The Politics of Compromise*

Alessandro Bonatti† and Heikki Rantakari‡

November 16, 2013

Abstract

A team must select among competing projects that differ in their payoff consequences for its members. Each agent chooses a project and exerts costly effort affecting its random completion time. When one or more projects are complete, agents bargain over which one to implement. Requiring unanimity 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. Delegating decision-making to an impartial third party leads agents to select extreme projects. Hiring agents with opposed interests can foster both effort and compromise in project selection.

Keywords: bargaining, compromise, conflict, deadlines, free riding.

JEL Classification: C72, D71, D83.

*We gratefully acknowledge the support of MIT Sloan's Program on Innovation in Markets and Organization (PIMO). We thank Ricardo Alonso, Chris Avery, Jay Pil Choi, Gonzalo Cisternas, Bob Gibbons, Bengt Holmström, Johannes Hörner, Arijit Mukherjee, Juuso Toikka, Mike Whinston, and Julie Wulf, as well as seminar participants at Boston University, MIT and Michigan State for helpful discussions.

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

‡USC Marshall School of Business, 3670 Trousdale Parkway, Los Angeles CA 90089, USA 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 organizations – from firms to hospitals, schools, agencies, and committees – members have conflicting preferences over the set of available alternatives: which product design to adopt, which patents to include in a technological standard or which candidate to hire. Yet in many settings, alternatives are not readily available. Instead, they are developed by the organization's members in the shadow of the future decision: building a prototype, patenting a new technology, 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; standards that all industry members can easily comply with; 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 a member 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 members' 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 agents must then select 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. The model can be applied both within individual firms, for example, to the conflict between division managers or board members, and to multi-firm organizations such as standards bodies.

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. Similarly, the existence of complementarities among project characteristics plausibly makes intermediate solutions less attractive than extreme ones, if at all feasible.[1] Finally, we do not allow agents to write contracts that condition payments or decision rights on the characteristics of the projects developed. In fact, we rule out all monetary payments; these are both unrealistic in most of our applications, and of limited use as a method to generate agreement.[2]

Our main results are the following:

(i) *Efficient compromise and effort can be sustained in equilibrium under a unanimity rule.* We begin by studying organizational performance when decision-making procedures are not contractible: the organization can only require unanimity, or assign irrevocable authority over implementation decisions to one or more agents.[3] Under a unanimity rule, each agent can block the other agent's project at will. Thus, 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 under a unanimity rule. These projects strike the optimal balance between compromise along the Pareto frontier and the ensuing equilibrium effort. However, the unanimity requirement in the negotiations phase does not yield a unique equilibrium outcome during the development phase. The reason for equilibrium multiplicity is that each agent's incentives to block a proposed project depend on

[1] For example, in the context of product design, seemingly minor modifications may entail significant costs. Vogelstein (2013) provides an entertaining account of the impossibility to combine features from several iPhone prototypes.

[2] Monetary transfers are unrealistic in a hiring committee, and antitrust concerns discourage their use in standard-setting organizations (Farrell and Simcoe, 2012). Section 4.3 contains a brief discussion of whether transfers eliminate compromise in project selection as a method to generate agreement.

[3] More than half of the standard-setting organizations surveyed by Chiao, Lerner, and Tirole (2007) require supermajorities or consensus for the adoption of a standard.

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. The multiplicity problem can be overcome by assigning authority to a single agent. However, the ranking of equilibrium payoffs across the two governance structures depends on which equilibrium is selected under unanimity. This provides motivation to identify which decision-making procedures can alleviate the selection problem.

(ii) *Deadlines for counteroffers achieve the efficient compromise and effort.* We turn next to an environment where organizational decision-making procedures are partially contractible: agents can commit to a procedure for resolving conflict when two projects have been developed. We set out to derive which decision rules can induce efficient project choice. An optimal rule allows the receiver of the first proposal to implement it immediately or to eliminate it. In the latter case, it 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. In order to induce the efficient project selection, it is necessary that agents can commit to ex-post inefficient actions ("dissipation") off the equilibrium path.[4] In particular, 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.

(iii) *An impartial decision-maker cannot induce any compromise.* We consider the potential advantages of delegating the right to implement any developed project to an impartial third party (the "mediator") who maximizes the sum of the agents' payoffs. If the mediator lacks commitment power, there exists a unique equilibrium, in which agents pursue their most preferred 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

[4] 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.

projects. In this case, the equilibrium outcome entails efficient effort levels, but the degree of compromise is inefficiently low.

(iv) *Conflicting goals may foster both compromise and equilibrium efforts.* We discuss the value of ex-ante alignment in the organization's members' preferences (e.g., via incentive contracts or selection of agents with known preferences). Alignment in the agents' objectives relaxes the immediate-acceptance constraints for project choice, and hence *reduces* the degree of equilibrium compromise. In addition, it may (but need not) reduce the incentives to exert effort. Therefore, conflicting goals in organizations are not only a necessary evil (because achieving full goal congruence is impossible), but also a desirable feature (because conflict may breed compromise and consensus without jeopardizing the incentives to work hard).

At a broad level, this paper joins a growing recent literature in adopting 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.

At a more detailed level, the paper is 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).[5]

Second, our work ties into a large literature focused on conflict resolution within a committee. In particular, Farrell and Saloner (1988), Farrell and Simcoe (2012), and Simcoe (2012) use a war of attrition to model decision-making in standard-setting organizations with consensus requirements. Their analyses focus on project selection and delay under asymmetric information about the two projects' qualities. Instead, in our model the development phase precedes the negotiation phase. The development phase is closely related to the R&D and patent-race models of Reinganum (1982), Harris and Vickers (1985), and Doraszelski (2003). The negotiations phase is a war of attrition in continuous time with

[5] 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 the information conveyed.

complete information, whose equilibrium characterization is due to Hendricks, Weiss, and Wilson (1988). In addition, Dewatripont and Tirole (1999), Che and Kartik (2009), and Moldovanu and Shi (2013), among others, analyze 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 off the equilibrium path that induce the choice of compromise projects.

2 Set-Up

We model an organization consisting of two agents $i = 1, 2$ working on competing projects. 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 effort 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.

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 $\lambda a_{i,t}$. 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 λa_i.

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*.[6] Once a project $x_{i,\tau}$ has been developed, it can be implemented. The implementation of a project is irreversible and ends the game. We compare several implementation rules: Section 4 considers basic governance structures, where agents are assigned unconditional implementation (or veto) rights; and Section 5 considers more complex decision structures,

[6] We discuss these assumptions further in Section 4.3.

some of which allow access to an impartial mediator.

Thus, an outcome of the game consists of: (1) 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 project $x_{i,\tau}$ implemented at time $\tau' \geq \tau$.

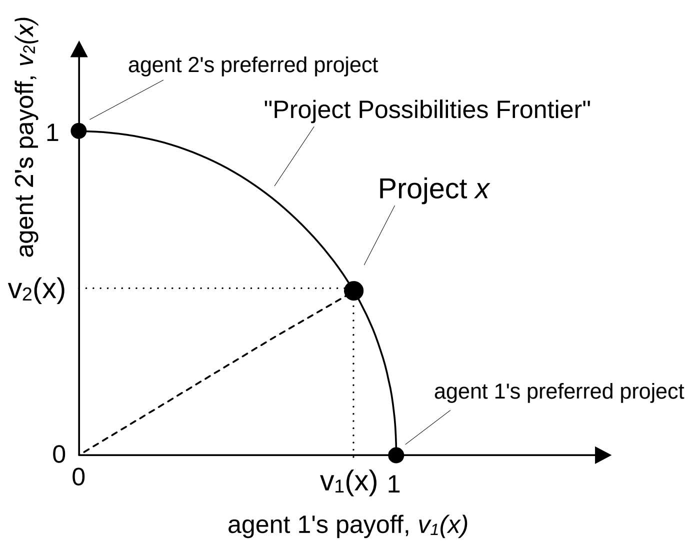
Implementation of project x yields a net present value of $v_i(x)$ to each agent i. As long as no proposal has been implemented, agents reap no benefits from any project. Both agents are impatient and discount the future at rate r. If project x is implemented at time τ, the discounted payoff to agent 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 $v_i\left(x\right)$ are monotone, differentiable and strictly concave. In particular, $v_1\left(x\right)$ is decreasing and $v_2\left(x\right)$ is increasing, with $v_1\left(1\right) = v_2\left(0\right) = 1$ and $v_1\left(0\right) = v_2\left(1\right) = 0$. Thus, the sum of the agents' payoffs $v_1\left(x\right) + v_2\left(x\right)$ 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 "project possibilities frontier," and we illustrate it in Figure 1.

Figure 1: Project Possibilities Frontier



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.

Finally, we assume that 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.[7]

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 completion. Once one or more projects have been developed, negotiations take place over which one is implemented. Our focus is on how the rules in the negotiations phase influence the initial choice of projects and the effort exerted to develop them. Before analyzing the negotiations phase, we characterize the equilibrium efforts in a simplified framework in which projects are exogenously assigned to the two agents.

3 Development Phase with Fixed Projects

We begin by considering a model where each agent i works on a fixed project x_i, and the first project to be developed is implemented immediately. We illustrate the strategic relationship between the agents' effort levels as a function of the projects pursued. We then characterize the *second-best* projects that would be chosen if project characteristics (but not effort levels) were contractible.

In this simplified framework, each agent i chooses his effort level $a_{i,t}$ to maximize the following expected discounted payoff:

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

The exponential term in the objective function is the effective discount factor used by the agents: because projects are implemented upon development, 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

[7] The assumption of orthogonal preferences over projects is not crucial for the analysis. We relax this assumption in Section 6.

rate. Therefore, his incentives to exert effort at time t are driven by the value of ending the game with a payoff of $v_i(x_i)$. This can be seen more clearly by rewriting agent i's value function $V_{i,t}$ recursively through the Hamilton-Jacobi-Bellman equation:

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

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, for a general cost function, each agent i chooses an effort level $a^*_{i,t}$ that satisfies

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

The characteristics of the two projects x_i and x_{-i} affect the sign of the externality that each agent's actions impose 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 $v_i(x_{-i})$ 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 $v_i(x_{-i})$ 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 $v_i(x_i) \approx v_i(x_{-i})$. In this case, the payoff $v_i(x_{-i})$ 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

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

This heuristic argument suggests that the nature of the payoff externality imposed by one agent's effort 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 effort levels in the noncooperative solution may be above or below the levels that would maximize the agents' joint surplus, just as in racing vs. free-riding. In order to formalize this intuition, we now characterize the equilibrium effort levels for a fixed choice of projects.

3.1 Equilibrium Effort Levels

We maintain the following symmetry assumption throughout this section.

Assumption 1 (Symmetric Quadratic Environment)

1. *The agents' cost functions are symmetric and quadratic, i.e.,*

$$c_i(a_i) = ca_i^2/2.$$

2. *The payoff frontier is symmetric, i.e.,*

$$v_i(x) = v_{-i}(1-x).$$

Under Assumption 1, we can set $\lambda = 1$ without loss of generality. Furthermore, because our benchmark environment is entirely symmetric, we now restrict attention to stationary strategies, i.e. $a_{i,t} = a_i$ for all i and t. Lemma 1 establishes the existence and uniqueness of an equilibrium in which agents use stationary strategies, and identifies conditions on the projects' characteristic under which the two agents' effort levels are strategic complements or substitutes.

Lemma 1 (Stationary Equilibrium)

1. *For any pair of projects (x_i, x_{-i}), there exists a unique stationary equilibrium.*
2. *Agent i's best response $a_i^*(a_{-i})$ is increasing in a_{-i} if and only if*

$$v_i(x_i) - v_i(x_{-i}) - \sqrt{2v_i(x_{-i})cr} \geq 0. \tag{6}$$

Condition 6 confirms the intuition that projects that differ sharply in their payoff consequences for each agent induce strategic complements (i.e., a race between the two agents). In order to derive a sharper characterization of the equilibrium effort levels, we focus on the case of symmetric projects, i.e. $x_i = 1 - x_{-i}$. We denote by $\Delta(x_i)$ the distance between the two projects, measured by the difference in the payoffs they generate for each agent i:

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

Proposition 1 characterizes the equilibrium effort levels when agents choose symmetric projects with a distance of $\Delta(x_i)$.

Proposition 1 (Symmetric Equilibrium Effort)

1. *For any pair of symmetric projects* (x_i, x_{-i})*, the equilibrium effort levels are given by*

$$a_i^*(x_i) = \frac{\Delta(x_i) - cr + \sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3c}. \tag{7}$$

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

We define the *first-best* effort levels $a_i^{FB}(x_i, x_{-i})$ 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 establish in the proof of Proposition 2, the first-best effort levels in a symmetric quadratic environment are given by

$$a_i^{FB}(x_i) = \frac{-cr + \sqrt{c^2r^2 + 4r(v_i(x_i) + v_i(1 - x_i))}}{2c}. \tag{8}$$

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

We now investigate the welfare properties of the equilibrium as a function of the projects pursued by the agents.

Proposition 2 (Racing vs. Free Riding)

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

$$\Delta(x_i^E) - \sqrt{2v_i(1 - x_i^E)cr} = 0 \tag{9}$$

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

2. *The equilibrium effort levels* $a_i^*(x_i)$ *exceed* $a_i^{FB}(x_i)$ *if and only if* $\Delta(x_i) > \Delta(x_i^E)$*.*

Conditions (6) in Lemma 1 and (9) in Proposition 2 formalize the intuition discussed in (5) that inefficiently high effort levels, strategic complements, and negative payoff externalities occur simultaneously.[8] The intuition behind this result 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

[8] Beath, Katsoulacos, and Ulph (1989) and Doraszelski (2008) obtain analogous resuts in R&D races with imperfect patent protection, where losers receive positive flow payoffs from imitation.

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.

As the discount rate r or the cost of effort c increase, condition (9) implies that the payoff distance $\Delta(x_i^E)$ between the two projects x_i^E also increases. In other words, the agents' efforts are strategic substitutes for a wider choice of projects: 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. In particular, as either c or r grow without bound, we must have $v_i(1-x_i^E) \to 0$ and hence $\Delta(x_i^E) \to 1$.

Finally, we remark that the 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.

3.2 Efficient Project Selection

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 that yield the highest total value to the two agents. Thus, in a symmetric environment, each agent would work on project $x_i = 1/2$, and exert the first-best effort level $a_i^{FB}(1/2)$. In contrast, when effort levels are not contractible, Proposition 2 shows that pursuing these projects would yield inefficiently low equilibrium effort levels.

We now identify the efficient (*second-best*) projects x_i^* that maximize the sum of the agents' payoffs $V_i(x_i)$, when effort levels are chosen noncooperatively, i.e., $a_i = a_i^*(x_i)$. Using each agent's first-order condition (4), the symmetric equilibrium payoffs can be written as

$$V_i^*(x_i) = v_i(x_i) - c a_i^*(x_i).$$

Proposition 1 establishes that each agent's equilibrium effort level $a_i^*(x_i)$ is increasing in the value of his own project $v_i(x_i)$. Therefore, the second-best projects x_i^* must strike a balance between the total value generated and the provision of incentives for equilibrium effort.

In Proposition 3, 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 3 (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 levels $a_i^{FB}(x_i^*)$.*

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. In other words, the distance between the second-best projects satisfies $\Delta(x_i^*(\rho)) < \Delta(x_i^E(\rho))$ for all $\rho > 0$. 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, it is always optimal to induce some positive amount of compromise even as agents become arbitrarily impatient. As a result, 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 3 establishes that a high degree of conflict in the pursued projects is detrimental to the organization for two reasons: (a) the total value of the projects being developed is low and (b) the equilibrium effort levels are inefficiently high. By increasing the value of the projects being developed and simultaneously reducing the equilibrium effort levels, some compromise in project selection is always optimal. At the same time, too much compromise leads to free-riding and inefficiently low effort levels: a positive degree of conflict in project selection is, in fact, also optimal. In Sections 4 and 5, we endogenize project choice and examine how governance structures influence the projects pursued by the agents. We then identify conditions under which the second-best projects may be developed as a part of an equilibrium.

4 Basic Governance Structures

In this section, we examine how the allocation of decision rights within the team influences the agents' choice of projects. We consider environments in which ex-post decision rights cannot be contracted on. Rather, the two agents are allocated unconditional authority over project implementation. We contrast three basic governance structures that correspond to: (a) organizations in which either agent can implement a project (*unilateral implementation*); (b) organizations in which only one of the two agents can implement a project (*authority*); and (c) organizations that require consensus among their members (*unanimity*). We begin by describing the equilibrium project choices under unilateral implementation and authority. We then show that the set of equilibria under unanimity spans the outcomes of the former two governance structures.

4.1 Unilateral Implementation and Authority

Equilibrium project choice under unilateral implementation is straightforward: because either agent can implement any developed project, it is dominant for each agent to pursue his favorite project $x_i \in \{0, 1\}$. The first developed project is implemented immediately, ending the game. Therefore, unilateral implementation yields no equilibrium compromise and effort levels above the first best.

The projects developed in equilibrium under agent-i authority are slightly more involved. Because agent i can implement any project, it is dominant for him to pursue his most preferred project $x_i \in \{0, 1\}$. However, because developing his own project requires costly effort and delay, agent i is willing to implement immediately any project x_{-i} that yields a sufficiently high payoff $v_i(x_{-i})$. Likewise, agent $-i$ must develop a project that induces implementation by agent i: if presented with an unattractive proposal, agent i will develop and implement a project x_i worth $v_{-i}(x_i) = 0$.

In order to characterize the project chosen by agent $-i$, let $u(w)$ denote the value that an agent assigns to developing a project worth w by himself. This value is given by

$$u(w) \triangleq \max_a \frac{aw - c(a)}{r + a}. \tag{10}$$

Agent $-i$ must then choose the project that leaves agent i indifferent between implementing and developing his favorite project (worth $w = 1$). We then define agent $-i$'s *maximum-compromise* project $\bar{x}_{-i}$ as the solution to

$$v_i(\bar{x}_{-i}) = u(1). \tag{11}$$

Therefore, assigning authority to a single agent i yields one-sided compromise: agent i pursues his most preferred project, while agent $-i$ pursues his maximum compromise project.[9]

4.2 Unanimity Rule

Under a unanimity rule, 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. Since both sides have the ability to block a proposal, it is reasonable to expect unanimity to induce mutual compromise in project selection.

Proceeding by backward induction, 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 (see, for instance, Hendricks, Weiss, and Wilson (1988)) that any equilibrium of a war of attrition has three key properties: (i) at 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

[9] It can be shown that the agent endowed with authority (the "boss") exerts a lower effort level than the other agent (the "subordinate"). Intuitively, the subordinate has a lot at stake, while the two projects have more similar payoff consequences for the boss.

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

$$\begin{aligned} w_i &= p_{-i} v_i (x_i) + (1 - p_{-i}) v_i (x_{-i}), \; i = 1, 2 \\ &\text{s.t. } p_i \in [0, 1], \text{ and } p_i \cdot p_{-i} = 0. \end{aligned} \tag{12}$$

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.

A subgame-perfect equilibrium of the entire game must specify the continuation equilibrium in the negotiations phase 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 $\underline{\tau} = (\tau_i, \tau_{-i})$. Each agent's continuation payoff $w_i(\underline{x}, \underline{\tau})$ is then defined in (12).

In equilibrium, agent i can anticipate the outcome of the war of attrition as a function of which project he develops at which time. Knowing how the game will unfold once both projects are on the table, agent i can 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 accepts proposal x_{-i} immediately if and only if the value of the proposal $v_i(x_{-i})$ exceeds his continuation value.

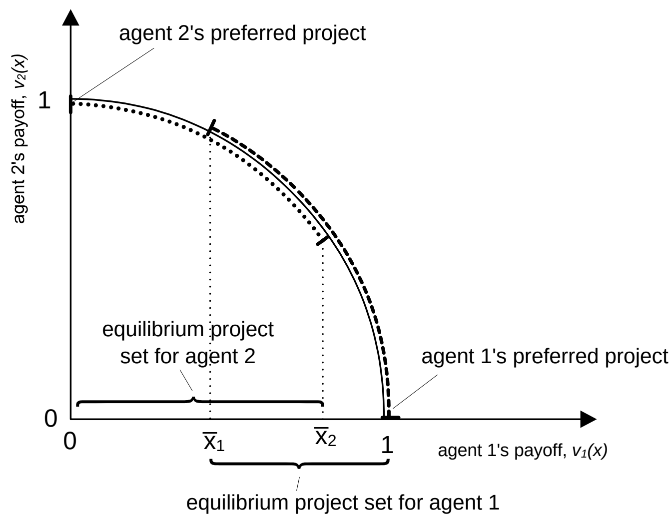
The possibility of inefficient continuation equilibria allows for a very rich set of equilibrium outcomes under unanimity. Intuitively, equilibrium selection in subgames with two developed projects is akin to the allocation of bargaining power between the two agents. In particular, the more an agent 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.

Proposition 4 characterizes (and Figure 2 illustrates) the set of projects developed as part of an equilibrium under a unanimity rule. It establishes that each agent can pursue any project ranging from his favorite project to his maximum-compromise project $\bar{x}_i$, which was defined in (11).

Proposition 4 (Equilibrium Projects Set)
Any pair of projects $(x_1, x_2) \in [\bar{x}_1, 1] \times [0, \bar{x}_2]$ can be developed in equilibrium under unanimity.

Thus, the choice of projects in organizations that require consensus is not uniquely de-

Figure 2: Projects Developed in Equilibrium



termined in equilibrium.[10] Furthermore, Proposition 4 shows that the unanimity rule need not induce any positive degree of equilibrium compromise. In particular, suppose that each agent expects the negotiations to be very contentious, i.e., the gradual-concessions phase to occur with probability one for any pair of developed projects.[11] Each agent i then knows that the prize for developing a counter-proposal x_i is equal to the value of accepting the current proposal x_{-i}. Because developing a counter-proposal requires additional delay and effort costs, this leads to immediate acceptance of any proposal at any time. Thus, the threat of full dissipation induces the development of each agent's favorite project on the equilibrium path, i.e., $x_1^* = 1$ and $x_2^* = 0$.

In the next subsection, we identify the equilibria 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.

4.3 Efficient Compromise under Unanimity

For the remainder of this section, we maintain Assumptions 1 and 2. The latter assumption requires the Pareto frontier to be sufficiently concave, i.e., the gains from compromise to be

[10] Restricting attention to Markov equilibria, in which concession probabilities condition on project characteristics only, would not reduce the set of equilibrium projects. We use time- and project-dependent concession probabilities in order to link equilibrium outcomes under unanimity to the rules and procedures analyzed in Section 5.

[11] This is also the unique equilibrium outcome in the limit of an incomplete-information game in which each player has a commitment type as in Abreu and Gul (2000).

sufficiently large.[12]

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

Proposition 5 characterizes the equilibrium outcome a under unanimity rule that yields the highest total payoff to the agents. We refer to the resulting project choices and effort levels as the *constrained-efficient compromise.* Let $\bar{\rho}$ denote the root of the following equation,

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

where $x_i^*(\rho)$ denotes the second-best projects identified in Proposition 3. In the proof of Proposition 5, we show this root is unique and strictly positive.

Proposition 5 (Constrained-Efficient Compromise)

1. *For* $\rho \leq \bar{\rho}$, *the second-best projects* $x_i^*(\rho)$ *are developed as part of an equilibrium.*
2. *For* $\rho > \bar{\rho}$, *the constrained-efficient projects coincide with the maximum-compromise projects* $\bar{x}_i(\rho)$.
3. *For all* $\rho \geq 0$, *the constrained-efficient projects are implemented immediately.*

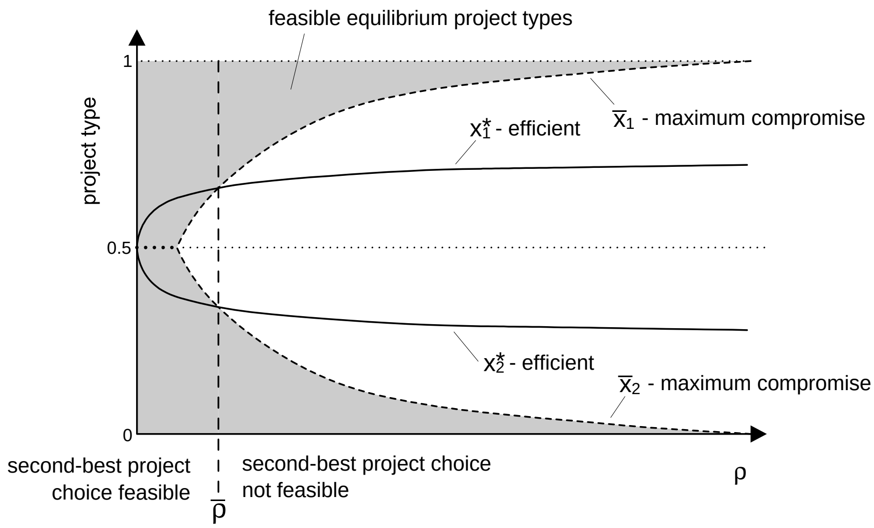
Thus, unanimity allows for the efficient project selection when agents are sufficiently patient and the costs of effort are sufficiently low. Conversely, the maximum degree of compromise is inefficiently low when effort costs and impatience levels are too high. Figure 3 illustrates the constrained-efficient projects as a function of ρ.

We remark that the results in Proposition 5 do not rely on the assumption of publicly observable project development. In other words, agents would immediately reveal a breakthrough even if they privately observed their project's development. This result is rather 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 5, this counteroffer is accepted with probability $p > 0$. However, under Assumption 2, we can show that this deviation is never profitable:[13] 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.

Perhaps more importantly, our analysis of equilibria under a unanimity rule uncovers several broader implications for organizational performance.

[12] For example, it is satisfied if $v_2(v_1) = (1 - v_1^n)^{1/n}$ and $n > 5/4$.
[13] The (tedious) proof of this result is in Lemma 2 in the Appendix.

Figure 3: Constrained-Efficient Project Values



Bargaining Power The amount of equilibrium compromise is tied to bargaining power of the receiver of the first proposal. Compromise can occur on the equilibrium path only if agent i has an incentive to block the implementation of agent $-i$'s project x_{-i} whenever it does not generate a sufficiently high payoff $v_i(x_{-i})$. In particular, the constrained-efficient compromise described in Proposition 5 is supported by war of attrition equilibria in which the immediate-concession probabilities (p_i, p_{-i}) depend only on the ranking of the breakthrough times (τ_i, τ_{-i}), and reward the second agent who develops his project:

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

In terms of payoffs, this means the receiver of the first proposal can develop his favorite project as a counteroffer and implement it with probability p. This probability determines the continuation payoff that the first proposer must generate for the other agent in order to induce acceptance. In particular, $p = 1$ induces the choice of the maximum-compromise projects $\bar{x}_i(\rho)$. When $p = 0$, full dissipation occurs in the war of attrition, which yields the choice of each agent's favorite project.

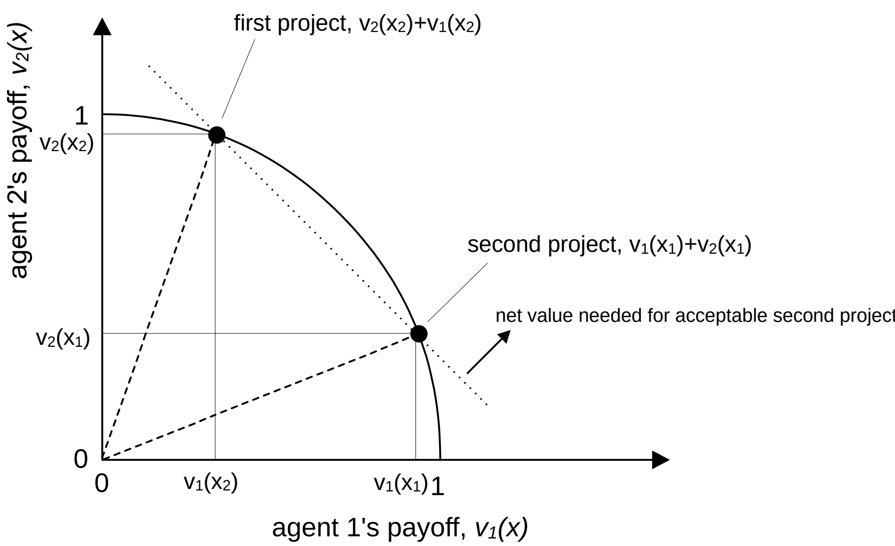
When agents are sufficiently patient ($\rho < \bar{\rho}$), there exists an equilibrium in the negotiations phase with $p < 1$ that induces the choice of the second-best projects. As agents grow impatient ($\rho > \bar{\rho}$), the bargaining power of the agent receiving the first proposal becomes very low even for $p = 1$. As a consequence, the payoff distance between the maximum-compromise projects $\Delta(\bar{x}(\rho)) \to 1$, while the distance between the second-best projects $\Delta(x_i^*(\rho))$ is bounded away from one (recall Proposition 3). In other words, for high values of ρ, there is no equilibrium in the negotiations phase that induces the optimal degree of compromise, and the highest equilibrium total payoff is obtained by completely empowering the receiver of the first proposal.

Dissipation Agents must be able to coordinate on ex-post inefficient behavior off the equilibrium path in order to support the highest equilibrium payoff. To obtain some intuition, consider the "efficient continuation" equilibrium, in which agents select the more socially valuable project whenever two projects have been developed. Therefore, agent i chooses the immediate-concession probability $p_i = 1$ if and only if $\Sigma_j v_j(x_i) < \Sigma_j v_j(x_{-i})$. In other words, 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}. With this continuation play, if project x_{-i} is already on the table, agent i can develop and implement 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. $v_{-i}(x_i) = v_i(x_{-i})$. Therefore, in the efficient-continuation equilibrium, each agent i accepts any proposal x_{-i} such that

$$v_i(x_{-i}) \geq u(v_i(1 - x_{-i})) = u(v_i(x_i)).$$

Figure 4 illustrates the equilibrium outcome.

Figure 4: Equilibrium Projects under Efficient Continuation



In equilibrium, each agent i receives from agent $-i$'s proposal a payoff equal to his continuation value, and agent $-i$'s effort does not impose an externality on agent i. This means agents choose the threshold projects $x_i^E(\rho)$ that induce the efficient effort levels. However, we know from Proposition 3 that projects x_i^E yield suboptimal levels of compromise. Thus, efficient continuation play off the equilibrium path is detrimental to compromise incentives, compared to the inefficient continuation equilibria specified by (14).

Monetary Transfers As a side note, allowing ex-post transfers to support negotiations between the two agents is unlikely to replace compromise as a way of reaching agreement. A complete analysis of monetary transfers could not abstract from a specific bargaining protocols. However, because compromise generates efficiency gains, ex-post transfers will be of limited use in equilibrium quite generally. Intuitively, pursuing a project that yields a slightly higher value to the other agent is a more efficient way of buying his 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, the ability to make ex-post transfers may actually reduce the degree of equilibrium compromise and welfare.

4.4 Comparing Governance Structures

We now revisit all three basic governance structures (i.e., unanimity, authority, unilateral implementation). An immediate consequence of Proposition 4 is that the equilibrium projects set under unanimity contains the projects developed under the other two structures. In Proposition 6, we compare the welfare properties of the projects developed under each basic structure.

Proposition 6 (Basic Governance Structures)

1. *If a project is developed in equilibrium under a basic governance structure, it is developed as part of an equilibrium under unanimity.*

2. *The unique equilibrium outcome with unilateral implementation is equivalent to unanimity with full dissipation.*

3. *For all $\rho \geq 0$, the total equilibrium payoff under agent-i authority is higher than under unilateral implementation and lower than under unanimity with constrained-efficient compromise.*

Proposition 6 emphasizes the importance of equilibrium selection for organizational performance. Under a unanimity rule, equilibrium multiplicity is driven by the agents' expectations regarding how negotiations would unfold after two projects have been developed.

Thus, seemingly identical organizations operating under a unanimity requirement may generate significantly heterogeneous levels of performance if they anticipate different continuations off-path in the negotiations phase. In other words, persistent performance differences among seemingly similar enterprises are related to the ability to induce beliefs in a less conflictual negotiations phase.

However, both in the constrained-efficient compromise and the full-dissipation outcome, these negotiations never occur on the equilibrium path, as the agents initially work on projects that yield immediate acceptance. Therefore, agents' expectations are never tested, and switching from one equilibrium to another requires a shift in the organization's beliefs about off-path events.[14]

Finally, Proposition 6 shows that equilibrium selection affects the welfare ranking of the basic governance structures. Therefore, different off-path conjectures can generate not only performance differences among organizations operating under unanimity, but also heterogeneity in governance structures, if agents can choose the allocation of authority to maximize joint expected payoffs.

To summarize, in an environment where decision rights are not contractible, a unanimity rule can yield the second-best level of compromise, but it suffers from a severe multiplicity problem. Conversely, while unilateral implementation and agent-i authority guarantee uniqueness of the equilibrium outcome, they do not achieve the constrained-efficient equilibrium selection. Therefore, in order to achieve the efficient equilibrium selection, an organization cannot rely on the unconditional allocation of authority. Instead, the organization must be able to commit to more complex mechanisms that assign ex-post decision rights to agents. This provides a motivation to study settings where time- and development-contingent rules can be contracted on ahead of time.

5 Rules and Delegation

We introduce an environment in which agents can commit to rules that dynamically assign decision rights over the implementation of a project. Such rules can condition on the development times and developer identities (but not on the projects' characteristics). In other words, the decision-making procedure is contractible, though effort levels and project choices are not. We then consider the delegation of ex-post decision rights to an impartial third party who lacks commitment power in the use of those decision rights. We contrast the

[14] The consequences of different continuation play 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).

case of full delegation (in which the third party can implement any project) with arbitration (in which the third party can only break ties when two projects have been developed).

5.1 Commitment to Procedures

We consider procedures (mechanisms) that assign ex-post decision rights to the agents as a function of the history of the 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. Because we assume non-contractibility of project characteristics, we allow the mechanism to condition on agent identities and project development times only, and not on the entire public history. We first describe two deterministic mechanisms that achieve the *constrained-efficient* compromise (i.e., project choices and effort levels) characterized in Proposition 5. We then turn to alternative, perhaps more intuitive mechanisms (including stochastic ones), and we discuss the reasons behind their failure to perform as well as the former two.

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 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 7 and 8, we use the threshold $\bar{\rho}$ defined in (13).

Proposition 7 (Delayed Authority to Second Developer)

1. *The optimal delayed-authority rule induces the constrained-efficient compromise.*
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 loss, however, is not alone sufficient to generate the second-best degree of compromise. The reason is that inducing acceptance by the second agent might require excessive compromise. Thus, it is also necessary that the second agent who develops a project can implement it only with delay. Such delay introduces an ex post inefficiency analogous to the dissipation in a war of attrition with gradual concessions, which limits the attractiveness of vetoing the first alternative. 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. Agent $-i$ can accept it or *eliminate* it. If agent $-i$ eliminates project x_i, a deadline for counteroffers specifies a time T such that he can implement any project developed 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 8 (Deadline for Counteroffers)

1. *The optimal deadline for counteroffers induces the constrained-efficient compromise.*
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 an optimal mechanism must introduce some *dissipation* off the equilibrium path in order to induce the second-best project choice on path. Dissipation mirrors the role of inefficient continuation equilibria under a unanimity rule. With commitment to procedures, dissipation is introduced in the form of deterministic delay in Proposition 7 and in the form of probabilistic abandonment in Proposition 8. 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.

Both of these mechanisms can thus induce the constrained-efficient outcome under unanimity. In Proposition 9, we establish that the constrained-efficient outcome under unanimity provides a tight upper bound on equilibrium payoffs, and that dissipation (even if off the equilibrium path) is necessary for achieving this outcome when agents are patient.

Proposition 9 (Optimal Mechanisms)

1. *Any optimal mechanism induces the constrained-efficient compromise under unanimity.*
2. *As $\rho \to 0$, any optimal mechanism requires dissipation off the equilibrium path.*

For part (1.), the simple intuition is that as long as the project characteristics are not contractible, the degree of equilibrium compromise by either agent cannot exceed the one given by the (aptly named) *maximum-compromise* projects $\bar{x}_i$. Because the agents' effort levels are uniquely determined by the projects being developed, it then follows that no rule is able to expand upon the set of equilibrium outcomes under unanimity.

To gain some intuition for part (2.), 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.[15]

Intuitively, an optimal mechanism must satisfy two incentive-compatibility constraints. First, the second-mover have an incentive to accept the proposed project instead of delaying its implementation. Second, the first-mover must prefer a compromise project that is implemented immediately to a selfish project that has a positive probability of being implemented, even if with delay. As the agents become more patient, giving full authority with no deadlines to the second agent would induce too much compromise from the first agent. But if we counter this by giving the first agent some chance of implementing his project, for low enough discount rates, he prefers to pursue purely selfish projects. Thus, we need to dissipate part of that value.

The role of dissipation is not diminished if lotteries are allowed. For instance, the optimal deadline for counteroffers is 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. For instance, as agents become very patient, each agent would find it optimal to develop his favorite project, induce the other agent to develop a counteroffer, and take his chances in the ensuing lottery.

5.2 Delegation without Commitment

So far, the organization relied on equilibrium selection (in Proposition 5), or on commitment to rules (in Proposition 7). We now consider delegating decision rights over the implementation of developed projects to a third party ("the mediator"). The mediator is impartial:

[15] 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.

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 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 10 (Mediator Makes Implementation Decision)
If the mediator makes all implementation decisions, agents develop their most preferred 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.[16] Proposition 11 summarizes the equilibrium outcome.

[16] This setting is reminiscent of Major League Baseball's salary arbitration, where an arbitrator resolves disputes by choosing either the player's or the team's offer. Similarly, Chiao, Lerner, and Tirole (2007) report that some standard-setting organizations require firms to bring disputes before an internal adjudicary body.

Proposition 11 (Mediator Breaks Ties)

If the mediator breaks ties in favor of the proposal x_i *that maximizes* $\Sigma_j v_j(x_i)$*, each agent* i *develops project* $x_i^E(\rho)$*. Thus, effort levels are efficient, but compromise is inefficiently low.*

When the mediator breaks ties, she is able to select a specific equilibrium of the baseline model, namely the "efficient continuation" equilibrium. This is because, in order to prevail in the arbitration 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}. See Figure 4 for the illustration. In equilibrium, agent i receives from agent $-i$'s proposal a payoff equal to his continuation value, which means agents choose the threshold projects $x_i^E(\rho)$ that induce the efficient effort levels.

To summarize, decision-making by the mediator fails due to the lack of a direct access to viable alternatives. Tie-breaking by the mediator, on the other hand, provides alternatives that are limited by the agents' ex-ante project choices. In particular, Proposition 3 allows us to conclude that the mediator is able to select an equilibrium outcome that induces a positive but suboptimal degree of compromise.

6 Preference Alignment

We extend our baseline model to address the following question: Should teams be composed of agents with aligned preferences? 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,

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

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.[17]

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

[17] We interpret alignment as a characteristic of the two agents' preferences, though alignment can also be induced by 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.

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 12, we denote by $x_i(\alpha, p)$ the solution to (16) holding with equality.

Proposition 12 (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.

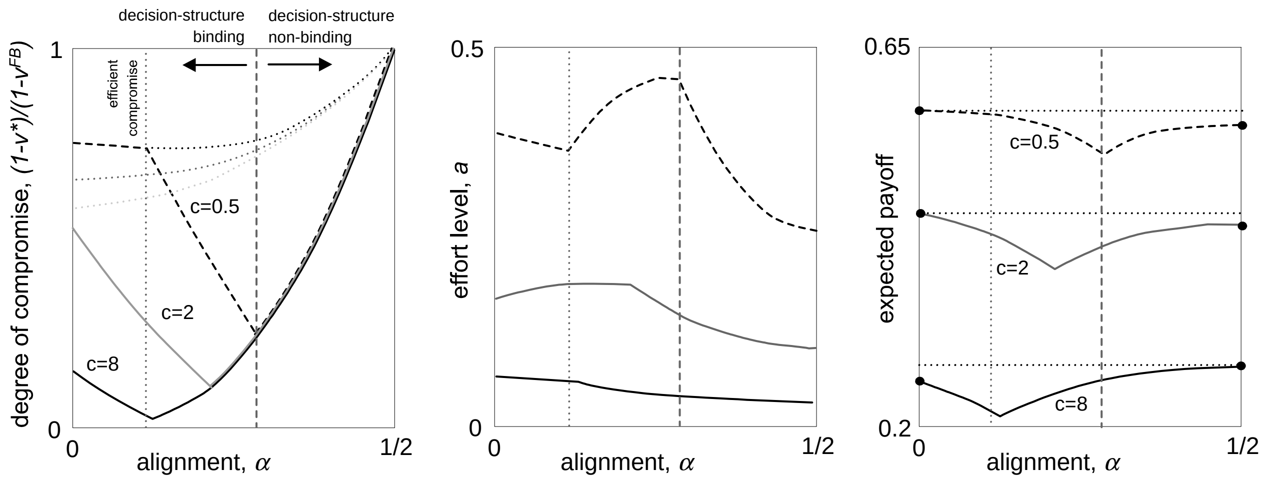
This result illustrates the basic message of our baseline model (with its unanimity requirement): the presence of conflict achieves alignment of *projects*, because having one project implemented requires the acquiescence of both agents. The larger the conflict, the larger the compromise that each agent 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 5, we illustrate the team's performance in terms of project choices, effort levels, and payoffs.[18] For each level of α, we select the probabilities p yielding the highest equilibrium total payoff.

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;

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

Figure 5: Preference and Project Alignment



(i) degree of compromise *(ii) effort level* *(iii) expected payoff*

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.[19] 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 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*, in which 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. Furthermore, agents will be able to reduce the degree of compromise by choosing more ambitious methods.

A further natural extension of the model consists of assuming that the quality of any project is randomly determined upon its completion. In particular, if agents can produce several versions of the same type of project, the development phase becomes analogous

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

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. 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. Consider an environment with quadratic costs and fixed project characteristics (x_i, x_{-i}). Under stationary strategies, value functions $V_{i,t}$ are also stationary and can be computed in closed form. In particular, each agent i solves the following problem

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

Therefore, agent i's best response is given by

$$a_i^* (a_{-i}) = - (r + a_{-i}) + \sqrt{(r + a_{-i})^2 + \frac{2}{c} (r v_i (x_i) + a_{-i} (v_i (x_i) - v_i (x_{-i})))}.$$

Differentiating with respect to a_{-i} yields

$$\frac{\partial a_i^*}{\partial a_{-i}} = \frac{v_i (x_i) - v_i (x_{-i}) + c (a_{-i} + r)}{c \sqrt{(r + a_{-i})^2 + \frac{2}{c} (r v_i (x_i) + a_{-i} (v_i (x_i) - v_i (x_{-i})))}} - 1.$$

Simplifying, we obtain condition (6) for $\partial a_i^* / \partial a_{-i} \geq 0$ in the text. This establishes part (2.). To establish part (1.), note that an equilibrium must satisfy the following condition

$$- (r + a_{-i} (a_i^*)) + \sqrt{(r + a_{-i} (a_i^*))^2 + \frac{2}{c} (r v_i (x_i) + a_{-i} (a_i^*) (v_i (x_i) - v_i (x_{-i})))} - a_i^* = 0.$$

Let $v (x_i) \triangleq v_i$, and $d_i \triangleq (v_i (x_i) - v_i (x_{-i}))$. Substituting agent $-i$'s best response and simplifying, we obtain the following function of a_i

$$G (a_i) \triangleq a_i^2 - 2 a_i d_i + 2r (v_i - d_i) + 2 (d_i - a_i) \sqrt{a_i^2 + 2 a_i (d_{-i} + r) + r (r + 2 v_{-i})}. \tag{17}$$

An equilibrium is then characterized by $G (a_i) = 0$. Notice first that

$$G (0) = 2r (v_i - d_i) + 2 d_i \sqrt{r (r + 2 v_{-i})} > 0.$$

Now consider $G' (a_i)$, and let $F (a_i) \triangleq \sqrt{a_i^2 + 2 a_i (d_{-i} + r) + r (r + 2 v_{-i})}$. The resulting expression can be written as

$$G' (a_i) \propto - (a_i - d_i) (a_i + d_{-i} + r - F (a_i)) + F (a_i)^2 . \tag{18}$$

Next, identify the positive root $\bar{a}_i$ of (18), and further differentiate the right-hand side of

(18) with respect to a_i. Plugging in $\bar{a}_i$ we obtain

$$G''(\bar{a}_i) \propto -\sqrt{d_i + d_{-i} + F(\bar{a}_i) + r} - \sqrt{d_i + d_{-i} - 3F(\bar{a}_i) + r} < 0.$$

Therefore, because $G(0) > 0$ and $G(a_i)$ is strictly quasiconcave, there exists at most one root a_i^* of $G(\cdot)$. Finally, a root exists, because $G(\cdot)$ is continuous, and it diverges to $-\infty$ as a_i grows without bound. ■

Proof of Proposition 1. (1.) We first look for a symmetric equilibrium with a constant value $V_{i,t} = V^*$, and therefore constant effort levels $a_{i,t}^* = a^*$. When agents pursue symmetric projects $(x_i, 1 - x_i)$, a symmetric equilibrium effort level must satisfy condition (17) for both players. Substituting $d_i = d_{-i} = \Delta(x_i)$ and $v_i = v_{-i} = v(x_i)$ into (17) and setting $G(a^*) = 0$ yields the following condition

$$(v(x_i) - ca^*)(r + 2a^*) = a^*(2v(x_i) - \Delta(x_i)) - c(a^*)^2/2,$$

and the expression for a^* given in (7) is the unique positive root to this equation. Each agent's symmetric equilibrium payoff is then given by

$$V_i^*(x_i) = v_i(x_i) - \frac{\Delta(x_i) - cr + \sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3}. \tag{19}$$

(2.) The comparative statics with respect to x_i, c, and r follow immediately from differentiation of $a_{i,t}^*$ in (7). ■

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

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

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 (8).

Setting $a_{i,t}^*$ in (7) equal to $a_{i,t}^{FB}$ in (8) 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 (9) 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 (8) is decreasing in x_i for all $\Delta(x_i) \geq 0$, while the equilibrium effort level $a_{i,t}^{*}$ in (7) is strictly increasing in x_i. Therefore, the sign of $a_{i,t}^{*} - a_{i,t}^{FB}$ 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 (9). ■

Proof of Proposition 3. (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 (19) 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

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

which ends the proof. ■

Proof of Proposition 4. We construct the set of projects developed in any equilibrium. Consider immediate-concession probabilities in the negotiations phase p_i that depend on the order of project development. In particular, let

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

Let agent $-i$ be the receiver of the first proposal, and consider his incentives to develop a counteroffer. Following a counter-proposal x_{-i}, the first proposer i will concede with probability p_i, and the gradual-concessions phase occurs with the complement probability. Thus, agent $-i$ should either accept x_i or develop his favorite project $x_{-i}^{**} \in \{0, 1\}$. Agent $-i$'s continuation payoff from rejecting is then is given by

$$w_{-i}(p_i, x_i) = p_i + (1 - p_i) v_{-i}(x_i).$$

Given these continuation equilibria, the first proposer i knows he must induce immediate acceptance, or else face an expected payoff of $v_i\left(x^{**}_{-i}\right) = 0$. with , *i.e.*, zero. Therefore, agent i's equilibrium project choice depends on p_i only. In particular, each agent i pursues the project x_i that makes agent $-i$ indifferent between accepting and pursuing a project worth p_i in expectation, *i.e.*,

$$v_{-i}(x_i) = u(w_{-i}(p_i, x_i)),$$

with $u(w)$ defined in (10). The unique solution x_i of the previous equation is continuous in p_i and ranges from agent i's favorite project x^{**}_i (when $p_i = 0$ and $v_{-i}(x^{**}_i) = 0$) to $\bar{x}_i$ (which obtains when $p_i = 1$).

Therefore, we only need to show that the equilibrium compromise cannot exceed the *maximum-compromise* level defined by projects $\bar{x}_i(\rho)$. The previous analysis shows that a project with $v_i(x_i) < v_i(\bar{x}_i)$ cannot be implemented *immediately* in any equilibrium, because that would require the continuation payoff of agent $-i$ to exceed its maximum level $u(1)$. Suppose instead that, in an equilibrium, the development of a project x such that $v_i(x) < v_i(\bar{x})$ for both i were triggered by the development of an earlier project x'. Let agent i be the developer of x'. It must then be the case that agent $-i$ prefers to develop project x instead of accepting project x'. But project x is worth less than $\bar{x}_i$ to agent i. Agent i should therefore develop $\bar{x}_i$ instead of x', and agent $-i$ must accept it because his continuation value cannot exceed $u(1) = v_{-i}(\bar{x}_i)$. ■

Proof of Proposition 5. (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 (10). 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 (10) 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 2 (Hiding a Breakthrough)
Any agent who develops the second-best project $x^*(\rho)$ proposes it immediately.

Proof of Lemma 2. 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,

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

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 6. (1.) Under agent-i authority, agent $-i$ must work on a project that offers sufficient compromise in order to be acceptable by agent i. Because agent i can develop his preferred project x_i^{**} by himself, which involves time and effort costs, agent i accepts all proposals x_{-i} such that $v_i(x_{-i}) \geq u(1) = v_i(\bar{x}_{-i})$. However, we know that the pair of projects $(x_i^{**}, \bar{x}_{-i})$ can be developed as part of an equilibrium under unanimity when the concession probabilities are given by $p_i = 0$ and $p_{-i} = 1$ after all histories with two developed projects.

(2.) Under unilateral implementation, the game ends as soon as one agent develops his project. Therefore, both agents pursue their favorite projects $x_i^{**} \in \{0,1\}$. The equilibrium outcome then coincides with the unanimity case when concession probabilities $p_i = 0$ after all histories with two developed projects.

(3.) We first establish that agent-i authority yields a higher total equilibrium payoff than unilateral implementation. Under unilateral implementation, the agents' total equilibrium payoff is given by

$$V_{UI} = \Sigma_j V_j = \frac{a_1^*(1,0) + a_2^*(1,0) - c(a_1^*(1,0)) - c(a_2^*(1,0))}{r + a_1^*(1,0) + a_2^*(1,0)},$$

where $a_i^*(1,0)$ is the equilibrium action as in (7) given the choice of projects 1 and 0. Suppose agent $i = 1$ is assigned authority. Then agents develop projects $x_1 = 1$ and $x_2 = \bar{x}_2$. Now notice that

$$\begin{aligned}
V_{UI} &< \frac{a_1^*(1,0) + a_2^*(1,0)(v_1(\bar{x}_2) + v_2(\bar{x}_2)) - c(a_1^*(1,0)) - c(a_2^*(1,0))}{r + a_1^*(1,0) + a_2^*(1,0)} \\
&< \frac{a_1^*(1,\bar{x}_2) + a_2^*(1,0)(v_1(\bar{x}_2) + v_2(\bar{x}_2)) - c(a_1^*(1,\bar{x}_2)) - c(a_2^*(1,0))}{r + a_1^*(1,\bar{x}_2) + a_2^*(1,0)},
\end{aligned}$$

where the first inequality follows from the concavity of the frontier. The second inequality follows from Proposition 1, which implies $a_1^*(1,\bar{x}_2) < a_1^*(1,0)$, and from the fact that agent 1's action imposes a negative externality on agent 2. Therefore, $a_1^*(1,\bar{x}_2) > a_1^{FB}(1,\bar{x}_2)$. Finally, notice that $v_1(\bar{x}_2) = V_1$ by construction. Hence, agent 2's effort imposes no externalities on agent 1. Therefore, $a_2^*(1,\bar{x}_2) = a_2^{FB}(1,\bar{x}_2)$ and therefore the total value under authority V_A satisfies

$$V_{UI} < \frac{a_1^*(1,\bar{x}_2) + a_2^*(1,\bar{x}_2)(v_1(\bar{x}_2) + v_2(\bar{x}_2)) - c(a_1^*(1,\bar{x}_2)) - c(a_2^*(1,\bar{x}_2))}{r + a_1^*(1,\bar{x}_2) + a_2^*(1,\bar{x}_2)} = V_A.$$

We now show that the agents' best equilibrium payoff under unanimity exceeds the payoff under agent-i authority. Let agent 1 be assigned authority. It suffices to show that

$$\Sigma_j V_j(\bar{x}_1,\bar{x}_2) \geq \Sigma_j V_j(1,\bar{x}_2),$$

since the left-hand side provides a slack lower bound on the best payoff under unanimity when $\rho < \bar{\rho}$. To do so, consider the agents' incentives to exert effort under agent-1 authority. From first-order condition (4), we know that

$$\begin{aligned}
c'(a_1) &= 1 - V_1^A \\
c'(a_2) &= v_2(\bar{x}_2) - V_2^A.
\end{aligned}$$

Conversely, when both agents develop projects $\bar{x}_i$, their symmetric equilibrium effort levels are given by

$$c'(a_i) = v_i(\bar{x}_i) - V_i.$$

Finally, the first-best effort under unanimity is characterized by

$$c'\left(a_i^{FB}(\bar{x}_i)\right) = v_i(\bar{x}_i) + v_{-i}(\bar{x}_i) - 2V_i.$$

Therefore, using the fact that $v_1(\bar{x}_2) = V_1^A$, we obtain

$$c'\left(a_i^{FB}(\bar{x}_i)\right) - c'(a_2) = V_1^A + V_2^A - 2V_i.$$

In other words, unanimity achieves a higher payoff than agent-1 authority if and only if agent 2's equilibrium effort exceeds the first-best level given the choice of the *maximum-compromise* projects $\bar{x}_i$. Using the quadratic-cost assumption, and defining $v \triangleq v_i(\bar{x}_i)$, we can rewrite

$$\begin{aligned} a_i^{FB}(\bar{x}_i) &= \frac{-\rho + \sqrt{\rho\left(4 + 5\rho - 4\sqrt{\rho(2+\rho)} + 4v\right)}}{2c}, \\ a_2^*(1, \bar{x}_2) &= \frac{-\sqrt{\rho(2+\rho)} + \sqrt{\rho(2+\rho) + 2\sqrt{\rho(2+\rho)}v}}{c}. \end{aligned}$$

Because the ranking if the two is independent of c we can set $c = 1$. Furthermore, we observe that

$$v_{-i}(\bar{x}_i) = u(1) = 1 + \rho - \sqrt{\rho(2+\rho)}.$$

Solving for ρ, we obtain the threshold function $\bar{\rho}(y)$ defined in (29), for $y \triangleq v_{-i}(\bar{x}_i)$. Solving $a_2^*(1, \bar{x}_2) = a_i^{FB}(\bar{x}_i)$ for v, and replacing ρ with $\bar{\rho}(y)$, we obtain

$$a_2^*(1, \bar{x}_2) > a_i^{FB}(\bar{x}_i) \iff v > \hat{v}(y), \tag{34}$$

where

$$\hat{v}(y) = (1-y)\left(\frac{y}{1+3y} + \sqrt{\frac{1+y}{1+3y}}\right).$$

Finally, notice that $\hat{v}(y) \leq 1 - y$ for all $y \in [0, 1]$, and therefore the concavity of the payoff frontier ensures that (34) is satisfied. ■

Proof of Proposition 7. (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 (10). 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 5 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 8. (1.) This proof mirrors that of Proposition 7. 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

$$r\hat{T}(\rho) = \sqrt{\frac{\rho}{2+\rho}} \ln\left(\frac{1 - y(\rho)\left(1 + \rho - \sqrt{\rho(2+\rho)}\right)}{1 - y(\rho)\left(1 + \rho + \sqrt{\rho(2+\rho)}\right)} \right). \tag{35}$$

The right-hand side of (35) 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 (35) 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 $y'(\rho)$,

$$y'(\rho) > -\frac{(1-y(\rho))\,y(\rho)}{(1+y(\rho))\,\rho}. \tag{36}$$

Now let $y = y(\rho)$ in expression (35), differentiate totally with respect to ρ, and use the bound in (36). We obtain

$$(2+\rho)\frac{d(rT)}{d\rho} > \frac{-2y}{1+y} + \frac{1}{\sqrt{\rho(2+\rho)}}\ln\frac{1-y\left(1+\rho-\sqrt{\rho(2+\rho)}\right)}{1-y\left(1+\rho+\sqrt{\rho(2+\rho)}\right)}. \tag{37}$$

We then note that the right-hand side of (37) 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 9. We denote the history of project developments up to time t as

$$\tilde{H}^t := \{(j,\tau) \mid j \in \{i,-i\}, \tau \leq t\}.$$

This is a subset of the public history H^t which includes the characteristics of each project $x_{j,\tau}$ as well. Formally, a mechanism is a time-dependent function

$$B_t : \tilde{H}^t \to \{\emptyset, i, -i\}^2$$

that assigns agents implementation rights *on each developed project separately*, as a function of project developments and calendar time. Clearly, the function B_t must assign "no authority" $\emptyset$ to any project that has not been developed yet. Furthermore, it cannot assign different agents authority over different projects at the same time t.
(1.) We wish to show that, in any mechanism, neither agent i develops a project x_i such that $v_i(x_i) < v_i(\bar{x}_i)$. We establish this result in the following steps.

Claim 1 *In any mechanism, after agent i has developed a project x_i, agent $-i$ pursues his favorite project $x^{**}_{-i} \in \{0,1\}$.*

Fix a mechanism, and consider any equilibrium outcome. Suppose, towards a contradiction, that agent $-i$ develops a project x_{-i} with $v_{-i}(x_{-i}) < 1$. Further, fix agent $-i$'s effort level, and consider his expected payoff if he develops his favorite project instead. Because the mechanism cannot condition on the characteristics of the projects developed, the allocation of authority is not affected by agent $-i$'s deviation. In particular, at any history in which agent i has the authority to implement a project, he selects his own project x_i. Thus, agent $-i$'s deviation to x_{-i}^{**} can only improve $-i$'s his payoff, because agent i changes his decision only if agent $-i$'s original project was such that $v_i(x_{-i}) > v_i(x_i)$, and so $v_{-i}(x_i) > v_{-i}(x_{-i})$. Finally, at any history in which agent $-i$ has the authority to implement a project, he can now obtain a payoff of 1, thus strictly improving his payoff.

Claim 2 *In any mechanism, before the first project has been developed, agent i pursues a project $x_{i,t} \in \{\hat{x}_{i,t}, x_i^{**}\}$, where $\hat{x}_{i,t}$ maximizes agent i's payoff $v_i(x_i)$ subject to agent $-i$ implementing it before developing project x_{-i}^{**}.*

Fix a mechanism, and consider a history h^t in which player $-i$ develops a counterproposal. By the Claim 1, agent $-i$ develops project x_{-i}^{**}, and his continuation payoff is then given by

$$w_{-i}\left(h^t\right) \triangleq p_{-i}\left(h^t\right) + p_i\left(h^t\right) v_{-i}\left(x_i\right),$$

where p_j denotes the probability that each agent j can implement a project. Before he develops a counterproposal, agent $-i$'s continuation value at any time t' following agent i's proposal x_i at time τ_i is given by

$$U_{-i,t'}\left(x_i, \tau_i\right) = \max_{a_{i,t}} \int_{t'}^{\infty} e^{-\int_{t'}^{t}(r+a_{i,s})\mathrm{d}s} \left[a_{i,t} w_i\left(h^t\right) - c_i\left(a_{i,t}\right)\right] \mathrm{d}t.$$

Agent $-i$ accepts proposal x_i at time t if

$$v_{-i}\left(x_i\right) \geq U_{-i,t}\left(x_i, \tau_i\right).$$

Therefore, at time τ_i, agent i can choose to induce implementation of his project by agent $-i$ at some future date t if he develops a project x_i that compromises sufficiently. Let $\hat{x}_{i,t}$ denote the project that maximizes agent i's expected profit under the mechanism, subject to being implemented by agent $-i$ at some history. Alternatively, agent i develops his favorite project x_i^{**}.

Claim 3 *The highest degree of compromise is obtained by assigning authority to the agent who develops a counteroffer.*

Suppose agent $-i$ receives a proposal x_i at time τ_i. His continuation payoff $U_{-i,t}\left(x_i, \tau_i\right)$ at any future date $t \geq \tau_i$ is maximized by assigning him authority over all projects at all times. To see this, compare the outcome under authority with any equilibrium outcome under a different mechanism. When assigned authority, agent $-i$ can develop the same set of projects as under any mechanism, but can implement (weakly) more projects than in the alternative mechanism. Therefore, the expected payoff level $u(1)$ defined in (10) provides a tight upper bound on his continuation payoff $U_{-i,t}(x_i, \tau_i)$. Finally, if agent i knows agent $-i$ is the only one able to implement a project (as is the case under authority), he develops a project x_i satisfying agent $-i$'s acceptance constraint,

$$v_{-i}(x_i) = u(1),$$

which is the definition of project $\bar{x}_i(\rho)$.
(2.) In order for the efficient projects to be developed and implemented in equilibrium, it must be the case that each agent i prefers to develop $x_i^*(\rho)$ and that each agent $-i$ wishes to implement it without delay. In particular, we need

$$v_{-i}(x_i^*(\rho)) \geq W_{-i}(x_i^*, \rho).$$

However, as $\rho \to 0$, if the mechanism introduces no dissipation $W_{-i}(x_i^*, \rho)$ converges to a weighted average of the payoffs from implementing the original proposal x_i^* and any counterproposal x_{-i}. Because the mechanism cannot condition on project characteristics, it must be that

$$v_{-i}(x_i^*(\rho)) \geq \tilde{p}_i v_{-i}(x_i^*(\rho)) + (1 - \tilde{p}_i),$$

as agent $-i$ can develop her favorite project as a counterproposal. This requires $\tilde{p}_i \to 1$. However, consider the first agent's incentives to develop project $x_i^*(\rho)$. It must be that, for each agent i,

$$v_i(x_i^*(\rho)) \geq \tilde{p}_i,$$

as agent $-i$ would develop her favorite project next. But then, as $\rho \to 0$ and $\tilde{p}_i \to 1$, no agent can develop project $x_i^*(\rho)$ in equilibrium. In particular, each agent i should develop his favorite project instead. ■

Proof of Proposition 10. 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 11. 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

$$y(v) = v + \rho - \sqrt{\rho(2v + \rho)}. \tag{38}$$

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 (38) into (9) satisfies the condition with equality. Proposition 2 then establishes that the resulting equilibrium effort levels are efficient. ■

Proof of Proposition 12. (1.) Fix a concession probability p, and the degree of preference alignment α. Let

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

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

$$(1-\alpha)y(v) + \alpha v - u(p((1-\alpha)v_\alpha + \alpha y(v_\alpha)) + (1-p)((1-\alpha)y(v) + \alpha v)) = 0. \tag{39}$$

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 (39) 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 (39) is equal to

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

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

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

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 (39) 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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