private and public goods are represented by the utility function,

$$U(c_i, g) = I(c_i) + H(g) \tag{1}$$

where both $I(.)$ and $H(.)$ are strictly increasing, strictly concave, continuous and twice continuously differentiable functions from R_+ to R. Each voter needs to consume at least a small amount of each good: both $I'(0)$ and $H'(0)$ converges to infinity.

There are two competing candidates, $j \in \{1, 2\}$. In elections, first each candidate simultaneously announces a policy platform, (t_j, g_j). Then, the voting takes place.

The winner produces the public good from the available public funds using a technology that depends on his (non-verifiable) ability, α_j. For simplicity, I assume that the public good production technology is linear. The net public funds used in the production of public good is equal to collected tax revenues minus the salary of the leader, $w > 0$, and an amount that he chooses to steal, s_j. Thus, the winner produces

$$g_j = (t_j - w - s_j)\alpha_j. \tag{2}$$

The competing candidates I study here are career politicians; honest or corrupt, each candidate realizes the adverse effects of cheating on his election promises on his future. Thus, the winner of the election implements the policy that he announced, instead of stealing all the tax revenue after winning the election.[2] (Although he keeps his promises, as I discuss below, a corrupt politician may still promise a suboptimal fiscal policy.)

Each candidate's goal is to maximize his expected rents and each candidate's outside option is normalized to zero. In addition to salary, the winning candidate receives ego rents, η, as well. Further, each candidate j knows that for each dollar he steals from the public budget, a fraction, $(1 - \theta_j) > 0$, will be lost.[3]

A corrupt politician thinks that he will get caught and be punished with probability $\pi \geqslant 0$. Then, he will be deprived of his position, lose the legal rents w and η, and pay a legal penalty worth $q + vs_j$, where $q \geqslant 0$ and $v \geqslant 0$. Thus, when he is elected, j expects to receive

$$R_j(s_j) = w + \eta + \mathbf{1}_{\{s_j>0\}}[\theta_j s_j - (vs_j + q + w + \eta)\pi],$$

where $\mathbf{1}_{\{s_j>0\}}$ is equal to 1 if $s_j > 0$, and equal to 0 otherwise.

The voting is probabilistic: i votes for j when $U_i^j > U_i^k$, and flips a coin when $U_i^1 = U_i^2$, where

$$U_i^j = I((1 - t_j)Y_i) + \ H(g_j) + (j - 1)(\beta + \beta_2 + \beta_{i2}). \tag{3}$$

The term $\beta + \beta_2 + \beta_{i2}$ in (3) captures the non–policy issues that affect the voting decision: β is the electorate's average bias in favor of Candidate 2 and it is known *ex ante*. From the candidates' point of view, β_2 and β_{i2} are independent random variables uniformly distributed on $[\frac{-1}{2\sigma}, \frac{1}{2\sigma}]$ and $[\frac{-1}{2\phi}, \frac{1}{2\phi}]$, where both $\frac{1}{2\sigma}$ and $\frac{1}{2\phi}$ are assumed to be sufficiently large but finite. The first term, β_2, reflects a correlated preference shock,[4]

[2] Evrenk (2008b) studies an infinitely repeated but simplified version of this model, and proves that when his discount factor is large enough, a corrupt candidate will keep his election promises. The intuition is the same as in Barro (1974).

[3] The parameter θ_j is known as the "deadweight loss of corruption". Also note that, setting $\theta_j = 0$ allows us to consider a candidate who will never steal.

[4] Such as the candidate's performance on a televised debate just before the elections; a scandal; an unexpected success or failure of a policy that the candidate strongly defended in the past.

while β_{i2} reflects an idiosyncratic shock on individual i's preferences. Let $\mathbf{E}[h(Y_i)]$ denote $\int h(Yi)dF(Y_i)$ for any function $h(.)$. The probability that j wins the election can be calculated as[5]

$$\rho_j = \frac{1}{2} + \sigma[\mathbf{E}[U((1-t_j)Y_i, g_j) - U((1-t_k)Y_i, g_k)] + 2(j - \frac{3}{2})\beta]. \tag{4}$$

Each candidate j chooses his equilibrium policy platform, (t_j^*, g_j^*), to maximize his expected rents, $\rho_j R_j$. Let (t_j^0, g_j^0) denote the first-best policy platform, that is, the platform that maximizes the voters' expected welfare. Evrenk (2008a) shows that the voters' expected welfare can be written as

$$\mathbf{E}[\mathbf{W}] = \mathbf{E}[U_i((1-t_j)Y_i, g_j)] + (j-1)\beta + \frac{1}{2\sigma}(\rho_k)^2,$$

where $k \neq j$, and that the first-best involves no corruption, $g_j^0 = (t_j^0 - w)\alpha_j$, with $t_j^0 = \arg\max \mathbf{E}[U_i((1-t_j)Y_i, g_j((t_j - w)\alpha_j))]$. There is an agency problem, when $(t_j^*, g_j^*) \neq (t_j^0, g_j^0)$.

To determine the equilibrium policy platforms one needs two first order conditions (f.o.c.'s) from each candidate's optimization problem. The f.o.c. with respect to tax rate is that

$$\sigma R_j \frac{\partial \mathbf{E}[U_i^j(.)]}{\partial t_j} = 0 \text{ for both } j \in \{1, 2\}.$$

As σR_j is always larger than zero, in equilibrium each candidate chooses a tax rate that maximizes voters' expected welfare conditional on the amount he steals, s_j. Then, for each candidate there exists an equilibrium tax rate function with slope[6]

$$\frac{dt_j^*(s_j)}{ds_j} = \frac{(\alpha_j)^2 H''((t_j - w - s_j)\alpha_j)}{\mathbf{E}[Y_i^2 I''((1-t_j)Y_i)] + (\alpha_j)^2 H''((t_j - w - s_j)\alpha_j)}. \tag{5}$$

Similarly, there exists an equilibrium public good level function, $g_j^*(s_j) = \alpha_j(t_j^*(s_j) - w - s_j)$. Let us note that in our model, political corruption is the only agency problem, i.e., $t_j^*(0) = t_j^0$ and $g_j^*(0) = g_j^0$.[7] Also note that $\frac{dt_j^*(s_j)}{ds_j}$ is strictly between zero and one: political corruption is financed by both inefficiently high taxes and inefficiently low public good levels.

As (2) indicates, the variables t_j, g_j, and s_j are interdependent. So, j's second policy variable can be considered either as g_j or as s_j. Choosing the latter, we find,

[5] See Evrenk (2008a) for the derivation.

[6] To derive (5), I differentiate $\frac{\partial \mathbf{E}[U_i(.)]}{\partial t_j} = 0$ with respect to s_j.

[7] This is due to our assumptions that (i) candidates do not have policy preferences; (ii) voters are equally influential and equally well informed (β_{i2} has the same support for all i); (iii) there are no special interest lobbies.

in equilibrium we should have $\frac{\partial \rho_j R_j}{\partial s_j} \leq 0$, i.e.,

$$\sigma R_j \frac{\partial [H((t_j - w - s_j)\alpha_j)]}{\partial s_j} + (\theta_j - \pi v)\rho_j \leq 0 \text{ (with equality when } s_j^* > 0). \quad (6)$$

Note that $\frac{\partial \rho_j R_j}{\partial s_j}$ is equal to a weighted average of two marginal gains: (i) the average marginal disutility of voters from corruption (weighted by σR_j), and (ii) the marginal increase in rents due to corruption (weighted by the probability that j will have the opportunity to receive these rents). Further, $\frac{\partial \rho_j R_j}{\partial s_j}$ depends on s_k (via ρ_j): when both candidates steal, the equilibrium corruption levels will be determined through strategic interaction.

As the voter preferences are also part of the parameter space, at this level of generality, the equilibrium of the model cannot be calculated in closed-form. Still, the following result allows us to use comparative statics.

Theorem 1 (Evrenk 2008a, Propositions 2 and 3) *The PSNE of the model always exists. When there is no legal punishment for corruption, the PSNE is unique. When there is legal punishment, the game has at most two distinct (one interior, and one corner) PSNE.*

3 Effectiveness of Reforms

In this section, I examine when (i) high salaries for the elected politician, (ii) high penalties for corruption, and (iii) constitutional constraints on the size of the government are effective in reducing corruption and increasing voters' welfare. Each reform either changes a parameter of the model (w, q, v) or adds another constraint in each candidate's optimization problem. To calculate the effectiveness of a given reform, first, I specify the type of the equilibrium (whether both candidates are stealing, CC, or only one candidate is stealing, HC). For each j who steals, we have $\frac{\partial \rho_j R_j}{\partial s_j} = 0$. Then, by applying Implicit Function Theorem to these f.o.c.'s, I calculate how a given change in one parameter (or, a constraint) affects the equilibrium level of corruption, s_j^*.[8] Then, using $t_j^*(s_j^*)$ and $g_j^*(s_j^*)$, I calculate the effects of the reform on fiscal policy, and finally, on voters' welfare.

[8] I discuss the derivation of comparative statics in more detail in Evrenk (2008a). Note that, even when the game has two equilibria, by Theorem 1, (i) they are not of the same type, and (ii) these equilibria are distinct from each other. So, generically, a small change in a parameter or in a constraint due to reform does not lead to a different type of equilibria. (Non-generically, it does, because there is a (measure zero) set of parameters under which an infinitesimal change leads to a switch from multiple equilibria to a single equilibrium, or, vice versa.)

3.1 Salary Reform

Efficiency wages are proposed by many authors in the literature as a solution to high level political corruption. For instance, Wittman (1995, p.27) argues that "...opportunism by politicians is mitigated when they are paid above-market salaries and then threatened with losing the office if they shirk". Higher wages make winning the election more attractive. In response, a candidate reduces the amount he steals.[9] Still, lower corruption does not necessarily mean higher welfare, as the wage increases have to be financed from the public budget. An increase in salary is welfare increasing only when[10]

$$\frac{d\mathbf{E}[\mathbf{W}]}{dw} = -\sum_{j\in\{1,2\}} \rho_j \alpha_j \frac{d\mathbf{E}[U_i(.)]}{dg}(1 + \frac{ds_j^*(w)}{dw}) \tag{7}$$

is larger than zero. Intuitively, if we increase the wage candidate j receives by one dollar, there is a benefit (a decrease in s_j) as well as a cost (now there is one dollar less to produce the public good). If this one dollar salary increase reduces corruption more than one dollar, $\frac{ds_j^*(w)}{dw} < -1$, then, the benefit is larger than the cost; it increases the voters' welfare from that candidate.[11] Note that the net benefit from one candidate affects voters' welfare proportional to the likelihood of that candidate winning the election. In *CC*, increasing the wage increases voters' welfare, $\frac{d\mathbf{E}[\mathbf{W}]}{dw} > 0$, only if $\frac{ds_j^*(w)}{dw} < -1$ for at least one j, and if $\frac{ds_j^*(w)}{dw} < -1$ for both $j \in \{1, 2\}$. The following proposition provides necessary and sufficient conditions in terms of the parameters of the model.

Proposition 1 *If both candidates steal in equilibrium, then for a small increase in wages to be welfare-increasing, a necessary condition is* $\min\{\theta_1, \theta_2\} - \pi v < 1 - \pi$, *while a sufficient condition is* $\max\{\theta_1, \theta_2\} - \pi v < 1 - \pi$.

Less formally, Proposition 1 shows that when both candidates are corrupt, the salary reform is welfare increasing only when stealing is not quite valuable for politicians (or, when it is quite costly for them). To see the intuition, consider the symmetric case. Then each candidate wins with equal probability in equilibrium. When the wage increases one dollar, for each corrupt candidate, the expected benefit from this extra dollar is equal to $1 - \pi$ (with probability π the candidate will get caught and will lose the wage). The expected benefit from a stolen dollar is equal to $\theta - \pi v$. A corrupt candidate will give up the latter to get the former only when the net expected

[9] Although higher ego rents would have the same effect, it is easier to increase the monetary compensation than rents based on psychological factors.

[10] Lemma 2 in Appendix provides the derivation for (7).

[11] In our model the set of competing candidates is fixed; a small increase in wage does not attract better candidates to politics. For models of endogenous candidate quality, see Caselli and Morelli (2004) and Messner and Polborn (2004).

benefit, $1-\pi-(\theta-\pi v)$, is positive. The same intuition applies when both candidates are corrupt, even if they are not identical.

When only one candidate steals, *HC*, however, a dollar increase in salary is less likely to reduce equilibrium corruption more than a dollar:[12]

Lemma 1 *When only Candidate j steals in equilibrium, $\frac{ds_j^*(w)}{dw} < -1$ if and only if $(\theta_j - \pi v)(1 + \frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}) < (1-\pi)$.*

As the careful reader notes, Lemma 1 provides only a necessary condition for the salary reform to be effective in *HC*. This condition guarantees that $\frac{ds_j^*(w)}{dw} < -1$, but, in *HC* $\frac{d\mathbf{E}[\mathbf{W}]}{dw}$ is larger than zero only when $\frac{ds_j^*(w)}{dw} < -1 - \frac{1-\rho_j}{\rho_j}\frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}$.[13] That the sufficient condition in *HC* is more strict[14] is intuitive: in *HC*, the corrupt candidate does not always win, and paying a higher wage to the honest candidate (who would implement the first-best policy anyway) is a loss from the voters' point of view. More surprising, Lemma 1 shows that in *HC* the necessary condition, *too*, is more strict. That is, for $\frac{ds_j^*(w)}{dw} < -1$ to hold we need $(\theta_j - \pi v)(1 + \frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}) < (1-\pi)$ in *HC,* but in *CC* it would hold when $(\theta_j - \pi v) < (1-\pi)$. This difference is due to existence of strategic interaction among the candidates. More specific, it is because the equilibrium levels of corruption are strategic complements when both candidates steal. Since this strategic complementarity affects the effectiveness of any given reform in the duopoly model of political agency, below, I discuss it in detail.[15]

In *HC* the honest candidate, say, Candidate 1, always proposes the first-best policy. Whether or not there is strategic interaction between the competing politicians, the reform has a *direct* effect that will be captured by any type of agency model: the corrupt Candidate 2 always responds to an increase in the salary: when w increases by Δw, winning becomes more attractive; so, Candidate 2 reduces s_2^*, say, by Δs, to increase the probability that he wins the election.

When both candidates steal, *CC*, the equilibrium corruption levels are strategic complements; a wage increase has a *strategic* effect on s_2^* as well: when the wage increases (now, the corrupt) Candidate 1, too, steals less; s_1^*, too, decreases. Since ρ_2^* depends on both s_1^* and s_2^*, in this case Candidate 2 cannot achieve the same increase in ρ_2 by reducing his level of corruption by Δs. He has to reduce s_2^* further.

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[12]To obtain Lemma 1, note that when only j steals $\frac{ds_j^*(w)}{dw} = -(\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial w})/(\frac{\partial^2(\rho_j R_j)}{(\partial s_j)^2})$. Then $\frac{ds_j}{dw} < -1$ iff $\frac{\alpha_j}{\alpha_k}(\frac{1-p+\theta_j-pv}{\theta_j-pv}) < (\frac{\partial \mathbf{E}[U_i(t_k^o, g_k^o)]}{\partial g})/(\frac{\partial \mathbf{E}[U_i(t_j^*, g_j^*)]}{\partial g})$. By rearranging the terms, we get the condition in Lemma 1.

[13]Setting $\frac{ds_k^*(w)}{dw} = 0$, and $\frac{d\mathbf{E}[U_i(.)]}{dg} = \alpha_k H'(g_k^0)$, this condition can be obtained from (7). Note that in our model, an increase in wages will not attract more able people to politics.

[14]That is, in this case a one dollar wage increase is effective only if it reduces equilibrium corruption significantly more than one dollar .

[15]It is worth noting that strategic interaction is absent when a large number (continuum) of candidates compete with each other.

We cannot calculate the exact value of $\frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}$, so, we cannot calculate exactly how much Candidate 2 should lower s_2^*. But, it would be reasonable to assume that $\frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}$ is close to one.[16] Then, the existence of strategic complementarity (approximately) doubles the upper bound on the expected benefit from a stolen dollar, $\theta_j - \pi v$, for $\frac{ds_j^*(w)}{dw} < -1$ to hold.

3.2 Legal Penalties

Sufficiently harsh (expected) penalties for corruption would eliminate political corruption. When the expected gain from stealing is negative, a politician chooses not to steal. So, increasing either πv (when $\pi v > 1$, the expected gain from stealing, $\theta_j - \pi v$, becomes negative) or πq (when the expected constant penalty is large enough, even stealing the whole budget does not provide a net benefit) sufficiently would solve the agency problem. Although harsh (expected) penalties could eliminate corruption, in countries with widespread corruption, such penalties are not always feasible due to administrative and legal constraints. When for example, most of the judges, prosecutors, and investigators are corrupt, increasing the probability that a corrupt politician is going to be punished, π, is not easy.[17] A solution to the costly (or, ineffective) auditing, suggested by Becker (1968), is to increase the penalty, v or q: this would make law enforcement effective, despite the low probability of detection. Yet, again, if, for instance, the judges themselves are corrupt, then the (corrupt) winner can use a severe penalty for corruption to deter opposition and increase his corruption. Due to such administrative constraints, significant increases in penalties may not be always feasible. But, a small increase is always possible. I find, however, that it may be counterproductive.

Proposition 2 *An infinitesimal increase in the constant penalty, q, always leads to more corruption. An infinitesimal increase in the variable penalty, v, leads to less (more) corruption when the net expected legal rents are positive (negative), $\pi q < (>)(1-\pi)(w+\eta)$.*

Proposition 2 can be easily proved by applying Implicit Function Theorem to the equality $\frac{\partial \rho_j R_j}{\partial s_j} = 0$. The intuition is that an increase in the constant penalty, q,

[16] If the corrupt candidate is proposing higher (lower) taxes in equilibrium, then, $\frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}$ is less (higher) than one. (When the preferences are quasi-linear, $\frac{\alpha_k H'(g_k^0)}{\alpha_j H'(g_j^*)}$ is always equal to one.)

[17] In the Philippines, where two past presidents, Ferdinand Marcos and Joseph Estrada, are believed to have embezzled 5 to 10 billion and 78 to 80 million US dollars, Eufemio Domingo, the head of the Presidential Commission Against Graft and Corruption, said that Phillipines has all the laws, rules and regulations to eliminate corruption. But, he says, "[t]he problem is that these laws, rules and regulations are not being faithfully implemented." Balgos (1998, p. 267-268), –quoted in Quah (1999).

reduces the expected rents from office. As a result, a corrupt politician puts a lower weight on voters' disutility from corruption (the first marginal benefit in (6)), and, thus, steals more. We have the same effect for the variable penalty, v, as well. For v, however, another effect works in the opposite direction: the higher the v, the lower is $\theta_j - \pi v$, i.e., the expected penalty per dollar stolen increases. If the net expected legal rents are positive, $(1-\pi)(w+\eta) > \pi q$, then, as v increases, the *relative* weight on voters' disutility from corruption increases; the second effect dominates and the equilibrium level of s_j^* decreases.

It is straightforward to derive the welfare effects of an increase in penalties. Since a small increase in these penalties is costless, an infinitesimal increase in either the constant or the variable penalty would be welfare increasing if and only if it *reduces* equilibrium corruption. Thus, the conditions in Proposition 2 also characterize the set of parameters under which increasing the penalty increases voters' welfare.[18]

3.3 Constitutional Constraints

Geoffrey Brennan and James M. Buchanan (1980) discuss how an individual member of society who decides behind a "veil of ignorance" would like to impose constraints on the domain of the political outcomes.[19] They discuss that when the policy maker is a Leviathan, the exact opposite of the benevolent dictator, such constraints could increase taxpayers' welfare.[20]

The Leviathan cares only about its own welfare, and, more important, it does not face any political competition. Note that this is a limit case of the duopoly model: when the variance of the aggregate popularity shock converges to infinity (σ converges to zero), a candidate's policy has no effect on his probability of winning the election; both candidates have equal chance. Then, political competition would not restrict a candidate's behavior. Except this special case, and however imperfect it may be, political competition *does* restrict a candidate's behavior. For this reason, here, I study the effectiveness of constitutional constraints on tax rates and public good levels when there is political competition.

Consider the effect of a constitution with the provision that the tax rate cannot exceed an upper bound, T.[21] Candidate j's optimization problem under this constraint can be written as

$$\max_{s_j,t_j} \rho_j R_j \text{ subject to } t_j \leq T. \tag{8}$$

[18] So, the optimal penalty scheme would have no (or a very small) constant penalty, and a significantly high variable penalty for corruption. Note, however, that a very high variable penalty is feasible only if the administrative constraints mentioned above are not binding.

[19] For example, Proposition 13, approved by voters in California in 1978, restricts the tax on real property to one percent of market value.

[20] See also Wilson (1989).

[21] Note that, in our model the aggregate income is constant. So, T can be considered as an expenditure limit as well.

First, note that a constraint on tax rate alone cannot implement the first-best.

Proposition 3 *It is impossible to implement the first-best policy platform through imposing only a tax-rate constraint.*

Proof. When there is an upper limit on t_j, the f.o.c. with respect to t_j in a Nash equilibrium is $\sigma R_j \frac{\partial \mathbf{E}[U_i((1-t_j)Y_i,(t_j-w-s_j)\alpha_j)]}{\partial t_j} - \lambda_j = 0$, where λ_j is a Kuhn-Tucker multiplier satisfying $\lambda_j(t_j - T) = 0$. Suppose that j is corrupt and that there exists a T that implements the first-best. Then, in equilibrium the constraint has to be binding, $t_j = T$, and $\lambda_j > 0$. But, then, evaluated at the equilibrium tax rate, T, we have $\frac{\partial \mathbf{E}[U_i((1-t_j)Y_i,(t_j-w-s_j)\alpha_j)]}{\partial t_j} > 0$, that is, $\mathbf{E}[Y_i I'((1-T)Y_i)] < \alpha_j H'((T-w-s_j(T))\alpha_j)$. In the first-best, however, we should have $\mathbf{E}[Y_i I'((1-t_j^0)Y_i)] = \alpha_j H'(g_j^0)$. Contradiction. ■

A tax rate constraint alone cannot implement the first-best; because, in addition to its possible benefits, it has a cost: an upper limit on tax rate reduces the equilibrium level of public good. When we enforce the corrupt candidate to propose the first best rate, he steals from the public good; he proposes a public good level that is less than the first-best, g_j^0. Yet, Proposition 3 does not mean that the constraint is totally useless. It is still possible that the constraint implements a second-best.

Let us first study the effectiveness of T when the candidates are *ex-ante* identical and corrupt, (then, I return to the case of unidentical candidates). With identical candidates, the effect of a marginal change in T on voters' welfare, $\frac{\partial \mathbf{E}[\mathbf{W}]}{\partial T}$, is equal to

$$\alpha H'(g)(1 - \frac{ds^*(T)}{dT}) - \mathbf{E}[Y_i I'((1-T)Y_i)]. \tag{9}$$

To evaluate (9), note that the second f.o.c. for (8), $\frac{\partial \rho_j R_j}{\partial s_j} = 0$, implies that, for $s^*(T) > 0$, we have

$$\frac{ds^*(T)}{dT} = \frac{R_j(s^*(T))\alpha H''(g)}{R_j(s^*(T))\alpha H''(g(s^*(T),T)) - (\theta - \pi v)H'\left(g(s^*(T),T)\right)}. \tag{10}$$

$H(.)$ is strictly concave, thus, $\frac{ds^*(T)}{dT} \in (0,1)$. At the unconstrained equilibrium, we have $\frac{\partial \rho_j R_j}{\partial t_j} = 0$, thus, $\alpha H'(g^*) = \mathbf{E}[Y_i I'(Y_i(1-t^*)]$. Then, imposing a slightly binding tax rate constraint is welfare increasing. That is, $\frac{\partial \mathbf{E}[\mathbf{W}]}{\partial T} < 0$ at $T = t^*$. More formally,

Proposition 4 *If the identical candidates steal in equilibrium, then there exists a binding constraint on tax rates; this constraint reduces corruption and increases voters welfare.*

Intuitively, a tax rate constraint reduces corruption because for a given s^*, a binding constraint lowers the public good level a candidate can provide, raising marginal utility of public good, and thus increasing the voters' marginal disutility from corruption. Then, the cost of stealing last dollar (in terms of votes foregone) becomes higher, the candidate steals less. A slightly binding constraint increases voters' welfare, because, at the margin, the benefit from higher private good consumption due to the lower tax rate compensates the lower public good level. When the candidates are not identical, however, this is not necessarily the case.

When the candidates are not identical, (generically) each candidate proposes a different tax rate in equilibrium. Then, the candidate who proposes the higher tax rate, say Candidate 1, can easily be targeted by choosing an appropriate constraint. The constraint would be very effective if Candidate 1 is proposing higher taxes because he is corrupt, and Candidate 2 is proposing lower taxes because he is honest. But, the opposite case is also possible. If his ability to produce public good is lower, then a corrupt Candidate 2 who happens to be popular with the voters may propose lower tax rates in equilibrium. That is, we may have $t_2^* < t_1^*$ even when $s_2^* > s_1^* = 0$.[22] If this is the case, then a constitutional constraint that is binding only for the honest candidate will always be counterproductive.

Proposition 5 *If only Candidate 2 is corrupt with $t_2^* < t_1^*$, then a tax rate constraint that binds only for Candidate 1 reduces voters' welfare and increases corruption.*

I prove Proposition 5 in the Appendix. To see the intuition, note that (i) the constraint will tie the hands of the clean candidate, now he has to offer a suboptimal policy platform (the direct effect), and (ii) as Candidate 1 one *cannot* offer the optimal platform anymore, Candidate 2's popularity advantage becomes more prominent (for a given level of s_2^*, ρ_2 and, thus, $\frac{\partial \rho_2 R_2}{\partial s_2}$ will increase); so, he will steal more (the strategic effect). Both effects lead to a decrease in voters' welfare, but only the strategic effect leads to an increase in equilibrium level of corruption.

We find that reducing the T lowers the voters' welfare as long as the tax-rate constraint binds only for the honest candidate. Let us consider a constraint low enough that it just binds for both candidates, $T = t_2^*(T)$. Reducing the tax-rate constraint below this point may reduce or increase corruption. The constraint reduces the level of public good that Candidate 2 can provide, thus, for the reasons we discuss following Proposition 4, he has incentives to steal less. At the same time, it ties the hands of the honest candidate further (now he has to propose a fiscal policy further away from the optimal policy), thus, Candidate 2 has incentives to steal more as well. Analytically, it is difficult to determine if candidate 2 ends up stealing more or less. Yet, as Example 1 below shows, even when a lower T *reduces* corruption, the constraint may still be undesirable.

Example 1: Assume that there is only one voter with $I(c) = \sqrt{c}$, $H(g) = \sqrt{g}$ and $\alpha_1 = 7/10$, $\alpha_2 = 1/2$, $\beta = 1/100$, $\sigma = 2$, $\theta_1 = 0$, $\theta_2 = 0.4$, $\pi = 0$, $w = 0$, $\eta = 1/10$. Then,[23] $t_1^* = t_1^0 = 0.4118$, and $g_1^* = g_1^0 = 49/170$, but $t_2^* = 0.3475$ and $g_2^* = 0.1631$. In equilibrium, the popular candidate steals 2.12 percent of total income: $s_2^* = 0.0212$.

[22] See, for instance, Example 1 below.

[23] These values are rounded after the fourth digit.

Yet, due to his popularity advantage ($\beta = 1/100$), he still has a 33.57 percent chance of winning the election. Any $T \in [0.4118, 0.3488]$ binds only for the honest Candidate 1, and as Proposition 5 shows, in this region, the lower the T, the *higher* are both ρ_2^* and s_2^*. When $T < 0.3488$, the constraint binds for both candidates. In this region, reducing T *reduces* s_2^*. However, at the same time, it reduces the voter welfare as well. This is because, for it to bind for both candidates, the constraint should be significantly lower than the first-best tax rate for Candidate 1, t_1^0. Although such a low T reduces corruption, it also forces the honest (and, high ability) candidate to produce the public good using a level of public funds that is significantly less than the optimal level. The welfare loss resulting from this inefficiency, however, is larger than any welfare gain due to lower corruption that the tax-rate limit brings.[24] Thus, with unidentical candidates, it is possible that *any* tax-rate constraint (whether it binds for one or two candidates) reduces voters' welfare.

Next, let us consider another constitutional constraint, one that has received little attention from economists[25]: a *lower* limit on the public good level, G. Then, each candidate j's optimization problem becomes

$$\max_{s_j,t_j} \rho_j R_j \text{ subject to } (t_j - w - s_j)\alpha_j \geq G.$$

The way G works is similar to the way T works. First, it is straightforward to show that using only a minimum public good level constraint, the first best cannot be implemented (that is, one can extend Proposition 3 to constraints on public good levels). Second, when candidates are ex-ante identical, there exists a G that would implement a second-best allocation. Following the steps that led to Proposition 4, one can show that

$$\frac{\partial \mathbf{E}[\mathbf{W}]}{\partial G} = \alpha H'(G) - \mathbf{E}[Y_i I'((1-t)Y_i)](\frac{1}{\alpha} + \frac{ds^*}{dG}),$$

and, that

$$\frac{ds^*(G)}{dG} = \frac{-1}{\alpha} \frac{R\mathbf{E}[Y_i^2 I''(c_i^*)]}{R\mathbf{E}[Y_i^2 I''(c_i^*)] - (\theta - \pi v)\mathbf{E}[Y_i I'(c_i^*)]}.$$

The marginal utility from private good consumption is strictly concave, that is, $\frac{-1}{\alpha} < \frac{ds^*(G)}{dG} < 0$. Since in the unconstrained equilibrium we have $\alpha H'(g^*) = \mathbf{E}[Y_i I'((1-t)Y_i)]$, imposing a binding limit would increase voters' welfare.[26] That is,

[24] The Mathematica notebook for the calculations is available from the author upon request.

[25] To my knowledge, Inman (1985) is the first (and the only) one to consider a similar limit. In his discussion of limits imposed by citizens on a bureaucrat–politician with monopoly power, Inman (1985, p.750) considers a contract that allows the monopolist to choose the public good level only from a given interval.

[26] Again, intuitively, a binding G reduces corruption because it increases the taxes, reducing after tax income, and increasing the marginal utility of private good consumption for a voter. And, again, a slightly binding limit increases voters' welfare because, at the margin, voters' gain from less stealing is larger than their loss from higher taxes. Note that the public good limits would not work

we have $\frac{\partial \mathbf{E}[\mathbf{W}]}{\partial G} > 0$ at $G = g^*$, or, more formally:

Proposition 6 *If the identical candidates steal in equilibrium, then there exists a binding lower limit on the size of public good such that imposing this limit reduces corruption and increases voters" welfare.*

Less formally, Proposition 6 shows that with identical candidates, another (second-best) solution to political corruption is a constitution that enforces a large government. When the candidates are identical, however, imposing only one constraint is clearly suboptimal.

Proposition 7 *If the candidates have identical ability, then constitutional constraints on both the tax rates and public good levels are enough to implement the first-best.*

Proof. Note that when the candidates have the same ability, we have $t_1^0 = t_2^0 = t^0$, and $g_1^0 = g_2^0 = g^0$ (first-best fiscal policy does not depend on a candidate's popularity). Then, by simply setting $T = t^0$, and $G = g^0$ one can implement the optimal fiscal policy. ■

In the special case of $\alpha_1 = \alpha_2$, and, only in this case, there is no need for a penalty against corruption or any salary for the politicians. When candidates differ in their ability, however, the first-best policy platforms are candidate specific; there is a total of four optimal policy variables. Only two instruments are not enough to implement that optimum. For this case, again, one can extend Proposition 5 and show that a G that binds only for the honest candidate is welfare reducing and corruption increasing. Similarly, one can provide a numerical example showing that there exists parameters under which any G alone could reduce voters' welfare.

To summarize, imposing a constitutional constraint only on the tax-rate (the public good level) is only partially effective when the candidates have the same ability. Yet, when the candidates differ in their ability and ethics, using only one constraint may reduce voters' welfare. When the candidates have the same level of ability one can implement the first best by using both constrains. When $\alpha_1 \neq \alpha_2$, even both constraints are not enough to implement the first-best.

4 Conclusion

In a series of papers, I study the political economy of anti-corruption reform in countries in which political competition is among a small set of career politicians. In several countries a few politicians dominate political arena for a long time, for some examples, see Evrenk (2008a).

had one consider a very common specification: voters with quasi-linear preferences where marginal utility from private good consumption is constant.

In this paper, I study the effectiveness of some commonly discussed anti-corruption reforms. Although each reform may be effective under certain conditions, I find that each reform may increase corruption or reduce the voters' welfare as well. The conditions under which the reforms are ineffective, such as candidates who differ in their ability, popularity or corruptibility and ineffective law enforcement are not rare. Thus, before implementing any of these reforms, the specific conditions of the country in question has to be studied.

There is another issue with implementation that requires further discussion: the political support for the reform. A reform may increase welfare, yet it may not have enough political support. The politicians' and the voters' incentives to support an effective reform have been studied in (respectively) Evrenk (2008b) and Evrenk (2008c). To combat political corruption, one needs carefully designed policies taking all these issues into account. I hope that the analysis here informs to design of such policies.

5 Appendix

Lemma 2 $\frac{d\mathbf{E}[\mathbf{W}]}{dw} = -\sum_{j\in\{1,2\}} \rho_j \alpha_j \frac{d\mathbf{E}[U_i(.)]}{dg}(1 + \frac{ds_j^*(w)}{dw})$

Proof. $\frac{d\mathbf{E}[\mathbf{W}]}{dw} = \frac{d\mathbf{E}[U_i((1-t_2(w))Y_i, g_2(w))]}{dw} + \rho_1(\frac{d\mathbf{E}[U_i((1-t_1(w))Y_i, g_1(w))]}{dw} - \frac{d\mathbf{E}[U_i((1-t_2(w))Y_i, g_2(w))]}{dw})$ $= ((1-\rho_1)\frac{d\mathbf{E}[U_i((1-t_2(w))Y_i, g_2(w))]}{dw} + \rho_1 \frac{d\mathbf{E}[U_i((1-t_1(w))Y_i, g_1(w))]}{dw})$. Note that, $\frac{d\mathbf{E}[U_i((1-t_j(w))Y_i, g_j(w))]}{dw} = \frac{\partial\mathbf{E}[U_i((1-t_j(w))Y_i, g_j(w))]}{\partial s_j}\frac{ds_j^*(w)}{dw} + \frac{\partial\mathbf{E}[U_i((1-t_j)Y_i, \alpha_j(t_j-w-s_j))]}{\partial w}$ (the f.o.c. with respect to tax rate implies that $\frac{\partial\mathbf{E}[U_i((1-t_j(w))Y_i, g_j(w))]}{\partial t_j}\frac{dt_j(w)}{dw} = 0$). Also note that, since $\frac{\partial\mathbf{E}[U_i((1-t_j(w))Y_i, g_j(w))]}{\partial s_j} = \frac{\partial\mathbf{E}[U_i((1-t_j)Y_i, \alpha_j(t_j-w-s_j))]}{\partial w} = -\alpha_j \frac{\partial\mathbf{E}[U_i(c_i^j, g_j)]}{\partial g}$, $\frac{d\mathbf{E}[U_i((1-t_j(w))Y_i, g_j(w))]}{dw} = -\alpha_j \frac{\partial\mathbf{E}[U_i(c_i^j, g_j)]}{\partial g}(1+\frac{ds_j^*(w)}{dw})$, and $\frac{d\mathbf{E}[\mathbf{W}]}{dw} = -\sum_{j\in\{1,2\}} \rho_j \alpha_j \frac{d\mathbf{E}[U_i(.)]}{dg}(1+\frac{ds_j^*(w)}{dw})$. ■

Proof of Proposition 1. Note that the derivative of $\frac{\partial\mathbf{E}[U_i((1-t_j)Y_i, \alpha_j(t_j-w-s_j))]}{\partial t_j}$ with respect s_j is equal to the derivative with respect to wage, w. Then, differentiating both $\frac{\partial\rho_1 R_1}{\partial s_i} = 0$ and $\frac{\partial\rho_2 R_2}{\partial s_2} = 0$ with respect to w we find

$$\left[\frac{ds_j^*}{dw}\right] = \left[\frac{\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k}\frac{\partial^2(\rho_k R_k)}{\partial s_k \partial w} - \frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2}\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial w}}{\frac{\partial^2(\rho_1 R_1)}{(\partial s_1)^2}\frac{\partial^2(\rho_2 R_2)}{(\partial s_2)^2} - \frac{\partial^2(\rho_1 R_1)}{\partial s_1 \partial s_2}\frac{\partial^2(\rho_2 R_2)}{\partial s_1 \partial s_2}}\right].$$

Evrenk (2004) proves that, evaluated at the equilibrium values, $D = \frac{\partial^2(\rho_j R_j)}{(\partial s_j)^2}\frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2} - \frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k}\frac{\partial^2(\rho_k R_k)}{\partial s_k \partial s_j}$ is negative. Thus

$$\frac{ds_j^*}{dw} < -1 \text{ iff } \frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k}\frac{\partial^2(\rho_k R_k)}{\partial s_k \partial w} - \frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2}\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial w} > -D. \tag{11}$$

Both stealing and wages reduce the available public funds: an increase in legal and illegal rents has the same effect on equilibrium policies, $\frac{\partial t_j^*(s_j)}{\partial s_j} = \frac{\partial t_j^*(w)}{\partial w}$ and $\frac{dg_j^*(s_j)}{ds_j} = \frac{dg_j^*(w)}{dw}$. Then, $\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial w} = \frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2} + \frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k} - A_j$, where $A_j = \alpha_j \sigma[1-\pi-\theta_j+\pi v]H'(g_j^*)$. Using this in (11), we have $\frac{ds_j}{dw} < -1$ iff $\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k} A_k - \frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2} A_j > 0$. By Lemma 3 from Evrenk (2004), at equilibrium, we have $\frac{\partial^2(\rho_j R_j)}{\partial s_j \partial s_k} > 0$ and $\frac{\partial^2(\rho_k R_k)}{(\partial s_k)^2} < 0$. Thus $\min\{A_k, A_j\} > 0$ is necessary and $\max\{A_k, A_j\} > 0$ is sufficient for $\frac{ds_j^*}{dw} < -1$. ■

Proof of Proposition 5. Suppose that $k \neq j$ is the only candidate who steals when there are no constitutional constraints, i.e., $t_j^* > t_k^*$ and $s_k^* > s_j^* = 0$. Below, I show that a T that binds only for j reduces both $\mathbf{E}[U_i^k]$ and ρ_j (these two together imply that it reduces $\mathbf{E}[\mathbf{W}]$). Note that under a tax rate constraint, j proposes the policy platform $(T, (T-w)\alpha_j)$. The policy platform that k proposes is determined by the following two first-order conditions:

$$-\mathbf{E}[Y_i I'((1-t_k^*)Y_i)] + \alpha_k H'((t_k^* - w - s_k^*)\alpha_k) = 0, \tag{12}$$

and

$$(\theta_k - \pi v)\rho_k - R_k \sigma \alpha_k H'((t_k^* - w - s_k^*)\alpha_k) = 0, \tag{13}$$

where $\rho_k = \frac{1}{2} + \sigma(\mathbf{E}[I((1-t_k^*)Y_i) - I((1-T)Y_i)] + H((t_k^* - w - s_k^*)\alpha_k) - H((T - w)\alpha_j) + 2\beta(\frac{3}{2} - j))$. Applying the Implicit Function Theorem we find

$$\frac{dt_k^*}{dT} = \frac{(\alpha_k)^2 H''((t_k^* - w - s_k^*)\alpha_k)}{(\alpha_k)^2 H''((t_k^* - w - s_k^*)\alpha_k) + \mathbf{E}[(Y_i)^2 I''((1-t_k^*)Y_i)]} \frac{ds_k^*}{dT},$$

and

$$\frac{ds_k^*}{dT} = \frac{-(\theta_k - \pi v)(\mathbf{E}[Y_i I'((1-T)Y_i) + H'((T-w)\alpha_j)\alpha_j)\sigma}{2(\theta_k - \pi v)\sigma\alpha_k H'((t_k^* - w - s_k^*)\alpha_k) - \frac{\mathbf{E}[(Y_i)^2 I''((1-t_k^*)Y_i)] R_k \sigma \alpha_k^2 H''((t_k^* - w - s_k^*)\alpha_k)}{(\alpha_k)^2 H''((t_k^* - w - s_k^*)\alpha_k) + \mathbf{E}[(Y_i)^2 I''((1-t_k^*)Y_i)]}} < 0$$

That is, as T becomes smaller, s_k^* increases, (thus, $\frac{d\mathbf{E}[U_i^k]}{dT} > 0$).

To see $\frac{d\rho_j}{dT} > 0$, note that $\rho_j = 1 - \rho_k$. Thus, it suffices to show that $\frac{d\rho_k}{dT} < 0$. Differentiating (13), one can show that

$$(\theta_k - \pi v)\frac{d\rho_k}{dT} = \frac{ds_k^*}{dT}[(\theta_k - \pi v)\sigma\alpha_k H'(g_k^*) - \frac{\mathbf{E}[(Y_i)^2 I''((1-t_k^*)Y_i)] R_k \sigma \alpha_k^2 H''(g_k^*)}{(\alpha_k)^2 H''(g_k^*) + \mathbf{E}[(Y_i)^2 I''((1-t_k^*)Y_i)]}].$$

Simply note that, $\frac{ds_k^*}{dT} < 0$, and that the expression in the brackets is positive as both $I(.)$ and $H(.)$ are strictly concave. ■

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