Interactions across multiple games: cooperation, corruption, and organizational design

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Abstract

Teams face a variety of strategic situations. It is socially beneficial for teams to cooperate in productive but not in corrupt ones. However, cooperation in one situation may depend on expectations of cooperation in others. We identify when it is that sustaining socially desirable cooperation necessitates undesirable cooperation. We characterize how cooperation is shaped by the absolute and relative payoffs to cooperation across various tasks, as well as the frequency with which people are reshuffled across teams and whether teams can be specialized in the tasks they face.

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Keywords: Teams, Organizational Design, Cooperation, Corruption, Police, Bureaucracy, Multi-Games

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1 Introduction

Organizations require teamwork: informal cooperation among members. However, team members can also cooperate in ways that are harmful to the organization or society. Importantly, "good" and "bad" forms of cooperation are intertwined. For example, building a cooperative culture among police not only induces productive cooperation, such as aiding other officers in dangerous circumstances, but can also lead them to cooperate in corrupt or destructive ways, such as the "blue wall of silence" (police officers under-reporting misconduct).[1] If a police officer does not collude with a partner who has taken a bribe or used excessive force, that partner may not back the officer up in a future dangerous situation.[2] Similar interactions between good and bad forms of cooperation arise in a wide variety of organizations including in government, military, hospitals, consulting, construction, manufacturing, and retail.

We study when and how the structure/design of organizations encourages socially beneficial forms of cooperation while inhibiting harmful forms of cooperation. We model a team that faces a random arrival of games over time. When a game arrives, each team member chooses whether to cooperate with others. In any given game, a team member prefers overall team cooperation to a lack of cooperation but individually prefers not to cooperate. Thus, the games have a prisoners' dilemma-like structure. This is not a simple repeated game: the stage games take two different forms. In some of the games, cooperation is beneficial to society ("good games"); in the other games cooperation is harmful ("bad games"). Socially optimal equilibria are those in which team members cooperate in good games only. Yet as Tirole (1988) conjectured, "...it may be worth tolerating some minor acts of detrimental co-operation to allow trust between employees to develop." We show that the team-design problem is nontrivial because of interdependencies between the different stage games: equilibrium structure depends on the arrival frequencies of both good and bad games as well as their payoff structures.

A key design dimension is team durability. Some organizations, such as the military or police, keep teams together over time to foster cooperation. Others—e.g., diplomacy, retail, logistics, and services—frequently reshuffle members across teams, eliminating the repeated interaction necessary for cooperation. In which settings should teams be kept together

[1]See Chevigny (1995). Similarly, some scholars (e.g., Gibson and Singh (2003)) document a "white wall of silence": doctors not reporting colleagues' malpractice.

[2]Famously, in 1970, Frank Serpico, then a police detective in the NYPD, exposed police corruption by contributing to a New York Times article. A year later, after being shot and wounded during a drug raid, Serpico alleged that his police partners led him into a dangerous situation to be murdered (Phalen, 2012). Ostracism of whistleblowers is anticipated and widespread: "Officers who report misconduct are ostracized and harassed; become targets of complaints and even physical threats; and are made to fear that they will be left alone on the streets in a time of crisis. This draconian enforcement of the code of silence fuels corruption because it makes corrupt cops feel protected and invulnerable" (Mollen Commission (1994)).

versus reshuffled? Again, this issue is nontrivial as Tirole (1988) anticipated: "Fighting the detrimental cooperation by keeping the employees' relationship short may also kill the beneficial co-operation." We identify conditions that make detrimental cooperation necessary to sustain socially beneficial cooperation. We also examine how changing payoffs can enable cooperation in good but not bad games.

A second dimension that we analyze is team specialization. Organizations typically have a variety of tasks that must be completed, and each task faces inherently different rates of good and bad games. In some organizations, different teams work on different tasks; in others, all teams work on the same tasks. When teams are specialized, some more frequently find themselves in situations where cooperation is socially beneficial (e.g., dangerous situations where police officers need back-up), while other teams more often face opportunities to collude (e.g., to accept bribes). We study when it is optimal to specialize teams, essentially creating two parts of the organization, as opposed to when optimality requires leveraging substantial interdependencies between good and bad cooperation and precluding specialization.

As a basis for these analyses, we first characterize the player-optimal symmetric equilibrium as a function of the payoffs to cooperation and defection in both good and bad games, the games' arrival probabilities, and a team's durability (how frequently team memberships are reshuffled). Equipped with the characterization of equilibrium play, we ask when does there exist an equilibrium in which team members cooperate in good games only. Our first result states it is possible to get a team to cooperate only in good games if three conditions hold:

(i) it is more tempting to deviate in bad games than in good ones,

(ii) good games are sufficiently likely to arrive (in absolute terms) to sustain cooperation on them alone, and

(iii) good games are sufficiently likely to arrive (in relative terms) to permit an optimal level of team durability that enables cooperation in good games but not in bad ones.

If all three conditions hold, to achieve teams cooperating only in good games partial reshuffling of teams may be required—occasionally reassigning team members may be socially optimal. If team members expect enough—but not too much—future interaction with their teammates, then cooperation can be supported in one game but not the other.

If any of these three conditions fails, the organization is faced with a difficult choice: either keep teams together and end up with cooperation in all games (including bad ones) or reshuffle teams enough to preclude all kinds of cooperation. Hence, in some settings corruption may be a necessary price of inducing productive cooperation. For example, in policing or certain types of military activities, the benefits of cooperation in good situations—e.g., supporting one's team saves lives—may be high relative to the damage caused by cooperation in bad ones. However, the temptation to deviate from cooperation may also be high as agents may need to risk their lives to save teammates. Thus, cooperation in good situations can only be sustained with durable teams and may *require* cooperation in bad situations. In contrast, consider warehouse workers fulfilling orders. The organization may rarely need employees to collaborate; the more frequent and costly concern is that workers can collude to steal merchandise. There "teams" are reshuffled frequently, creating a more anonymous workforce with no cooperation—effectively, no teams.

If some of the conditions that enable cooperation in good games only are not satisfied, then an organizational designer may want to change the games' payoffs to try to encourage good cooperation while deterring bad collusion. Our next set of results examines altering the benefits of cooperation in good games (for instance, giving bonuses for overall profits) or increasing the temptations of defecting in bad games (for instance, offering whistleblower rewards). Interestingly, these behave quite differently than they do in standard repeated games, where only the ratio of benefits to temptations matters. With multiple games, benefits from cooperation in a given game have spillovers that enable cooperation in *all* games, while temptations to deviate affect *only one* game's incentives at a time. Thus the latter is more selective than the former.

The effective costs of altering the benefits from cooperation or temptations of defecting also vary. Because bonuses are paid, a policy of giving bonuses for cooperative behavior imposes an actual cost on an organization. In contrast, whistleblower rewards deter collusion and are not dispersed on the equilibrium path.

For our last set of results, we consider situations in which different teams can be assigned to different tasks, affecting the likelihood with which they face good and bad games. The designer can then keep certain teams (those facing mostly good games) together to encourage cooperation while reshuffling others (those facing mostly bad games) to deter collusion. For instance, the chief of a large police force might have some units respond to dangerous armed situations, while others deal with tasks such as routine traffic stops that allow for bribes. In such circumstances only the former teams would stay together over time. We show that if facing only good games is enough to sustain cooperation, then fully specializing teams is optimal. In this case, interdependencies across games are removed. However, when this is not the case and cooperation from only facing good games is infeasible, then the designer may benefit from allowing for some interdependencies; i.e., having teams face both games to allow for cooperation.

We discuss several applications, from the differences in team structure in large versus small organizations (e.g., police forces in large cities versus towns), why corruption is more common in countries and organizations with lower funding levels (see Section 4), and why retail organizations regularly rotate teams and tolerate lower levels of productivity (see discussion following Proposition 1).

The Relationship to the Literature. There is a small literature concerned with cooperation across multiple games (Karnani and Wernerfelt, 1985; Bernheim and Whinston, 1990; Watson, 1999, 2002; Rauch and Watson, 2003) to which we contribute. Relative to existing work, ours is the first to analyze interactions across games in which cooperation is desired in some but not others, as well as the implications for organizational design.

There is extensive study of cooperation and the patterns of bilateral relationships such as (Kandori, 1992; Ellison, 1994; Kranton, 1996; Ghosh and Ray, 1996), the incentives to oust dissidents (Ali and Miller, 2016), monitoring technologies (Wolitzky, 2012; Nava and Piccione, 2014), community network structure (Lippert and Spagnolo, 2011; Jackson et al., 2012; Balmaceda and Escobar, 2017), and what types of punishment are preferred (Acemoglu and Wolitzky, 2019). We abstract from many of these issues, focusing instead on how organizational structure affects cooperation.

Our model is a stochastic game (introduced by Shapley, 1953; see Solan and Vieille, 2015 for a short review). Our model's special structure—the players' current actions do not affect the distribution over subsequent games—may be useful for extensions. This environment allows us to characterize equilibria, which are typically difficult to solve for (Solan and Vieille, 2015).

A number of studies analyze corruption as a by-product of institutional and organizational structures (e.g., Basu et al. (1992); Shleifer and Vishny (1993); Myerson (1993); Acemoglu and Robinson (2019)). Our analysis contributes by showing how corruption depends not only on the benefits and costs of corrupt collusion but also on how parties interact in other domains. Additionally, our analysis provides insights into why corruption may be tolerated in some countries and organizations and why eliminating it requires wide-ranging interventions.

A few studies have asked how "walls of silence," where group members conceal information that may harm other members, are sustained (Benoît and Dubra, 2004; Muehlheusser and Roider, 2008). In Benoît and Dubra (2004), honest agents may vote for a regime that conceals misconduct in fear of a type 2 error. Muehlheusser and Roider (2008) show how reputational concerns and the threatened loss of future cooperation may induce agents to remain silent. Our model differs: agents are homogeneous and there is no private information. Instead, loss of future cooperation is an equilibrium response. Our comparative statics also differ: we consider how cooperation relates to organizational design and how a designer may benefit from changes in payoff parameters.

2 The Model

We consider a stochastic game in which n players choose actions at an infinite random sequence of times, $t = 0, \ldots, \infty$. The stage games, or simply games for brevity, played at those times are of two varieties, $\{G, B\}$, with generic element g. As we formalize later, the notation G, B denotes that the first type of game involves cooperation that is socially good; the second, cooperation that is socially bad. Stage game g occurs with probability $p_g > 0$ such that $p_G + p_B \leq 1$. We write $p_\emptyset \equiv 1 - (p_G + p_B)$ to denote the probability of no game arriving. For example, police patrols might be told to respond to crimes that occur at random times.

Players discount payoffs received at time t by δ^t, where the discount factor $\delta \in (0, 1)$.[3]

Cooperation in the stage games produces overall benefits to the players but there are also temptations to deviate from cooperating. For simplicity we assume binary actions: in each game g, a player i chooses either to 'cooperate' or 'not': $A = \{C, N\}$. For element $\mathbf{a} \in A^n$, let a_i denote the action of player i and $\mathbf{a_{-i}}$ the action profile of the other players. Stage games satisfy the following properties.

Properties. *Stage games g are symmetric with game-dependent stage payoff function, $\pi_g(\cdot;\cdot) : A \times A^{n-1} \to \mathbb{R}$, describing the payoff to a given player in g as a function of the player's action and the profile of other team-members' actions. Let C^n denote the profile of all players choosing cooperate, and similarly for N^n, etc. The payoff function π_g satisfies the following properties:*

1. $\pi_g(a_i; \mathbf{a}_{-i}) = \pi_g(a_i; \mathbf{a}'_{-i})$ *for all* $a_i, \mathbf{a}_{-i}$ *and* $\mathbf{a}'_{-i}$ *such that* $\mathbf{a}'_{-i}$ *is a permutation of* $\mathbf{a}_{-i}$,

2. *aggregate payoffs are maximized when all players cooperate; i.e.,*

$$C^n = \underset{\mathbf{a} \in A^n}{\arg\max} \sum_i \pi_g(a_i; \mathbf{a}_{-i}),$$

3. *if all other players cooperate then any given player gains by not cooperating; i.e.,*

$$\pi_g(N; C^{n-1}) > \pi_g(C; C^{n-1}),$$

4. *each player minimizes their worst-case loss by not cooperating; i.e.,*

$$N \in \underset{a_i \in A}{\arg\max} \left[\min_{\mathbf{a_{-i}} \in A^{n-1}} \pi_g(a_i, \mathbf{a_{-i}}) \right],$$

[3] [[In Section X, we consider limit as we take the length of time periods to zero.]]

and furthermore the punishment is achieved by complete non-cooperation, i.e.,

$$N^{n-1} \in \underset{\mathbf{a_{-i}} \in A^{n-1}}{\arg\min}\, \pi_g(N, \mathbf{a_{-i}}),$$

5. *complete non-cooperation is a Nash equilibrium of* g*, i.e.,*

$$\pi_g(N; N^{n-1}) \geq \pi_g(C; N^{n-1}),$$

6. *and aggregate payoffs in this equilibrium are larger than in any asymmetric play; i.e.,*

$$(N, \ldots, N) = \underset{\mathbf{a} \in A^n \setminus \{C^n\}}{\arg\max} \sum_i \pi_g(a_i; \mathbf{a_{-i}}),$$

7. *and the gain from playing* N *instead of* C *is smallest when all other players play* C*, i.e.,* $\pi_g(N; C^{n-1}) - \pi_g(C; C^{n-1}) \leq \pi_g(N; \mathbf{a_{-i}}) - \pi_g(C; \mathbf{a_{-i}})$ *for all* $\mathbf{a_{-i}} \in A^{n-1}$*.*

Property 6 ensures that convex combinations of asymmetric payoffs are no better than the pure strategy Nash equilibrium. This requires, for instance, that having $n-1$ players cooperate while one defects hurts the cooperators more than it helps the defector. This simplifies the strategic interactions and ensures that "grim-trigger" arguments apply. It also allows us to characterize the games using just a few parameters, described below. Thus we can focus our attention on interactions across games, rather than the details of dynamics within a game which can be quite complex absent such structure.[4]

The incentives in game g are captured by the following parameters. Complete cooperation generates a benefit, c_g, relative to complete non-cooperation for all players: $c_g \equiv \pi_g(C; C^{n-1}) - \pi_g(N; N^{n-1})$. There is a deviation temptation, d_g, which captures the gain in stage payoff to any agent who deviates when the others cooperate: $d_g \equiv \pi_g(N; C^{n-1}) - \pi_g(C; C^{n-1})$. Hence, the stochastic game is described by the number of players, n, the discount factor, δ, and the cooperation benefit c_g, deviation temptation d_g, and likelihood p_g of each stage game g.

For example, in a prisoner's dilemma game g there are $n = 2$ players, with payoffs:

		Player 2: C	Player 2: N
Player 1	C	(c, c)	$(-a, c+d)$
	N	$(c+d, -a)$	$(0, 0)$

[4]For example, see Olszewski and Safronov (2018). Beyond the dynamic differences, their game also involves private information.

where $c, d > 0$ and $a > c + d$. All players cooperating (e.g., exerting high effort) maximizes the total payoff, but a player can benefit by unilaterally deviating (e.g., free-riding). The condition that $a > c + d$ ensures that the game satisfies Properties 6 and 7. The resulting cooperation benefit and deviation temptation are $c_g \equiv c$ and $d_g \equiv d$, respectively.

Other games, such as a favor exchange game in which players randomly have chances to either give or receive favors—both good and bad (e.g., lending money vs not reporting a friend's crime)—also satisfy these properties. Different players move at different points in time, but a similar analysis applies.

Equilibria. A team's history at time t is a sequence of time-dated stage-game action profiles. A player's strategy specifies an action for each history and each stage game. With this setup, we consider subgame-perfect equilibria.

2.1 Cooperation

We say that an equilibrium strategy profile has *cooperation in game* g if on the equilibrium path players cooperate whenever game g is played. We say there is *no cooperation in game* g if on the equilibrium path players defect whenever game g is played. This leads to four types of canonical cooperation:

	C^n in B	N^n in B
C^n in G	*total cooperation*	*cooperation only in* G
N^n in G	*cooperation only in* B	*no cooperation*

The different kinds of cooperation can be partially ordered by some social criterion. Let $s_G > 0$ denote the social benefit from cooperation in game G, the good game, from the perspective of a social planner or designer. Similarly, $s_B < 0$ denotes the social harm from cooperation in the bad game B. Thus, cooperation only in game G is clearly most preferred; we call this *optimal cooperation*. Cooperation only in game B is clearly the worst. The social value of total cooperation, $p_G s_G + p_B s_B$, and the social value of no cooperation, 0, lie in-between the best and worst outcomes; their ordering depends on the relative social impact of cooperation in the two games and on their frequencies.

In what follows we sometimes refer to organizational design and a designer. However, we remain agnostic about who designs the organization or whether they are benevolent. In some situations these are decision-makers, say a police chief or a firm's executives, who can purposefully implement an organizational design such as reshuffling teams. Sometimes, however, there is no explicit designer; in such circumstances, our results clarify if it is possible to reach optimal cooperation as a function of the environment.

2.2 Player-Optimal Equilibria

As there can be multiple equilibria (usual folk-theorem arguments apply), we focus on the equilibrium that is optimal for the players. Given the game's symmetry and its required properties, we characterize the equilibrium that maximizes the sum of players' expected discounted payoffs.

Characterizing such player-optimal equilibria makes sense for two reasons. First, they are extremal—supporting maximal cooperation—and thus define the frontier and so the full set of payoffs of symmetric equilibria, regardless of what one believes about equilibrium selection. Second, it is not robust to presume that a designer can guide players to one equilibrium if all players prefer another.

Lemma 1 characterizes the player-optimal equilibrium as a function of the games' parameters.

LEMMA **1** (Characterization of the Player-Optimal Equilibrium)**.** *In the player-optimal subgame-perfect equilibrium, there is total cooperation if*

$$\max_g\{d_g\} \leq \sum_g \frac{\delta}{1-\delta} p_g c_g; \tag{1}$$

there is cooperation only in game g if

$$d_g \leq \frac{\delta}{1-\delta} p_g c_g \tag{2}$$

and (1) *does not hold; and otherwise there is no cooperation.*

Proof. Let σ be a subgame-perfect equilibrium. Let M be the set of stage games for which, at some on-path history, some players have positive probability of cooperating in σ, and M^c be the remaining stage games. We define a new strategy profile σ' which prescribes full cooperation for games in M on path ($\sigma'(h,g) = C^c$ for all on-path histories h and stage games $g \in M$), and full defection in all other scenarios ($\sigma'(h,g) = N^n$ for all on-path histories h and stage games $g \in M^c$ and also for all off-path play). By Properties 2 and 6, σ' strictly improves the sum of players' expected discounted payoffs. It remains to show that σ' is an equilibrium satisfying the stated equations.

As N^n is a Nash equilibrium by Property 5, off-path play is subgame perfect and hence part of an equilibrium. For on-path play, as σ' is Markovian, in that strategy profiles are independent of the history on-path, it suffices to prove the equilibrium conditions hold in the first period for each game with the null history $\emptyset$. For games $g \in M^c$, we have $\sigma'(\emptyset, g) = N^n$. As N^n is a Nash equilibirum by Property 5, and σ' prescribes full defection in off-path play, players are incentivized to play N. For games $g \in M$, $\sigma'(\emptyset, g) = C^n$. For ease of notation, we normalize $\pi_g(N^n) = 0$ for all g.[5] Hence, we must show:

$$\pi_g(C^n) + \left[\sum_{g \in M} \frac{\delta}{1-\delta} p_g \pi_g(C^n)\right] \geq \pi_g(N; C^{n-1}).$$

To do so, we will leverage the incentive constraints of σ. Suppose $\sigma(\emptyset, g) = \Delta$. We know:

$$E_{a \sim \Delta}[\pi_g(a) + \nu(g, a)] \geq E_{a \sim \Delta}[\pi_g(N; a_{-i}) + \nu(g, (N; a_{-i}))]$$

where $\nu(g, a)$ is the expected continuation payoff after playing action profile a in game g in the first period. First note that, since σ' improves aggregate expected payoffs, some player must benefit, call this player i. We will show the incentive constraint holds for player i. Since the payoff and the action profiles are symmetric in σ', this will imply our result.

$$\begin{aligned}
\pi_g(C^n) + \left[\sum_{g \in M} \frac{\delta}{1-\delta} p_g \pi_g(C^n)\right] &\geq E_{a \sim \Delta}[\pi_g(a_i; a_{-i}) + \nu(g, a)] && (3)\\
&\geq E_{a \sim \Delta}[\pi_g(N; a_{-i}) + \nu(g, (N, a_{-i}))] && (4)\\
&\geq E_{a \sim \Delta}[\pi_g(N; C^{n-1}) + \nu(g, (N, a_{-i}))] && (5)\\
&\geq E_{a \sim \Delta}[\pi_g(N; C^{n-1})] && (6)\\
&= \pi_g(N; C^{n-1}) && (7)
\end{aligned}$$

where equation 3 follows by choice of i, equation 4 follows by the incentive constraints of σ, equation 5 follows by Property 7, and equation 6 follows by Property 4 which implies that perpetual full defection is the strongest sustainable punishment strategy (along with our normalization $\pi_g(N^n) = 0$).

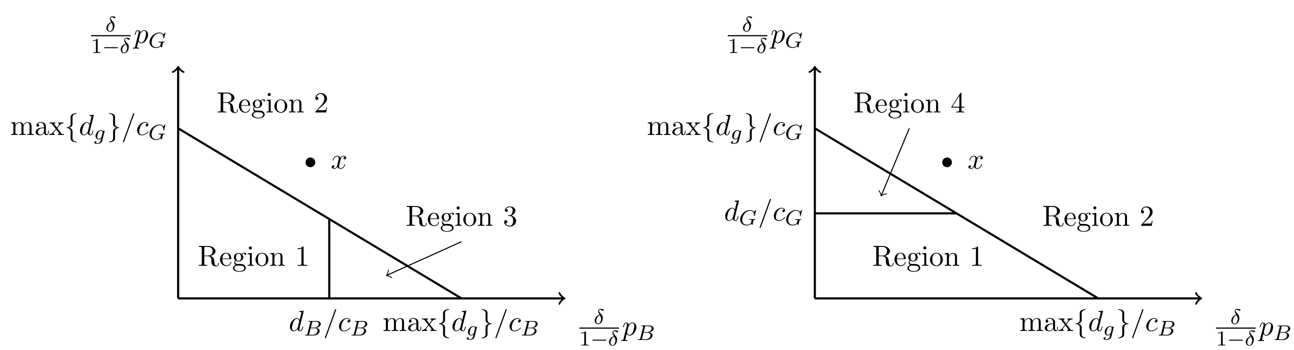
This implies that player-optimal equilibria partition games into those with cooperation and those without. To conclude the statement of the lemma, note that it is always player-optimal to maximize cooperation. Noting that $\pi_g(N; C^{n-1}) - \pi_g(C^n) = d_g$, this implies if equation 1 is satisfied, then there is total cooperation in the the player-optimal subgame-perfect equilibrium. If there are many stage games, the characterization depends on games' payoffs. However, if there are only two stage games, as in the statement of the lemma, we have further showed that if total cooperation is not sustainable, but cooperation on the game with lower deviation temptation d_g is sustainable, then the player-optimal subgame-perfect equilibrium has cooperation on game g only. Otherwise, there is no cooperation. $\square$

Since we characterize the player-optimal subgame-perfect equilibrium, we often drop explicit reference to it henceforth, and often just refer to equilibrium.

[5] This is without loss since the incentive constraints are invariant to linear transformations.

The arguments of the proof follow standard repeated-game arguments and so we only provide a sketch. When Inequality (1) holds, the grim-trigger strategy 'cooperate in all games unless some player did not cooperate in the past at which point never cooperate in any game again' constitutes an equilibrium: no player has an incentive to deviate in either game, and players play the stage game Nash equilibria during the punishment stage. Similarly, when (1) does not hold, but (2) does for game g, then 'cooperate in g only unless any player deviated from doing so in the past, in which case do not cooperate in either game' constitutes an equilibrium: since (1) fails, players cannot cooperate in both games as otherwise they would deviate, and so their payoffs cannot be improved. Lastly, since any equilibrium-path cooperation in both games requires (1), and cooperation in game g requires (2), when both conditions fail, players maximize payoffs by playing the stage Nash equilibria.

Visually depicting the different cases of equilibrium cooperation characterized in Lemma 1 is useful. Figure 1 represents the different cases as functions of the effective arrival probabilities $(\frac{\delta}{1-\delta}p_G, \frac{\delta}{1-\delta}p_B)$. Taking Inequality (1) as an equality delineates the region of effective arrival probabilities where total cooperation prevails. Cooperation only in some game g precludes total cooperation, so the former region must be southwest of the latter. For cooperation to be sustainable, Inequality (2) must hold; its equality delineates the region with (some) cooperation. Note: there cannot be cooperation only in game g if the temptation to deviate in that game exceeds the deviation-temptation in the other game; thus, only one such region exists. The two cases are depicted in the left and right panels of Figure 1. The point labeled x indicates the outcome of the game when teams face a particular pair of arrival probabilities p_G, p_B and discount factor δ. As shown in the figure, for these parameters, the teams will exhibit total cooperation.



(a) Case $d_G > d_B$.

(b) Case $d_G < d_B$.

Figure 1: Different types of cooperation. In region 1, there is no cooperation. In region 2, there is total cooperation. In region 3, there is cooperation in the bad game only. In region 4, there is cooperation in the good game only.

Though the games are independent, their strategic interactions necessitate a holistic analysis to understand players' actions in one of them. For example, increasing the benefit of cooperation in one game can promote cooperation in another. Similarly, reducing the temptation to deviate or increasing the frequency of one game affects equilibrium play in the other. Thus, a change that facilitates cooperation in *one* game can facilitate cooperation in *all* games.

3 How Cooperation Depends on Team Durability

Given the characterization of equilibria, we next examine how cooperation depends on team durability. We model "reshuffling teams" (reducing team durability) as a probability r, with which a team's history is reset. If teams are frequently (and randomly) reshuffled, future benefits from cooperation with current team members are reduced.[6] Indeed, reshuffling is equivalent to changing δ, the factor players exponentially discount future payoffs. In particular, the type of cooperation in equilibrium with reshuffling probability r and discount factor δ will be the same as that without reshuffling and discount factor $(1-r)\delta$ ([[See Section Y for details). Essentially, the designer can induce any effective discount factor most δ by reassigning teams with random probability at the end of a period. With a low likelihood of reshuffling, the effective discount factor is close to δ, but then the discount decrease as reshuffling becomes more likely.

Reshuffling requires sufficiently many workers so that 1) the designer can create new teams (those whose members have not collaborated in the past), and 2) workers are anonymous outside their teams (deviations can be punished only by current team members). These conditions are more likely to hold in large organizations. This causes some differences between large and small organizations that we discuss below.

Proposition 1 (Optimal Reshuffling). *There exists a reshuffling probability r such that there is optimal cooperation if and only if all of the following hold:*

1. *The temptation to deviate is less in the good game: $d_G < d_B$;*
2. *Cooperation is sustainable in the good game by itself: $d_G \leq \frac{\delta}{1-\delta} p_G c_G$;*
3. *The good game's frequency is high compared to that of the bad game: $\frac{p_G c_G}{p_B c_B} > \frac{d_G}{d_B - d_G}$.*

The temptation to deviate in good games must be no higher than in bad games (see Section 2.2); otherwise, whenever good cooperation is possible then so is bad. Thus, condition 1 is necessary. Cooperation being sustainable in the good game by itself (condition

[6] Random reshuffling helps in sustaining good cooperation, as deterministic reshuffling has incentives unravel from the final date at which a team knows it will be together and thus cannot sustain any cooperation.

2) is also necessary because for optimal cooperation there are no strategic interdependencies across the games. Lastly, good games must arrive sufficiently often, relative to bad games, (condition 3) to make it feasible (possibly by reshuffling) to induce players to cooperate in the good game but not in the bad one: it ensures that there exists effective discount rate such that Equation (1) fails while (2) holds for the good game. The proposition then follows from a careful application of Lemma 1.

When any of the above conditions fail there is a trade-off between two evils: accept corruption in bad as well as good games or face cooperation in neither game. If total cooperation is feasible then it is preferred to no cooperation if and only if $p_G s_G + p_B s_B > 0$.

In policing, for example, productive team cooperation is vital to society: s_G is high. However, because police misconduct imposes significant harm, s_B can also be large (Mollen Commission, 1994). Thus, whether frequent rotations or long-term partnerships are optimal depends on the relative frequency of situations in which (a) police need to back each other up or perform other important team duties versus (b) they can be corrupt or abusive.

In other settings—e.g., low-skilled jobs in retail, fast food, and warehouse industries—cooperation increases profits only slightly ($p_G s_G$ is small), whereas employee collusion to steal products is a major cost for retailers: $p_B s_B$ is largely negative (Greenberg and Barling, 1996). This helps to explain why retail teams, unlike police or military units, are reshuffled frequently.

Lastly, consider sport teams and academics. While both professions have instances of collusion (Muehlheusser and Roider, 2008), they tend to be rare and the social value of cooperation outweighs the collusive harm and teamwork is often encouraged.

4 Comparative Statics in Payoffs and Design Implications

Given that payoffs in one game have spillover effects on the other game, organizations can use bonuses and penalties to alter game payoffs and thereby induce optimal (or better) cooperation. Next, we study how such changes in payoffs affect the potential for cooperation. Doing so also provides comparative statics results that help us understand why some organizations or countries have optimal cooperation, while others facing budgetary constraints are stuck with tolerating bad cooperation or having no cooperation at all.

We also identify a fundamental difference in the incentives provided by changing the benefits from cooperation (the c_g's, e.g., giving bonuses for team production) versus the temptations to deviate (the d_g's, e.g., rewarding whistle-blowing).

When examining a single repeated game in isolation, incentives depend only on the *relative* size of deviation temptations to cooperation benefits—the ratio of d_g/c_g. There exists a subgame-perfect equilibrium in which players cooperate perpetually if and only if $\frac{d_g}{c_g} \leq \frac{\delta}{1-\delta}p_g$. This is not so with more than one game: cooperating in one game provides incentives to cooperate in another, but deviation payoffs affect the incentives in one game at a time.

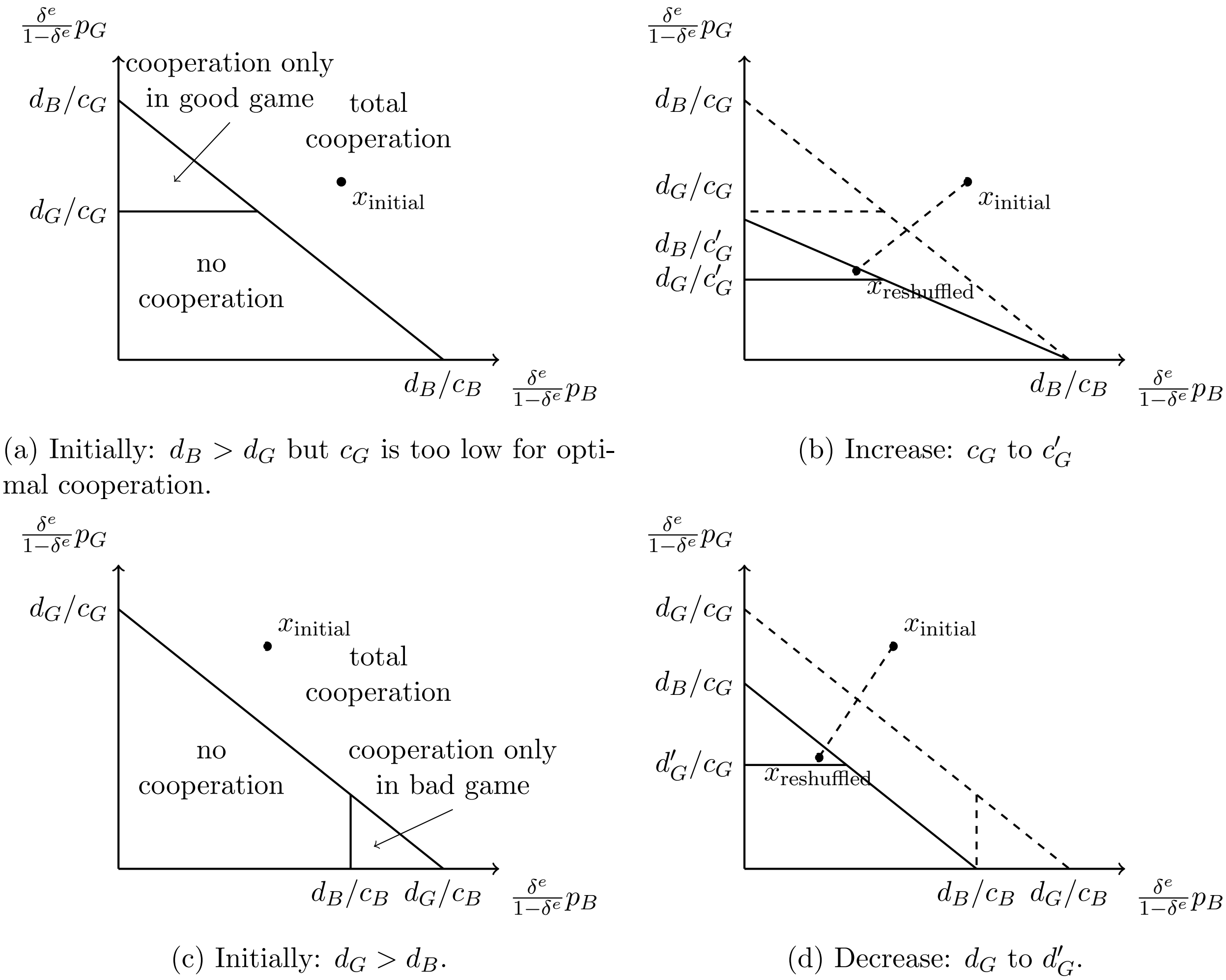
This asymmetry makes the comparative statics of multiple games differ from those of standard repeated games. In our setting, changes in the benefits from cooperation and the temptations to deviate differ. For example, one might expect that improving the benefits from good cooperation would enable cooperation in the good game only, possibly with (some) reshuffling. But this is not always so. To see why, consider the case of $d_G \geq d_B$. Then, whenever team members can sustain cooperation in good situations then the temptation to deviate from bad cooperation is also less than the continuation value: hence they can collude in bad situations as well. This is true regardless of the level of payoffs to cooperation. Thus in order for policies that increase c_G to impact optimal cooperation at all, deviation temptations must already be lower in the good game than the bad. In that case ($d_G < d_B$), optimal cooperation can be enabled via sufficient increases to c_G. These come at a cost: the organization must pay these on the equilibrium path.

We summarize the comparative statics implications of Proposition 1 as follows. Fix the exogenous discount rate r_0, deviation temptations d_G and d_B, the benefit of bad cooperation c_B, and the initial benefit of good cooperation c_G. Increasing the benefit of good cooperation to $c'_G \geq c_G$ and the discount rate to $r' \geq r_0$ leads to optimal cooperation if and only if:

- the deviation temptation is larger in the bad game: $d_B > d_G$;
- cooperation is feasible in the good game alone: $\frac{c'_G f_G}{r_0} \geq d_G$; and
- the fraction of benefits possible from cooperation in the good game only compared to total cooperation is sufficiently high: $\left(\frac{c'_G f_G}{c'_G f_G + c_B f_B}\right) > d_G/d_B$.

Doing so is organizationally optimal if and only if $f_B s_B > f_G(c'_G - c_G)$.

Panels (a) and (b) of Figure 2 depict how changing the benefits from cooperation in the good game can make optimal cooperation feasible. Let $\delta^e \equiv \delta(1-r)$, be the effective discount factor when teams are reshuffled with probability r. Reshuffling decreases the effective discount factor δ^e, moving the outcome of the game towards the origin, i.e., from $x_{\text{initial}} = (\frac{\delta}{1-\delta}p_B, \frac{\delta}{1-\delta}p_G)$ to $x_{\text{reshuffled}} = (\frac{\delta^e}{1-\delta^e}p_B, \frac{\delta^e}{1-\delta^e}p_G)$. Panel (a) displays an initial situation where $d_B > d_G$ but c_G is too low to reshuffle teams appropriately and achieve optimal cooperation. Increasing c_G to some c'_G rotates the line delineating the region of total cooperation counter-clockwise. For a large enough increase (see Panel (b)), reshuffling teams and inducing optimal cooperation is feasible.



(a) Initially: $d_B > d_G$ but c_G is too low for optimal cooperation.

(b) Increase: c_G to c'_G

(c) Initially: $d_G > d_B$.

(d) Decrease: d_G to d'_G.

Figure 2: Changing benefits from cooperation, c_G, and deviation temptations, d_G.

If $d_G > d_B$, optimal cooperation can be achieved only by changing the temptations to deviate. These include introducing rewards to whistle-blowing (increasing d_B) or reducing the cost of cooperating in good games (decreasing d_G). If d_G can be pushed sufficiently close to zero then optimal cooperation is feasible (with reshuffling). However, the temptations to deviate in the good game may be inherent to the situation; hence reducing d_G may be difficult. Or reshuffling teams may be infeasible: e.g., because the organization is small or only a few players, such as an organization's top executives, are relevant. In such circumstances, whistle-blowing rewards can hinder collusion in the bad game. In fact, reshuffling is unnecessary for optimal cooperation if the temptation to deviate in bad games can be increased sufficiently. Simply set $d_B > c_G \frac{\delta}{1-\delta} p_G + c_B \frac{\delta}{1-\delta} p_B$. Then as long as condition 2 in Proposition 1 is satisfied (cooperation is sustainable in the good game), optimal cooperation is feasible without reshuffling. Furthermore, in contrast to changing the benefit of good cooperation, changing the deviation temptations does not raise the organization's costs because these rewards and risks are not incurred on the equilibrium path.

These observations lead to the following further comparative statics implications of Proposition 1. Fix the exogenous discount rate r_0, benefits of cooperation c_G and c_B, and initial deviation temptations d_G and d_B with $d_G > d_B$. For any change in deviation temptations to d'_G and d'_B, there exists a discount rate $r' \geq r_0$ such that there is optimal cooperation if and only if:

- cooperation is feasible in the good game alone: $d'_G \leq c_G \frac{f_G}{r_0}$; and
- the temptations to deviate are sufficiently low in the good game and sufficiently high in the bad game: $d'_G/d'_B < \left(\frac{c_B f_B}{c_G f_G + c_B f_B}\right)$.

Doing so is always organizationally optimal.

Panels (c) and (d) of Figure 2 depict how decreasing the temptation to deviate in the good game can make optimal cooperation feasible. Panel (c) displays an initial situation with $d_G > d_B$ so that initially having cooperation in the good game necessitates cooperation in the bad game. We then consider decreasing d_G to some d'_G (see panel (d)). For d'_G smaller than d_B, i) the region with total cooperation shifts inwards, and ii) a region where optimal cooperation is the equilibrium outcome appears. If d'_G is small enough so that reshuffling can maneuver the outcome of the game into that region (as displayed), optimal cooperation again becomes feasible ($d'_G < d'_B \left(\frac{p_G c_G}{p_G c_G + p_B c_B}\right)$, by Proposition 1). A formal proof is omitted.

Do these results imply that an organization always welcomes large rewards for whistle-blowing? Our model says "no," even if one abstracts from the cost of paying large rewards. While increasing d_B relaxes two of the three conditions, the third might still not be satisfied. Note that the requirement that cooperation is sustainable in the good games is independent of d_B. If this condition fails and whistle-blower rewards are introduced, total cooperation becomes more difficult, possibly yielding no cooperation whatsoever. Therefore, whistle-blower rewards are useful only when good games arrive with high enough probability to sustain cooperation in the good game alone, or deviation payoffs or benefits from cooperation in the good game can be adjusted.

Note that there are situations in which the optimal policy is a combination of multiple changes in payoffs. For example, consider a situation in which deviation payoffs are higher in the good game ($d_G > d_B$) and it is impossible to decrease d_G; e.g., reducing danger below some level for the police or military may be infeasible. If good games are infrequent and cooperation in the good game only could not be sustained as an equilibrium even if one increased whistle-blowing payoffs enough to reverse the inequality of $d_G > d_B$, then the optimal policy is a combined one: increasing deviation temptations in the bad game allows one to separate cooperation in the good game only, but one must also increase the benefits to cooperation in the good game in order to sustain cooperation in that game only.

5 Assigning teams to tasks

[[fixme: note: we need to be very careful in defining tasks versus games played. Different tasks have different relative arrival rates of the different games. There are now discrete periods of time, and there are different tasks that the teams can be assigned to, which have different relative rates of arrival of the game. For instance, a police patrol could be assigned to different locations (the tasks) on different days (the periods). Those tasks have different relative mixes of the arrival rates of the games – any convex combination of pure bad games and pure good games, and we specify this with the T's below, but we should redo the discussion.]]

Assignment of teams to tasks that have fixed arrival ratios

- A team is assigned to some task that has a given ratio of arrival rates of good and bad. Instead of all teams doing all tasks randomly, now some teams can have higher arrival rates of good games and others of bad games.
- Games still arrive according to a Poisson process.
- Proposition: Have some "productive" teams on tasks that mix in just enough bad games to sustain good behavior and they cooperate on all games they play, and the rest are "unproductive" teams just assigned to bad tasks to balance the total arrival process, and then those unproductive teams shuffled to prevent bad behavior.

Reactive assignment of teams based on tasks but not games

- the designer can now completely control whether a team faces only good game arrival or bad game arrival, by assigning teams to "good tasks" (e.g., being at the front in a battle) or "bad tasks" (e.g., working in the supply tent). However the designer cannot react to/reassign based on/see when games actually arrive.
- Each period, a team is assigned to either the good or bad task. Now, however, these assignments can depend on the history of tasks the team has completed. E.g., if the team was on the good task in the last period, then it may be put on the bad task for a number of periods.
- As before, when the team is on task g, then game g may or may not occur as it comes with a Poisson arrival.
- From now on, we focus on the case where d_B is small (in a particular sense), so that bad cooperation is easy to incentivize but good is the one that takes both games in some mix.

- Proposition: The uniquely (in a particular sense) optimal assignment is: Teams get one period on the good task then play the bad task for some number of periods for some fixed number of periods and then randomly play the bad task/good task for at most one period and then are put back on the good task for certain if they played bad again.
- This can be purified across teams, but from any given productive team's perspective is one period of good task followed by a number of periods of the bad task, then at most one period of random transition, and then sure transition back to good task if the random transition is not made in the random period.

Reactive assignment based on games

- As before, each period, a team is assigned to either the good or bad task. This time, these assignments can depend on the history of previous tasks *and the actual realizations of games* the team has completed. E.g., a team may be treated differently depending on whether game g occurred or not in the previous period when it was assigned to the good task.
- Proposition: The uniquely (in a particular sense) optimal assignment is: Teams stay on the good task until they face a good game; then they play the bad task for a fixed number of periods (regardless of whether the bad game arrives) followed by a single period of random bad task (possibly 0) and then the good task if they did not return to it already in the last period.
- Note that the designer does not need to know whether a bad game occurred when a team is on the bad task.

Normalizing the gain in payoffs of a bad vs good game to be 1. Start at a good game. Characterize an assignment by a string of p_t, which is probability at each future point in time that one is playing the bad game and has not switched back to the good game. Let $\tau = \min\{t : p_t = 0\}$, which is possibly infinity. Solve:

$$\min_{(p_t)_t} \lim_{T\to\infty} \frac{\sum_{t=1}^{T} p_t}{T}$$

subject to

$$V \equiv \sum_{t\leq\tau} \delta^t \left(p_t + (1-p_t)\delta V\right) \geq X.$$

where X is the incentive constraint from deviating (normalized to fit the 0-1 payoffs).

Claim: solution is to set $p_t = 1$ for a min number of periods, then $p_t < 1$ and then 0.

The proof seems straightforward: Noting that $V = X$, and that the constraint will bind, the constraint becomes

$$\sum_{t \leq \tau} \delta^t \left(p_t + (1 - p_t)\delta X\right) = X.$$

Then note that $\delta X < 1$ as otherwise the incentive solution is trivial as the good game is already incentivized by less than one bad period. Then any two periods with positive but $p_t < 1$ are better shifting some mass to the earlier period.

We now consider a second dimension of organizational design that affects cooperation: teams can be specialized—assigned different tasks. The assignment of teams to tasks matters because good and bad games may arrive at different rates in different tasks. For example, in a police force, the task of responding to emergencies might create frequent situations where backup is required (good games), whereas the task of traffic policing might present frequent opportunities for accepting bribes (bad games). For simplicity, we consider a situation in which there are two tasks G and B and that team members completing task G only face good games, while team members completing task B only face bad games.

Tasks require a given amount of time to complete. Let T_g be the average time spent on the task that generates game g, in the unspecialized case in which every team faces the same mixture of games. We assume that teams have a fixed budget of time (e.g., a workday) and the time spent on tasks generating game $g' \neq g$ must satisfy $T'_g + T'_{g'} = T_G + T_B \equiv T$. Given that game g arrives with frequency f_g, this means it occurs with frequency $f_g \left(\frac{T_g}{T}\right)^{-1}$ if all time is spent on the task generating game g (full specialization of teams). Therefore, in general, if a task assignment requires a team to spend an average time of T'_g on game g, they face that game with frequency

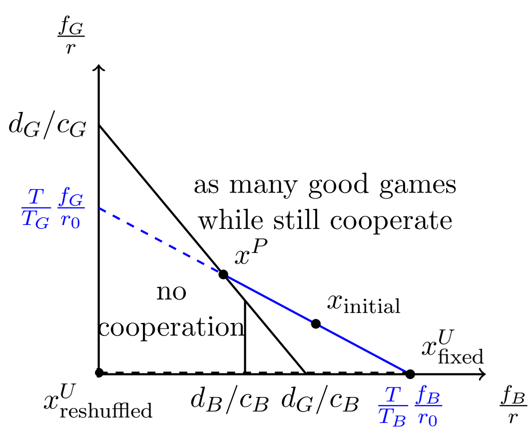
$$f'_g = f_g \left(\frac{T_g}{T}\right)^{-1} \frac{T'_g}{T} = f_g \frac{T'_g}{T_g}.$$

When teams are fully specialized, i.e., one type of team only encounters good games (with frequency $f'_G = f_G \frac{T}{T_G}$) and the other only bad games (with frequency $f'_B = f_B \frac{T}{T_B}$), the designer optimally reshuffles the latter teams so as to prevent collusion, while teams encountering good games are kept together to promote cooperation.

Fully specializing teams overcomes two of the three conditions required for optimal cooperation from Proposition 1 (conditions 1 and 3): First, greater temptation to deviate in good than bad games still means that desirable cooperation leads to collusion; however, the only teams that encounter bad games are frequently reshuffled and hence never cooperate. Second, good and bad games are fully separated; hence there are no spillovers constraining the relative frequencies of good and bad games. Also, because cooperation becomes easier when interactions occur more frequently, the condition for optimal cooperation with full specialization on good games is weaker than its analog (condition 2).

Next, we ask whether flexibility in assigning tasks to teams can help if the above condition fails—fully specializing teams does not create optimal cooperation, for instance if good games are too infrequent or have large deviation payoffs. The answer is 'yes': partial specialization can be optimal. To grasp the intuition, suppose that a team facing only good games cannot sustain cooperation, but there is some task assignment for which teams facing those relative game frequencies can sustain cooperation in both games. An optimal task assignment can then involve creating two types of teams: one that faces a task composition with the minimum frequency of bad games needed to sustain total cooperation (the 'productive teams'); and another whose task composition is all bad (or all good)—ensuring aggregate balance—but that is shuffled and does not cooperate (the 'unproductive team'). This generates a candidate task assignment, and either this candidate assignment or no cooperation is optimal.

Figure 3 depicts two such cases. In Panel (a), total cooperation is possible in the initial situation Some teams are specialized—they have relatively more good games (x^P)—but not so many that cooperation cannot be supported. Those teams are not shuffled. The remaining teams are specialized exclusively to the bad games and then shuffled. In Panel (b), total cooperation is not sustainable in the initial situation. There the teams that can support cooperation are the ones assigned to more bad games.



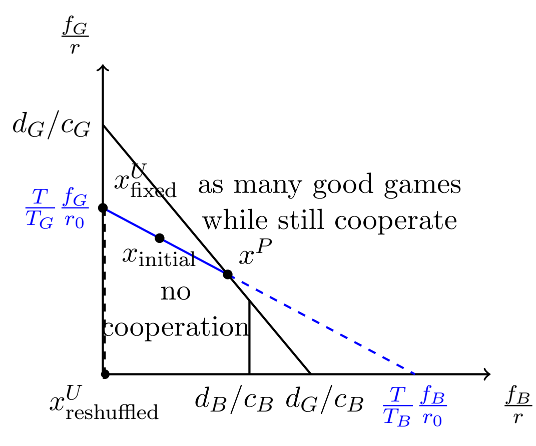


Figure 3: Optimal team assignment when bad games are necessary to sustain cooperation.

This discussion suggests that organizations may benefit by specializing their teams and reshuffling them at different rates. For example, police officers could be tasked with either responding to emergencies or traffic policing. In the former case, good cooperation—backing up one's partner in dangerous situations—can be supported by keeping officers together; in the latter, bad cooperation—colluding in taking bribes—can be stopped by reshuffling partnerships often.

6 Concluding remarks

Our analysis shows that a systemic approach is important in understanding and designing organizations. Nominally independent tasks and situations become dependent if team members interact repeatedly. Thus, myopically improving the incentives for desirable actions in one type of situation may backfire, generating detrimental behaviors elsewhere. Conversely, this also provides a warning about the design of organizations. Naive approaches to minimizing collusive behavior may be to eradicate situations where it occurs (decreasing f_B), reduce its benefits (decreasing c_B), or incentivize team members to stop colluding or to report it (increasing d_B). Although all these may serve their intended purpose of reducing collusion, they also can impair productive cooperation in other situations if incentives elsewhere are not adjusted to compensate.

The dual of this warning highlights missed opportunities: a myopic design-approach may overlook opportunities to reduce bad cooperation by overlooking opportunities to reduce the need for good cooperation. For example, the Mollen Commission (1994), discussing corruption and policing, describes an empirical regularity showing the importance of a systemic view: "[the code of silence] is strongest where corruption is most frequent. This is because the loyalty ethic is particularly powerful in crime-ridden precincts where officers most depend upon each other for their safety each day." The "loyalty ethic" corresponds to cooperation in bad situations and the "depend[ence] upon each other for their safety" describes the benefits from cooperation in good situations. The report then suggests that "crime-ridden precincts" are those with a high frequency of the good game (e.g., more dangerous situations) which facilitates cooperation in bad games—an important instantiation of spillover effects. Making policing safer can help reduce corruption.

Our analysis also relates to the cohesion of communities and societies. Banfield (1958); Putnam (2000), in their studies of an Italian city and the US over time, respectively, document these spillovers. Banfield (1958) describes communities with nuclear families as uncooperative actors. As Lemma 1 shows, a lack of interaction in some dimensions may lead to a breakdown of all cooperation (public goods, commons, etc.). Similarly, the resulting need for cooperation within the family can create powerful incentives to act as a single unit, which could enhance the ability to coordinate on being corrupt.

Relatedly, Putnam (2000) warns about the consequences of an erosion of civic interactions ("good cooperation") in the US for other kinds of institutions that require cooperation; e.g., political discourse. Lemma 1 supports his warning of spillovers from cooperation on leisurely activities, such as bowling, to more general foundations of civic behavior. It further provides some insight into what may have caused such a decline in civic norms: formal institutions, such as insurance markets and markets, replacing informal interactions—such as reciprocal insurance and favor exchange—thereby reducing necessary cooperation.

In closing we discuss a few extensions of our analysis.

Reactive task assignments. Consider teams for which specialization does not produce optimal cooperation, hence some cooperation on bad tasks are necessary to help support cooperation on good ones. If the designer can observe when games arrive, then the designer can improve the incentives and overall productivity by reassigning teams to different tasks in reaction to the games just played.

The idea is as follows. If bad games are need to sustain good cooperation, then when playing a good game the incentives to cooperate come from having enough bad games in the future to provide the sufficient future payoffs from cooperation In that case, switching the team to the bad task immediately after it plays a good game improves the incentives by reducing the waiting time to the next bad game's arrival. This makes the games arrive closer to when they are needed, which decreases the overall number of bad games that must be played to induce cooperation in good games. The team can then be switched back to the good task and can spend more time on that task than would be possible otherwise. An example of this is immediately assigning a military unit to noncombat status after it has faced combat, and then at some random time reassigning those soldiers to the front where the combat game becomes more likely again.

Introducing additional benefits from cooperation. When supporting optimal cooperation is challenging, it can be advantageous to introduce new activities which provide benefits from cooperation. These new activities might not benefit society or directly increase organizational productivity, but they might help sustain cooperation in good games. For instance, scheduling "team-building" exercises, social events, and non-production related contests in which team members must cooperate with each other can help induce cooperation in other games as well. Many organizations use such team-building to enhance the loyalty that people feel towards the units in which they are involved, fostering cooperation. Although such events may be time consuming and thus reduce the time that teams spend directly on productive activities, they may end up enhancing productivity, and substitute for bad games, by enabling cooperation in good games when that might have otherwise been infeasible.

The organization may also affect the degree of altruism team members feel toward each other.[7] When altruism is high, teams can achieve an outcome that maximizes aggregates

[7] For a discussion of cooperation when one party internalizes another's welfare, see Kreps (2022).

payoffs; when it is low there is no cooperation. If the organization can influence the degree of altruism, for instance by determining how much time team members spend together, it may want to choose enough altruism to encourage cooperation in some situations (the good ones) but too little to support collusion in bad games. Our analysis can serve as a base for such an extension.

The role of technology. Surveillance and other technological innovations also play an important role. Improved monitoring can make cooperation directly enforceable in good games and punishable in bad ones, thereby making incentive issues less relevant. Thus, organizations can benefit from investing in technologies to monitor behavior. For example, if cooperation in the good game can be directly enforced by a monitoring technology, reshuffling teams to reduce residual collusion makes good sense. However, Section 5 shows that an organization can benefit from the games' strategic interdependencies. For example, suppose that the organization prefers total cooperation to no cooperation. If no cooperation in the bad game is directly enforced via some new technology then cooperation in the good game may be impaired as players can now only punish in that game. All cooperation may thereby break down.

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A A Discrete Version of the Poisson Multi-Game

Given the issues of defining strategies and subgame perfect equilibria in games with continuous time (without contributing any economic content to the games we consider), we work with a discrete version of the game that has the same expectations in terms of frequencies of future arrival rates but then has a finite set of possible histories through any finite time, and so standard definitions then apply.

Time proceeds in discrete time $t \in \{1, 2, \ldots\}$. At each time t, a single game is played. Game g is selected to be played with probability $\rho_g = \frac{f_g}{T}$, where $T > f_G + f_B$, and players discount the future with discount factor $\delta = \frac{1}{1+\frac{r}{T}}$. $1/T$ is the "length" of a time period, and needs to be sufficiently small so that the expected number of games per period can be at most one and still generate the required arrival frequencies. As $T \to \infty$, this discrete version converges to the continuous-model with Poisson arrival.

A history is then a list of which games were played at which times, and which actions were played, all of which are observed perfectly by all players. That is, a history up through time t is a list $h \in H^t \equiv (\{\emptyset\} \cup (\{G, B\} \times A^n))^t$ of which game (or none) was played at each date and then which action profile was played (if a game was played). Let $H = \cup_t H^t$ denote the set of all histories. A strategy for a player i is a function $\sigma_i : H \times \{G, B\} \to \Delta(A)$, which specifies what mixed action a player chooses as a function of the history $h \in H$ and current game $g \in \{G, B\}$. Subgame perfection is then the requirement that strategies form a Nash equilibrium starting from any history and current stage game, given the payoffs of $\{G, B\}$, the discount factor, and the probabilities ρ_g.

B Proofs Omitted from the Text

As the logic of some of the proofs follow folk-theorem-like reasoning, we provide sketches of the more standard constructions, and provide more detail on the novel aspects of the proofs.

Proof of Lemma 1. Consider the player-optimal subgame-perfect equilibrium.

Case i): Suppose (1) holds. As aggregate stage game payoffs are maximized when all players cooperate, a grim-trigger strategy such as 'always cooperate unless any player did not cooperate in the past at which point always do not cooperate' constitutes a subgame-perfect equilibrium: Facing game g, no player benefits from deviating given that $d_g \leq \sum_{g'} c'_g \frac{f_{g'}}{r}$ by (1). Note also that not cooperating for ever after is also a Nash equilibrium in all proper subgames.

Case ii): Suppose (2) holds for game g but (1) fails. Call the other game g'. First, we show that cooperating only in game g is an equilibrium. Consider the strategy 'cooperate in g only unless any player deviated from this strategy in the past, in which case do not cooperate in either game'. Facing game g, a player has no incentive to deviate given that $d_g \leq c_g \frac{f_g}{r}$ by (2). There is no benefit from deviation in game g' as all players not cooperating is a Nash equilibrium and payoffs are lower in the punishment stage. Next, note that, as before, the punishment stage is a Nash equilibrium. Second, we show that there is no other equilibrium that has higher total payoffs than cooperating only in game g. As always cooperating in game g generates the highest aggregate payoffs in that game, and as all asymmetric payoffs in either game are below all cooperating and all not cooperating in that game, it must be that any equilibrium with strictly higher payoffs in the Poisson multi-game must have all players cooperating in game g' with some probability for some histories. Consider some such history in which g' is played and all players cooperate. As cooperation in both games maximizes aggregate payoffs, there exists a player i whose maximum discounted payoff in the equilibrium continuation is at most $c_g \frac{f_g}{r} + c_{g'} \frac{f_{g'}}{r}$. As each player minimizes her worst-case loss by not cooperating, the largest loss from deviating for player i is thus their discounted payoff. However, as $d_{g'} = \max\{d_g, d'_g\}$ and (1) fails, player i has a profitable deviation.

Case iii): Suppose that we are not in either of the above cases. 'Always do not cooperate' is an equilibrium. Given that every player cooperating is the only strategy profile that generates a higher aggregate payoff than all players not cooperating, it must be that any equilibrium with strictly higher payoffs in the Poisson multi-games must have all players cooperating in some game g with some probability for some histories. If there is no cooperation on the equilibrium path in game g', the other game, then, as cooperation in game g and no cooperation in game g' maximizes aggregate payoff, there exists a player i whose maximum discounted payoff is at most $c_g \frac{f_g}{r}$. As each player minimizes her worst-case loss by not cooperating, the largest loss from deviating for player i is thus her discounted payoff. However, as (1) fails for game g, player i has a profitable deviation. If here is cooperation on the equilibrium path in game g' as well, then we reach a contradiction with arguments analogously to those in case ii). □

Proposition 1. Suppose conditions 1.-3. hold. Define $r = c_G \frac{f_B}{r}$. By condition 2, $r \geq r_0$ and hence can be implemented through reshuffling. Clearly, (2) holds for game G; what remains to be shown is that (1) does not. We have

$$c_G \frac{f_G}{r} + c_B \frac{f_B}{r} = d_G + \frac{c_B f_B}{c_G f_G} d_G < d_G + \frac{d_B - d_G}{d_G} d_G = d_B, \tag{8}$$

where the first equation follows from the definition of r and the inequality from condition 3. Hence (1) does not hold.

If condition 1 fails, then (2), for any r for game G, implies (1) so that there cannot be optimal cooperation.

If condition 2 fails, (2) for game G fails for any $r \geq r_0$, and again there cannot be optimal cooperation.

Suppose condition 3. fails. Pick any r. We need to show that (2) for game G cannot hold while (1) fails. As the right-hand side of (1) decreases in r, it suffices to check for r that solves (2) for game G with equality. A set of equations analogous to those in (8) with the inequality reverse as 3. fails then reveals that (1) does not hold.

The frequency weighted value of total cooperation to the designer is $f_G s_G + f_B s_B$; for no cooperation it is 0. Hence, the final claim in the proposition follows. $\square$