Francesco Lancia[1] / Alessia Russo[2]

Sustaining Cooperation Through Strategic Self-Interested Actions

[1] University of Salerno and CSEF, Napoli, Italy, E-mail: flancia@unisa.it
[2] BI Norwegian Business School, Oslo, Norway, E-mail: alessia.russo@bi.no

Abstract:
This paper studies how organizations seek to promote cooperation between their members when individual contributions to an organization's output are imperfectly observable. It considers an overlapping-generations game in which members with conflicting interests expend effort in pursuing activities outside the organization, in addition to the effort they devote to increasing the organization's output. We show that cooperation is easier to enforce when organizations link rewards and punishments to effort in outside activities. In the best public perfect equilibrium, effort in outside activities is distorted in order to signal a member's willingness to cooperate inside the organization.

Keywords: imperfect monitoring, intergenerational cooperation, limited enforcement, organizations
JEL classification: C73, D62, M54
DOI: 10.1515/bejte-2017-0157

1 Introduction

Consider an organization such as a public agency or a private firm that over time recruits junior members to replace retiring ones. When they join the organization, members become recipients of, as well as contributors to, the organization's output. The success of the organization therefore depends on its members' willingness to refrain from opportunistic behaviour. If, however, individual contributions are hidden, as they are in most organizations, then intertemporal incentives are difficult to provide. Indeed, the inability to detect a member's opportunistic behavior with certainty results in inefficient punishment. Nonetheless, we observe organizations that explicitly permit outside activities that benefit the member alone and do not directly increase the organization's output.[1]

This paper shows that the likelihood of inefficient punishment is reduced and, in turn, cooperation is easier to enforce when an organization links rewards and punishments to its members' effort in multiple activities, some of which are only privately beneficial. To do so, we consider a repeated game à la Cremer (1986). The basic structure is that of an organization whose members belong to two different generations at any point in time. Members interact via a prisoner's dilemma type of game in which they choose how much to contribute to producing the organization's output. The novel aspects of the game are that (i) individual contributions are hidden and (ii) members expend effort in pursuing outside activities, which can either complement or substitute the effort devoted to increasing the organization's output. In this framework, we characterize the best public perfect equilibrium (PPE) at a fixed discount factor and study what strategies support it, by exploiting the machinery developed by Abreu, Pearce, and Stacchetti (1990).

The key feature in enforcing cooperation is the likelihood of punishment, which is endogenous to the equilibrium. To characterize the best PPE what matters is how small the likelihood can be made without giving a member an incentive to deviate. The minimum likelihood of punishment is attained when a member's gain from deviation, as measured by the difference in flow utilities between cooperation and defection, is minimized. This can be accomplished by enforcing a level of effort devoted to outside activities that is higher than what is individually optimal in the case of complementarity of efforts and lower in the case of substitutability. The intuition behind this result is straightforward: A strategic distortion of effort in outside activities signals a member's willingness to cooperate inside the organization. If continuation utilities can be made contingent on a member's privately beneficial effort by means of, for instance, mandatory reporting rules that make it possible to monitor effort, then the organization can afford to mete out less severe punishments, while satisfying enforceability. Strategic distortions of privately beneficial effort remain optimal even when this type of effort is imperfectly observable or when more than two generations inhabit the organization. In the former case, the

Alessia Russo is the corresponding author.

organization can set a threshold of information disclosure, taking into account both organizational considerations and members' incentive constraints. In the latter case, the organization needs a larger distortion in the case of younger members who are more likely to be punished during their lifetime and therefore more tempted to deviate.

While our contribution is mostly applied, it is methodologically related to the literature on repeated games with imperfect public monitoring, which deals with optimal penal codes (see, e.g., Abreu, Pearce, and Stacchetti 1986, 1990; Green and Porter 1984). The model presented here differs in that it allows for multiple actions and various monitoring structures. Moreover, the methodology is extended to a setting with overlapping generations where continuation utilities differ with age. By focussing on overlapping generations, the paper is related to the literature on sustainability of cooperation in ongoing organizations (see, e.g., Cremer 1986; Hammond 1975; Kandori 1992; and Kreps 1996). In contrast to those papers, we focus on the best PPE when cooperation is hidden.

The paper is also connected to the literature on strategic interactions with multiple actions (see, e.g., Spence 1977; Dixit 1980; Fudenberg and Tirole 1984; and Benoit and Krishna 1987). In this literature, an agent invests preemptively in technology if such investment makes it more costly for other agents to deviate. In contrast, we consider multiple actions that are interdependent. This leads to a new mechanism which facilitates cooperation by endogenously undermining the short-run gain from deviation rather than by varying the retaliatory power of the punishment scheme. The idea that an action can affect the ex-post constraint on another action is also present in the literature of relational contracts (see, e.g., Ramey and Watson 1997; and Halac 2015) and environmental agreements (see, e.g., Harstad, Lancia, and Russo 2018). We depart from this literature by considering an overlapping-generation demographic structure whose members take multiple actions in every period.

The paper proceeds as follows: Section 2 presents the model's setup. Section 3 derives the best PPE. Section 4 discusses strategic distortions from limited enforcement. Section 5 extends the results to include more than two generations and imperfect monitoring of outside activities. Section 6 concludes.

2 Model

Time is discrete and indexed by $t = 0,1,...$ The model consists of an ongoing organization with an overlapping-generations demographic structure, whose members live for two periods and share a common discount factor $\delta \in (0,1]$. Each generation is composed of a single member.[2] At each time t, a new member i enters the organization. She is young, denoted by y, in the first period and old, denoted by o, in the second period.

Actions The organization's members make choices in both periods of life and can simultaneously exert effort along two dimensions: a privately beneficial effort $b_t^i \in \mathbb{R}_+$ and a collectively beneficial effort $a_t^i \in \{\underline{a}, \overline{a}\}$ with $0 \leq \underline{a} < \overline{a}$. Choosing $\overline{a}$ is interpreted as cooperation, whereas choosing $\underline{a}$ is interpreted as shirking. This effort goes toward producing the organization's output $g_t = G\left(a_t^i, a_t^{-i}\right)$ where a_t^{-i} denotes the effort expended by the other member and $G(\cdot)$ is an increasing function of individual effort. Exerting effort is costly, where the total cost $C\left(a_t^i, b_t^i\right)$ borne by each member is strictly increasing in both types of effort and strictly convex in b_t^i.

Payoffs Each member derives utility from the organization's output as well as from her privately beneficial activity. We assume quasi-linear preferences and therefore the flow utility of member i at time t can be written as $\lambda g_t + \theta b_t^i - C\left(a_t^i, b_t^i\right)$, where $\lambda > 0$ captures the preference weight on the organization's output and $\theta > 0$ measures the marginal benefit of the privately beneficial action.

Assumption 1.
$\lambda\left(G\left(\overline{a}, a_t^{-i}\right) - G\left(\underline{a}, a_t^{-i}\right)\right) < C\left(\overline{a}, b_t^i\right) - C\left(\underline{a}, b_t^i\right)\ \forall b_t^i, a_t^{-i}.$

The organization's output is clearly maximized when both generations cooperate. Under Assumption 1, however, no cooperation is the organization's outcome in the absence of institutions that provide members with the necessary incentives to exert $\overline{a}$. Let $\Delta\left(b_t^i\right) := C_b\left(\overline{a}, b_t^i\right) - C_b\left(\underline{a}, b_t^i\right)$ measure the marginal impact of varying b_t^i on member i's gain from deviating from cooperative behavior. The efforts can be either complements, i.e., $\Delta(b) < 0$, or substitutes, i.e., $\Delta(b) > 0$. In the former case, the incremental gain from choosing $\underline{a}$ decreases as b increases. The opposite holds in the latter case.[3] These types of interdependence between efforts are commonly observed in organizations, as discussed in the Introduction.

Information Apart from the economic scope, the efforts also differ in observability. The effort a_t^i is hidden, although the realized output g_t is publicly observable. Without loss of generality, we let $g_t \in \left\{\underline{g}, \overline{g}\right\}$ and denote $\pi\left(g_t|a^i, a^{-i}\right) := \Pr\left[g_t|a^i, a^{-i}\right]$.

Assumption 2.
The signal g_t is informative about a_t, i.e., $\pi\left(\underline{g}|\underline{a}, \underline{a}\right) > \pi\left(\underline{g}|\overline{a}, \underline{a}\right) = \pi\left(\underline{g}|\underline{a}, \overline{a}\right)$.

Unlike a_t^i, the effort b_t^i is observable.[4] This can be justified by the existence of mandatory reporting rules in the organization, which enable the monitoring of outside activities and make them known to the other members.[5] Let $h_t := \{g_0, ..., g_{t-1}; b_0, ..., b_{t-1}\}$ be a public history and H_t be the set of all publicly observed histories up to time t.

Equilibrium The organization wishes to maximize realized output. In the absence of external enforcement, the only way to enforce cooperation is through repeated interactions. The public perfect equilibrium (PPE) serves as the equilibrium concept of the repeated game played among successive generations.[6] A pair of strategies is then $a_t^i : H_t \to \{\underline{a}, \overline{a}\}$ and $b_t^i : H_t \to \mathbb{R}_+$. As is standard in the literature, we allow for a public randomization device $\phi_t \in [0, 1]$ drawn from a uniform distribution at the beginning of each period to randomize over members' continuation utilities (see, e.g., Mailath and Samuelson 2006).

We note that the old member will exit the organization before the next period. Hence, she is always better off by shirking rather than cooperating. Then, in any PPE, $(a_t^o, b_t^o) = (\underline{a}, \hat{b})$ where $\hat{b}$ solves $\theta = C_b(\underline{a}, \hat{b})$. We can therefore simplify the notation by writing the expected flow utility of the young member as $u\left(a_t^y, b_t^y\right) := \lambda \mathbb{E}\left[g_t | a_t^y, a_t^o = \underline{a}\right] + \theta b_t^y - C\left(a_t^y, b_t^y\right)$ and the highest and lowest feasible continuation utilities as $\overline{\omega} := \lambda \mathbb{E}\left[g_t | a_t^y = \overline{a}, a_t^o = \underline{a}\right] + \theta \hat{b} - C(\underline{a}, \hat{b})$ and $\underline{\omega} := \lambda \mathbb{E}\left[g_t | a_t^i = \underline{a} \forall i\right] + \theta \hat{b} - C(\underline{a}, \hat{b})$, respectively. Hereafter, we omit the superscripts y and o since the young member is the only one who might cooperate.

Assumption 3.
$\hat{v} < v^*$ with $\hat{v} := u(\underline{a}, \hat{b}) + \delta \underline{\omega}$ and $v^* := u\left(\overline{a}, b^*\right) + \delta \overline{\omega}$ where b^* solves $\theta = C_b\left(\overline{a}, b^*\right)$.

To create scope for cooperation, Assumption 3 states that the intertemporal utility when all young members are committed to cooperate is larger than that when they defect. This implies that $\delta \in (\underline{\delta}, 1]$ with $\underline{\delta} := (u(\underline{a}, \hat{b}) - u(\overline{a}, b^*))/(\overline{\omega} - \underline{\omega})$. Clearly, if $\delta \le \underline{\delta}$ there exist no strategies that can enforce cooperation. As we will see, however, $\delta > \underline{\delta}$ is not sufficient for cooperation to be sustained in equilibrium.

3 Self-Enforcing Intergenerational Cooperation

Strategies contingent on past histories and enforced by reputation allow for multiple equilibria. However, we confine our attention to the characterization of the best PPE, i.e., the one that simultaneously yields the upper bound of individual intertemporal utility and maximizes the organization's expected output at a fixed δ. Let V be the set of PPE intertemporal values v_t. This set is nonempty since it contains the trivial equilibrium $\hat{v}$, which coincides with the worst PPE according to the following argument: First, $\hat{v}$ is sustainable. If it is known that no one will ever cooperate, it is individually optimal not to cooperate. Second, there can be no lower equilibrium value, since each member is at the reservation utility. To characterize the set V, we employ the recursive techniques developed by Abreu, Pearce, and Stacchetti (1990). In what follows, unless otherwise specified, we omit t indexes. The value $v \in V$ is enforceable on a set $W \subset \mathbb{R}$ for a given strategy $(a, b) \in \{\underline{a}, \overline{a}\} \times \mathbb{R}_+$ if there is a continuation utility $w : \{\underline{g}, \overline{g}\} \times \mathbb{R}_+ \to W$ such that:

$$v = u\left(a, b\right) + \delta \sum_{g \in \{\underline{g}, \overline{g}\}} \pi\left(g | a\right) w\left(g, b\right), \tag{1}$$

$$v \ge u\left(a', b'\right) + \delta \sum_{g \in \{\underline{g}, \overline{g}\}} \pi\left(g | a'\right) w\left(g, b'\right) \forall a', b', \tag{2}$$

$$\underline{\omega} \le w\left(g, b\right) \le \overline{\omega}. \tag{3}$$

Eq. (1) defines the intertemporal utility. It is decomposed into current-period strategies and continuation utilities for each public signal. Inequalities (2) are the self-enforcement constraints. They capture the inefficiencies generated in the presence of hidden cooperation and limited enforcement. Constraint (3) ensures that continuation utilities are feasible. The best PPE is the largest v that satisfies eqs. (2) and (3) at a given history.[7] If no solution exists, then $v = \hat{v}$. Under Assumption 3, cooperation is desirable. Hence, the highest v must be enforceable for $a = \overline{a}$ and a given equilibrium b. A young member can deviate from either privately or collectively beneficial effort or both simultaneously. Nonetheless, deviations from b can be fully detected since the action is perfectly observable. According to Abreu (1988), it is optimal in this case to revert to the worst credible punishment off the equilibrium path, i.e., to the lowest feasible $w\left(g, b'\right) = \underline{\omega}$ for $b' \neq b$ and any g. The member's optimal response is then to also deviate from cooperation. Hence, the equilibrium b is enforceable if and only if:

$$v \geq \hat{v}. \tag{4}$$

As long as every member prefers the best equilibrium to the value achieved when no members cooperate, eq. (4) is trivially satisfied. We herein assume this to be the case.[8] Thus, it only remains to determine the continuation utilities that make a deviation from $a = \bar{a}$ not profitable given b, i.e.,

$$u(\bar{a}, b) + \delta \sum_{g \in \{\underline{g}, \bar{g}\}} \pi(g|\bar{a}) \, w(g, b) \geq u(\underline{a}, b) + \delta \sum_{g \in \{\underline{g}, \bar{g}\}} \pi(g|\underline{a}) \, w(g, b). \tag{5}$$

This constraint must hold with equality, since otherwise it would be possible to increase the continuation utilities $w(g, b)$ while maintaining enforceability and by doing so increase the intertemporal utility on the equilibrium path. Constraint (5) can then be written as:

$$\delta(w(\bar{g}, b) - w(\underline{g}, b)) = \frac{u(\underline{a}, b) - u(\bar{a}, b)}{\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a})}. \tag{6}$$

For notational purposes, we let $L := \pi(\underline{g}|\underline{a}) / \pi(\underline{g}|\bar{a}) > 1$. Plugging eq. (6) into eq. (1) yields:

$$v = v(b) := u(\bar{a}, b) + \delta w(\bar{g}, b) - \frac{u(\underline{a}, b) - u(\bar{a}, b)}{L - 1}. \tag{7}$$

Since v is increasing in $w(\bar{g}, b)$, it must be that the best PPE is attained for $w(\bar{g}, b) = \bar{\omega}$.

Proposition 1 (Necessary Condition).
Assume that a PPE exists in which $v \geq \hat{v}$ for $a = \bar{a}$. Then, eq. (6) must be satisfied. In this case the best PPE is unique and characterized by:

$$v^e = v(b^e) := u(\bar{a}, b^e) + \delta\bar{\omega} - \frac{u(\underline{a}, b^e) - u(\bar{a}, b^e)}{L - 1}, \tag{8}$$

where b^e solves $u_b(\bar{a}, b^e) = \Delta(b^e) / (L - 1)$.

Proof.
For a pair $(\bar{a}, b)$ to be a PPE, there must be no profitable one-shot deviations. Hence, eq. (6) must hold and in turn a value $v \geq \hat{v}$ enforceable for $(\bar{a}, b)$ is equal to $v(b)$ in eq. (7). The best PPE is then attained by maximizing $v(b)$ with respect to b, assuming that an interior solution exists.[9]

Embedded in the upper bound eq. (8) is the efficiency loss associated with the punishment, which occurs with some probability along the equilibrium path. For L approaching infinity, the efficiency loss vanishes and v^e tends to v^*. It now remains to determine when a best PPE exists. Let $\bar{\delta} = \bar{\delta}(b^e) := (u(\underline{a}, b^e) - u(\bar{a}, b^e)) / ((\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a}))(\bar{\omega} - \underline{\omega}))$. Then, we can establish the following result:

Proposition 2 (Sufficient Condition).
A threshold level $\bar{\delta} \in (\underline{\delta}, 1]$ exists, so that $V = [\hat{v}, v^e]$ for any $\delta \geq \bar{\delta}$ and $V \subset [\hat{v}, v^e]$ otherwise.

Proof.
Plugging $w(\bar{g}, b^e) = \bar{\omega}$ into eq. (6) yields $w(\underline{g}, b^e) = \bar{\omega} - (u(\underline{a}, b^e) - u(\bar{a}, b^e)) / \delta(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a}))$, which is feasible if it is at least $\underline{\omega}$. This is true when $\delta \geq \bar{\delta}$, with $\bar{\delta} \in (\underline{\delta}, 1]$ for $\pi(\underline{g}|\underline{a}) - (u(\underline{a}, b^e) - u(\bar{a}, b^e)) / (u(\underline{a}, \hat{b}) - u(\bar{a}, b^*)) < \pi(\underline{g}|\bar{a}) \leq \pi(\underline{g}|\underline{a}) - (u(\underline{a}, b^e) - u(\bar{a}, b^e)) / (\bar{\omega} - \underline{\omega})$. If $\delta < \bar{\delta}$, there is no feasible $w(\underline{g}, b^e)$. In this case, the best PPE $v(b) < v^e$ is enforceable for $\bar{a}$ and some $b \in [\underline{b}, \bar{b}] \setminus \{b^e\}$, with the extremes $\{\underline{b}, \bar{b}\}$ determined by $v(b) = \hat{v}$. There also exists a threshold level $\check{\delta} < \bar{\delta}$ such that the pair $(\bar{a}, b)$ cannot be sustained as a PPE for any $b \in [\underline{b}, \bar{b}]$ and $V = \{\hat{v}\}$ if $\delta < \check{\delta}$.

We have so far determined the best PPE. When $\delta \geq \bar{\delta}$, there exist feasible continuation utilities that can enforce $(\bar{a}, b^e)$ and in turn attain the intertemporal utility (8). To understand the mechanics of the equilibrium, we now consider the bang-bang strategy that generates v^e in the presence of a public device ϕ_t, which makes it possible to randomize $w(g,b)$ between $\underline{\omega}$ and $\bar{\omega}$ and fine tune the severity of the punishment.

As illustrated in Figure 1, the strategy features two phases which encode the entire history of public signals: a cooperation phase, in which the young member exerts $\overline{a}$ and b^e, and a punishment phase, in which the young member exerts $\underline{a}$ and $\hat{b}$. Members start in the cooperation phase at time t. Provided that $b_t = b^e$, if $g_t = \overline{g}$, the cooperation phase restarts in period $t+1$; otherwise, there is transition to the punishment phase with some probability $1-\phi^e$. If $b_t \neq b^e$ for any g_t, then there is transition to the punishment phase with certainty. In both cases, the punishment phase is absorbing. Since $w(\underline{g}, b^e) = \phi^e \overline{\omega} + (1-\phi^e)\,\underline{\omega}$, we have $\phi^e = \phi(b^e) := 1 - \frac{u(\underline{a}, b^e) - u(\overline{a}, b^e)}{\delta(\overline{\omega}-\underline{\omega})\left(\pi\left(\underline{g}|\underline{a}\right) - \pi\left(\underline{g}|\overline{a}\right)\right)}$. The equilibrium likelihood of punishment is then a monotonic transformation of $\phi(b^e)$ and equal to $l^e = l(b^e) := \pi(\underline{g}|\overline{a})\,(1-\phi(b^e))$.

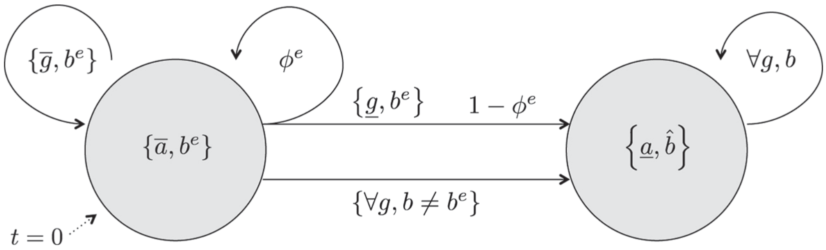

Figure 1: Automaton representation of the equilibrium strategy with correlation device.

4 Strategic Distortions from Limited Enforcement

To see how the best PPE is related to the optimal level of privately beneficial effort, we consider how the equilibrium would differ under some alternative levels of $b \neq b^e$.

Corollary 1.

When $\Delta(b) < (>) 0$, as b increases the likelihood of punishment $l(b)$ and the critical discount factor $\overline{\delta}(b)$ decrease (increase).

Proof.

Differentiating $\phi(b)$ and $\overline{\delta}(b)$ with respect to b yields $\phi_b = -\Delta(b)/(\delta(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\overline{a}))(\overline{\omega} - \underline{\omega}))$ and $\overline{\delta}_b = -\phi_b \overline{\delta}(b)$. Hence, $\phi_b > 0$, $l_b < 0$, and $\overline{\delta}_b < 0$ when $\Delta(b) < 0$, and $\phi_b < 0$, $l_b > 0$ and $\overline{\delta}_b > 0$ otherwise.

In the case of effort complementarity, a higher b reduces the individual gain from abandoning cooperation and slackens a member's self-enforcement constraint. It follows that punishment must be less severe in order to provide the young with incentives to cooperate. Corollary 1 implies that an optimal level of privately beneficial effort must be the highest feasible b that minimizes the probability of punishment and maximizes the range of discount rates that support cooperation. The extent of privately beneficial effort, however, cannot be overly large since otherwise, the cost borne by the young in terms of a lower flow utility for $b > b^*$ will be high enough to offset the benefits associated with a lower likelihood of punishment and in turn a larger expected continuation utility. The reverse argument applies when efforts are substitutes. This insight allows us to better characterize the optimal level b^e.

Corollary 2.

When $\Delta(b) \neq 0$, the difference $|b^* - b^e|$ is positive and decreases with L.

Proof.

Recall that b^e solves $u_b(\overline{a}, b^e) = \Delta(b^e)/(L-1)$. For $\Delta(b^e) < (>) 0$, $u_b(\overline{a}, b^e) < (>) 0$ and $b^e > (<) b^*$ since b^* solves $u_b(\overline{a}, b^*) = 0$ and $u(\cdot)$ is concave in b. By the implicit function theorem, $b^e_L = -\Delta(b^e)/((u_{bb}(\overline{a}, b^e)(L-1) - \Delta_b(b^e))(L-1))$, where the denominator is negative since the second-order condition of $v(b)$ with respect to b is satisfied. Hence, $b^e_L < (>) 0$ if $\Delta(b^e) < (>) 0$. Given that $b^*_L = 0$, this implies that $|b^* - b^e|$ decreases with L.

When efforts are interdependent, it is best to shift b away from the individually optimal level exerted by the young members if they were committed to cooperation, i.e., $b^e \neq b^*$. Such a distortion embeds the inefficiency associated with limited enforcement and its extent depends on the monitoring imperfection of cooperative decisions. A level $b > b^*$ is required in the case of effort complementarity, since more effort exerted in privately beneficial activities signals less incentive to deviate to $\underline{a}$. A similar argument applies to the case of effort substitutability, albeit with reverse implications. However, the effectiveness of b in signaling a member's willingness to cooperate declines as the monitoring of the cooperative behavior improves. This weakens the strategic role of b and in turn implies a smaller distortion $|b^* - b^e|$. This result is illustrated in Figure 2.

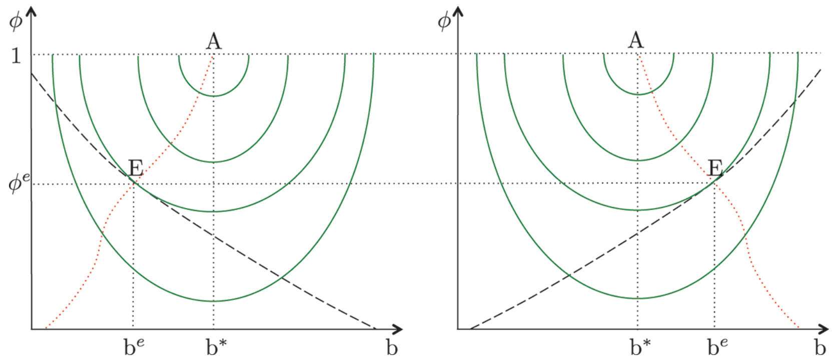

Figure 2: The best PPE for $\Delta(b) > 0$ (left-side panel) and $\Delta(b) < 0$ (right-side panel). The green solid lines represent the iso-utility curves of $u(\bar{a}, b) + \delta\left[\overline{\omega} - \pi(\underline{g}|\bar{a})(1-\phi)(\overline{\omega} - \underline{\omega})\right]$; the black dashed line plots $\phi(b)$; and the red dotted line is the locus (b^e, ϕ^e) resulting from variations in L. Point A is the pair $(b^*, 1)$ that generates v^* and point E is the pair (b^e, ϕ^e) that enforces v^e.

Although a privately beneficial effort does not directly increase the organization's output, it can do so indirectly by altering incentives and reducing the likelihood of punishment. As a result, cooperation is more likely to be sustained in the long run and the organization's expected output is larger when b^e is enforceable than when it is not. To see this, consider the extreme scenario in which the privately beneficial effort is hidden and cannot be publicly monitored, because, for example, the organization does not have a mandatory reporting rule. In this case, all members optimally choose the level of b that maximizes flow utility from cooperation, that is, b^*, and deviation, that is, $\hat{b}$. This yields $u(\underline{a}, \hat{b}) - u(\bar{a}, b^*)$ as the gain from shirking, which is larger than the corresponding gain when b^e is enforceable. It now becomes more difficult to incentivize a member to exert $\bar{a}$. An organization therefore cannot punish less severely without weakening incentives, thereby reducing the value of cooperation to the organization. This is formally proved in the following proposition, where $\tilde{l} := (\pi(\underline{g}|\bar{a})/(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a})))(u(\underline{a}, \hat{b}) - u(\bar{a}, b^*))/(\delta(\overline{\omega} - \underline{\omega}))$ and $\tilde{v}^e$ denote, respectively, the equilibrium likelihood of punishment and intertemporal utility enforced when privately beneficial effort cannot be publicly monitored:

Proposition 3.
The organization's expected output is always higher when privately beneficial effort is chosen strategically, i.e., $l(b^e) < \tilde{l}$.

Proof.
Let b be a hidden action. Then, a public history up to time t is $h_t := \{g_0, ..., g_{t-1}\}$ and a continuation utility is $w : \{\underline{g}, \bar{g}\} \to W \subset \mathbb{R}$ with $\underline{\omega} \le w(g) \le \overline{\omega}$. In this case, the optimal b must be at the level that maximizes a member's flow utility. Hence, the best PPE is attained by plugging the necessarily binding self-enforcement constraint $\delta(w(\bar{g}) - w(\underline{g})) \ge (u(\underline{a}, \hat{b}) - u(\bar{a}, b^*))/(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a}))$ into the intertemporal value $\tilde{v} = u(\bar{a}, b^*) + \delta(\pi(\underline{g}|\bar{a})w(\underline{g}) + (1 - \pi(\underline{g}|\bar{a}))w(\bar{g}))$. This yields the highest level when $w(\bar{g}) = \overline{\omega}$, i.e., $\tilde{v}^e = u(\bar{a}, b^*) + \delta\overline{\omega} - (u(\underline{a}, \hat{b}) - u(\bar{a}, b^*))/(L-1)$. From Corollary 2, $b^e > b^*$ when $\Delta(b) < 0$ and $b^e < b^*$ otherwise. In both cases, $u(\underline{a}, b^e) - u(\bar{a}, b^e) < u(\underline{a}, b^*) - u(\bar{a}, b^*)$. Since $u(\underline{a}, b^*) < u(\underline{a}, \hat{b})$, it is true that $u(\underline{a}, b^e) - u(\bar{a}, b^e) < u(\underline{a}, \hat{b}) - u(\bar{a}, b^*)$, which implies that $w(\underline{g}) < w(\underline{g}, b)$. In the strategy supporting $w(\underline{g})$, the likelihood of punishment must then be larger than in the strategy supporting $w(\underline{g}, b)$ when b is publicly observable. To see this, consider the bang-bang strategy that generates $\tilde{v}^e$ in the presence of a public device $\tilde{\phi}$, such that $w(\underline{g}) = \tilde{\phi}\overline{\omega} + (1 - \tilde{\phi})\underline{\omega}$. There are two phases: a cooperation phase, in which the young member exerts $\bar{a}$ and b^*, and a punishment phase, in which the young member exerts $\underline{a}$ and $\hat{b}$. Members start in the cooperation phase at time t. Regardless of b_t, if $g_t = \bar{g}$, the cooperation phase restarts in period $t+1$; otherwise, there is transition to the punishment phase with some probability $1 - \tilde{\phi}$. Using a binding self-enforcement constraint, $\tilde{\phi} := 1 - (u(\underline{a}, \hat{b}) - u(\bar{a}, b^*))/(\delta(\overline{\omega} - \underline{\omega})(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\bar{a})))$ and in turn the likelihood of punishment is $\tilde{l} := \pi(\underline{g}|\bar{a})(1 - \tilde{\phi})$. In order to have $w(\underline{g}) < w(\underline{g}, b)$, it must then be that $l(b^e) < \tilde{l}$.

Unlike the organization, members face the following intertemporal trade-off associated with b being public rather than private information: a short-term loss due to the reduction in flow utility, i.e, $u(\bar{a}, b^e) < u(\bar{a}, b^*)$, versus a long-term gain associated with a higher expected continuation utility implied by a lower likelihood of punishment. Proposition 4 below shows that the long-term gain unambiguously offsets the short-term loss for any L and δ. As eq. (8) makes clear, b^e is chosen so that the marginal cost of exerting a distorted level of effort is equalized to the associated marginal gain. Therefore, there cannot be any enforceable $b \neq b^e$ that attains a higher intertemporal utility. Moreover, the gain from shirking is the highest when b is private information. This makes cooperation enforceable at an even lower intertemporal utility.

Proposition 4.
The intertemporal utility of an organization's member is always higher when privately beneficial effort is chosen strategically, i.e., $v^e > \tilde{v}^e$.

Proof.
From Proposition 1, $v^e > v(b)$ *for any* $b \neq b^e$. *Therefore,* $v^e > u(\bar{a}, b^*) + \delta\overline{\omega} - \left(u\left(\underline{a}, b^*\right) - u(\bar{a}, b^*)\right)/(L-1)$. *Since* $u\left(\underline{a}, b^*\right) < u(\underline{a}, \hat{b})$, *it must be that* $u(\bar{a}, b^*) + \delta\overline{\omega} - \left(u\left(\underline{a}, b^*\right) - u(\bar{a}, b^*)\right)/(L-1) > \tilde{v}^e$, *where* $\tilde{v}^e$ *is defined in the proof of Proposition* 3. *Thus, we conclude that* $v^e > \tilde{v}^e$.

In summary, a strategic distortion of effort in outside activities is always of value to the organization and its members, since it reduces the need to threaten a punishment with high probability. To show this, we required a member who just joined the organization to perfectly recall past realizations of the organization's output, as well as the privately beneficial effort expended by each of his predecessors. While it is easy to keep track of an organization's past performance, the requirement to fully recall the outside activities of other members is much less plausible, especially in an ongoing organization in which members overlap for a finite number of periods before retiring. It is worth emphasizing, however, that whether members know the full history of privately beneficial effort is immaterial. Indeed, even under the most severe memory restriction, in which members are informed only about the action b taken by their immediate predecessor but are able to keep track of the organization's past performance, the best PPE value remains equal to v^e, as reported in eq. (8). This is because current play and continuation utilities are fully determined by the organization's output in the previous period and the young member's outside activity, conditional on being in the cooperation or punishment phase. Memory of one period of action b is therefore sufficient to induce members to refrain from opportunistic behaviour when they are in the cooperation phase, since otherwise they would be punished by their successor who observes the deviation. Furthermore, in this limited memory scenario, the punishment phase remains absorbing, since a deviation from action b does not induce a switch to the cooperative phase. Strategic distortions of outside activities in order to promote cooperation in an organization can thus be viewed as a robust prediction, since it occurs even when information requirements are less restrictive.

5 Extensions

The benchmark model ignores two additional issues: (i) the possibility that more than two generations inhabit the organization at any point in time; and (ii) the possibility that outside activities are imperfectly, though publicly, observable. In what follows, we discuss these issues and show that our main conclusions are largely unaffected.

Multiple Generations Consider an organization whose members live for three periods: young, middle-aged, and old. Let m denote the middle-aged member and $u\left(a^i, b^i\right) := \lambda\mathbb{E}[g|a^i, a^{-i} = \bar{a}, a^o = \underline{a}] + \theta b^i - C\left(a^i, b^i\right)$ be member i's flow utility when the old member shirks and the other member cooperates. As before, we are interested in characterizing the best PPE in which all members, with the exclusion of the old, cooperate.[10] In this context, the best PPE is enforceable for given strategy profiles, $(\bar{a}, b^y)$ for the young and $(\bar{a}, b^m)$ for the middle-aged, if there is a continuation utility $w^i : \left\{\underline{g}, \overline{g}\right\} \times \mathbb{R}^2_+ \to W \subset \mathbb{R}$ for each $i \in \{y, m\}$ such that:

$$\begin{aligned}
v^i &= u\left(\bar{a}, b^i\right) + \delta \sum_{g \in \left\{\underline{g}, \overline{g}\right\}} \pi\left(g|a^i = \bar{a}, a^{-i} = \bar{a}\right) w^i\left(g, b^y, b^m\right), \\
v^i &\geq u\left(\underline{a}, b^i\right) + \delta \sum_{g \in \left\{\underline{g}, \overline{g}\right\}} \pi\left(g|a^i = \underline{a}, a^{-i} = \bar{a}\right) w^i\left(g, b^y, b^m\right), \\
\underline{\omega}^i &\leq w^i\left(g, b^y, b^m\right) \leq \overline{\omega}^i.
\end{aligned}$$

As in Section 3, this formulation is made possible by the existence of a publicly observable randomization device that coordinates all members' play.[11] In addition to a richer signal space, the above problem to determine the best PPE differs from that with two generations because continuation utilities depend on age. This is because a young member will become middle-aged in the next period. Hence, differences in lifetime horizon are captured by differences in $w^i(\cdot)$. Of course, the extreme feasible values of $w^i(\cdot)$ also differ with ages. The extreme feasible continuation utilities of the middle-aged are $\overline{\omega}^m := \lambda\mathbb{E}[g|a^y = a^m = \overline{a}, a^o = \underline{a}] + \theta\hat{b} - C(\underline{a},\hat{b})$ and $\underline{\omega}^m := \lambda\mathbb{E}[g|a^i = \underline{a}\ \forall i] + \theta\hat{b} - C(\underline{a},\hat{b})$, while for the young the lowest continuation utility is the one when no members cooperate, i.e., $\underline{\omega}^y := \hat{v}$, and the highest is the best PPE enforceable for the middle-aged, i.e., $\overline{\omega}^y := v^m$, which is endogenous to the problem.

We begin the analysis with the problem of the young member. The best PPE for the young is achieved by choosing the highest v^m, so that the intertemporal utility v^y is maximized and the self-enforcing constraint is slackened. Since the middle-aged members lives only two periods, the highest v^m is obtained as in Section 3, i.e., $v^{m,e} = u(\overline{a}, b^{m,e}) + \delta\overline{\omega}^m - (u(\underline{a}, b^{m,e}) - u(\overline{a}, b^{m,e}))/(L-1)$ where $b^{m,e}$ solves $u_b(\overline{a}, b^{m,e}) = \Delta(b^{m,e})/(L-1)$. We can then show the following preliminary result:

Lemma 1.
$v^{m,e} - \hat{v} < \overline{\omega}^m - \underline{\omega}^m$.

Proof.
By contradiction, let $v^{m,e} - \hat{v} > \overline{\omega}^m - \underline{\omega}^m$. *Then,* $\delta > \dot{\delta} := 1 - [u(\overline{a}, b^{m,e}) - u(\underline{a},\hat{b}) - (u(\underline{a}, b^{m,e}) - u(\overline{a}, b^{m,e}))/(L-1)]/(\overline{\omega}^m - \underline{\omega}^m)$. *Since* $u(\overline{a}, b^{m,e}) - u(\underline{a},\hat{b}) - (u(\underline{a}, b^{m,e}) - u(\overline{a}, b^{m,e}))/(L-1) < 0$, *then* $\dot{\delta} > 1$. *This implies that there cannot exist a feasible δ such that* $\delta > \dot{\delta}$, *which proves the contradiction.*

Lemma 1 states that the largest feasible expected gain from cooperation is always smaller for the young than for the middle-aged. This is because the young stay in the organization for more time periods and are more likely to be punished during their lifetime as compared to the middle-aged. Since the identity of a deviator cannot be inferred by observing g, punishment must be triggered with the same likelihood in all generations. Hence, in equilibrium it must be that $w^y(\overline{g},\cdot) - w^y(\underline{g},\cdot) < w^m(\overline{g},\cdot) - w^m(\underline{g},\cdot)$. As a consequence, the young are always more tempted to deviate than the middle-aged and may find it optimal not to cooperate unless the organization provides them with incentives to distort the privately beneficial effort even more. This is shown in the following proposition.

Proposition 5.
$|b^* - b^{m,e}| < |b^* - b^{y,e}|$.

Proof.
Using the unique device ϕ *to coordinate all members' play yields* $w^m(\underline{g},\cdot) = \phi\overline{\omega}^m + (1-\phi)\underline{\omega}^m$ *and* $w^y(\underline{g},\cdot) = \phi v^m + (1-\phi)\hat{v}$. *Since* v^i *is increasing in* $w^i(\overline{g},\cdot)$ *for each* $i \in \{y, m\}$, *it must be that* $w^m(\overline{g},\cdot) = \overline{\omega}^m$ and $w^y(\overline{g},\cdot) = v^m$. *In equilibrium, the self-enforcement constraints of the young and middle-aged are* $(u(\underline{a}, b^{y,e}) - u(\overline{a}, b^{y,e}))/\delta(v^{m,e} - \hat{v})(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\overline{a})) = 1 - \phi^e$ *and* $(u(\underline{a}, b^{m,e}) - u(\overline{a}, b^{m,e}))/\delta(\overline{\omega}^m - \underline{\omega}^m)(\pi(\underline{g}|\underline{a}) - \pi(\underline{g}|\overline{a})) = 1 - \phi^e$, *respectively. Since the right-hand side of the two equalities must be the same and, by Lemma* 1, $v^{m,e} - \hat{v} < \overline{\omega}^m - \underline{\omega}^m$, *it must be that* $u(\underline{a}, b^{y,e}) - u(\overline{a}, b^{y,e}) < u(\underline{a}, b^{m,e}) - u(\overline{a}, b^{m,e})$. *This is true when* $b^{y,e} > (<)\, b^{m,e}$ *if* $\Delta(b) < (>)\, 0$.

This result is of particular interest since it suggests that organizations that aim at maximizing output should require different levels of effort in outside activities according to age. Specifically, the level of effort in outside activities should decrease monotonically with a member's seniority in the case of complementarity and increase in the case of substitutability.[12] The result can easily be generalized to $n > 3$ generations.

Noisy Monitoring of Outside Activities Consider an organization with a monitoring technology that provides a public signal $y \in Y \subset \mathbb{R}$ of a member's outside activity. Although not directly related, the signal y can be used to draw inferences on a member's cooperative behavior since it is informative about b, which interacts with a. This is the case when g is not a sufficient statistic for a, i.e., the signal y is at least as informative about action b as g is about action a. Let $f(y|b)$ be the density function of y conditioned on b and assume that the monotone likelihood ratio property holds. Then, the ratio $f_b(y|b)/f(y|b)$ is strictly increasing in y. This implies that y is good news about a member's behavior outside the organization when $\Delta(b) < 0$, in the sense that a high y means that a member is more likely to choose a higher b, which signals her willingness to cooperate inside the organization. For the opposite reason, a high y is bad news when $\Delta(b) > 0$. In this context, the best PPE is enforceable for $a = \overline{a}$ if there is a continuation utility $w: \{\underline{g}, \overline{g}\} \times Y \to W \subset \mathbb{R}$ such that:

$$v = \max_b u(\overline{a}, b) + \delta \int_{y\in Y} \sum_{g\in\{\underline{g},\overline{g}\}} \pi(g|\overline{a})\, w(g, y)\, f(y|b)\, dy, \tag{9}$$

$$v \geq \max_b u\left(\underline{a}, b\right) + \delta \int_{y \in Y} \sum_{g \in \left\{\underline{g}, \overline{g}\right\}} \pi\left(g|\underline{a}\right) w\left(g, y\right) f\left(y|b\right) dy,$$
$$\underline{\omega} \leq w\left(g, y\right) \leq \overline{\omega}. \tag{10}$$

Since b is hidden, members can choose their most profitable level of effort both under cooperation and deviation. In doing so, they now take into account not only the benefits in terms of flow utility, but also how the realized y will affect expected continuation utility. Hence, the optimal b solves:

$$u_b\left(a, b\right) + \delta \int_{y \in Y} \sum_{g \in \left\{\underline{g}, \overline{g}\right\}} \pi\left(g|a\right) w\left(g, y\right) f_b\left(y|b\right) dy = 0 \ \forall a, w\left(g, y\right). \tag{11}$$

Let b^C be the solution of eq. (11) when $a = \overline{a}$ and let b^D be the solution when $a = \underline{a}$. Note that since the monotone likelihood ratio property holds, equilibria that attain the highest v satisfy a cut-point property (see, e.g., Levin 2003). Apart from the realized g, continuation utilities also depend on whether the signal y is above or below a given (endogenous) threshold y^*. Let $\Theta\left(y^*\right) \subset Y$ such that if $y \in \Theta\left(y^*\right)$, then y is a bad signal of b, denoted by y^-; otherwise, it is a good signal, denoted by y^+. The following proposition shows that strategic distortions are present also in the case of hidden b when $M := F\left(y^-|b^D\right)/F\left(y^-|b^C\right) \geq \pi(\underline{g}|\underline{a})/\pi(\underline{g}|\overline{a})$, where $F\left(\cdot\right)$ is the cdf corresponding to $f\left(\cdot\right)$.[13]

Proposition 6.
A threshold level $\overline{\delta} \in (\underline{\delta}, 1]$ exists, so that for any $\delta \geq \overline{\delta}$, the best PPE is unique and characterized by:

$$v^e = u(\overline{a}, b^C) + \delta\overline{\omega} - \frac{u(\underline{a}, b^D) - u(\overline{a}, b^C)}{M - 1},$$

where $b^C > (<)\, b^*$ and $b^D > (<)\, \hat{b}$ if $\Delta\left(b\right) < (>)\, 0$.

Proof.
Given y^*, the best PPE is obtained by plugging the necessarily binding constraint (10) into eq. (9). This yields:

$$v = u(\overline{a}, b^C) - \frac{u(\underline{a}, b^D) - u(\overline{a}, b^C)}{M - 1} \tag{12}$$
$$+\delta \frac{M\pi(\underline{g}|\overline{a}) - \pi(\underline{g}|\underline{a})}{M - 1} w(\underline{g}, y^+) + \delta \frac{M(1 - \pi(\underline{g}|\overline{a})) - (1 - \pi(\underline{g}|\underline{a}))}{M - 1} w\left(\overline{g}, y^+\right).$$

The coefficient $(M(1 - \pi(\underline{g}|\overline{a})) - (1 - \pi(\underline{g}|\underline{a})))/(M - 1)$ is always positive, while the coefficient $(M\pi(\underline{g}|\overline{a}) - \pi(\underline{g}|\underline{a}))/(M - 1)$ is positive if $M \geq \pi(\underline{g}|\underline{a})/\pi(\underline{g}|\overline{a})$. In this case, eq. (12) is maximized when $w\left(\overline{g}, y^+\right) = w(\underline{g}, y^+) = \overline{\omega}$ and simplifies to $v = u(\overline{a}, b^C) + \delta\overline{\omega} - (u(\underline{a}, b^D) - u(\overline{a}, b^C))/(M - 1)$, where b^C and b^D solve:

$$\frac{u_b\left(\overline{a}, b^C\right)}{F_b\left(y^-|b^C\right)} = \frac{u_b\left(\underline{a}, b^D\right)}{F_b\left(y^-|b^D\right)} = \frac{u(\underline{a}, b^D) - u(\overline{a}, b^C)}{F\left(y^-|b^D\right) - F\left(y^-|b^C\right)}. \tag{13}$$

Eq. (13) implies that $b^C > (<)\, b^*$ and $b^D > (<)\, \hat{b}$, since by the monotone likelihood ratio property $F_b\left(y^-|b\right) < (>)\, 0$ if $\Delta\left(b\right) < (>)\, 0$. Plugging $w\left(\overline{g}, y^+\right) = w(\underline{g}, y^+) = \overline{\omega}$ into constraint (10) yields $(1 - \pi(\underline{g}|\overline{a}))w\left(\overline{g}, y^-\right) + \pi(\underline{g}|\overline{a})w(\underline{g}, y^-) = \overline{\omega} - (u(\underline{a}, b^D) - u(\overline{a}, b^C))/\delta(F(y^-|b^D) - F(y^-|b^C))$, which is feasible when

$$\overline{\omega} - \frac{u(\underline{a}, b^D) - u(\overline{a}, b^C)}{\delta(F(y^-|b^D) - F(y^-|b^C))} > \underline{\omega}. \tag{14}$$

The best PPE is obtained by choosing the threshold y^* that maximizes v subject to constraint (14). Such a PPE is enforced for any $\delta \geq \overline{\delta} \in (\underline{\delta}, 1]$ with $\overline{\delta} := (u(\underline{a}, b^D) - u(\overline{a}, b^C))/\left(\overline{\omega} - \underline{\omega}\right)(F(y^-|b^D) - F(y^-|b^C))$.

Perfect monitoring of outside activities is difficult in practice. For this reason, we commonly observe organizations that set an information disclosure threshold for outside appointments, taking into account both organizational considerations and the members' incentive constraints.[14] Thus, the equilibrium of the extended model can capture actual practices in organizations regarding outside appointments.

6 Conclusion

The model presented here attempts to capture the role played by privately beneficial activities in promoting cooperation within an organization when individual contributions to the organization's output are imperfectly observable. Two fundamental features of the model drive the results: the interdependence between multiple activities and the repeated interaction between members. Agents endogenously undermine the short-run gain from deviation by distorting the effort in outside activities in order to signal their willingness to exert effort in activities inside the organization.

These two features fundamentally distinguish the model from existing theories of commitment. Although a commitment device may improve cooperation even in a static setting and without requiring interdependence between multiple efforts, it would require members to make mutual pledges of commitment by means of complete contracts written by an outside party, a regime that is often difficult to implement. In contrast, the mechanism presented here achieves cooperation with less complexity since actions are self-enforcing and therefore the existence of an outside party able to construct commitment spaces is unnecessary.

Clearly, there are many interesting applications that fit the setting. For example, the mechanism can be used to highlight the role of socially responsible practices in corporations, which can be viewed as an optimal organizational response in an uncertain environment, such as a volatile financial market. If socially responsible practices reduce gains from unobservable deviation, then they can also foster trust among shareholders (see, e.g., Baron 2010).

While the mechanism, which involves strategic distortions due to limited possibilities of enforcement, was applied to overlapping generation games with imperfect public monitoring, its use is not restricted to any specific demographic structure. Hence, it may have interesting applications in an infinite horizon environment in which immortal agents can retaliate if others do not cooperate. We leave these explorations for future research.

Acknowledgements

We thank the Editor Yuk-Fai Fong and two referees, as well as Alberto Bennardo, Daniel Garcia, Bård Harstad, David K. Levine, Anirban Mitra, Nicola Pavoni, Nicola Persico, Debraj Ray, Karl Schlag, Paolo Siconolfi, and Timothy Worrall for helpful suggestions. We also benefitted from comments made by participants in the 2nd Personnel Economics and Public Finance conference in Ravello, the 11th SAET meeting in Faro, the 17th ISNIE conference in Firenze, and the seminars at the EIEF and the universities of Amsterdam, Bergen, Bologna, Firenze, Innsbruck, Modena, Napoli, Oslo, and Vienna. We also acknowledge the support of an EIEF research grant and the European Research Council under the EU's 7th Framework Programme, ERC GA no. 283236.

Notes

1 A mixture of both inside and outside activities is a very common practice in organizations. In academia, for example, faculty members, whose research and teaching activities are imperfectly observable through publication records and teaching evaluations, are allowed to undertake outside activities, such as consultancies and other appointments, which consume time that would otherwise be devoted to university duties. According to the U.S. Department of Education, in 1999 the average faculty member spent 43.7 hours per week on activities inside their institution and 3.8 hours outside it (see, nces.ed.gov/pubs2002/2002154.pdf). While this is a case of effort substitutability, examples of complementarity are also widespread. Firms often offer their workers free ongoing general training opportunities, such as courses that teach computer or literacy skills, which do not directly benefit the organization, though they contribute to the worker's general human capital. In Germany, for example, where apprenticeship training provides largely general skills, firms training apprentices must follow a prescribed curriculum and worker councils in the firms monitor the training. According to the German Qualification and Career Survey, during the 1990s the average participation rate in training was about 35% each year, and average hours of training per participant was about 60 (see, bibb.de/en/14781.php). Similar apprenticeship programs also exist in other countries. For a survey of general training practices, see Acemoglu and Pischke (1999).

2 The assumption that there is one agent in each generation simplifies the analysis, but is not essential to the argument. Allowing for multiple agents within each generation would change the intratemporal incentive structure without modifying the intertemporal tradeoff that is the focus of the analysis.

3 A simple parameterization of the cost would be the quadratic form $C(a, b) = a^2 + 2kab + b^2$, since this allows for the case of substitutability when $k > 0$ and complementarity otherwise.

4 The observability of the effort b_t^i facilitates exposition. The assumption will be relaxed in Section 5.

5 In reality, holding an outside position is generally subject to the approval of the organization and must be disclosed. For an example of university guidelines for the disclosure of outside activities, see admin.ox.ac.uk/personnel/staffinfo/academic/approvaltoholdoutsideappointments/ .

6 See Fudenberg and Tirole (1991) for a formal definition of PPE.

7 The arguments of Abreu, Pearce, and Stacchetti (1990) can be adapted to show that the set of PPE payoffs is compact, so that the best PPE is well-defined.

8 This assumption implies that the analysis is limited to cases in which the self-enforcement constraint for a is harder to satisfy than that for b at any $\delta < 1$. If it is violated, constraint (4) binds before the self-enforcement constraint for a. This, however, would not change the highest achievable intertemporal utility, while it would affect the range of discount factors for which a PPE is sustainable.
9 The existence of an interior solution simplifies the analysis in the remainder of the paper, but it is not essential for the main results on strategic distortions from limited enforcement.
10 We restrict our attention to equilibria in which the young and middle-aged take the same action a after every history. However, we allow members of different age groups to choose different levels of b even after the same history.
11 As before, we assume that the self-enforcing constraints associated with the action b are satisfied, since a violation would not affect the main conclusions.
12 This result is related to that of Shepsle and Nalebuff (1990) who adapt Cremer (1986)'s model to show how a seniority system can help a political party to self-enforce cooperation by front-loading cooperative effort, namely, by requiring junior members to pay their dues while the most senior members fully enjoy the perks of office. Unlike the model presented here, they do not allow members to exert self-interested efforts nor do they characterize the best equilibrium.
13 The condition $M \geq \pi(\underline{g}|\underline{a})/\pi(\underline{g}|\overline{a})$ is sufficient for the result to be true when action b is imperfectly observable. Although it is stronger than necessary to prove the result, it allows the quality of the signal generated by outside activities to be the same as that of the signal generated by efforts within the organization, even when the level of quality is very low, i.e., $\pi(\underline{g}|\underline{a})/\pi(\underline{g}|\overline{a})$ is close to one. In the case that organizations maintain information disclosure mechanisms to monitor its members' outside activities, this condition is indeed plausible.
14 For an example of practical implementation of thresholds for information disclosure of outside activities at an academic institution, see krieger.jhu.edu/wp-content/uploads/2013/04/Handbook-Conflict-of-Interest.

References

Abreu, D. 1988. "On the Theory of Infinitely Repeated Games with Discounting." *Econometrica* 56: 383–396.

Abreu, D., D. Pearce, and E. Stacchetti. 1986. "Optimal Cartel Equilibria with Imperfect Monitoring." *Journal of Economic Theory* 39 (1): 251–269.

Abreu, D., Pearce, D., and E. Stacchetti. 1990. "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring." *Econometrica* 58 (5): 1041–1063.

Acemoglu, D., and J. Pischke. 1999. "Beyond Becker: Training in Imperfect Labour Markets." *Economic Journal* 109: 112–142.

Baron, D. P. 2010. "Morally-Motivated Self-Regulation." *American Economic Review* 100 (4): 1299–1329.

Benoit, J. P., and V. Krishna. 1987. "Dynamic Duopoly: Prices and Quantities." *Review of Economic Studies* 54 (1): 23–36.

Cremer, J. 1986. "Cooperation in Ongoing Organizations." *Quarterly Journal of Economics* 101 (1): 33–49.

Dixit, A. 1980. "The Role of Investment in Entry-Deterrence." *Economic Journal* 90 (357): 95–107.

Fudenberg, D., and J. Tirole. 1984. "The Fat-Cat Effect, the Puppy-Dog Ploy, and the Lean and Hungry Look. *American Economic Review* 74 (2): 361–366.

Fudenberg, D., and J. Tirole. 1991. *Game Theory*. Cambridge, MA: MIT Press.

Green, E., and R., Porter. 1984. "Noncooperative Collusion under Imperfect Price Information." *Econometrica* 52 (1): 87–100.

Halac, M. 2015. "Investing in a Relationship." *RAND Journal of Economics* 46 (1): 165–185.

Hammond, P. 1975. "Charity: Altruism or Cooperative Egoism." In *Altruism, Morality, and Economic Theory*, edited by E. Phelps. New York: Russell Sage Foundation.

Harstad, B., F. Lancia, and A. Russo. 2018. *Compliance Technology and Self-Enforcing Agreements*, working paper, University of Oslo.

Kandori, M. 1992. "Repeated Games Played by Overlapping Generations of Players." *Review of Economic Studies* 59 (1): 81–92.

Kreps, D. 1996. "Corporate Culture and Economic Theory." In *Firms, Organizations and Contracts: A Reader in Industrial Organization*, edited by P. J. Buckley, and J. Michie. Oxford: Oxford University Press.

Levin, J. 2003. "Relational Incentive Contracts." *American Economic Review* 93: 835–857.

Mailath, G., and L. Samuelson. 2006. *Repeated Games and Reputations*. Oxford: Oxford University Press.

Ramey, G., and J. Watson. 1997. "Contractual Fragility, Job Destruction, and Business Cycles." *Quarterly Journal of Economics* 112 (3): 873–911.

Shepsle, K., and B. Nalebuff. 1990. "The Commitment to Seniority in Self-Governing Groups." *Journal of Law, Economics, & Organization* 6: 45–72.

Spence, A. M. 1977. "Entry, Capacity, Investment and Oligopolistic Pricing." *Bell Journal of Economics* 8 (2): 534–544.