The Politics of Compromise*

Alessandro Bonatti† and Heikki Rantakari‡

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Abstract

A team must select among competing projects. Projects differ in their payoff consequences for each agent. Each agent selects a project and exerts costly effort that affects its random completion time. When one or more projects are complete, the agents bargain over which one to implement. A unanimity rule can (but need not) induce the efficient balance between compromise in project selection and equilibrium effort. Imposing deadlines for presenting counterproposals or delaying their implementation is beneficial, while relying on an impartial third party as the decision-maker always leads to the selection of purely selfish projects. Finally, the organization can foster both effort and compromise in project selection by hiring agents with opposed interests.

Keywords: bargaining, committees, compromise, conflict, deadlines, free riding, search, war of attrition.

JEL Classification: C72, D71, D83.

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†MIT Sloan School of Management, 100 Main Street, Cambridge MA 02142, USA bonatti@mit.edu.

‡University of Southern California, Marshall School of Business rantakar@marshall.usc.edu.

1 Introduction

Fifty years ago, Cyert and March (1963: 32-33) noted that "the existence of unresolved conflict is a conspicuous feature of organizations, [making it] exceedingly difficult to construct a useful positive theory of organizational decision making if we insist on internal goal consistency."

Indeed, in many settings – from firms to hospitals, schools, agencies, and committees – members have conflicting preferences over the set of available alternatives: which product design to adopt, which policy to implement or which candidate to hire. Yet in many instances, alternatives are not readily available. Instead, they must be developed by the organization's members themselves: building a prototype, completing a feasibility study, and searching for a candidate require time and effort. In such a scenario, where the organization's choice set is endogenous, conflict can arise both at the project-development stage and at the decision-making stage.

In most instances, some degree of compromise between the various members' goals is beneficial to the entire organization. Examples include: product designs that are both appealing to customers and cost-efficient; moderate (i.e. not entirely partisan) policy proposals; and candidates with a balanced background. Members must then be provided with incentives to develop such compromise projects, as opposed to purely selfish ones. However, the more an agent is motivated to compromise on project selection, the less interested he is in the ultimate implementation of his project and the more willing to accept other agents' proposals. This reduces his incentives to exert effort towards developing his project in the first place. A central theme in our analysis is that the organization therefore faces a trade-off between the quality (i.e. the degree of compromise) of the projects pursued in equilibrium and their timely completion.

To analyze how organizations can manage this trade-off, we formulate a dynamic model consisting of a *development phase* and a *negotiations phase*: each agent chooses which project to develop, and both agents must then agree on which project to implement. Our goal is to identify decision-making procedures that harness the existing preference conflict and convert it into equilibrium compromise and timely completion.

There are three key features of our model: (a) *Agents have conflicting interests, and compromise is efficient*: There exists a continuum of potential projects that generate different payoffs for each agent. The agents' payoffs form a strictly concave Pareto frontier. Therefore, "intermediate" or "compromise" projects are socially desirable. A key tension then arises because conflict between agents (i.e. developing very different projects) yields strong incentives for effort. At the same time, since the payoff frontier is strictly concave, conflict reduces the total value of the projects being pursued. (b) *Developing projects requires effort, and completion times are uncertain*: The development of a project requires a breakthrough. The probability of a breakthrough is increasing in the agent's effort. In other words, each project's completion time is stochastic, and each agent can affect its probability distribution by exerting effort. This assumption is meant to capture the research-intensive nature of generating a proposal in many of our settings. (c) *Projects cannot be combined, and their characteristics are not contractible:* While projects can be ranked in terms of their payoffs for the two agents, the space of their underlying characteristics can be quite complex. The complexity of the projects suggests that it can be exceedingly difficult to describe them in a contract and to forecast the payoff implications of a convex combination of their characteristics (e.g., a "hybrid product design").[1] Similarly, the existence of complementarities among project characteristics plausibly makes intermediate solutions less attractive than extreme ones, if at all feasible. Consequently, we do not allow agents to write contracts that condition payments or decision rights on the characteristics of the projects developed. In fact, we initially rule out all monetary payments; and we are exploring the role of side payments in ongoing work.

Our main results are the following:

(i) *Efficient compromise and effort can be sustained in equilibrium under a unanimity rule.* In our baseline model, we impose a unanimity requirement for the implementation of a project. In other words, each agent can block the other agent's project at will. When each agent has developed a project, negotiations take the form of a war of attrition. We show that the constrained-efficient projects are chosen as part of an equilibrium outcome. These projects strike the optimal balance between compromise along the Pareto frontier and the ensuing equilibrium effort. However, the unanimity requirement does not yield a unique equilibrium during the negotiations phase, and different equilibria in this phase yield levels of compromise that can be higher or lower than the efficient level. The reason for equilibrium multiplicity is that each agent's incentives to block a proposed project depend on his expectations of the outcome of the ensuing negotiations. For example, the fear of strongly contentious negotiations (i.e. slow concessions in the war of attrition when both agents have developed their projects) induces immediate acceptance once the first project is developed. This, in turn, leads agents to pursue their most preferred projects. Conversely, if both agents expect to hold considerable bargaining power once they develop a counterproposal, they are more willing to block initial proposals. This may lead, in fact, to an excessive degree of compromise in initial project choice.

[1] Most of our applications would fit the rugged-landscape framework introduced by Levinthal (1997) and Rivkin and Siggelkow (2003).

(ii) *Deadlines for counteroffers achieve the efficient compromise and effort.* If agents can commit to a procedure for resolving conflict when two projects have been developed, they can induce the constrained-efficient project selection. The optimal procedure allows the receiver of the first proposal to reject it and to begin developing a new project. However, it also specifies a deadline for counteroffers, i.e., the amount of time the second agent has to develop a new project: if he does develop an alternative project, his project is implemented; if time runs out, all projects are abandoned. The optimal deadline for counteroffers persuades the two agents to pursue projects that are immediately accepted and achieve the constrained-efficient degree of compromise: the fear of an unfavorable counteroffer disciplines the initial choice of projects; and the risk of failing to develop a counteroffer provides incentives to immediately accept reasonable proposals. It is important (in fact, we conjecture it is necessary) that agents can commit to ex-post inefficient actions ("dissipation") in order to discipline their initial choice of projects. Indeed, an outcome-equivalent procedure dispenses with the deadline, and instead requires a fixed lag between the development and the implementation of any counterproposal.[2]

(iii) *An impartial decision-maker cannot induce any compromise.* Delegating the implementation a project to an impartial decision-maker (the "mediator") who maximizes the sum of the agents' payoffs does not help the team. If the mediator lacks commitment power, there exists a unique equilibrium, in which the two agents pursue fully selfish projects. This result is based on a simple unraveling argument. The basic intuition is that the mediator's choice is constrained by the projects developed by the agents, which makes retaining the ultimate decision rights effectively useless. The outlook for the organization is less bleak if the mediator can only break ties between two developed projects. In this case, the equilibrium outcome entails efficient effort levels, but the degree of compromise is inefficiently low.

Finally, we discuss how our results can be generalized along several dimensions. In particular, we show how increasing the alignment in the agent's preferences relaxes the immediate-acceptance constraints for project choice under unanimity. Consequently, increasing the alignment in the agents' objectives (e.g., via incentive contracts or selection of agents with known preferences) *reduces* the degree of equilibrium compromise. In addition, it may (but need not) reduce the incentives to exert effort. In this sense, conflicting goals in organizations are not only a necessary evil because achieving full goal congruence is impossible, but also desirable because conflict may breed compromise and consensus without jeopardizing the incentives to work hard.

[2]Procedures that induce dissipation are rather plausible in our settings: for example, in a hiring committee, a deadline for counteroffers corresponds to "losing the slot" if any member vetoes a candidate and fails to suggest an alternative in a reasonable time; and a delay in implementation corresponds to requiring additional screening of any proposed candidate, if a consensus is not built around the first one.

In ongoing work, we explore whether allowing access to monetary transfers eliminates the use of compromise as a method to generate agreement. This is unlikely to occur: as long as compromise generates efficiency gains, pursuing a project that compromises slightly more is a more efficient way of buying the other agent's consent, compared to monetary transfers. Furthermore, allowing monetary transfers may invite agents to pursue highly polarized projects with the goal of holding up the other agent to extract rents at the bargaining stage. Therefore, we conjecture that the ability to make ex-post transfers may actually reduce the degree of equilibrium compromise and welfare.

Consistent with a growing literature, in this paper we adopt the political view of organizational decision-making initiated by March (1962) and Cyert and March (1963) and summarized by Pfeffer (1981): "to understand organizational choices using a political model, it is necessary to understand who participates in decision making, what determines each player's stand on the issues, what determines each actor's relative power, and how the decision process arrives at a decision." See Gibbons, Matouschek, and Roberts (2013) for a survey. We also follow Cyert and March (1963) closely when they note that "side payments [...] represent the central process of goal specification. That is, a significant number of these payments are in the form of policy commitments. [...] Policy commitments have (one is tempted to say always) been an important part of the method by which coalitions are formed." In our model, agents can effectively make side payments in the form of policy commitments by compromising on project selection.

This paper is also related to several strands of more recent literature. First, our model can be viewed as an analysis of real authority and project choice in organizations. The most closely related papers in this field are Aghion and Tirole (1997) and Rantakari (2012), in their focus on ex ante incentives, and Armstrong and Vickers (2010), in their analysis of endogenous proposals. The role of incentive alignment is discussed in Rey and Tirole (2001). Other papers have examined extensively the impact of organizational structure on information flows inside the organization, with Dessein (2002), Alonso, Dessein, and Matouschek (2008) and Rantakari (2008) considering the impact of the allocation of decision rights on strategic communication and decision-making, Dessein and Santos (2006) the impact of task groupings, and Dessein, Galeotti, and Santos (2013) the benefits of organizational focus. The present paper analyzes the development of projects and their subsequent implementation, while these papers have focused on the quality of decision-making.

Second, our work ties into a large literature focused on the role of conflict and advocacy within a committee. In particular, Dewatripont and Tirole (1999), Che and Kartik (2009), and Moldovanu and Shi (2013), among others, focus on the value of conflict for information acquisition in committees. In contrast, we focus on the role of ex-ante conflict and ex-post negotiation for achieving equilibrium compromise in the choice of projects.

Third, our paper is related to the provision of dynamic incentives to a team. In our model, deadlines for a breakthrough are not optimal, unlike Bonatti and Hörner (2011) and Campbell, Ederer, and Spinnewijn (2013). Dynamic distortions of team members' objectives, such as in the principal-agent model of Mason and Välimäki (2012), are not optimal either. Delay and deadlines can, however, serve as discipline devices that induce the choice of compromise projects. This is also the case in the delegated experimentation model of Guo (2013).

Finally, in our model the development phase precedes the negotiation phase. Our analyses of these two phases build on two separate classes of models. The development phase is closely related to the R&D and patent-race models of Reinganum (1982), Harris and Vickers (1985), and Doraszelski (2003). Contributions that emphasize the effect of imperfect patent protection on the strategic properties of an R&D race are given by Beath, Katsoulacos, and Ulph (1989) and Doraszelski (2008). The negotiations phase is a war of attrition in continuous time with complete information, whose equilibrium characterization is due to Hendricks, Weiss, and Wilson (1988).

2 Set-Up

We model an organization consisting of two agents $i = 1, 2$ working on competing projects, or "ideas." There exists a continuum of feasible projects indexed by $x \in [0, 1]$. As we will describe in detail, a project must be *developed* before it can be *implemented,* and yield payoffs to both agents.

To develop a project, agents exert over the infinite horizon $\mathbb{R}_+$. Effort is costly, and the instantaneous cost to agent $i = 1, 2$ of exerting effort $a_i \in \mathbb{R}_+$ is given by $c_i(a_i)$, for some function $c_i(\cdot)$ that is strictly increasing and strictly convex, with $c'(0) = 0$. In most of the paper, we assume that $c_i(a_i) = c_i \cdot a_i^2/2$, for some constant $c_i > 0$. Projects (i.e. choices of $x_{i,t}$) can be changed by the agent as desired during the game. Finally, the chosen projects and effort levels are assumed to be non-contractible and unobservable to the other player. Projects become observable when developed.

The development of each project is stochastic, and requires the arrival of a single breakthrough. A breakthrough on project $x_{i,t}$ occurs with instantaneous probability equal to $\lambda_i a_{i,t}$. Thus, if agent i were to choose a constant project x_i, and exert a constant effort a_i over some interval of time, then the delay until the development of project x_i would be distributed exponentially over that time interval with parameter $\lambda_i a_i$. Throughout the paper, we normalize $\lambda_i = \lambda$ for all i, and we capture any asymmetry between the two agents through differences in the effort cost functions.

The development (or "completion") of any project x is publicly observable. If agent i obtains a breakthrough at time τ, he stops working, and we refer to project $x_{i,\tau}$ as agent i's *proposal*.[3] Implementation of proposal $x_{i,\tau}$ requires acceptance of agent i's proposal by agent $-i$. Proposals cannot be taken off the table: agent $-i$ can accept agent i's proposal $x_{i,\tau}$ at any time $t \geq \tau$. Agent $-i$ can also keep exerting effort towards development of another project. If agent $-i$ develops another project $x_{-i,\tau'}$ at time τ', agent i can then accept it at any time $t \geq \tau'$. Acceptance of a proposal is irreversible, leads to the implementation of a project, and ends the game.

Thus, an outcome of the game consists of: (1) a pair of measurable functions $a_i : \mathbb{R}_+ \to \mathbb{R}_+$ and $x_i : \mathbb{R}_+ \to [0, 1]$, with the interpretation that $a_{i,t}$ is the level of effort exerted by i at time t towards development of project $x_{i,t}$; (2) the set of projects $x_{i,\tau}$ developed by either agent i at any time τ; and (3) at most one implemented project.

Implementation of project x yields a net present value of $v_i(x)$ to each agent i. As long as no proposal has been implemented, agents reap no benefits from any project. Both agents are impatient and discount the future at rate r. If project x is implemented at time τ, the discounted payoff to agent i is given by

$$V_i = e^{-r\tau} v_i(x) - \int_0^{\tau} e^{-rt} c_i\left(a_{i,t}\right) \mathrm{d}t. \tag{1}$$

The payoff functions $v_i(x)$ are monotone, differentiable and strictly concave. In particular, $v_1(x)$ is decreasing and $v_2(x)$ is increasing, with $v_1(1) = v_2(0) = 1$ and $v_1(0) = v_2(1) = 0$. Thus, the sum of the agents' payoffs $v_1(x) + v_2(x)$ is strictly concave in x with a unique interior maximum.

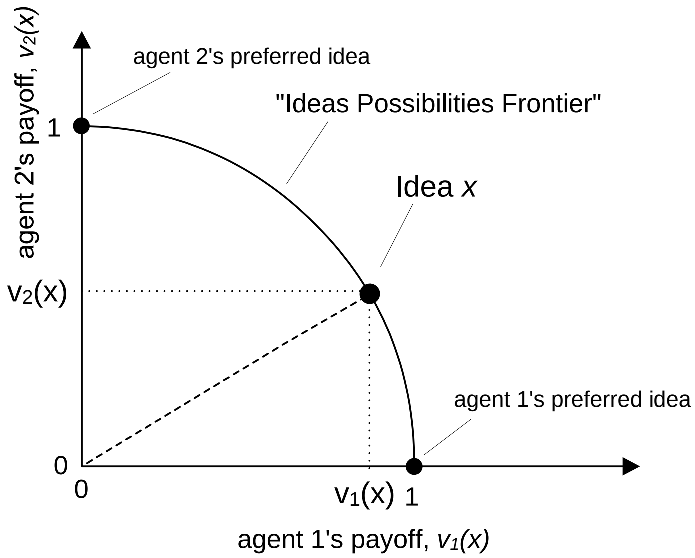
In other words, agents have conflicting preferences over projects, with $x = 1$ characterizing agent 1's preferred project and $x = 0$ agent 2's preferred project. Moreover, compromise is efficient: the agents' payoffs $(v_1(x), v_2(x))$ form a continuously differentiable and strictly concave payoff frontier. We denote this locus as the "ideas possibilities frontier," and we illustrate it in Figure 1.

This formulation is based on the premise that agents may know what constraints and characteristics they desire for their project, but they still need to exert effort to develop a proposal that could be implemented. For example, a development team may have a target fuel efficiency and weight for a new car, but they still need to develop a prototype that meets these targets.

While projects x can be ranked in terms of their payoffs to each agent, we assume projects

[3] We discuss these assumptions further in Section 5.

Figure 1: Ideas Possibilities Frontier



cannot be combined or divided. Thus, no convex combination of projects x and x' is feasible unless developed on its own. In many applications, the underlying characteristics space is multi-dimensional and payoffs are not smooth (much less monotone) in characteristics, as in the rugged-landscape framework noted above. Thus, we should think of projects $x \in [0, 1]$ as a collection of feasible designs, ranked in terms of the two agents' relative preferences.[4]

To summarize, our model consists of two phases: a *development phase* and a *negotiations phase*. In the development phase, having chosen their projects, agents exert effort to bring them to fruition. Once one or more projects have been developed, negotiations take place over which one is implemented. In our baseline model, implementation requires unanimity, and negotiations are modeled as a war of attrition. Our focus is on how play in the negotiations phase influences the initial choice of projects and effort to develop them. Before analyzing the negotiations phase, we characterize the equilibrium development efforts in a simplified framework in which projects are exogenously assigned to the two agents.

3 Development Phase with Fixed Projects

We consider a model where each agent i works on a fixed project x_i, and the first project to be developed is implemented immediately. In this simplified framework, each agent i chooses

[4]The assumption of orthogonal preferences over projects is not crucial for the analysis. We relax this assumption in Section 7.

his effort level $a_{i,t}$ to maximize the following expected discounted payoff:

$$V_i\left(x_i, x_{-i}\right) = \int_0^\infty e^{-\int_0^t (r+\lambda a_{i,s}+\lambda a_{-i,s})\mathrm{d}s} \left(\lambda a_{i,t} v_i\left(x_i\right) + \lambda a_{-i,t} v_i\left(x_{-i}\right) - c\left(a_{i,t}\right)\right) \mathrm{d}t. \quad (2)$$

The exponential term in the objective function is the effective discount factor used by the agents: under immediate acceptance, the game ends with an instantaneous probability of $\Sigma_i \lambda a_{i,t}$.

Each agent controls the expected development time of his own project: by exerting higher effort, agent i increases the probability of achieving a breakthrough at a constant rate. Therefore, his incentives to exert effort at time t are driven by the value of ending the game with a payoff of $v_i\left(x_i\right)$. This can be seen more clearly by rewriting agent i's value function $V_{i,t}$ recursively through the Hamilton-Jacobi-Bellman equation:

$$rV_{i,t} = \max_{a_{i,t}} \left[\lambda a_{i,t}(v_i(x_i) - V_{i,t}) + \lambda a_{-i,t}(v_i(x_{-i}) - V_{i,t}) - c_i\left(a_{i,t}\right) + \dot{V}_{i,t}\right]. \quad (3)$$

This formulation of the agent's problem relates the optimal choice of effort to the gains from developing his own project over and above his continuation value. In particular, each agent i chooses an effort level $a^*_{i,t}$ that satisfies

$$c'(a^*_{i,t}) = \max\left\{\lambda\left(v_i(x_i) - V_{i,t}\right), 0\right\}. \quad (4)$$

The characteristics of the two projects x_i and x_{-i} affect the sign of the externality that each agent's actions exert on the other player: an increase in agent $-i$'s effort at time t increases the probability that the game will end, in which case agent i obtains a payoff $v_i\left(x_{-i}\right)$ but loses his continuation payoff $V_{i,t}$. Therefore, when the two projects are sufficiently different, agent $-i$'s effort imposes a negative externality on agent i, because the payoff $v_i\left(x_{-i}\right)$ falls short of his equilibrium continuation value $V_{i,t}$. For example, suppose agent $-i$ pursues his favorite project x^*_{-i}: while this project is worthless for agent i, the continuation value $V_{i,t}$ is strictly positive because agent i has a positive probability of developing and implementing his own project x_i. The opposite holds when the two projects are very similar and $v_i\left(x_i\right) \approx v_i\left(x_{-i}\right)$. In this case, the payoff $v_i\left(x_{-i}\right)$ exceeds the continuation value $V_{i,t}$, because the latter accounts for costly effort and delay.

Consequently, an increase in agent $-i$'s effort may motivate or discourage high effort levels by agent i, depending on whether agent $-i$'s effort imposes a negative or positive externality on agent i. To see this more formally, we use the first-order condition (4) and apply the envelope theorem to the objective function (3). We conclude that

$$\frac{\partial a_{i,t}^*}{\partial a_{-i,t}} > 0 \iff \frac{\partial V_{i,t}}{\partial a_{-i,t}} < 0 \iff v_i\left(x_{-i}\right) < V_{i,t}. \tag{5}$$

This heuristic argument suggests that the nature of the payoff externality that one agent's effort exerts on the other agent determines whether the game has the strategic properties of a patent race or of a moral hazard in teams problem, where each agent has incentives to free-ride on the other agent's effort. In turn, the team problem (in which agents maximize the sum of their individual payoffs) may lead to higher or lower effort than the noncooperative solution, just as in racing vs. free-riding. In order to formalize this intuition, we now introduce the following assumption on technology and payoffs.

Assumption 1 (Symmetric Quadratic Environment)

1. *Each agent's cost function is given by*

$$c_i\left(a_i\right) = c a_i^2 / 2.$$

2. *The payoff frontier is symmetric, and agents work on symmetric projects, i.e.*

$$\begin{aligned} v_i\left(x\right) &= v_{-i}\left(1-x\right), \\ x_i &= 1 - x_{-i}. \end{aligned}$$

We maintain Assumption 1 throughout this section. While our results rely on symmetry, it would not be difficult to extend the analysis to more general cost functions (e.g., constant-elasticity costs functions as in Doraszelski (2008)). Under Assumption 1, we can set $\lambda = 1$ without loss of generality.

Lemma 1 establishes the existence and uniqueness of a symmetric equilibrium, which is stationary, and characterizes the equilibrium effort levels. We denote by $\Delta\left(x_i\right)$ the distance between the two projects in terms of their payoffs to each agent i:

$$\Delta\left(x_i\right) \triangleq v_i\left(x_i\right) - v_i\left(1-x_i\right).$$

Lemma 1 (Symmetric Equilibrium)
For all $\Delta\left(x_i\right) \geq 0$, there exists a unique symmetric equilibrium, in which the effort level of each agent i at all $t \geq 0$ is given by

$$a_i^*\left(x_i\right) = \frac{\Delta\left(x_i\right) - cr + \sqrt{\left(\Delta\left(x_i\right) - cr\right)^2 + 6crv_i(x_i)}}{3c}. \tag{6}$$

Finally, we define the *first-best* effort levels conditional on x_i as the effort levels chosen by a social planner who maximizes the sum of the agents' payoffs $V_i(x_i, x_{-i})$ defined in (2). As we show in the Appendix, in a symmetric quadratic environment, the first-best effort levels are given by

$$a_i^{FB}(x_i) = \frac{-cr + \sqrt{c^2 r^2 + 4r(v_i(x_i) + v_i(1-x_i))}}{2c}. \tag{7}$$

Intuitively, the equilibrium effort levels depend on the difference $\Delta(x_i)$ between the two projects' payoffs to each agent, while the first best levels depend on their sum $v_i(x_i) + v_i(1-x_i)$.

3.1 Racing vs. Free Riding

We now use the characterization of the effort levels to investigate the welfare properties of the equilibrium as a function of the projects pursued by the agents. Lemma 2 formalizes the intuition discussed in (5) that inefficiently high effort levels, strategic complements, and negative payoff externalities occur simultaneously. It extends the results of Beath, Katsoulacos, and Ulph (1989) and Doraszelski (2008), who analyze R&D races with imperfect patent protection, under the assumption of constant effort levels.

Lemma 2 (Comparative Statics)

1. *The unique pair of projects $(x_i^E, 1-x_i^E)$ that satisfies*

$$\Delta(x_i^E) - \sqrt{2v_i(1-x_i^E)cr} = 0 \tag{8}$$

   induces the first-best effort levels $a_i^*(x_i^E) = a_i^{FB}(x_i^E)$ in the symmetric equilibrium.

2. *Effort choices are strategic complements, and the equilibrium effort levels $a_i^*(x_i)$ exceed the first-best levels $a_i^{FB}(x_i)$ if and only if $\Delta(x_i) > \Delta(x_i^E)$.*

3. *The equilibrium effort levels $a_i^*(x_i)$ are decreasing in c and increasing in $\Delta(x_i)$ and r.*

The intuition behind parts (1.) and (2.) of Lemma 2 is as follows. An increase in agent $-i$'s effort level has two effects on agent i. The first effect is the collaborative element familiar from Aghion and Tirole (1997): since agent $-i$ is more likely to generate positive benefits $v_i(x_{-i})$ to agent i, the marginal value of effort by agent i is lower. This effect is thus the standard free-riding motive that arises whenever the outputs of the two parties are (imperfect) substitutes. The second effect is the competitive element of Rantakari (2012): while agent i is now more likely to realize the benefits $v_i(x_{-i})$, the downside is that he is less likely to realize the benefits $v_i(x_i)$ that he will get if he develops his project first. This effect then *increases* the marginal value of effort because agent i has the possibility of preempting agent $-i$ by also working harder. The incremental payoff $\Delta(x_i)$ that each agent i obtains by implementing his project x_i determines the "stakes of the game" and whether the free-riding effect is stronger than the preemptive effect.

This preemptive motive separates our setup with dynamics from a static game where the agents choose both projects and effort levels. In such a model (which would resemble Aghion and Tirole (1997) with directed efforts), agent $-i$'s action reduces the value of agent i's effort both in the event of success and in the event of failure of agent i's attempt at developing his project. Thus, in a static model, the agents' effort levels are strategic substitutes for any exogenous pair of pursued projects.

Finally, we turn to the role of the discount rate r and of the cost of effort c. In particular, given projects x_i and x_{-i}, there exists a threshold for the product $c \cdot r$ that induces the first-best effort levels. The agents' efforts are strategic substitutes when $c \cdot r$ is above the threshold: if an agent is either very impatient or finds effort to be very costly, he is more likely to benefit from the other agent developing his project and hence to free ride on the other agent's effort.

3.2 Second-Best Projects

If a benevolent social planner could select which projects the agents work on, in addition to dictating the effort levels, she would assigns the projects x_i that yield the highest total value $\Sigma_j v_j(x_i)$. Thus, in a symmetric setting, the agents would work on projects $x_{i,t} = 1/2$, and exert the first-best effort levels $a_i^{FB}(1/2)$. As we will describe in detail, under noncontractibility, these projects cannot be chosen in equilibrium. More importantly, even if they were chosen, Lemma 2 shows that the equilibrium effort levels would be inefficiently low.

We now identify the projects that maximize the sum of the agents payoffs, when effort levels are chosen noncooperatively, i.e., $a_i = a_i^*(x_i)$. Lemma 1 implies that each agent's payoff in a symmetric equilibrium is given by

$$V_i^*(x_i) = v_i(x_i) - \frac{\Delta(x_i) - cr + \sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3}. \tag{9}$$

In Proposition 1, we characterize the *second-best* projects x_i^* that maximize the sum of the agents' equilibrium payoffs $V_i^*(x_i)$. As the previous analysis made clear, these projects must strike a balance between the total value generated and the provision of incentives for equilibrium effort.

In what follows, we denote by ρ the product of the discount rate and the marginal cost parameter,

$$\rho \triangleq c \cdot r.$$

We also define the *expected cost of delay* as $1 - \mathbb{E}\left[e^{-r\tau}\right]$, where τ is the random time of the first breakthrough.

Proposition 1 (Second-Best Projects)

1. *If agents select the second-best projects x_i^*, their effort choices are strategic substitutes, and the equilibrium effort levels $a_i^*(x_i)$ are lower than the first best $a_i^{FB}(x_i^*)$.*

2. *The distance between the second-best projects $\Delta(x_i^*(\rho))$ is strictly increasing in ρ, with $\lim_{\rho\to 0}\Delta(x_i^*(0)) = 0$ and $\lim_{\rho\to\infty}\Delta(x_i^*(\rho)) < 1$.*

3. *The expected cost of delay under the second-best projects is increasing in ρ.*

4. *Each agent's equilibrium payoff $V_i^*(x_i^*(\rho))$ is decreasing in ρ.*

The second-best projects trade-off the expected cost of delay and the quality of the implemented projects. Part (1.) shows that the delay vs. quality trade-off is resolved by projects x_i^* that induce a game of strategic substitutes with equilibrium effort levels below the first best. Intuitively, starting from the efficient effort levels, inducing more compromise entails a second-order loss due to reduced effort, but a first-order gain due to the increased social value of the implemented project.

Part (2.) shows how the resolution of the tension between free-riding and project quality varies with the discount rate and with the cost of effort. As either c or r increases, the second-best projects become more distant, because a higher degree of conflict stimulates effort when the implementation of a project is more urgent or more costly. However, part (3.) shows that this compensation effect is only partial: a higher impatience or a higher cost of effort leads to lower-quality projects and to more costly delays in expectation. Finally, part (4.) shows that payoffs decrease as a result of higher impatience or higher cost.

To summarize, Proposition 1 establishes that a high degree of conflict is detrimental to the organization for two reasons: (a) the value of the projects being developed is low, and (b) the equilibrium effort level is inefficiently high. Compromise in project selection can alleviate the former source of inefficiency, but cannot eliminate the latter, because pursuing high-value projects entails free-riding in equilibrium. A positive degree of conflict in project selection is, in fact, always optimal. In Section 4, we turn to the negotiations phase; and in Sections 5 and 6, we identify conditions under which the second-best projects may be selected in equilibrium.

We conclude this section by discussing the robustness of our efficiency benchmark to non-stationary effort levels and project choices. First, the agents would not benefit from the ability to commit to a deadline, after which no project is implemented. This is unlike the linear-cost model of Bonatti and Hörner (2011), despite free-riding playing a key role in both analyses. Intuitively, a deadline will increase equilibrium effort as time goes by, but may actually yield excessive effort when agents are faced with a significant chance of no project being developed into a proposal. Second, agents would not benefit from committing to work on sequence of projects $x_{i,t}$ that induces lower payoff levels in the future, in order to provide incentives for higher effort early on. This result is unlike the principal-agent model of Mason and Välimäki (2012).

4 Negotiations Phase

We now endogenize the agents' choice of projects when implementation of a project requires their unanimous approval. Specifically, at each time following the development of project x_i, agent $-i$ can choose to implement agent i's proposal. Alternatively, agent $-i$ can try to develop a different project x_{-i}, blocking agent i's initial proposal by refusing to implement it.

Naturally, the incentives to accept or to block a proposal depend on the outcome agent $-i$ expects once he has developed his own project. Our exposition proceeds by backward induction, beginning with the analysis of negotiations over two developed projects. We then consider the agents' incentives to implement the first project developed, and we finally consider the resulting initial project choices.

4.1 Bargaining over Two Projects

We characterize the set of equilibrium payoffs of the subgame that starts once two projects x_i and x_{-i} have been developed. Negotiations take the form of a complete-information war of attrition in continuous time. Let τ_i denote the time at which player i's project x_i is developed. At any $t > \max \tau_i$, each player i can concede and end the game with payoffs $v_j (x_{-i})$, $j = 1, 2$.

It is well known that any equilibrium of a war of attrition has three key properties:[5] (i) at

[5] See, for example, the analysis in Hendricks, Weiss, and Wilson (1988) or the bargaining game with concessions in continuous time by Abreu and Gul (2000).

most one of the agents concedes immediately with positive probability; (ii) after time 0, agent i concedes at a constant hazard rate $rv_i(x_{-i}) / (v_i(x_i) - v_i(x_{-i}))$, which leaves agent $-i$ just indifferent between continuing and quitting; and (iii) if the game does not end immediately, the concessions phase can last forever.

An immediate implication of these properties is that the expected payoff to both parties, once the gradual concessions phase starts, is equal to the value of an immediate quit. Let p_i denote the probability that agent i quits immediately. The equilibrium payoffs of the continuation game with realized proposals x_i and x_{-i} are thus given by

$$\begin{aligned} w_i &= p_{-i} v_i(x_i) + (1 - p_{-i}) v_i(x_{-i}), \; i = 1, 2 \\ \text{s.t. } p_i &\in [0,1], \text{and } p_i \cdot p_{-i} = 0. \end{aligned} \tag{10}$$

The two equilibria with $\Sigma_j p_j = 1$ are Pareto-efficient. Conversely, the unique equilibrium with $\Sigma_j p_j = 0$ entails *full dissipation*, as both agents receive the value of conceding.

4.2 Acceptance Sets

In the negotiations phase, we must specify the continuation equilibrium after any history leading to two developed projects. We restrict attention to equilibria that depend on public histories only, i.e. to immediate concession probabilities p_i that are a function of the developed projects $\underline{x} = (x_i, x_{-i})$ and of their development times $\underline{\tau} = (\tau_i, \tau_{-i})$. Knowing how the game will unfold once both projects are on the table, we consider the incentives of one of the agents to accept the first proposal.

Suppose that agent $-i$ has developed project x_{-i} at time τ_{-i}, and let the functions $p_i(\underline{x}, \underline{\tau})$ characterize the continuation equilibria in the war of attrition. If agent i concedes immediately, he realizes a payoff of $v_i(x_{-i})$. If he decides to block proposal x_{-i}, and he develops project x_i at time τ_i, the expected value of the project that is ultimately implemented is given by

$$w_i(x_i, x_{-i}, \tau_i, \tau_{-i}) \triangleq p_{-i}(x_{i,}, x_{-i}, \tau_i, \tau_{-i}) v_i(x_i) + (1 - p_{-i}(x_{i,}, x_{-i}, \tau_i, \tau_{-i})) v_i(x_{-i}).$$

Agent i can anticipate the unfolding of the war of attrition as a function of which project he develops at which time. Agent i can then optimize his efforts and project choice; in particular, agent i can choose a new project x_i' after agent $-i$ develops project x_{-i}, even if agent i had previously been trying to develop project x_i. However, developing his own project is costly for agent i, in terms of both effort and time. Thus, agent i's continuation value from rejecting a proposal x_{-i} at time τ_{-i} is given by

$$U_i(x_{-i}, \tau_{-i}) \triangleq \max_{\{a_{i,t}, x_{i,t}\}} \int_0^\infty e^{-\int_0^t (r+a_{i,s})\mathrm{d}s} \left[a_{i,t} w_i(x_{i,t}, x_{-i}, t, \tau_{-i}) - c_i(a_{i,t})\right] \mathrm{d}t.$$

Agent i accepts proposal x_{-i} immediately if and only if the value of the proposal $v_i(x_{-i})$ exceeds the continuation value $U_i(x_{-i}, \tau_{-i})$. We can then define the acceptance set $A_{i,t}$ of player i at time t as

$$A_{i,t} = \{x \in [0,1] : v_i(x) \geq U_i(x,t)\}.$$

The more an agent expects to earn from the negotiations phase with two projects on the table, the more the other agent's project must generate compromise in order to be accepted immediately. We illustrate the agents' acceptance sets through two examples.

Example 1 (Full Dissipation) *Let $p_i \equiv 0$ for all i. At the concessions phase, each agent expects a continuation payoff $w_i = v_i(x_{-i})$. Because $U_i < w_i$ for all choices of actions and projects, each agent's acceptance set is given by $A_{i,t} = [0,1]$.*

Intuitively, if agent i expects the negotiations to be very contentious, he knows that the prize for developing project x_i is equal to only the value of the proposal x_{-i} currently on the table, but delayed until the project is realized. Because delay and effort are costly, this leads to immediate acceptance of any proposal at any time.

We define the operator $u(\cdot)$ as the value that each agent assigns to developing a project worth w by himself.

$$u(w) \triangleq \max_a \frac{aw - c(a)}{r+a}. \tag{11}$$

Example 2 (Authority) *Let $p_1 \equiv 0$ and $p_2 \equiv 1$. Thus, with probability one, the negotiations phase ends immediately with a concession by player 2. This means $w_1 = v_1(x_1)$ and $w_2 = v_2(x_1)$. Therefore, agent 2 will accept any proposal: $A_{2,t} = [0,1]$. Following any proposal x_2, agent 1 can choose to develop his preferred project $x_1^* = 1$ by himself. Because this is costly, agent 1 will accept all proposals x_2 above a threshold $\bar{x}_2 < 1$. Agent 1's acceptance set is then given by $A_{1,t} = \{x : v_1(x) \geq u(1)\}$.*

To summarize, we have shown that the requirement of unanimity does not pin down how conflict is resolved. Instead, conflict resolution may take on various forms. In particular, if one agent expects the other agent to never back down from his proposal, then the first agent must compromise on his project and consent to the immediate implementation of the other agent's proposal. Immediate acceptance occurs even if the other agent's proposal offers only minimal value, in order to avoid any further cost of delay. In Sections 5 and 6, we return to the logic of Example 2 in order to characterize the highest degree of equilibrium compromise in project selection.

5 Project Choice under Unanimity

We now relate the continuation equilibria in the negotiations phase to the initial choice of projects and effort levels in the development phase. Each agent i may choose between two strategies: (a) inducing immediate acceptance by developing a project x_i that satisfies agent $-i$; or (b) taking his chances in the negotiation game that follows the completion of both projects. Agent i's choice of project x_i in the development phase depends on the equilibrium he anticipates in the negotiations phase. Moreover, continuation play can induce a scenario where one agent pursues a compromise project while the other agent prepares for the negotiations.

The richness allowed by selecting equilibria in the negotiations phase induces multiplicity of equilibria in the development phase of the game. To build intuition, we revisit Examples 1 and 2 above to complete the description of the subgame-perfect equilibria of the game.

Example 1 (Full Dissipation) *Let $p_i(\underline{x}, \underline{\tau}) = 0$ for all i, x, and τ. Both agents accept any proposal immediately. Therefore, each agent chooses his favorite project, $x_1^* = 1$ and $x_2^* = 0$.*

In Example 1, the expectation of contentious negotiations makes the unanimity requirement entirely ineffective: each agent expects to earn only the value of conceding, if the game ever reaches the war of attrition. Thus the first project to be developed will be implemented. Knowing this, agents engage in a race where each pursues his favorite project. In other words, under full dissipation, immediate concessions are made in the negotiations phase, and no compromise is induced in the development phase.

Example 2 (Authority) *Let $(p_1, p_2) = (0, 1)$ for all x and τ, so that $A_{2,t} = [0, 1]$, $t \geq 0$. Thus, agent 1 will work on his favorite project $x_1^* = 1$. Because $v_2(x_1^*) = 0$, agent 2 compromises and chooses the project $\bar{x}_2 \in (0, 1)$ that satisfies agent 1's acceptance constraint*

$$v_1(\bar{x}_2) = u(1). \tag{12}$$

In Example 2, the need to induce acceptance by agent 1 forces agent 2 to offer some compromise. Furthermore, it is easy to show that agent 2 works harder than agent 1 (intuitively, agent 2 has the most to lose), leading to a greater likelihood of implementing the compromise project $\bar{x}_2$.

5.1 Constrained-Efficient Compromise

We now characterize the equilibria under the unanimity requirement that maximize the agents' total payoff, the resulting initial project choices, and the strategies in the negotiations phase that support the choice of these projects. Following the logic of Example 1, we know that compromise can occur on the equilibrium path only if it is optimal for agent i to block the implementation of agent $-i$'s project x_{-i} whenever it does not generate a sufficiently high payoff $v_i(x_{-i})$.

We define *assigning authority to agent* i as selecting the equilibrium in the war of attrition where agent $-i$ concedes immediately with probability $p_{-i} = 1$ for any pair of projects and development times $(\underline{x}, \underline{\tau})$. We also define the *maximum-compromise* project $\bar{x}_i(\rho)$ as the project satisfying

$$v_{-i}(\bar{x}_i(\rho)) = u(1).$$

Thus, $\bar{x}_i(\rho)$ is the project in the acceptance set of an agent with authority that generates the most compromise.

Finally, we introduce the following assumption on the Pareto frontier.

Assumption 2 (Gains from Compromise)
The Pareto frontier $v_2(v_1)$ satisfies $v_2''(v_1) < v_2'(v_1)/2v_1$.

This assumption requires the frontier to be sufficiently concave, i.e., the gains from compromise to be sufficiently large. For example, it is satisfied if $v_2(v_1) = (1 - v_1^n)^{1/n}$ and $n > 5/4$. For the remainder of this section, we maintain Assumptions 1 and 2. Finally, we let $\bar{\rho}$ denote the root of the following equation,

$$v_{-i}(x_i^*(\rho)) + \sqrt{2\rho v_{-i}(x_i^*(\rho))} = 1. \tag{13}$$

In the proof of Proposition 2 we show this root is unique and strictly positive.

Proposition 2 characterizes the *constrained-efficient* project choices and effort levels that can arise as part of an equilibrium outcome a under unanimity rule.

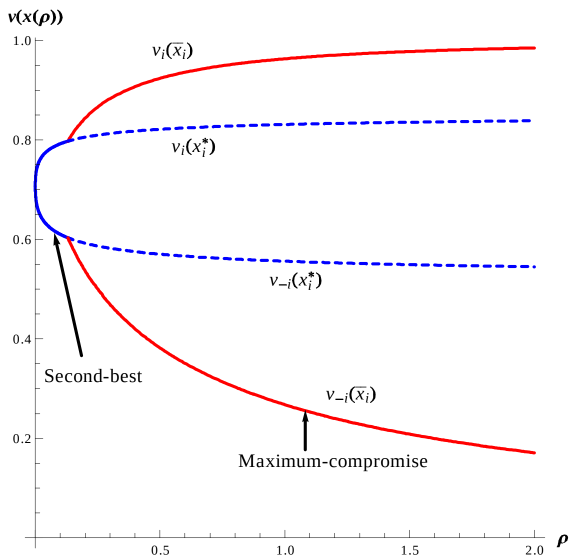
Proposition 2 (Constrained-Efficient Compromise)

1. *For all $\rho \leq \bar{\rho}$, there exists an equilibrium in which agents develop the second-best projects $x_i^*(\rho)$, and proposals are accepted immediately.*

2. *For $\rho > \bar{\rho}$, the highest equilibrium total payoff is obtained by assigning authority to the second agent who develops a project. Agents develop the maximum-compromise projects $\bar{x}_i(\rho)$, and proposals are accepted immediately.*

The constrained-efficient projects and effort levels coincide with the second-best when agents are sufficiently patient and the costs of effort are sufficiently low; and they induce the maximum equilibrium compromise when costs and impatience are too high. Figure 2 shows the values $v_i(x_i)$ and $v_{-i}(x_i)$ of the equilibrium projects x^* and $\bar{x}$ as a function of ρ.

Figure 2: Constrained-Efficient Project Values



Assigning authority to the agent who develops his project second causes each agent to develop project $\bar{x}_i(\rho)$. When agents are sufficiently patient ($\rho < \bar{\rho}$), the resulting degree of compromise is inefficiently high, i.e. $\Delta(\bar{x}(\rho)) < \Delta(x^*(\rho))$. There exist, however, other equilibria in the negotiations phase that are less extreme that the assignment of authority, and induce the second-best choice of projects and effort levels. More specifically, we consider a class of equilibria where the probabilities of immediate concession depend only on the ranking of the breakthrough times ($\tau_i \gtrless \tau_{-i}$) and reward the second agent who develops his project. In particular, let the immediate-concession probabilities be given by

$$p_i(\underline{x}, \underline{\tau}) = \begin{cases} 0 & \text{if} \quad \tau_i > \tau_{-i}, \\ p & \text{if} \quad \tau_i < \tau_{-i}. \end{cases} \tag{14}$$

As agents grow impatient, the bargaining power of the agent receiving the first proposal vanishes, and the highest degree of compromise is very low even as $p \to 1$. However, the distance between the second-best projects remains bounded, as shown in Proposition 1. Therefore, for high values of ρ, there is no immediate-concession equilibrium in the negotiations phase that can induce the second-best degree of compromise. The highest equilibrium total payoff is then obtained by assigning authority to the receiver of the first proposal. Note that several equilibria induce the second-best project choices when agents are patient. However, a unique equilibrium (which corresponds to setting $p = 1$ in (14)) induces the choice of the maximum-compromise projects $\bar{x}_i(\rho)$.

5.2 Discussion

In the equilibria described above, the agents initially work on projects that yield immediate acceptance, but they would switch to their favorite projects upon receiving an unacceptable offer (off the equilibrium path). Immediate acceptance is also a feature of the no-compromise result in Example 1. The difference in the projects chosen in the two scenarios is driven by the agents' expectations regarding how negotiations would unfold after two projects have been developed. In both scenarios, these negotiations never occur on the equilibrium path.

Therefore, seemingly identical organizations may generate significantly heterogeneous levels of performance if they anticipate different continuations off-path in the negotiations phase. Furthermore, there is no scope for learning in our model, and switching from one equilibrium to another requires a shift in the organization's beliefs about off-path events. In other words, the unanimity requirement can yield persistent performance differences among seemingly similar enterprises, as they relate to the ability to induce beliefs in a less conflictual negotiations phase.[6]

Finally, we remark that Proposition 2 does not rely on two of our modeling assumptions. In particular, agents would not exercise the option to develop more than one project on the equilibrium path (one before the other agent develops his project and the other after), even if we allowed them to. Moreover, agents would immediately reveal a breakthrough even if they privately observed their project's development.

The latter result is more nuanced: if breakthroughs are privately observed, agents can develop their favorite project, and present it as a counteroffer following the development of the other agent's project. In the continuation equilibria used in Proposition 2, this counteroffer

[6] These consequences of different continuations in the negotiations phase are analogous to the different cultural beliefs among the Genoese versus the Maghribi traders discussed by Greif (1994). The difficulty of switching equilibria as a source of persistent performance differences is discussed in Gibbons and Henderson (2013).

is accepted with probability $p > 0$. However, under Assumption 2, we can show that this deviation is never profitable:[7] when agents are very patient, the equilibrium probability of implementing counteroffers is too low; and as they grow impatient, the cost of waiting for the other agent's breakthrough is too high. Assumption 2 ensures that offering some compromise is sufficiently "cheap" for the agents, so that they prefer developing the constrained-efficient projects.

6 Rules and Delegation

In this section, we examine the following two team-design variables: (a) commitment to a mechanism that dynamically assigns decision rights over the implementation of a project, and (b) delegation of ex-post decision rights to an impartial third-party who lacks commitment power. These two scenarios correspond to two different contracting environments: in the former, rules that specify ex-post decisions are contractible, though effort levels and project characteristics are not; in the latter, ex-post decisions are not contractible, but ex-ante decision rights can be assigned to a single agent.[8]

6.1 Rules with Commitment

We assume that the agents can commit to ex ante rules that assign decision rights ex post as a function of the history of developed projects. In particular, when a project x_i is developed, a mechanism specifies which agent can implement it, and if so at what time. In principle, the allocation of decision rights could depend on the entire public history. However, because we assume non-contractibility of project characteristics, we allow the mechanism to condition on agent identities and project development times only.

We first describe two deterministic mechanisms that achieve the *constrained-efficient* project choices and effort levels characterized in Proposition 2. We then turn to alternative, perhaps more intuitive mechanisms (including stochastic ones), and we discuss the reasons behind their failure to perform as well.

The first mechanism consists of assigning *delayed authority* to the second agent who develops a project. It may be described as follows. Suppose agent i develops project x_i first. Agent $-i$ can accept project x_i at any time, in which case it is implemented immediately. If

[7] The (tedious) proof of this result is in Lemma 3 in the Appendix.

[8] In Subsection 6.2, we consider the assignment of decision rights to a third-party. In ongoing work, we compare these results to a setting closer to Aghion and Tirole (1997), in which one of the two agents is assigned formal authority.

agent $-i$ develops a competing project x_{-i} at time τ, he has the authority to implement it at any time $t \geq \tau + T$. In Propositions 3 and 4, we use the threshold $\bar{\rho}$ defined in (13).

Proposition 3 (Delayed Authority to Second Developer)

1. *The optimal delayed-authority mechanism induces the constrained-efficient project choices and effort levels.*

2. *If $\rho < \bar{\rho}$, the optimal delay $T^* (\rho)$ is strictly positive and strictly decreasing in ρ.*

3. *If $\rho \geq \bar{\rho}$, the optimal delay $T^* (\rho)$ is equal to zero.*

In the baseline model under unanimity, each agent can block the implementation of any project. Under the delayed-authority mechanism, the cost of developing the first project is losing all decision rights. This is not sufficient to generate the second-best degree of compromise. It is also necessary that the second agent who develops a project can implement it only with delay. Delay introduces an ex-post inefficiency analogous to the dissipation in a war of attrition with gradual concessions. In order to compensate for growing impatience or cost levels, the optimal delay (as well as the expected cost of delay) must decrease as ρ increases. The optimal delay vanishes when $\rho = \bar{\rho}$ and the second-best project choice is no longer attainable.

The second mechanism consists of a *deadline for counteroffers*. It may be described as follows. Suppose agent i develops project x_i at time τ. A deadline for counteroffers is a time T such that agent $-i$ can implement any project he develops between time τ and time $\tau + T$. If agent $-i$ does not develop any project before $\tau + T$, all projects are abandoned, and no project can be implemented.

Proposition 4 (Deadline for Counteroffers)

1. *The optimal deadline for counteroffers induces the constrained-efficient project choices and effort levels.*

2. *If $\rho < \bar{\rho}$, the optimal deadline $\hat{T} (\rho)$ is finite, and $\rho \hat{T} (\rho)$ is strictly increasing in ρ.*

3. *If $\rho \geq \bar{\rho}$, the optimal deadline $\hat{T} (\rho)$ is infinite.*

Both these mechanisms exploit the ability to commit to ex-post inefficient actions. A general picture then emerges where some *dissipation* off the equilibrium path appears necessary to induce the second-best project choice on path. Dissipation is introduced in the form of deterministic delay in Proposition 3 and in the form of probabilistic abandonment in Proposition 4. Procedures that induce dissipation are not unreasonable in many settings, such as a hiring committee that is part of a larger organization. Delayed authority to the second developer is then similar to a rule that requires additional screening or external evaluation of any candidate unless a consensus is built around the first candidate. Similarly, a deadline for counteroffers corresponds to “losing the hiring slot,” e.g., in favor of another department, if a committee member vetoes a candidate and fails to suggest an alternative candidate in a reasonable time.

Furthermore, we conjecture that every mechanism prescribing an ex-post efficient decision whenever choosing between two projects fails to induce the constrained-efficient outcomes for all parameter values. To gain more intuition, contrast the optimal deadline for counteroffers with a similar mechanism that implements the first project x_i at the deadline for counteroffers $\tau + T$. In the latter case, the receiver of the first proposal (agent $-i$) never accepts x_i immediately. Instead, he exerts effort until the deadline and pursues his favorite project. Intuitively, the flow cost of waiting is given by $rv_{-i}(x_i)$, but agent $-i$ can generate a much higher expected flow return by working on his favorite project. This mechanism does generate a positive degree of compromise, because a more favorable first proposal reduces the second agent’s incentives to exert effort towards a counteroffer. However, it fails to induce the constrained-efficient equilibrium outcome.[9]

The role of dissipation is not diminished if lotteries are allowed. For instance, the optimal deadline for counteroffers is clearly outcome-equivalent to a mechanism in which a coin is flipped upon development of the second project: with probability p, the second project is implemented; and with probability $1 - p$, all projects are abandoned. As in the case of a deadline, such a mechanism could not implement the first project with probability $1 - p$ and preserve the efficiency property. If it did, each agent would find it optimal to develop his favorite project, induce the other agent to develop a counteroffer, and then play the lottery. In particular, this strategy is profitable when agents are very patient.

6.2 Delegation without Commitment

So far, the organization relied on equilibrium selection (in Proposition 2), or on commitment to rules (in Proposition 3). We now consider delegating decision rights over the implementation of developed projects to a third party (“the mediator”). The mediator is impartial: she maximizes the sum of the agents’ payoffs. We compare the impact of the mediator on the agents’ choice of projects under two settings: one in which the mediator has the right to implement any developed project at any time; and another in which the mediator can only

[9] The basic logic of this discussion would not change if we required the second agent to wait until the deadline $\tau + T$ to implement any project he may have developed before then.

break ties between two developed projects by choosing which one to implement. In either case, the mediator cannot commit to a strategy.

We begin with full decision rights in the hands of the mediator. In spite of her preferences for compromise, the mediator is unable to induce any convergence between the agents' project choices.

Proposition 5 (Mediator Makes Implementation Decision)
If the mediator makes all implementation decisions, the agents develop their favorite projects, $x_1^* = 1$ *and* $x_2^* = 0$.

This result is based on a simple unraveling argument. Once the first agent has developed a project, the mediator can either implement it or wait for a second project. If she waits, the second agent develops a project that is only slightly better for the mediator (but substantially better for himself). The mediator would then accept the latter, and thus incur additional time and effort costs. Foreseeing this, the mediator will not wait, and she will implement whichever project is developed first. Therefore, each agent chooses his favorite project, and no compromise is possible.

An impartial mediator is unable to induce any compromise because her choice is constrained by the projects developed by the agents. In contrast, under a unanimity requirement, the possibility to pursue his own project gives each agent a credible outside option to block the implementation of the other agent's project. Since the mediator does not generate projects herself, her only outside option is to rely on the project provided by the other agent. Because this outside option is weak, retaining the ultimate decision rights is useless for the mediator: the resulting project choices could be obtained by imposing unanimity and letting the agents negotiate; but negotiation can lead to much more efficient outcomes as well.

We now consider a modified negotiations phase, in which the two agents can appeal to a mediator only when deadlocked, i.e., with two proposals on the table. The mediator then acts as a tie-breaker, and implements the project with the higher social value. Proposition 6 summarizes the equilibrium outcome.

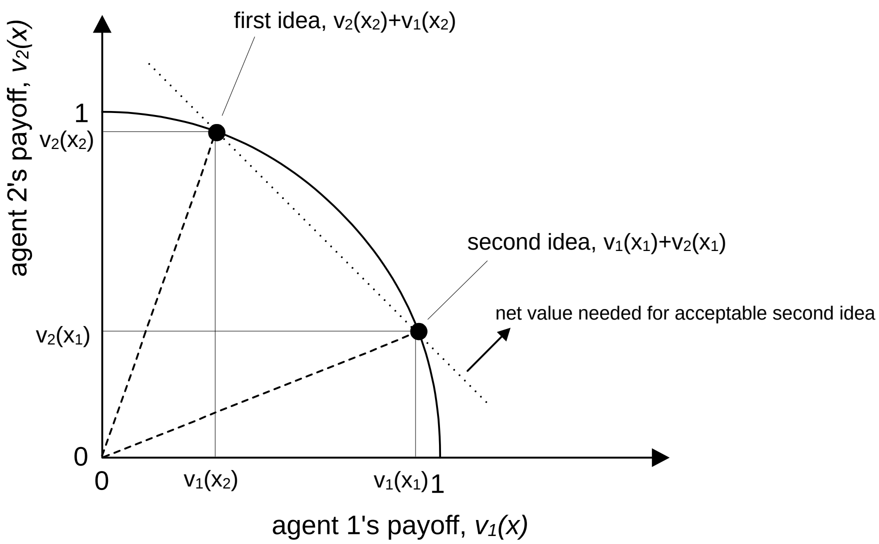
Proposition 6 (Mediator Breaks Ties)
If the mediator breaks ties in favor of the proposal x_i *that maximizes* $\Sigma_j v_j(x_i)$, *the agent* i *choose the projects* $x_i^E(\rho)$ *that induce the efficient effort levels, and the first proposal is accepted.*

When the mediator breaks ties, she is able to select a specific equilibrium of the baseline model. In this equilibrium, agents have an implicit understanding that if two projects have been developed, they will select the more socially valuable. In the negotiations phase of what we call the "efficient continuation" equilibrium, agent i chooses the immediate-concession probability $p_i = 1$ if and only if $\Sigma_j v_j(x_i) < \Sigma_j v_j(x_{-i})$. Under these strategies, the acceptance set of agent i is given by

$$A_i = \{x : v_i(x) \geq u(v_{-i}(x))\}.$$

In order to prevail in the negotiations phase, agent i must develop a project that gives the sum of the agents at least as much as under the standing proposal x_{-i}. Agent i makes this constraint bind, by selecting a project that yields slightly more total surplus than x_{-i} and grants agent $-i$ exactly as much as he received under the original proposal x_{-i}, i.e. $v_{-i}(x_i) = v_i(x_{-i})$. Figure 3 illustrates the equilibrium outcome.

Figure 3: Compromise under Tie-Breaking



In this equilibrium, agent i receives from agent $-i$'s proposal a payoff equal to his continuation value: agent $-i$'s effort does not impose an externality on agent i. In other words, agents choose the threshold projects $x_i^E(\rho)$ that induce the efficient effort levels. Recall that projects $x_i^E(\rho)$ satisfy the following condition

$$\Delta(x_i^E) = \sqrt{2v_i(1 - x_i^E)\rho}.$$

It follows that the equilibrium projects $x_i^E(\rho)$ become more polarized as impatience or costs increase.

To summarize, decision-making by the mediator fails due to the lack of a direct access to viable alternatives (as in Rantakari (2012)). Tie-breaking by the mediator, on the other hand, provides alternatives that are limited by the agents' ex-ante project choices. Recall from Proposition 1 that $\Delta(x_i^E) > \Delta\left(x_i^*\right)$. Therefore, the mediator is able to select an equilibrium outcome that induces a (positive but) suboptimal degree of compromise.

Finally, notice that our analysis of equilibria under unanimity (in Section 5) and of procedures for assigning decision rights (in Section 6) has focused exclusively on the choice of the constrained-efficient projects and effort levels. A complementary approach that we pursue in ongoing work consists of identifying more narrow classes of feasible team designs and deriving the optimal design and its induced outcome. This alternative approach is especially useful when (a) investigating the best design in the absence of dissipation and how its outcome differs from the constrained-efficiency benchmark, and (b) analyzing the efficiency properties of the outcome under delegation when the mediator can commit to a course of action.

7 Extensions

We now extend our baseline model to address two questions: Should teams be composed of agents with aligned preferences? Should monetary transfers be allowed as a part of ex-post negotiations? The answer to latter constitutes ongoing work.

7.1 Preference Alignment

The baseline model assumed that the conflict between the agents was maximal: each agent's favorite project generates no value for the other agent. We now extend the analysis to account for partial alignment of interests. In particular, we assume that agents $i = 1, 2$ have preferences of the following form,

$$w_i\left(\alpha, x\right) = \left(1 - \alpha\right) v_i\left(x\right) + \alpha v_{-i}\left(x\right), \tag{15}$$

where the functions $v_i(x)$, $i = 1, 2$ are as in the baseline model, and $\alpha \in [0, 1/2]$ measures the degree of preference alignment.[10]

We analyze the effect of alignment on the equilibrium choice of projects and effort levels. To keep the illustration simple, we assume the negotiations phase induces immediate concession by the first proposer with probability p. (As we showed in Proposition 3, this class

[10] We interpret alignment as a characteristic of the two agents' preferences, though alignment could also be obtained through explicit incentive contracts. For example, the reward function (15) arises if two division managers are compensated linearly based on both their division's performance and the firm's overall performance.

of equilibria is outcome-equivalent to a game with delayed authority or with a deadline for counteroffers.)

When the agents' preferences are given by (15), the immediate-acceptance constraint in the negotiations phase can be written as

$$w_{-i}(\alpha, x_i) \geq u\left(pw_{-i}\left(\alpha, x_{-i}^*(\alpha)\right) + (1-p)\, w_{-i}(\alpha, x_i)\right), \tag{16}$$

where $x_{-i}^*(\alpha)$ denotes agent $-i$'s favorite project. In Proposition 7, we denote by $x_i(\alpha, p)$ the solution to (16) holding with equality.

Proposition 7 (Effect of Preference Alignment)

1. *For any $p \in [0,1]$, there exists a threshold $\alpha^* \in (0, 1/2)$ such that the equilibrium project choice is given by $x_i(\alpha, p)$ for $\alpha < \alpha^*$, and by $x_i^*(\alpha)$ for $\alpha \geq \alpha^*$.*

2. *The difference in equilibrium projects $\Delta(x_i(\alpha, p))$ is increasing in α and decreasing in p for $\alpha < \alpha^*$. It is decreasing in α for $\alpha \geq \alpha^*$.*

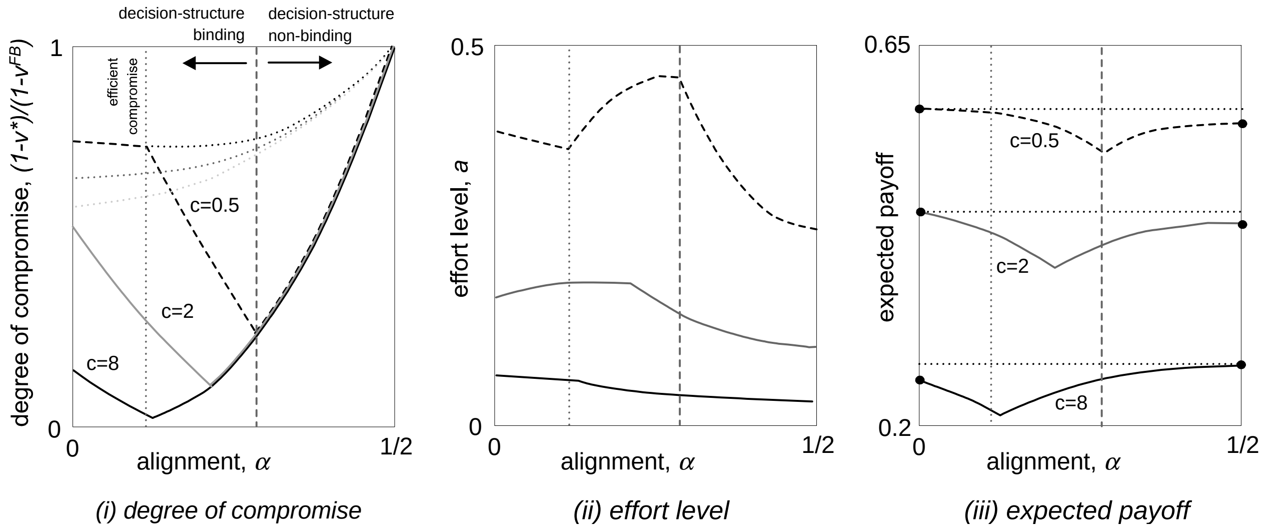
Part (1.) establishes that the immediate-acceptance condition (16) provides a binding constraint on the agents' choice of projects for low levels of α. Once incentives are sufficiently aligned, this acceptance constraint may no longer bind, because each agent's favorite project now generates sufficient value for the other agent. Part (2.) shows that, as long as (16) binds, increasing the preference alignment *reduces* the degree of compromise. As a corollary, we immediately obtain that the maximum level of equilibrium compromise is decreasing in α whenever (16) binds. If (16) does not bind, the degree of compromise is then increasing in α.

This result illustrates the basic message of our baseline model (with its unanimity requirement): the presence of conflict achieves alignment of *projects*, because having one project implemented requires the acquiescence of both agents. The larger the conflict, the larger the compromise that each agent must select in order to have his project accepted. As the agents' preferences become more aligned, the amount of compromise needed to win the other agent's support decreases, and the choice of projects actually diverges. Preference alignment may indeed weaken organizational performance by reducing each player's ability to credibly threaten a costly counteroffer.

In Figure 4, we illustrate the team's performance in terms of project choices, effort levels, and payoffs.[11] For each level of α, we select the probabilities p yielding the highest equilibrium total payoff.

[11] with $r = 0.1$ and $v_{-i}(v_i) = \sqrt{1 - v_i^2}$.

Figure 4: Preference and Project Alignment



Panel (i) illustrates the project choices: when the agents are sufficiently efficient ($c = 0.5$) and preference alignment is sufficiently low, the efficient degree of compromise is attainable; as the level of alignment increases, the level of compromise that can be induced begins to decrease, until (16) no longer binds; for even larger values of α, the level of alignment begins to increase again as the agents inherently desire increasingly balanced projects. For higher cost levels ($c \in \{2, 8\}$), the same logic holds, except that the efficient degree of compromise is not attainable even when $\alpha = 0$. Further, the acceptance constraint induces less alignment for any given α and becomes non-binding for a lower threshold α^*.

Panel (ii) shows that preference alignment has an ambiguous impact on the effort levels of the agents. On one hand, the divergence in the projects supports stronger incentives to work, but on the other hand, the increased degree of alignment increases the free-riding incentives.

Panel (iii) shows that the agents' expected payoff is U-shaped in α. Thus, maximal conflict is beneficial when the agents are either patient or efficient: unanimity is then able to harness the existing conflict to yield considerable compromise. Conversely, complete preference-alignment is preferred when the threat of negotiations is not sufficient to generate compromise, i.e. when the agents' cost of effort and discount rate are high.

To conclude, we should note that the effect of alignment depends on the continuation equilibrium in the negotiations phase. For instance, suppose the team is rather dysfunctional, and negotiations are (expected to be) carried out through a war of attrition without immediate concessions. In this case, no compromise is obtained in equilibrium in the absence of preference alignment. Therefore, the use explicit preference alignment will be valuable. Outside our model, alignment of interests may become valuable if the organization needs to rely on strategic communication to ascertain the actual value of proposals on the table.[12] In short, we do not claim that conflict is always good. What we have shown is that some decision structures (most notably, unanimity) are able to harness conflict to generate compromise, and that the efficiency of such decision structures can be undermined if the conflict in preferences is reduced.

7.2 Monetary Transfers

The analysis above showed the limitations of using ex-ante incentive alignment to reduce the equilibrium amount of conflict. In ongoing work, we consider allowing ex-post transfers to support negotiations between the two agents. A complete analysis is challenging because there are various bargaining protocols that one could consider, with potentially differing solutions. It appears, however, that ex-post transfers will be of limited use in equilibrium. In other words, while the exact outcome under ex post bargaining may depend delicately on the exact bargaining protocol one assumes, in many cases allowing ex post monetary transfers is, at best, irrelevant.

In the baseline model, the transfers needed to buy the acceptance of the other party are made in terms of the projects developed, rather than in cash. It is, in fact, often cheaper to buy such acceptance through an efficiency-enhancing policy compromise. To see this, suppose that transfers are feasible, and the first project x_i has been developed. Implementing that project will yield $v_i(x)$ to the originator i, while yielding $v_{-i}(x)$ to the other agent. If the second agent continues his search and agreement is deferred to that point, the net present value of the final payoffs to the two agents are given by V_i and V_{-i}. Then, agent i is willing to pay at most $v_i(x) - V_i$ to have the project accepted while agent $-i$ requires at least $V_{-i} - v_{-i}(x)$ to accept implementation. Assuming that the bargaining power of the agent without a project in this stage is β, the transfer satisfies

$$P(x) = (1-\beta)(V_{-i} - v_{-i}(x)) + \beta(v_i(x) - V_i).$$

Thus, we can write agent i's payoff at this stage as

$$(1-\beta)(v_i(x) + v_{-i}(x)) + \alpha V_i - (1-\beta)V_{-i}.$$

[12] In ongoing work, Rantakari (2013) analyzes a model of an organizational structure with some of these features.

In fact, for any project x, the agent can now compensate the other agent to induce acceptance by using the transfer P. Each agent will now optimize with respect to the project x. The first-order condition is given by

$$(1-\beta)\left(\frac{\partial v_i(x)}{\partial x}+\frac{\partial v_{-i}(x)}{\partial x}\right)+\beta\frac{\partial V_i}{\partial x}-(1-\beta)\frac{\partial V_{-i}}{\partial x}=0.$$

Denote the solution to this problem by x^*. If x^* is such that $P(x^*)\leq 0$, we know that agent i prefers to induce acceptance solely by providing a policy compromise instead of using a transfer. Conversely, if $P(x^*)>0$, then a positive transfer is made in equilibrium.

The equilibrium outcome depends on the payoffs V_i and V_{-i} in the bargaining game following the development of a second project. In particular, the agents' initial choice of projects is driven by the sensitivity of the continuation payoffs to the characteristics of the two projects on the table. However, the first term shows that each agent tends to prefer policy compromise over monetary transfers whenever the equilibrium proposals are biased in their favor relative to the first best. This follows directly from the concavity of the Pareto frontier. Then, it is simply more economical to compensate the other agent through a policy compromise, where \$1 compromise gives the other agent more than \$1 in return, than using monetary transfers.

Finally, we remark that in some cases, compromise may further expose the proposing agent to hold-up. As a result, money rather than policies will be used to induce acceptance. But such an approach is clearly detrimental to the organization. In fact, any initial excessive compromise can always be dealt with through changes in the decision-making structure, while the access to transfers potentially reduces the level of equilibrium compromise. In addition, if the Pareto frontier satisfies an Inada condition $\lim_{x\to 1}|\partial v_2(x)/\partial x|=\infty$, agent 1 will always propose some compromise.

8 Concluding Remarks

We have analyzed a collective decision-making problem in which members of an organization develop projects and negotiate over implementation decisions. A key trade-off emerges between the total value of the projects selected and the incentives to exert effort towards their development. Limits to contractibility of effort levels and project characteristics make the socially efficient outcome not attainable in equilibrium. Our main message is that the constrained-efficient level of compromise can be achieved in the presence of conflict between the agents' goals, provided that agents select the right equilibrium. In some cases, conflict is even beneficial, because it breeds compromise and consensus without jeopardizing the incentives to work hard. Moreover, if agents can commit to a procedure for resolving conflict when two projects have been developed, they can overcome the equilibrium selection problem. In particular, imposing deadlines for presenting counterproposals or delaying their implementation achieves the constrained-efficiency benchmark.

Our setting is quite stylized, and our results hold under a number of assumptions. We now discuss a few promising directions for enriching the current analysis.

Endogenous Project Quality. In our model, the agents' payoffs from implementing any project x are deterministic. In many cases, the overall value of a developed project is not known ahead of time, and agents may be able to influence it. Consider for example, a model with *endogenous ambition*: conditional on obtaining a breakthrough, agent i's value of project x is given by $q \cdot v_i(x)$, where $q \in \{0, \bar{q}\}$ measures product quality. Agents may choose whether to pursue: low-risk, low-return methods that deliver a low-quality project with high probability; or more challenging, but more rewarding methods that deliver a high-quality project with a lower probability. Agents then face a trade-off between more ambitious projects and the likelihood of developing them in a short time. Endogenous ambition will influence the equilibrium degree of compromise. In particular, agents will be able to reduce the extent of project alignment by choosing more ambitious methods.

A further extension of the model with endogenous ambition consists of assuming that the quality q of any project is randomly determined upon completion, with q drawn from an exogenous continuous distribution. If agents can produce several versions of the same type of project, the development phase becomes analogous to a sequential-sampling problem: each agent can generate multiple projects with similar characteristics and heterogeneous quality levels; he then chooses a threshold quality level above which he presents a project as a proposal. The ability to sample sequentially may then restore the ability of an impartial mediator to impose a "quality standard," and deliver new insights into the effects of delegating decision rights.

Multi-step Projects and Learning. The completion of a project is rarely an all-or-nothing outcome. Instead, most projects progress in multiple steps. In such a setting, completion of an intermediate step by an agent may encourage or discourage the other agent's further development efforts. In particular, if the degree of initial compromise is sufficiently high, the other agent may choose to abandon his own project, and join forces on the project closer to completion. Furthermore, the success of any particular project may be uncertain, with additional information learned during the development process or upon completion of an intermediate step. Agents take the possible arrival of news into account when choosing their initial projects. In such a setting, an important team-design variable is whether to publicly release information about the progress level of each project.

Agency Model and Moral Hazard. We have so far assumed that the team sets its own rules, and that any third-party is akin to a benevolent social planner. Some of the dynamics of our model would change if the team were managed by a principal. A natural starting point is one in which the principal has a taste for compromise projects, does not internalize the agents' cost of effort, and cannot contract on effort or project types. In an agency model, the analysis of the development phase with fixed projects is unchanged. However, the benchmark in which the principal could command project types would be substantially different. The principal values a timely completion relatively more than the agents. She may ask them to develop projects that entail effort levels above the socially efficient level, i.e. induce a race. Furthermore, the principal would make use of dynamic incentives, if given the option to do so. In particular, deadlines and other mechanisms (such as assigning the agents to projects with an increasing degree of compromise) may generate higher effort levels early on, compared to assigning the agents to a constant project. While these incentives are suboptimal from the point of view of the team, they may benefit the principal from an ex-ante perspective.

Appendix

Proof of Lemma 1. Each agent chooses an effort level $a_{i,t}$ to solve the maximization problem in (3). The first-order condition for optimal effort at time t is given by

$$c'\left(a_{i,t}\right) = \max\left\{v_i\left(x_i\right) - V_{i,t}, 0\right\}. \tag{17}$$

For any symmetric action profile $a_{i,s} = a_s$, $s \geq t$, the agent's continuation payoff at time t can be written as

$$V_{i,t} = \int_t^\infty e^{-\int_t^s (r+2a_z)\mathrm{d}z} \left(a_s\left(v_i\left(x_i\right) + v_i\left(x_{-i}\right)\right) - c\left(a_s\right)\right) \mathrm{d}s.$$

Because each project x_i is developed with equal probability, but effort and delay are costly, agent i's payoff $V_{i,t}$ is bounded by

$$V_{i,t} \in \left[0, \left(v_i\left(x_i\right) + v_i\left(x_{-i}\right)\right)/2\right), \tag{18}$$

for any symmetric action profile $a_{i,s} = a_s$. Furthermore, for all $\Delta\left(x_i\right) \geq 0$, the equilibrium payoff is strictly lower than $v_i\left(x_i\right)$. Hence, at a symmetric equilibrium, each agent's action is given by the interior solution

$$c'\left(a_{i,t}^*\right) = v_i\left(x\right) - V_{i,t} > 0 \quad \text{for all } t.$$

We first look for a symmetric equilibrium with a constant value $V_{i,t} = V^*$, and therefore constant effort levels $a_{i,t}^* = a^*$. In a symmetric quadratic environment, a symmetric equilibrium effort level must satisfy

$$a^* = \arg\max_a \left[\frac{a v_i\left(x_i\right) + a^* v_i\left(x_{-i}\right) - ca^2/2}{r + a + a^*}\right].$$

The first-order condition for this problem is

$$\left(v_i\left(x_i\right) - ca^*\right)\left(r + 2a^*\right) = a^*\left(v_i\left(x_i\right) + v_i\left(x_{-i}\right)\right) - c\left(a^*\right)^2/2,$$

and the expression for a_t^* given in (6) is the unique positive root to this equation. Each agent's symmetric equilibrium payoff is then given by (9).

Conversely, suppose there exists an equilibrium with non-constant effort levels a_t^* and payoffs V_t^*. Because we know equilibrium effort is positive for all t, we can substitute the interior solution to first-order condition (17) into the HJB equation (3), and obtain the following ordinary differential equation for the equilibrium payoff,

$$\dot{V}_t = rV_t - \frac{(v_i(x_i) - V_t)^2}{2c} - \frac{(v_i(x_i) - V_t)(v_i(x_{-i}) - V_t)}{c}. \tag{19}$$

The solution to this differential equation is given by

$$V_t^*(k) = v_i(x_i) - \frac{\Delta(x_i) - cr}{3} + \frac{\sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3} \frac{1 - ke^{-\frac{t}{c}\sqrt{(\Delta(x_i)-cr)^2+6crv_i(x_i)}}}{1 + ke^{-\frac{t}{c}\sqrt{(\Delta(x_i)-cr)^2+6crv_i(x_i)}}},$$

for some constant of integration k. However, the solution $V_t^*(k)$ in (19) satisfies

$$\lim_{t\to\infty} V_t^* = v_i(x_i) + \frac{-(\Delta(x_i) - cr) + \sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3}.$$

Therefore, for t large enough, we have

$$\lim_{t\to\infty} [V_t^* - v_i(x_i)] > 0,$$

which violates the bound in (18), and contradicts the hypothesis that V_t^* is a symmetric equilibrium payoff. ■

Proof of Lemma 2. (1.) If the social planner maximizes the sum of the agents' payoffs (2), her objective function is given by

$$W(x_i, x_{-i}) = \int_0^\infty e^{-\int_0^t (r+\Sigma_i a_{i,s})ds} \Sigma_{i=1}^2 \left(a_{i,t}\Sigma_{j=1}^2 v_j(x_i) - c_i(a_{i,t})\right) \mathrm{d}t.$$

The value function W_t can be written recursively as

$$rW_t = \max_{a_{i,t}} \left[\Sigma_{i=1}^2 \left(a_{i,t}\left(\Sigma_{j=1}^2 v_j(x_i) - W_t\right) - c_i(a_{i,t})\right) + \dot{W}_t\right].$$

In a symmetric quadratic environment, the optimal effort levels are then given by (7).

Setting $a_{i,t}^*$ in (6) equal to $a_{i,t}^{FB}$ in (7) and solving for $v_i(x_{-i})$, we obtain a unique solution $v_i(x_{-i}) \in [0, v_i(x_i)]$ that is given by

$$v_i\left(x_{-i}^E\right) = \frac{\Delta\left(x_i^E\right)^2}{2cr},$$

and corresponds to the solution of equation (8) in the text.

(2.) Let $i = 1$, so that $v_i(x_i)$ is increasing in x_i. It is immediate to see that $a_{i,t}^{FB}(x_i)$

in (7) is decreasing in x_i for all $\Delta(x_i) \geq 0$, while the equilibrium effort level $a^*_{i,t}$ in (6) is strictly increasing in x_i. Therefore, the sign of $a^*_{i,t} - a^{FB}_{i,t}$ coincides with the sign of $\Delta(x_i) - \sqrt{2v_i(1-x_i)cr}$, which we know is equal to zero for the projects x_i^E defined in (8).
(3.) These comparative statics follow immediately from differentiation of $a^*_{i,t}$ in (6). ■

Proof of Proposition 1. (1.) In a symmetric quadratic environment, let $v = v_i(x_i)$, and denote agent i's payoff from agent $-i$'s project $v_i(x_{-i})$ by

$$y(v) \triangleq v_i\left(1 - v_i^{-1}(v)\right).$$

We can then write each agent's equilibrium payoff in terms of v and ρ as

$$V_i(v) = \frac{2v + y(v) + \rho - \sqrt{(v - y(v) - \rho)^2 + 6\rho v}}{3}. \tag{20}$$

Differentiate with respect to v and obtain

$$V_i'(v) \propto 2 + y'(v) - \frac{(v - y(v) - \rho)(1 - y'(v)) + 3\rho}{\sqrt{(v - y(v) - \rho)^2 + 6\rho v}}. \tag{21}$$

Because the payoff frontier is symmetric, the sum of the agents' payoffs $\Sigma_i v_i(x)$ attains a maximum at $x = 1/2$. Therefore, we have $y(v) = v$ and $y'(v) = -1$. Substituting into (21), we obtain

$$1 - \frac{\rho}{\sqrt{\rho^2 + 6\rho v}} > 0.$$

As $x \to 1$, we obtain $v = 1$ and $y = 0$. Furthermore, by the concavity of the payoff frontier, we have $y'(1) < -1$. Substituting into (21), we obtain

$$1 - \frac{2 + \rho}{\sqrt{(1-\rho)^2 + 6\rho}} < 0,$$

which implies $V_i(v)$ attains its maximum at an interior v.

Now rewrite each agent's payoff in terms of v as follows,

$$V^*(v) = \frac{a(v)(v + y(v)) - ca(v)^2/2}{r + 2a(v)}. \tag{22}$$

The equilibrium effort level as a function of v can be written as

$$a(v) = \frac{v - y(v) - \rho + \sqrt{(v - y(v) - \rho)^2 + 6\rho v}}{3c}. \tag{23}$$

The total derivative of the agent's payoff is given by

$$V'(v) = \frac{\partial V}{\partial a} a'(v) + \frac{\partial V}{\partial v}.$$

Suppose $v^*(\rho)$ were such that $\partial V / \partial a \leq 0$, i.e. effort levels were above the first-best. Because $a'(v) > 0$ and $\partial V / \partial v \propto 1 + y'(v) < 0$, reducing v (i.e. induce more compromise) would increase the agents' payoffs. Hence, the optimal v^* must satisfy $\partial V / \partial a > 0$, and therefore induce strategic substitutes.

(2.) Differentiating $V^*(v)$ in (20) and setting equal to zero, we can solve for the inverse function $\rho^*(v)$ in closed form,

$$\rho^*(v) = -\frac{1 + 2y'(v)}{2(2 + y'(v))} \frac{(v - y(v))^2}{v + y(v) + vy'(v)}. \tag{24}$$

Notice that (24) implies $\rho^*(v) = 0$ when $y(v) = v$, which corresponds to the project $x_i = 1/2$ for both agents i. This also implies $y'(v^*(\rho)) \to -1$ as $\rho \to 0$. Therefore, for ρ close to zero, we have $y'(v^*(\rho)) > -2$ and $v + y(v) + vy'(v) > 0$. Then as v increases, the first term (which is positive) increases. The numerator of second term increases, while the denominator decreases (since $y'(v) < -1$). As v increases, the term $v + y(v) + vy'(v)$ decreases, and $y'(v) > -2$ as long as $v + y(v) + vy'(v) \geq 0$. Therefore $\rho^*(v)$ is increasing in v, and grows without bound as v approaches the root of $v + y(v) + vy'(v)$, which is itself bounded away from 1.

(3.) If both players exert constant effort a, the expected cost of delay is given by

$$1 - \mathbb{E}\left[e^{-r\tau}\right] = \frac{r}{r + 2a}.$$

Therefore, the expected cost of delay is decreasing in the ratio r/a. Set $V'(v) = 0$ in (21); solve for the square root term; and substitute into $a(v)/r$. Simplifying, one obtains the following expression

$$\frac{a(v)}{r} = \frac{v - y(v)}{3\rho(2 + y'(v))}. \tag{25}$$

Substituting $\rho = \rho^*(v)$ from (24), one obtains

$$\frac{a(v)}{r} \propto -\frac{v + y(v) + vy'(v)}{(v - y(v))(1 + 2y'(v))}.$$

It is then immediate to see that the numerator is decreasing in v, and both terms in the denominator are increasing in absolute value. Since $\rho^*(v)$ is increasing in v, it follows that $a(\rho)/\rho$ is decreasing in ρ.

(4.) The symmetric equilibrium payoff in (9) may be written in terms of ρ as

$$V_i(x_i, \rho) = v_i(x_i) - \frac{\Delta(x_i) - \rho + \sqrt{(\Delta(x_i) - \rho)^2 + 6\rho v_i(x_i)}}{3}. \tag{26}$$

Differentiating with respect to ρ yields

$$\frac{\partial V_i(x_i, \rho)}{\partial \rho} \propto 1 - \frac{2v_i(x_i) + v_i(1 - x_i) + \rho}{\sqrt{(\Delta(x_i) - \rho)^2 + 6\rho v_i(x_i)}}.$$

The last expression is negative since

$$\begin{aligned} & (\Delta(x_i) - \rho)^2 + 6\rho v_i(x_i) - (2v_i(x_i) + v_i(1 - x_i) + \rho)^2 \\ = \; & -3v_i(x_i)(v_i(x_i) + 2v_i(1 - x_i)) < 0, \end{aligned}$$

which ends the proof. ■

Proof of Proposition 2. (1.) We exhibit an equilibrium that induces the second-best project choices. Let the immediate-concession probabilities in the negotiations phase depend on the projects' completion times τ_i only. In particular, let $p_i(\underline{x}, \underline{\tau})$ be given as in (14). Because the concession probabilities do not depend on the two projects' characteristics, any agent who refuses the first proposal will pursue his favorite project. Therefore, in our class of equilibria, agent i's continuation value from rejecting proposal x_{-i} is given by

$$U_i(x_{-i}) = u(p + (1 - p) v_i(x_{-i})).$$

It follows immediately that each agent i's first proposal must be in the acceptance set: if it were not, agent $-i$ would pursue his favorite project, leaving him with an expected payoff of zero. Let $v_i = v$, and denote the Pareto frontier by $y(v)$. Thus, each agent i develops a project v that satisfies

$$y(v) = u(p + (1 - p) y(v)), \tag{27}$$

where $u(\cdot)$ is defined in (11). The right-hand side of (27) is increasing in p. Therefore, the solution $\bar{v}(\rho)$ to the equation

$$y(v) = u(1, \rho)$$

characterizes the maximum level of compromise (i.e. the lowest v) that can be achieved. Furthermore, if $p = 0$, the solution v to (27) is given by $y(v) = 0$ and $v = 1$. We denote the constrained-efficient projects in terms of their value for agent i by defining

$v^*(\rho) := v_i(x^*(\rho))$. Thus, if $\bar{v}(\rho) < v^*(\rho)$, by continuity we can then induce $v^*(\rho)$ choosing a concession probability $p < 1$.

Writing the function $u(\cdot)$ defined in (11) more explicitly for the case of quadratic costs ($c(a) = ca^2/2$), we obtain

$$y(v) = 1 + \rho - \sqrt{\rho(2+\rho)}. \tag{28}$$

Solving for ρ we obtain

$$\bar{\rho}(v) = \frac{(1 - y(v))^2}{2y(v)}. \tag{29}$$

We now compare this expression with the inverse function $\rho^*(v)$ in (24), which is given by

$$\rho^*(v) = -\frac{1 + 2y'(v)}{2(2 + y'(v))} \frac{(v - y(v))^2}{v + y(v) + vy'(v)}.$$

Note that both functions are strictly increasing in v. Furthermore, we know $\rho^*(v_0) = 0$ for $v_0 = y(v_0)$ while $\bar{\rho}(v_0) > 0$. Finally, we know $\bar{\rho} \to \infty$ as $v \to 1$ while $\rho^* \to \infty$ as v approaches the root of $v + y(v) + vy'(v)$, which is smaller than one. Therefore, the two function $\bar{\rho}$ must cross ρ^* from above at least once.

We now show these two functions can cross only once. For this purpose, define the function

$$\hat{\rho}(v) \triangleq \frac{(v - y(v))^2}{2y(v)}.$$

Now consider the ratio

$$\frac{\rho^*(v)}{\hat{\rho}(v)} = -\frac{1 + 2y'(v)}{2 + y'(v)} \frac{y(v)}{v + y(v) + vy'(v)}, \tag{30}$$

and rewrite it as

$$\frac{\rho^*(v)}{\hat{\rho}(v)} = 1 - \frac{(1 + y'(v))(3y(v) - 2vy'(v))}{(2 + y'(v))(v + y(v) + vy'(v))},$$

where the denominator is always positive because $y'(v^*(\rho)) \in (-2, -1)$. Furthermore, the first term on the numerator is increasing in absolute value. Both terms on the denominator are positive and decreasing in v. Differentiating the last term on the numerator we obtain

$$y'(v) - 2vy''(v),$$

which is positive under Assumption 2. Therefore, the ratio $\rho^*(v)/\hat{\rho}(v)$ is increasing in v. Finally, notice that

$$\hat{\rho}(v) = \bar{\rho}(v)\left(\frac{v - y(v)}{1 - y(v)}\right)^2,$$

where the last term is smaller than one and increasing in v. This implies the ratio $\rho^*(v)/\bar{\rho}(v)$ is strictly increasing in v. Therefore, the two functions can cross only once. The critical v for which $\rho^*(v) = \bar{\rho}(v)$ identifies the upper bound $\bar{\rho}$ above which the maximal degree of compromise is lower than the efficient degree of compromise. Using the definition of $\bar{\rho}(v)$ in (29), we obtain expression (13) in the text.

Finally, for all $\rho < \bar{\rho}$, the equation

$$y(v^*(\rho)) - u(p + (1-p)\, y(v^*(\rho))) = 0. \tag{31}$$

admits a unique solution $p < 1$, which is given by

$$p^*(\rho) = \frac{\sqrt{2\rho y(v^*(\rho))}}{1 - y(v^*(\rho))}.$$

Rewriting it in terms of v, we obtain

$$p^*(v) = \frac{\sqrt{2\rho^*(v)\, y(v)}}{1 - y(v)} = \sqrt{\frac{\rho^*(v)}{\bar{\rho}(v)}},$$

which we have shown is strictly increasing in v.
(2.) The agents' symmetric equilibrium payoffs (20) are concave in v and maximized by $v^*(\rho)$. When $v^*(\rho)$ is not attainable, the highest equilibrium total payoff is obtained by choosing the probability p so to minimize the equilibrium $v(\rho)$. Because v is decreasing in the continuation value $u(\cdot)$, it follows that v is minimized at $p = 1$. Hence, the value of the best equilibrium projects is given by $\bar{v}(\rho)$. ■

Lemma 3 (Hiding a Breakthrough)
Any agent who develops the second-best project $x^*(\rho)$ proposes it immediately.

Proof of Lemma 3. We verify that no agent i wishes to develop his favorite project (worth $v = 1$), wait for the second agent to develop the second-best project $x^*_{-i}(\rho)$, and present an immediate counteroffer.

Let $a^* = a^*(x^*(\rho))$ denote the equilibrium effort level, and let $y(v) = v_i\left(x^*_{-i}(\rho)\right)$. By developing his most favorite project, each agent obtains a payoff of

$$\max_a \left[\frac{aw + a^* y(v) - c(a)}{r + a + a^*}\right],$$

where the reward w is given by the value of waiting for agent $-i$'s proposal, which is worth

$y(v)$ to agent i.

$$w = (p + (1-p)\, y(v)) \frac{a^*}{r + a^*}.$$

This deviation is profitable if the reward w exceeds the equilibrium reward v. Writing the function $u(\cdot)$ explicitly for the quadratic-costs case, and applying $u^{-1}(\cdot)$ to both sides of (27), we obtain the following condition for equilibrium,

$$v - \left(y(v) + \sqrt{2\rho y(v)} \right) \frac{1}{1 + r/a^*(v)} \geq 0. \tag{32}$$

This condition holds with equality when $\rho = 0$ (and $v = y(v)$). We wish to show that (32) holds for all second-best projects $x^*(\rho)$. Thus, we substitute for r/a^* from (25), we plug-in the inverse function $\rho^*(v)$ from (24), and simplify terms. We obtain the following condition

$$1 - \frac{3v}{2} \frac{1 + 2y'(v)}{v + y(v) + vy'(v)} \geq \sqrt{1 - \frac{(1 + y'(v))(3y(v) - 2vy'(v))}{(2 + y'(v))(v + y(v) + vy'(v))}},$$

where $v = v^*(\rho)$. Lengthy and straightforward algebra delivers the equivalent condition

$$4(v + y(v) + vy'(v))(-4v - 7y(v) - (v - 2y(v))y'(v) - 3vy'(v)^2 + 9(v + 2y(v))^2 \geq 0.$$

This expression is strictly positive for $y(v) \to v$ and $y'(v) \to -1$, which corresponds to the case $\rho \to 0$. Differentiating with respect to v, using the upper bound on $y''(v)$ from Assumption 2, and the fact that $y(v) \in (0, v)$, we obtain the following condition,

$$-7 + y'(v)\left(-3(8 + v^2) - y'(v)\left(28 + 8v^2 + (14 + 9v^2)y'(v)\right)\right) \geq 0.$$

This condition defines a function of two variables, v and $y'(v)$, which is strictly positive for all $v \in [1/2, 1]$ and $y' \in [-2, -1]$. Therefore, no agent wishes to hide a breakthrough as long as $\rho \leq \bar{\rho}$, i.e. the second-best projects $x^*(\rho)$ are developed.

We now establish the same result for the case of $\rho > \bar{\rho}$, i.e. when the maximum-compromise projects $\bar{x}(\rho)$ are developed. Note that condition (32) is given by

$$\bar{v}(\rho) - \frac{1}{1 + r/a^*(\bar{v}(\rho))} \geq 0. \tag{33}$$

We know this condition is satisfied for $\rho = \bar{\rho}$. We wish to show that this expression is increasing in ρ. We rewrite this condition in terms of v by substituting for $a^*(v)$ from (23) and for r from (29). We obtain the following expression for the left-hand side of (33)

$$g(v,y) = \frac{-1 - v + 2y + 3(-1+v)y^2 + \sqrt{1 + y(-4 + 8v + 10y + 4(-4+v)vy - 12y^2 + 9y^3)}}{(1+y)(3y-1)}.$$

totally differentiating with respect to v, and solving for

$$y'(v) = -\frac{g_v(v,y)}{g_y(v,y)},$$

we find that the level curves of $g(v,y)$ have a slope larger than -1 for all $v \geq y$. Therefore, each level curve crosses the Pareto frontier (which has slope $y'(v) < -1$) only once. Finally, since $\bar{\rho}(v)$ is increasing in v, we conclude that the left-hand side of (33) is increasing in ρ. ■

Proof of Proposition 3. (1.) The equilibrium project choices induced by the concession probabilities in (14) can also be obtained by assigning authority with a delay $T(p)$ to the second agent who develops a project. Consider the continuation value $U_i(x_{-i}, p)$ of the agent receiving the first proposal when the immediate-concession probabilities are given by p and the first proposal is x_{-i},

$$U_i(x_{-i}, p) = u(p + (1-p)\, v_i(x_{-i})),$$

where the operator $u(\cdot)$ is defined in (11). Let p^* be the solution to

$$v_i(x_{-i}) = U_i(x_{-i}, p^*).$$

For each x_{-i}, this value is increasing in p and ranges from $u(v_i(x_{-i}))$ to $u(1)$.

Now consider the continuation payoff under a delay T,

$$U_i(x_{-i}, T) = u\left(e^{-rT}\right) \text{ for all } x_{-i}.$$

Furthermore, the first agent who develops a project must choose one in the other agent's acceptance set. Therefore, the implementation delay satisfying

$$e^{-rT} = p + (1-p)\, v_i(x_{-i}).$$

induces the choice of projects x_{-i} that corresponds to the equilibrium outcome when the receiver of the first proposal concedes with probability p. The optimal delay T^* then satisfies

$$\exp\left[-rT^*(\rho)\right] = \begin{cases} p^*(\rho) + (1 - p^*(\rho))\, v_i\left(x_{-i}^*(\rho)\right) & \text{for} \quad \rho < \bar{\rho}, \\ 1 & \text{for} \quad \rho \geq \bar{\rho}. \end{cases}$$

(2.) As ρ increases, we know that $p^*(\rho)$ increases and $v_{-i}(\rho)$ decreases. Using (27) to solving for the expected value $p + (1-p)\, v_i(x_{-i})$, we have

$$\exp\left[-rT^*(\rho)\right] = y^*(\rho) + \sqrt{2\rho y^*(\rho)}, \text{ for } \rho \in [0, \rho^*].$$

We can rewrite the expression as a function of v, using (24) as

$$\exp\left[-rT^*(v)\right] = y(v) + (v - y(v))\sqrt{\rho^*(v)/\hat{\rho}(v)},$$

where the ratio $\rho^*/\hat{\rho}$ is given in (30). Furthermore, the proof of Proposition 2 establishes that $\rho^*(v)/\hat{\rho}(v)$ is strictly increasing and larger than one for all $v \geq v_0$. Finally, because v^* is increasing in ρ, we know $\exp\left[-\rho T^*(\rho)\right]$ is increasing in ρ and hence T^* must be decreasing in ρ.
(3.) The result follows from part (1.). In particular, if assigning authority to the receiver of the first proposal yields the best symmetric equilibrium outcome, the resulting project choices can be replicated by a delay $T^*(\rho) = 0$. ■

Proof of Proposition 4. (1.) This proof mirrors that of Proposition 3. We first show that the equilibrium project choices induced by the concession probabilities in (14) can be obtained by imposing a deadline for counteroffers $T(p)$. Consider the continuation value $U_i(x_{-i}, p)$ of the agent receiving the first proposal when the immediate-concession probabilities are given by p and the first proposal is x_{-i},

$$U_i(x_{-i}, p) = u\left(p + (1-p)\, v_i(x_{-i})\right),$$

Let p^* be the solution to

$$v_i(x_{-i}) = U_i(x_{-i}, p^*).$$

For each x_{-i}, this value is increasing in p and ranges from $u(v_i(x_{-i}))$ to $u(1)$.

Now consider the continuation payoff under a deadline T,

$$U_i(x_{-i}, T) = V(0, T) \text{ for all } x_{-i},$$

where the value function $V(t,T)$ solves the following problem

$$\begin{aligned} rV(t,T) &= \max_a \left[a(1-V(t,T)) - ca^2/2 + V_t(t,T)\right], \\ \text{s.t. } V(T,T) &= 0. \end{aligned}$$

The solution to this problem is given by

$$V(t,T) = 1+\rho+\sqrt{\rho(2+\rho)}\frac{1+ke^{-r(t-T)\sqrt{1+2/\rho}}}{1-ke^{-r(t-T)\sqrt{1+2/\rho}}},$$

with

$$k = \frac{1+\rho+\sqrt{\rho(2+\rho)}}{1+\rho-\sqrt{\rho(2+\rho)}}.$$

Therefore, we let $y = v_i(x_{-i})$ and solve $V(0,T) = y$ for T. If we let $y(\rho) = v_i\left(x^*_{-i}(\rho)\right)$, we can write the optimal deadline as

$$r\hat{T}(\rho) = \sqrt{\frac{\rho}{2+\rho}}\ln\left(\frac{1-y(\rho)\left(1+\rho-\sqrt{\rho(2+\rho)}\right)}{1-y(\rho)\left(1+\rho+\sqrt{\rho(2+\rho)}\right)}\right). \tag{34}$$

The right-hand side of (34) vanishes as $\rho \to 0$ (which implies $v^* \to y(v^*)$), and grows without bound as $\rho \to \bar{\rho}(y) = (1-y)^2/2y$, which is the bound defined in (29). Furthermore, the first agent who develops a project must choose one in the other agent's acceptance set, else receive a payoff of zero. Therefore, the optimal deadline $\hat{T}(\rho)$ in (34) induces the second-best project choices $x^*_{-i}(\rho)$.

(2.) As ρ increases, we know that $y(\rho)$ decreases, and that the concession probability $p^*(\rho)$ in the best equilibrium increases. Using (27) to solving for p, we have

$$p = \frac{\sqrt{2y(\rho)\rho}}{1-y(\rho)}.$$

Because we know p is increasing in ρ, we obtain the following bound on $y'(\rho)$,

$$y'(\rho) > -\frac{(1-y(\rho))\,y(\rho)}{(1+y(\rho))\,\rho}. \tag{35}$$

Now let $y = y(\rho)$ in expression (34), differentiate totally with respect to ρ, and use the bound in (35). We obtain

$$(2+\rho)\frac{d(rT)}{d\rho} > \frac{-2y}{1+y} + \frac{1}{\sqrt{\rho(2+\rho)}}\ln\frac{1-y\left(1+\rho-\sqrt{\rho(2+\rho)}\right)}{1-y\left(1+\rho+\sqrt{\rho(2+\rho)}\right)}. \tag{36}$$

We then note that the right-hand side of (36) is increasing in y, and nil for $y=0$. Therefore, the optimal deadline normalized by the discount rate $\rho\hat{T}(\rho)$ is increasing in ρ
(3.) The result follows from part (1.). In particular, assigning authority to the receiver of the first proposal corresponds to setting an infinite deadline for counteroffers. ■

Proof of Proposition 5. Let $\Pi(x_i) = v_i(x_i) + v_{-i}(x_i)$ denote the payoff to the mediator from implementing project x_i. Suppose that agent i generates his project first and presents it to the mediator. The mediator can then either implement it or wait for agent $-i$'s project. She prefers to wait if and only if

$$\Pi(x_{-i}) > u(\Pi(x_{-i})) \geq \Pi(x_i),$$

because project x_{-i} has not been developed yet. But if the mediator does wait, agent $-i$ knows that once his project is presented, mediator will choose it as long as $\Pi(x_{-i}) \geq \Pi(x_i)$, and so wants to under-surprise the mediator by providing an alternative that is just barely better than the original project. Because the mediator foresees this, she chooses the first developed project, independent of the overall payoff, which in turn allows each agent to pursue their favorite projects. ■

Proof of Proposition 6. Given two developed projects x_i and x_{-i}, the mediator selects project x_i if and only if

$$\Sigma_j v_j(x_i) \geq \Sigma_j v_j(x_{-i}).$$

In a symmetric environment, agent i's acceptance constraint is given by

$$v_i(x_{-i}) \geq u(v_{-i}(x_{-i})),$$

as agent i can choose a project that leaves the mediator just indifferent and redistributes the surplus to himself. Thus, in a symmetric equilibrium,

$$v_i(x_{-i}) = u(v_i(x_i)),$$

or

$$y(v) = v + \rho - \sqrt{\rho(2v+\rho)}. \tag{37}$$

From the point of view of agent i, accepting the proposal of agent $-i$ is equivalent to continuing working on his own project alone. Indeed, substituting (37) into (8) satisfies the condition with equality. The efficiency of equilibrium effort levels follows from Lemma 2. ■

Proof of Proposition 7. (1.) Fix a concession probability p, and the degree of preference alignment α. Let

$$v_\alpha \triangleq v_i\left(x_i^*\left(\alpha\right)\right).$$

When the decision-making structure provides a binding constraint on the project choice, the equilibrium project values $(v, y(v))$ satisfy

$$(1-\alpha)\,y(v)+\alpha v-u\left(p\left((1-\alpha)\,v_\alpha+\alpha y(v_\alpha)\right)+(1-p)\left((1-\alpha)\,y(v)+\alpha v\right)\right)=0. \quad (38)$$

For a fixed v, the payoff $(1-\alpha)\,y(v)+\alpha v$ of the agent receiving the first proposal increases in α. Conversely, the payoff of each agent's favorite project $(1-\alpha)\,v_\alpha+\alpha y(v_\alpha)$ decreases in α. Furthermore, the left-hand side of (38) is increasing in the variable $v_i(x_{-i})=(1-\alpha)\,y(v)+\alpha v$. Therefore, v must increase (because $\alpha<1/2$ and $y'(v)<-1$), and as a consequence the difference in project characteristics widens. Finally, observe that, substituting $v=v_\alpha$, the left-hand side of (38) is equal to

$$(1-\alpha)\,y(v_\alpha)+\alpha v_\alpha-u\left(\left((1-p)\,\alpha+p\,(1-\alpha)\right)v_\alpha+\left(\alpha p+(1-p)\,(1-\alpha)\right)y(v_\alpha)\right).$$

As $\alpha\to 0$ we know $v_\alpha\to 1$, and so

$$y(v_\alpha)-u\left(pv_\alpha+(1-p)\,y(v_\alpha)\right)<0.$$

As $\alpha\to 1/2$ we obtain

$$\frac{y(v_\alpha)+v_\alpha}{2}-u\left(\frac{v_\alpha+y(v_\alpha)}{2}\right)>0.$$

(2.) The comparative statics for $\alpha<\alpha^*$ follow from part (1.). Moreover, as p increases, the acceptance constraint becomes more stringent, as in the baseline model. It follows that the solution v to equation (38) must decrease in p. Finally, because the agents' favorite projects $x_i^*(\alpha)$ are given by

$$\arg\max_x\left[(1-\alpha)\,v(x)+\alpha v(1-x)\right],$$

the degree of alignment is increasing in α when projects $x_i^*(\alpha)$ are chosen in equilibrium. ■

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