DISCUSSION PAPER SERIES

No. 9910

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INDUSTRIAL ORGANIZATION

Centre for Economic Policy Research

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ISSN 0265-8003

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Discussion Paper No. 9910
March 2014

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CEPR Discussion Paper No. 9910

March 2014

ABSTRACT

The Politics of Compromise*

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. A consensus requirement can (but need not) induce the efficient balance between compromise in project selection and equilibrium effort. Imposing deadlines for presenting counteroffers is beneficial, while delegating decision-making to an impartial third party leads agents to select extreme projects. Finally, hiring agents with opposed interests can foster both effort and compromise in project selection.

JEL Classification: C72, D71 and D83
Keywords: bargaining, compromise, conflict, consensus, deadlines and free-riding

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*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, Navin Kartik, Arijit Mukherjee, Andrea Prat, Juuso Toikka, Mike Whinston, and Julie Wulf, as well as seminar participants at Boston University, MIT, Michigan State, in the Columbia-Duke-MIT-Northwestern IO Theory Conference, and in the NBER Organizational Economics Meeting for helpful discussions.

Submitted 11 March 2014

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 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. Furthermore, in many settings, these alternatives are not readily available. Instead, they are developed by the organization's members themselves: building a prototype, patenting a new technology, and searching for a candidate require time and effort. Thus, the organization's choice set is endogenous, as its members generate project proposals in the shadow of the future adoption decision. In such a scenario, 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 of decision-making that consists of a *development phase* and a *negotiations phase*: each agent chooses which project to develop, and as these projects become available, agents must select which one 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 standard-setting bodies.

There are three key features to 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, and 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 and 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:* projects can be ranked in terms of their payoffs for the two agents, but the space of their underlying characteristics can be quite complex. Therefore, we do not allow the agents to implement convex combinations of projects with different characteristics.[1] Similarly, the complexity of the projects suggests that it can be exceedingly difficult to describe them in a contract. Consequently, we do not allow agents to write contracts that condition payments or decision rights on the characteristics of the projects developed.[2]

While project characteristics are not contractible, the ability to commit to rules and procedures may vary across organizations. Therefore, we contrast two environments that differ in the contractibility of decision rights: basic governance structures in which one or both agents are assigned irrevocable, unconditional implementation (or veto) rights; and procedures (requiring ex-ante commitment) for the dynamic allocation of decision rights, some of which allow access to an impartial mediator. Our main results uncover the drivers of equilibrium compromise and timely project completion in both decision-making environments.

(i) *A consensus requirement can achieve the efficient compromise and effort.* When decision-making procedures are not contractible, the organization can assign authority to one or more agents, or impose a *consensus* (i.e., unanimity) requirement. Under such basic governance structures, the ability to block a proposal and to implement a competing project (a "counteroffer") emerges as a necessary condition for inducing equilibrium compromise. For example, if only one agent is assigned authority, the other agent will be forced to make concessions by developing a project far from his ideal point to induce its implementation. When consensus is required, each agent can block the other agent's project at will. This makes mutual equilibrium compromise possible. Indeed, under this governance structure, the

[1] The existence of complementarities within a given project can make combining two distinct projects unprofitable, if at all feasible. 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] In fact, we rule out all monetary payments; these are unrealistic in most of our applications, e.g., antitrust concerns discourage their use in standard-setting organizations (see Farrell and Simcoe, 2012); furthermore, they are of limited use as a method to generate agreement (see Section 7 for a brief discussion).

constrained-efficient projects are chosen as part of an equilibrium outcome. These projects strike the optimal balance between compromise along the Pareto frontier and the ensuing equilibrium effort.[3] However, requiring consensus 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 his expectations of the negotiations that occur when both agents have developed their projects. For example, the fear of strongly contentious negotiations can induce 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 counteroffer, they are more willing to block initial proposals. This may, in fact, induce excessive degrees of equilibrium compromise. Furthermore, the ranking of equilibrium payoffs across the basic governance structures (and hence the efficient allocation of authority) depends on which equilibrium is selected under unanimity. This result demonstrates the value of commitment in our decision-making environment, and provides motivation to identify procedures that alleviate the equilibrium selection problem.

(ii) A *deadline for counteroffers achieves the efficient compromise and effort.* We turn next to an environment where agents can commit to a procedure for dynamically assigning decision rights as a function of the history of project developments (but not as a function of the projects' characteristics). We derive a rule that induces the efficient project choice. Under this rule, the receiver of the first proposal is allowed to implement it immediately or to eliminate it. In the latter case, a deadline for counteroffers specifies the amount of time the second agent has to develop a new project: if he does develop an alternative project, his project is implemented; if time runs out, all projects are abandoned. The optimal deadline for counteroffers persuades the two agents to pursue projects that are immediately accepted and achieves 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. However, while other procedures can also induce the efficient project selection, no procedure can improve upon the best equilibrium payoff under a consensus requirement. Furthermore, any optimal procedure must introduce "dissipation" off the equilibrium path, i.e. it must rely on the agents' ability to commit to ex-post inefficient actions.[4]

(iii) *Delegation to an impartial decision-maker yields inefficient compromise.* We consider

[3] This result may help explain why, for example, over 50% of the standard-setting organizations surveyed by Chiao, Lerner, and Tirole (2007) have a supermajority or consensus requirement for the adoption of a standard.

[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.

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 the 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 commit to making a decision at a fixed date. While delaying the implementation of a project fosters competition between the two agents, it does not induce the efficient level of compromise: in equilibrium, agents develop increasingly selfish projects as the decision date approaches; and any effort exerted after the first project development is socially wasteful. Overall, both the ability to generate new project proposals and to make decisions dynamically emerge as fundamental drivers of equilibrium compromise.

(iv) *Conflicting goals may foster both equilibrium compromise and effort.* We conclude the analysis by assessing the value of alignment in the organization's members' objectives (e.g., via the design of incentive contracts or the selection of agents with known preferences). We demonstrate that alignment in the agents' objectives reduces the incentives to block extreme project proposals, thereby limiting 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 necessary evil (because achieving full goal congruence is impossible), but also a desirable feature (because, under the right decision structure, conflict can 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), 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]

[5] Other papers have examined extensively the impact of organizational structure on information flows

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) study decision-making in standard-setting organizations with a consensus requirement. Their analyses focus on selecting between two exogenously developed projects when information about their qualities is asymmetric. 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). 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 dynamic provision of public goods. Specifically, developing (or agreeing to implement) a compromise project is analogous to providing a public good. An innovative feature of our framework is that it allows agents to choose which type of public good they wish to provide. Hirsch and Shotts (2013) develop a related model of competing policies under a static production function and fixed decision structure. In line with the results of Admati and Perry (1991) and Marx and Matthews (2000), we find that sequential contributions (where one agent conditions his contributions on the type of public good provided by the other player) are preferable to simultaneous contributions. Finally, deadlines for project implementation are not optimal in our model, unlike Bonatti and Hörner (2011) and Campbell, Ederer, and Spinnewijn (2013). 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 $c_i(a_i) = c_i \cdot a_i^2/2$, for some constant $c_i > 0$. Projects (i.e. choices of $x_{i,t}$) can be changed by the agent as

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.

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 time interval $\mathrm{d}t$, then the delay until the development of project x_i would be distributed exponentially over that time interval with parameter $\lambda a_i \mathrm{d}t$. The development (or "completion") of any project x is publicly observable.[6]

We assume throughout the paper that each agent i can develop one project only: if agent i obtains a breakthrough at time τ, he stops working, and we refer to project $x_{i,\tau}$ as his *proposal*. 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 analyze different procedures for selecting which developed project is, in fact, implemented. In all of our settings, 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

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

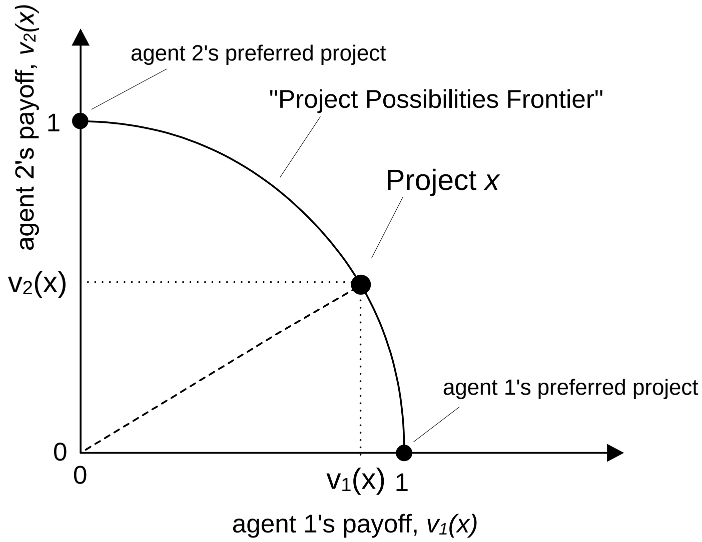
The payoff functions $v_i\left(x\right)$ are monotone, differentiable and strictly concave. In particular, $v_1\left(x\right)$ is decreasing and $v_2\left(x\right)$ is increasing, with $v_1\left(1\right) = v_2\left(0\right) = 1$ and $v_1\left(0\right) = v_2\left(1\right) = 0$. Thus, the sum of the agents' 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: $x = 1$ is agent 1's preferred project, and $x = 0$ is agent 2's preferred project.[7] 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.

[6] Our assumptions that projects are secret within an organization until they are developed reflect recent practices in the high-tech industry. See Vogelstein (2013) for a description of secrecy among competing teams at both Apple and Google.

[7] We discuss the case of partially aligned preferences in Section 6.

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. Furthermore, 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.

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 allocation of decision rights in the negotiations phase influences the initial choice of projects and the effort exerted to develop them.

3 Fixed-Projects Benchmark

In this section, we analyze a benchmark model with the following characteristics: each agent i works on an exogenously given project x_i; the first project to be developed is implemented immediately; and effort levels are chosen non-cooperatively. The goal of this section is twofold: to identify the *second-best* projects $\left(x_i^*, x_{-i}^*\right)$ that would be developed if agents could contract ex ante on project characteristics; and to derive the equilibrium effort levels given the exogenous projects (x_i, x_{-i}), which is instrumental to characterize *on-path* effort when the projects x_i are endogenously chosen.

In this setting, given projects (x_i, x_{-i}), each agent i chooses his effort level $a_{i,t}$ to maximize the following expected discounted payoff:

$$V_{i,0} = \int_0^\infty e^{-\int_0^t (r+\lambda a_{i,s}+\lambda a_{-i,s})\mathrm{d}s} \left(\lambda a_{i,t} v_i\left(x_i\right) + \lambda a_{-i,t} v_i\left(x_{-i}\right) - c\left(a_{i,t}\right)\right) \mathrm{d}t. \tag{2}$$

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

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

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, each agent i chooses an effort level $a_{i,t}^*$ that satisfies

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

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

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

This heuristic argument suggests that the nature of the *payoff externality* 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.

Intuitively, 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 free-riding motive 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 $v_i(x_{-i})$, he is also less likely to realize the benefits $v_i(x_i)$ that accrue from developing his project first. This effect then *increases* the marginal value of effort because agent i has the possibility of preempting agent $-i$ by working harder. Condition (5) shows that the free-riding effect is stronger than the preemptive effect whenever the payoff of each agent i from implementing *his opponent's project* x_{-i} is higher than *his own continuation value.*

Consequently, the characteristics of the two projects x_i and x_{-i} determine the nature of the externality that each player's actions impose on the other player. 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: while this project is worthless for agent i, his continuation value is strictly positive because he 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.

Depending on the nature of the payoff externality, the effort levels in the noncooperative solution may then 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 provide an explicit characterization of 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 (Symmetry)

1. *The agents' cost functions are symmetric.*
2. *The payoff frontier is symmetric, and the agents develop symmetric projects:*

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

We then set $\lambda = 1$ without loss of generality, and we denote by $\Delta(x_i)$ the payoff distance between two symmetric projects:

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

For any pair of symmetric projects, Proposition 1 establishes the existence and uniqueness of a symmetric equilibrium, which is stationary, and characterizes the equilibrium effort levels.

Proposition 1 (Symmetric Equilibrium Effort)

1. *For all $\Delta(x_i) \geq 0$, there exists a unique symmetric equilibrium, in which the effort level of each agent i is given by*

$$a_i^*(x_i) = \frac{\Delta(x_i) - cr + \sqrt{(\Delta(x_i) - cr)^2 + 6crv_i(x_i)}}{3c}, \text{ for all } t \geq 0. \tag{6}$$

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

In a symmetric setting, we define the *first-best* effort levels $a_i^{FB}(x_i)$ as the effort levels that maximize the sum of the agents' payoffs $V_{i,0}$ defined in (2), given the projects x_i. We then 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*

$$\Delta(x_i^E) - \sqrt{2v_i(1 - x_i^E)cr} = 0 \tag{7}$$

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 $\Delta(x_i) > \Delta(x_i^E)$.*

Proposition 2 formalizes the intuition discussed in (5) that inefficiently high effort levels, strategic complements, and negative payoff externalities occur simultaneously.[8] Consistent with intuition, equilibrium effort levels increase with the difference between the two projects' payoffs $\Delta(x_i)$, while the first best levels depend on their sum only. Thus, equilibrium effort levels are below the first best when $\Delta(x_i)$ is low and $\Sigma_j v_j(x_i)$ is consequently high.

[8] In the context of R&D races, Beath, Katsoulacos, and Ulph (1989) and Doraszelski (2008) obtain analogous results when patent protection is imperfect. We extend these results by endogenizing the choice of research project.

As the discount rate r or the cost of effort c increase, condition (7) implies that the payoff distance $\Delta(x_i^E)$ between the two projects x_i^E also increases. In particular, as either c or r grows without bound, we must have $v_i(1-x_i^E) \to 0$ and hence $\Delta(x_i^E) \to 1$. 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.

3.2 Second-Best Projects

If both effort levels and project characteristics were contractible, then (in a symmetric environment) each agent would develop 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, pursuing these projects yields inefficiently low equilibrium effort levels.

In Proposition 3, we identify the *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

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

where $a_i^*(x)$ is given in (6). Because each agent's equilibrium effort level $a_i^*(x_i)$ is increasing in the value of his own project $v_i(x_i)$, the second-best projects x_i^* must strike a balance between the total value generated and the provision of incentives for effort.

Proposition 3 (Second-Best Projects) *Let* $\rho \triangleq c \cdot r$.

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* $a_i^{FB}(x_i^*)$.

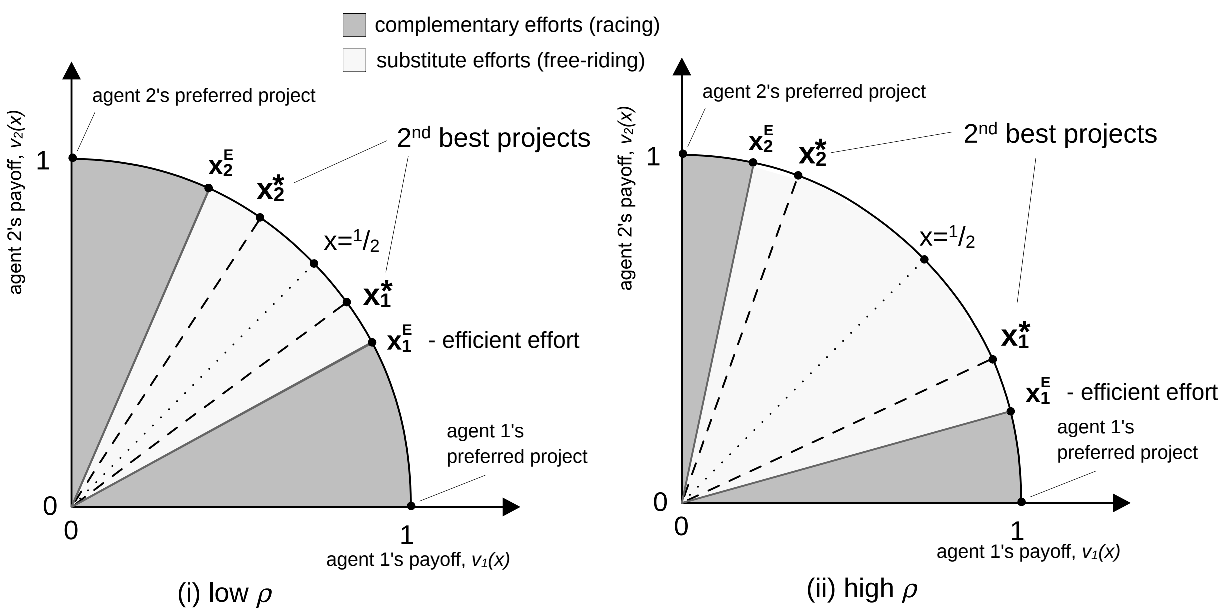
2. *The distance between the second-best projects* $\Delta(x_i^*(\rho))$ *is strictly increasing in* ρ*, with* $\lim_{\rho\to 0}\Delta(x_i^*(0)) = 0$ *and* $\lim_{\rho\to\infty}\Delta(x_i^*(\rho)) < 1$.

Thus, the second-best projects x_i^* 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.[9]

A high degree of conflict in the pursued projects is thus 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. Figure 2 summarizes the benchmark projects described in this section for different values of ρ.

Figure 2: Benchmark Projects



4 Basic Governance Structures

In this section, we endogenize the agents' choice of projects. We consider three basic governance structures that capture environments where only unconditional allocations of decision rights are available. In particular, we contrast: (a) organizations in which either agent can

[9] Because $\Delta(x_i^E(\rho)) < 1$, the above intuition applies for all (finite) ρ.

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 describe the equilibrium project choices under each governance structure and compare them to the second-best benchmark.

4.1 Unilateral Implementation

We begin with the most basic setting in which each agent has unconditional rights to implement any developed project at any time. Because effort levels and projects are not observable, each agent i chooses an effort profile $a_{i,t}$ and a sequence of projects $x_{i,t}$, taking as given his opponent's actions $a_{-i,t}$ and $x_{-i,t}$. Since it is optimal for agents to pursue projects that will be implemented immediately, the game ends at a Poisson rate $a_{i,t} + a_{-i,t}$. Therefore, each agent i's expected discounted payoff may be written as follows:

$$V_{i,0} = \max_{\{a_{i,t}x_{i,t}\}} \int_0^\infty e^{-\int_0^t (r+a_{i,s}+a_{-i,s})\mathrm{d}s} \left(a_{i,t}v_i\left(x_{i,t}\right) + a_{-i,t}v_i\left(x_{-i,t}\right) - ca_{i,t}^2/2\right) \mathrm{d}t. \tag{8}$$

Because players' actions are unobservable, equilibrium project choice under unilateral implementation is then straightforward: for any effort profile, each agent's payoff is maximized by choosing $v_i\left(x_{i,t}\right) = 1$ at all times $t \geq 0$. In other words, it is a dominant strategy for each agent to pursue his favorite project: unilateral implementation yields no equilibrium compromise.

Finally, note that unilateral implementation induces a stationary equilibrium outcome. In general, however, the time-pattern of effort levels and project choices will depend on the details of the decision-making environment.[10]

4.2 Authority

Now consider a setting in which agent i has the right to implement any developed project at any time. Conversely, agent $-i$ must obtain agent i's "approval." As under unilateral implementation, it is dominant for agent i to pursue his most preferred project $x_i \in \{0, 1\}$. Furthermore, agent i has the option to turn down any project x_{-i} developed by agent $-i$ and to keep pursuing his favorite project (worth $v_i\left(x_i\right) = 1$). 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 $v_i\left(x_{-i}\right)$. 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 $v_{-i}\left(x_i\right) = 0$. In other words, the

[10] See Section 5.3 for an instance of a non-stationary equilibrium outcome.

possibility of preempting agent i with a sufficiently attractive proposal, thus ending the game, induces agent $-i$ to compromise.

In order to quantify agent i's option value of rejecting the project chosen by agent $-i$, let $u(w)$ denote the value that an agent assigns to developing by himself a project x worth $v(x) = w$. This value is given by

$$u(w) \triangleq \max_{a_{i,t}} \int_0^\infty e^{-\int_0^t (r+a_{i,s})\mathrm{d}s} \left(a_{i,t}w - ca_{i,t}^2/2\right) \mathrm{d}t = w + \rho - \sqrt{\rho^2 + 2w\rho}, \tag{9}$$

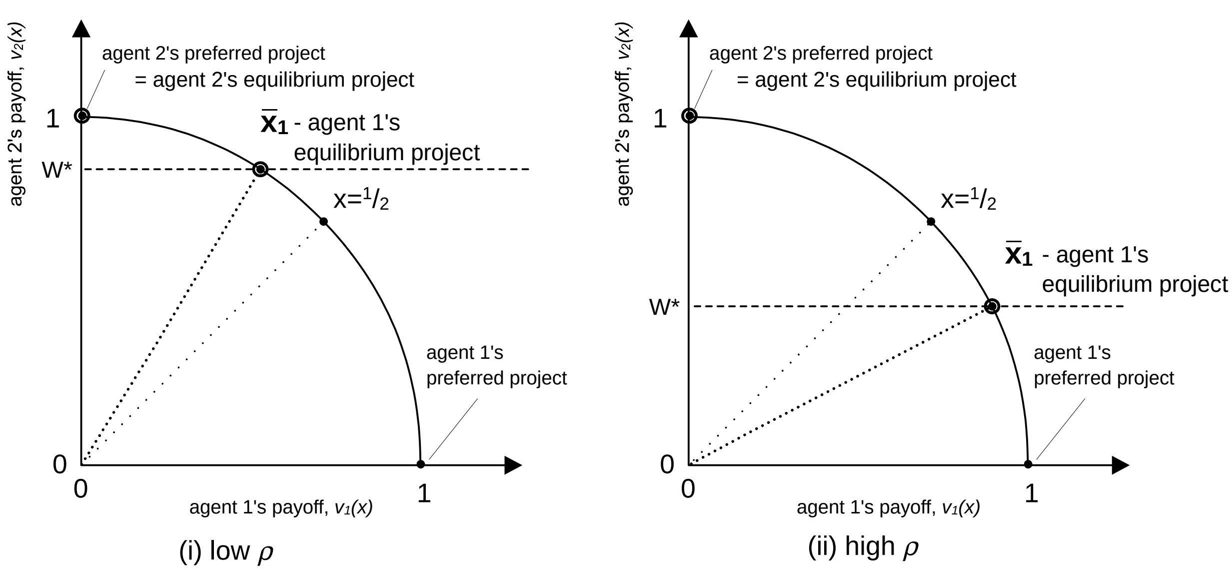
where we let $\rho = cr$. Agent $-i$ must then develop the project x_{-i} that leaves agent i indifferent between implementing x_{-i} and developing his favorite project, which is worth $w = 1$ to him. We define agent $-i$'s *maximum-compromise* project $\bar{x}_{-i}$ as the solution to

$$v_i(\bar{x}_{-i}) = u(1) \triangleq W^*. \tag{10}$$

Assigning authority to agent i thus yields a unique equilibrium with one-sided compromise: agent i pursues his most preferred project, while agent $-i$ pursues his maximum-compromise project.

Furthermore, note that agent i's option value W^* of rejecting agent $-i$'s proposal decreases as agents become more impatient or less efficient. Consequently, the degree to which agent $-i$ must compromise also decreases. In particular, (9) and (10) imply that $v_i(\bar{x}_{-i}) = 1$ for $\rho = 0$ and $v_i(\bar{x}_{-i}) \to 0$ as ρ grows without bound. Figure 3 illustrates the projects pursued in equilibrium under agent-2 authority for different values of ρ.

Figure 3: Projects under Agent-2 Authority



Finally, note that equilibrium compromise under authority relies on one agent's power to reject extreme proposals and to implement counteroffers. Absent this dynamic decision-making opportunity, both agents can find it optimal to pursue their most preferred projects. This would be the case, for instance, if one were to introduce project choice in the static model of Aghion and Tirole (1997). Because the *agent*'s project would be chosen only if the *principal* had developed no alternative, no compromise would emerge in equilibrium.

4.3 Unanimity

We now examine project selection under unanimity, i.e., when consensus is required. Inherent to the idea of consensus is that both sides have the ability to block a proposal from being implemented. It is then reasonable to expect unanimity to induce mutual compromise.

More specifically, we consider a game in which, at each time following the development of the first 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. It is then crucial to understand how negotiations unfold in the subgame that starts once two projects x_i and x_{-i} have been developed.

Our model of the negotiations phase seeks to capture two crucial aspects of the bargaining process: (a) agents are able to condition their play on the public history $(\underline{x}, \underline{\tau})$ leading to the negotiations phase; and (b) because developed projects are publicly observable, each agent i can anticipate the outcome of the negotiations phase as a function of which project he develops at which time. Furthermore, we do not analyze a specific extensive-form bargaining game. Instead, we follow the approach to (re)negotiation introduced by Tirole (1986) in the context of procurement. Thus, we posit a *selection function*

$$\xi(\underline{x}, \underline{\tau}) \in \{x_i, x_{-i}\} \tag{11}$$

that indicates which proposal is implemented if projects $\underline{x} = (x_i, x_{-i})$ were developed at times $\underline{\tau} = (\tau_i, \tau_{-i})$.

Any function $\xi(\underline{x}, \underline{\tau})$ corresponds to an equilibrium-selection criterion under a number of complete-information bargaining protocols. For instance, suppose negotiations unfold as a complete-information war of attrition in continuous time: each agent i can "concede" at any time, leading to the implementation of project x_{-i}. Under this protocol, the function $\xi(\underline{x}, \underline{\tau})$ selects one of the two Pareto-efficient equilibria: for example, $\xi(\underline{x}, \underline{\tau}) = x_i$ selects the equilibrium in which agent $-i$ concedes immediately.[11]

Given a selection function, agents know how the game will unfold once both projects are on the table. Each agent i can then optimize his effort 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.

4.3.1 Efficient Continuation

To illustrate how the observability of project developments and the possibility to block proposals drives the initial choice of projects, consider a very natural selection function $\xi(\underline{x}, \underline{\tau})$. In particular, let $\xi(\underline{x}, \underline{\tau}) = x_i$ if and only if $\Sigma_j v_j(x_i) > \Sigma_j v_j(x_{-i})$. In other words, agents select the more socially valuable project whenever two projects have been developed.

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 (agent i) would receive under the original proposal x_{-i}. Agent i therefore develops project $x_i = 1 - x_{-i}$. It follows that each agent i accepts any proposal x_{-i} such that

$$v_i(x_{-i}) \geq u(v_i(1 - x_{-i})), \tag{12}$$

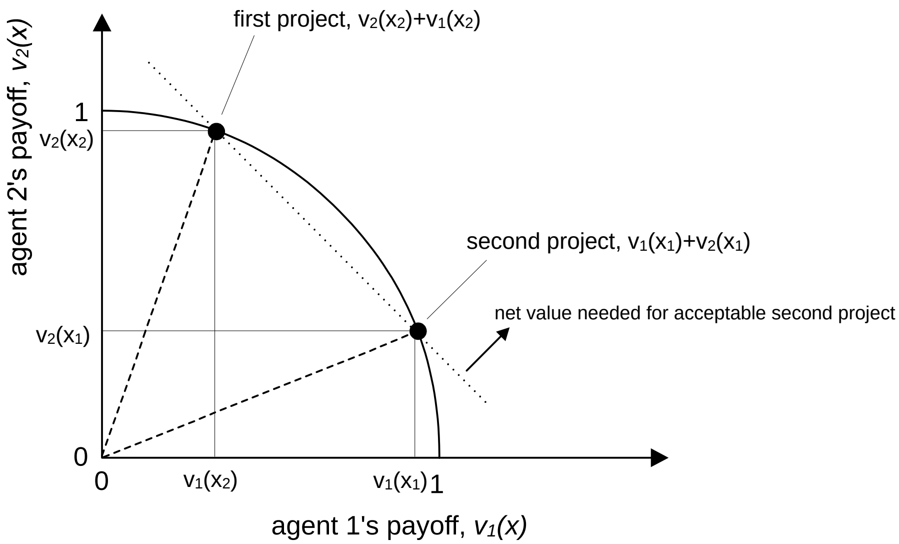
where the value of the single-agent problem $u(\cdot)$ was defined in (9). Figure 4 illustrates the equilibrium outcome under the ex-post efficient selection function.

In equilibrium, constraint (12) binds, and each agent i receives from agent $-i$'s proposal a payoff equal to his continuation value. Thus, agent $-i$'s effort does not impose an externality on agent i. It then follows that agents choose the projects (x_i^E, x_{-i}^E) that induce the efficient effort levels. However, we know from Proposition 3 that projects (x_i^E, x_{-i}^E) yield suboptimal levels of compromise.

We conclude that efficient continuation play off the equilibrium path generates insufficient incentives for compromise. In other words, inducing efficient compromise requires the agents to sometimes implement the less valuable project.

[11] The selection function (11) implicitly assumes the negotiations phase has at least one efficient equilibrium. Several bargaining games (including the war of attrition) also have inefficient equilibria, such as those with costly delay characterized by Hendricks, Weiss, and Wilson (1988). Our analysis can be extended to inefficient continuation equilibria without expanding the set of subgame-perfect equilibrium outcomes characterized in Proposition 5.

Figure 4: Equilibrium Projects under Efficient Continuation



4.3.2 Constrained-Efficient Compromise

We now identify conditions under which the second-best projects x_i^* are developed in equilibrium, and characterize the highest equilibrium payoff when they are not. We shall refer to a pair of projects (x_i, x_{-i}) as developed in equilibrium if there exists a selection function $\xi(\underline{x}, \underline{\tau})$ that induces agents to develop projects (x_i, x_{-i}) on the equilibrium path. In addition, we refer to the best equilibrium project choices and effort levels as the *constrained-efficient* levels of compromise.

Proposition 4 (Constrained-Efficient Compromise)

1. *If ρ is sufficiently low, the second-best projects $x_i^*(\rho)$ are developed in equilibrium.*
2. *If ρ is sufficiently high, the maximum-compromise projects $\bar{x}_i(\rho)$ are developed in the best equilibrium.*
3. *If the Pareto frontier $\phi(v)$ satisfies*

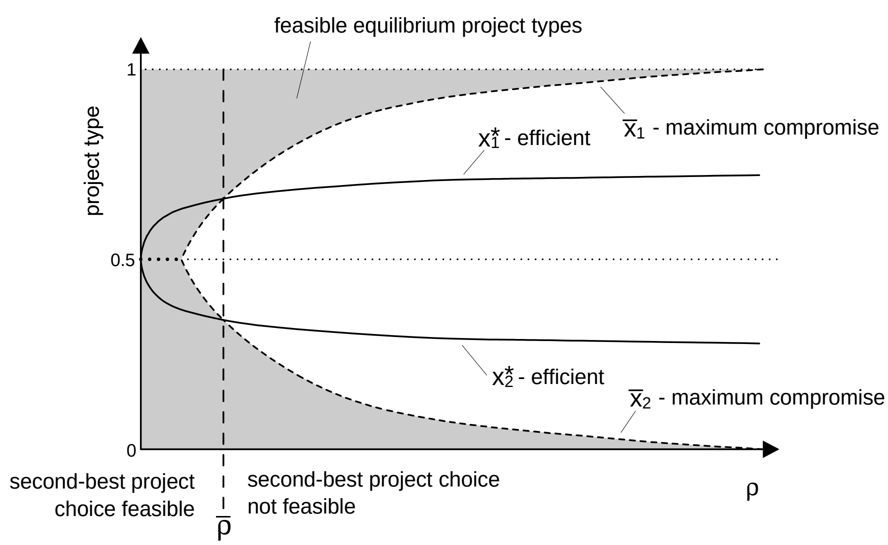
$$\phi''(v) < \frac{\phi'(v)}{2v}, \tag{13}$$

the second best projects $x_i^*(\rho)$ are developed in equilibrium if and only if $\rho \leq \bar{\rho}$.

Proposition 4 shows that when agents are sufficiently patient, there exists a selection function in the negotiations phase that induces the choice of the second-best projects. As agents grow impatient, however, the bargaining power of the agent receiving the first proposal becomes too low, even if he is granted unconditional authority from then on. (Recall that the payoff distance between the maximum-compromise projects $\Delta(\bar{x}(\rho)) \to 1$ as $\rho \to \infty$, while the distance between the second-best projects $\Delta(x_i^*(\rho))$ is bounded away from one.) In other words, for high values of ρ, no selection function in the negotiations phase can induce the optimal degree of compromise on the equilibrium path. The highest equilibrium payoff is then obtained by effectively empowering the receiver of the first proposal, which leads to the development of projects $\bar{x}_i(\rho)$.

Under condition (13), the functions $x_i^*(\rho)$ and $\bar{x}_i(\rho)$ cross only once. In this case, there exists a single threshold $\bar{\rho}$ below which the second-best projects are developed in equilibrium.[12] Figure 5 illustrates the constrained-efficient projects as a function of ρ.

FIGURE 5: CONSTRAINED-EFFICIENT PROJECT VALUES



4.3.3 Equilibrium Projects Set

Unlike unilateral implementation and authority, a consensus requirement does not uniquely determine the type of projects developed by the agents. In particular, the flexibility in choosing the selection function $\xi(\underline{x}, \overline{x})$ allows for a very rich set of equilibrium outcomes. Intuitively, 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 5 characterizes the set of projects developed as part of an equilibrium under unanimity.

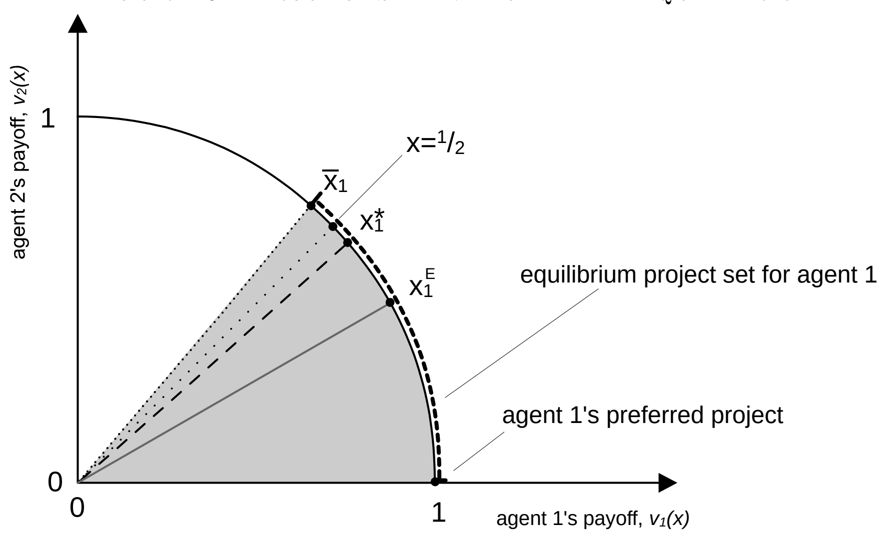
[12] Condition (13) requires the Pareto frontier to be sufficiently concave, i.e., the gains from compromise to be sufficiently large. For example, it is satisfied if $\phi(v) = (1 - v^n)^{1/n}$ and $n > 5/4$.

Proposition 5 (Equilibrium Projects Set)
For all $\rho \geq 0$, any pair of projects $(x_1, x_2) \in [\bar{x}_1(\rho), 1] \times [0, \bar{x}_2(\rho)]$ is developed in equilibrium.

In other words, any project ranging from an agent's favorite project $x_i \in \{0, 1\}$ to his maximum-compromise project $\bar{x}_i$ is, in fact, developed in an equilibrium. Because the equilibrium projects set is bounded by the (aptly named) maximum-compromise projects, it is sensitive to the discount rate ρ.

The proof of Proposition 5 uses simple selection functions to construct equilibria where any pair of projects in the equilibrium set is developed and immediately implemented. In particular, for any pair $(\hat{x}_1, \hat{x}_2)$, we can choose a function $\xi(\underline{x}, \underline{\tau})$ that selects the first project developed (x_i) if $x_i = \hat{x}_i$ and the second project developed otherwise. This type of "punishment" strategy implements any desired $(\hat{x}_1, \hat{x}_2)$ as long as $v_i(\hat{x}_{-i}) \leq W^*$: if agent $-i$ were to receive a payoff $v_i(\hat{x}_{-i}) > W^*$ from agent $-i$'s project, then agent $-i$ could deviate to a more favorable project x'_{-i} that agent i would also prefer to implement immediately.[13] Figure 6 illustrates the equilibrium projects set for agent 1.

FIGURE 6: PROJECTS DEVELOPED IN EQUILIBRIUM



Finally, note that requiring consensus need not induce any positive degree of equilibrium compromise. For example, suppose each agent expects the negotiations to be very contentious: the first agent who develops a project never backs down; and the selection function implements the first project developed. Because no agent i has an incentive to develop a counter-proposal, this leads to the development and immediate implementation of each agent's favorite project.

[13] Under these equilibrium strategies, agents would immediately reveal a breakthrough even if they privately observed their project's development. In other words, the results in Propositions 4 and 5 do not rely on the assumption of publicly observable project development.

4.4 Comparing Governance Structures

We now revisit the three basic governance structures (i.e., unilateral implementation, authority, and unanimity), and compare the welfare properties of the projects developed under each one. We then discuss the importance of equilibrium selection for organizational performance and organizational design.

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. *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.*

Some broader implications for organizational performance emerge from this comparison. A general theme is that the amount of equilibrium compromise is tied to the bargaining power of the receiver of the first proposal. In particular, compromise along the equilibrium path requires that agent i has both the incentive and the authority 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 the case of unanimity, this reservation value depends on the agents' implicit understanding of 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, the negotiations phase is never reached 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]

Furthermore, Proposition 6 shows that equilibrium selection affects the welfare ranking of the basic governance structures. Therefore, different off-path conjectures (i.e., selection functions) can generate not only performance differences among organizations operating under

[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).

unanimity, but also heterogeneity in governance structures, if agents choose the allocation of authority (i.e., decision rights) that maximizes their joint expected payoffs.

To summarize, in order to achieve efficient equilibrium compromise as a unique equilibrium outcome, an organization cannot rely on an unconditional allocation of authority. This provides a motivation to study settings where the organization is able to commit to more complex mechanisms that assign ex-post decision rights to agents.

5 Decision-Making Procedures

In this section, we examine an environment in which agents can commit *ex ante* to a decision-making procedure. First, we consider rules that dynamically assign decision rights to the two agents as a function of the history of project developments. We illustrate how the optimal rule is able to uniquely induce the best equilibrium under unanimity, but can do no better. Second, we consider the possibility of delegating decision rights to an impartial third party who maximizes the sum of the agents' payoffs. We assess the value of such delegation under alternative assumptions on the third party's commitment power.

5.1 Dynamic Allocation of Authority

We shall refer to a *mechanism* as a procedure that dynamically assigns authority (i.e., 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 has the right to implement x_i at what time. Importantly, because project characteristics are assumed not to be contractible, the mechanism is allowed to condition the assignment of authority on agent identities and project development times only. In other words, a mechanism $D(h^t)$ does not describe a general procedure for decision-making. Instead, we are focusing on the role of time- and project-specific authority to quantify the value of a flexible allocation of decision rights, and of the commitment power necessary to enforce it.

More formally, let $h^t = (\tau_1, \tau_2, t)$ denote a history of project developments up to time t, with the convention that $h_i^t = \infty$ if agent $i = 1, 2$ has not developed a project yet. Let H^t denote the set of time-t histories. We define a mechanism as a function

$$D : H^t \to \{0, 1, 2\}^2,$$

where $D_i(h^t)$, $i = 1, 2$, indicates which agent (if any) has the right at time t to implement the project x_i that was originally developed by agent i. Thus, a mechanism assigns authority over each project separately, as a function of project development times (τ_1, τ_2) and calendar time. We focus on symmetric mechanisms, and we impose two additional restrictions on the mapping $D(h^t)$: no agent may be assigned authority over a project that has not been developed yet; and two different agents cannot be assigned authority over two different projects at the same time.[15]

Consider, for example, a mechanism that imposes a *deadline for counteroffers*: suppose agent i develops project x_i at time τ. Agent $-i$ is assigned authority over it *at time* τ only. In other words, agent $-i$ can accept project x_i immediately or *de facto* eliminate it. If agent $-i$ does not implement project x_i, he is assigned authority over any project he develops before time $\tau + T$. If agent $-i$ does not develop any project ("counteroffer") by that date, no agent is assigned authority thereafter, and all projects are abandoned.

We now show that the optimal mechanism in this class induces the *constrained-efficient* compromise (i.e., project choices and effort levels) characterized in Proposition 4. Furthermore, any optimal mechanism must induce this outcome, and several more intuitive mechanisms (including stochastic ones), fail to perform as well.

Proposition 7 (Deadline for Counteroffers)

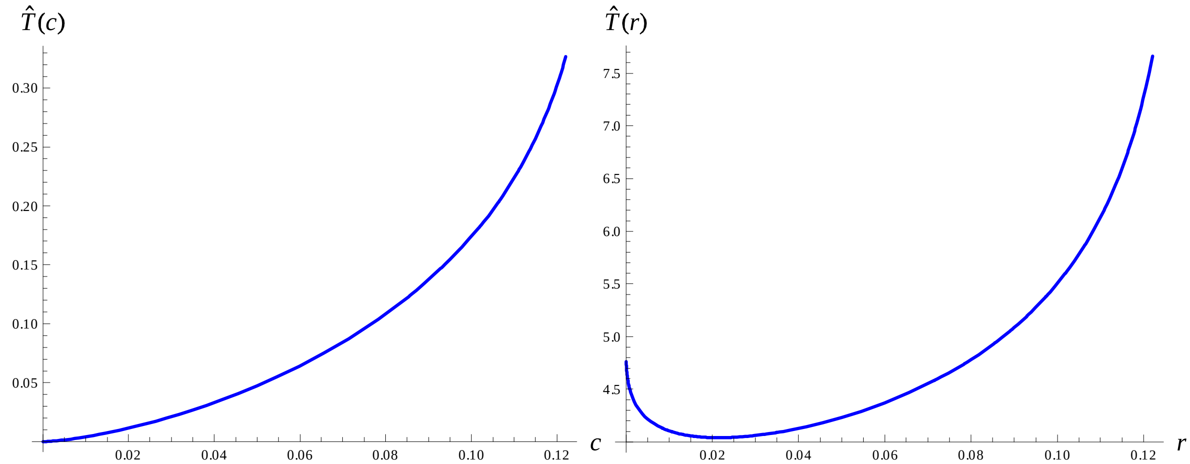
1. *The optimal deadline for counteroffers induces the constrained-efficient compromise.*
2. *The optimal deadline $\hat{T}$ is finite if and only if $\rho < \bar{\rho}$.*
3. *The normalized optimal deadline $r\hat{T}$ is increasing in ρ.*

A deadline for counteroffers replicates the distribution of bargaining power under a consensus requirement, where each agent can block the implementation of any project. But, unlike continuation equilibria under unanimity, a mechanism cannot condition on the characteristics of the developed projects. Therefore, incentives for compromise must rely on the dynamic allocation of authority. Under this mechanism, developing the first project entails the loss of all future authority, and forces each agent to submit a proposal that is immediately accepted by the other agent.

However, assigning unconditional authority to the second agent (who can then pursue his favorite project) may induce degrees of equilibrium compromise that exceed the second-best. In other words, it can be necessary to limit the second agent's bargaining power. A finite deadline for counteroffers allows the mechanism to fine-tune the continuation payoff of the receiver of the first proposal, i.e., the value necessary to induce immediate acceptance. In particular Proposition 7 establishes that the optimal deadline is increasing in the cost of effort, but it need not be monotone in the discount rate. Figure 7 illustrates the optimal deadline as a function of c and r.

[15] Formally, this means $h_i^t = \infty \Rightarrow D_i(h^t) = 0$ and $D_i(h^t) \neq D_{-i}(h^t) \Rightarrow D_i(h^t) D_{-i}(h^t) = 0$.

Figure 7: Optimal Deadline for Counteroffers



$\phi(v) = \sqrt{1 - v^2}, r = 1$ $\phi(v) = \sqrt{1 - v^2}, c = 1$

The probabilistic abandonment of all projects induced by a deadline is only one means of limiting the receiver's continuation payoff. For instance, imposing a deterministic delay in the implementation of any counteroffer is an outcome-equivalent procedure. A general picture then emerges where an optimal mechanism must introduce *dissipation* off the equilibrium path. Procedures that induce dissipation are not unreasonable in many settings.[16] However, one may wonder whether other mechanisms (including ones that dispense with off-path inefficiency) can induce higher expected payoffs for the two agents. In Proposition 8, we establish that the constrained-efficient level of compromise provides a tight upper bound on equilibrium payoffs. Moreover, dissipation off the equilibrium path is necessary for achieving the constrained-efficient outcome when agents are patient.

Proposition 8 (Optimal Mechanisms)

1. *Any optimal symmetric mechanism induces the constrained-efficient project choices and effort levels.*

2. *For sufficiently low ρ, any optimal symmetric mechanism requires dissipation off the equilibrium path.*

Part (1.) of Proposition 8 shows that an optimal mechanism cannot improve payoffs compared to the best equilibrium under unanimity. This is slightly surprising because we

[16] A hiring committee may require additional costly screening or external evaluation of any candidate unless a consensus is built around the first candidate. Similarly, a committee may "lose the hiring slot," e.g., in favor of another department, if a member vetoes a candidate and fails to suggest an alternative candidate in a reasonable time.

know (Proposition 3) that the equilibrium effort associated with the second-best projects is below the first-best level. A mechanism could then boost equilibrium effort, for example, through on-path deadlines or other time incentives. However, in the proof we establish that any optimal mechanism induces stationary choices of projects and effort levels and avoids dissipation along the equilibrium path. Thus, while higher effort levels are attainable over a finite period, they are, in fact, suboptimal.[17]

To gain some intuition for part (2.), contrast the optimal deadline for counteroffers with a mechanism that allows the receiver of the first proposal ($-i$) to implement the first project (x_i) when the deadline for counteroffers expires. 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. When agents are very patient or very efficient, 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 because (a) any project will be implemented with delay, and (b) the originator of the first proposal assigns positive probability to his alternative being implemented at the deadline. The latter effect limits the incentives to compromise in the first place, relative to the case where a rejection by the other agent permanently eliminates a proposal.

To summarize, the ability to dynamically allocate authority to the agents (and to commit to dissipation off the equilibrium path) allows an organization to overcome the equilibrium selection problem induced by a consensus requirement. This form of commitment does not, however, improve upon the best equilibrium outcome under basic governance structures.

5.2 Delegation without Commitment

So far, the organization relied on equilibrium selection (in Proposition 4), 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: 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 can 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

[17] Both the second-best projects and the outcome of the optimal mechanism would not be stationary if, for example, the organization faced an exogenous deadline for the development and implementation of any project.

mediator cannot commit to a strategy.

Proposition 9 (Impartial Mediator)
If an impartial mediator makes all implementation decisions, agents develop their most preferred projects, $x_1^* = 1$ and $x_2^* = 0$.

Thus, in spite of her preferences for compromise, the mediator is unable to induce any convergence between the agents' project choices. 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.

The outcome of delegation is less bleak if 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.[18] As a result, delegation to a tie-breaking mediator induces the same outcome as selecting the efficient continuation equilibrium under unanimity, which leads to a positive but suboptimal degree of compromise. Finally, the agents can anticipate the response of the mediator, as in the unanimity case. Therefore, in equilibrium, the first alternative is immediately accepted, and the mediator is never actually appealed to.

5.3 Delegation with Limited Commitment

We conclude our analysis of delegation by exploring the value of (limited) commitment in a realistic setting. We assume that the mediator can set a fixed date T at which she implements

[18] This procedure is analogous to 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 adjudicatory body.

a project: at time T, the mediator chooses the most valuable project among those developed so far. If no project has been developed by that date, no project is implemented. This procedure is reminiscent of the capital-budgeting meetings used in many large firms.

The main advantage of this procedure is to give agents time to develop counterproposals. In other words, the mediator uses her commitment power to "play off" two developed projects against one another. Therefore, at a basic level, this procedure trades off fiercer competition between the agents with delay implementation decisions. At a closer look, however, this procedure introduces a further source of inefficiency. Consider the subgame starting with a project $x_{i,\tau}$ developed by agent i at time τ_i. Agent $-i$ will immediately switch to a project $x_{-i,t} = 1 - x_{i,\tau}$ for all $t \in [\tau, T]$, i.e., he will try to undercut the first agent.[19] If developed, agent $-i$'s project is implemented at T. However, because the two projects are equally valuable to the team, the second-phase effort is worthless from a social perspective.

To derive the equilibrium effort and project choices under this procedure, consider the problem of agent $-i$ after agent i develops the first project x_i. Because agent $-i$ switches to project $x_{-i} = 1 - x_i$, he obtains a discounted reward of $e^{-r(T-t)}v_{-i}(1 - x_i)$ if he develops his project at time $t \leq T$, and a reward of $v_{-i}(x_i)$ if he fails to develop a project by the deadline. Therefore, agent $-i$'s continuation payoff $V_{-i,t}(x_i)$ can be written recursively as

$$\begin{aligned} rV_{-i,t}(x_i) &= \max_a [a(e^{-r(T-t)}v_{-i}(1 - x_i) - V_{-i,t}(x_i)) - c(a) + \dot{V}_{-i,t}(x_i)] \\ \text{s.t. } V_{-i,T}(x_i) &= v_{-i}(x_i). \end{aligned} \tag{14}$$

Under quadratic costs, we can solve this problem in closed form for the value function $V_{-i,t}(x_i)$ and for the effort path $\hat{a}_{-i,t}(x_i)$, which is increasing over time. The probability of agent $-i$ successfully developing the "counteroffer" $x_{-i} = 1 - x_i$ over the interval $[\tau, T]$ is then given by

$$\alpha_\tau(x_i) \triangleq 1 - e^{-\int_\tau^T \hat{a}_{-i,t}(x_i)\mathrm{d}t}. \tag{15}$$

We now turn to agent i's initial project choice. The expected discounted reward for completing project x_i at time t is given by

$$\beta_t(x_i) = e^{-r(T-t)}(v_i(x_i)(1 - \alpha_t(x_i)) + \alpha_t(x_i)v_i(1 - x_i)).$$

Recalling that projects are not observable until they are developed, agent i's optimal choice of $x_{i,t}$ maximizes the reward $\beta_t(x_i)$ at each time t. In Proposition 10, we characterize the projects pursued on the equilibrium path by the two agents.

[19] This is assuming that $v_{-i}(x_{i,t}) < v_i(x_{i,t})$, which will be the case in equilibrium for all $t \leq T$.

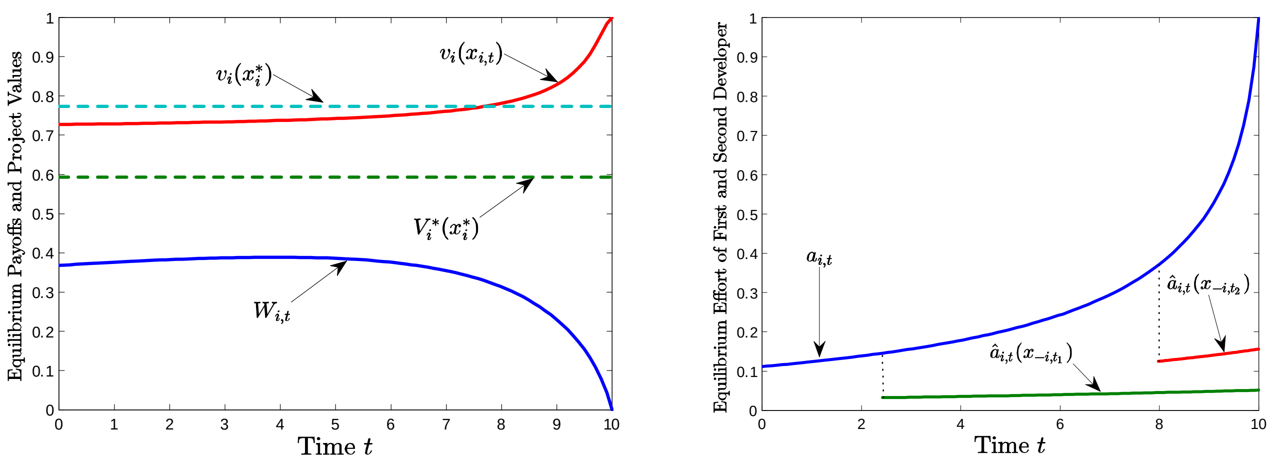
Proposition 10 (Fixed Implementation Date)
Suppose the mediator commits to making a decision at date T.

1. *The distance $\Delta(x_{i,t})$ between the projects pursued on the equilibrium path is increasing in t and decreasing in T, with $\Delta(x_{i,T}) = 1$ and $\lim_{T\to\infty} \Delta(x_{i,0}) > 0$.*

2. *If agent i develops the first project $x_{i,\tau}$ at time τ, agent $-i$ begins developing project $x_{-i,t} = 1 - x_{i,\tau}$ and pursues it until time T.*

Thus, agents initially develop projects with a high degree of compromise. This demotivates their opponent from exerting high levels of effort, both in the current phase, and in the "counteroffer" phase that follows the initial development. The degree of compromise is increasing in the amount of time available $T - t$, which influences the probability of completing two projects (15). Conversely as the decision approaches, agents shift towards their favorite projects, confident that their opponent will not be able to produce a counteroffer in the residual time. Figure 8 illustrates the equilibrium payoff and effort levels.

Figure 8: Decision at $T = 10$ (with $c = 1, \phi(v) = \sqrt{1 - v^2}, r = 0.04$)



The agents' equilibrium payoff prior to the first development $W_{i,t}$ is hump-shaped in the residual time, reflecting a trade-off between the probability of a development and the delay in implementation. The equilibrium effort levels $a_{i,t}$ and $\hat{a}_{i,t}$ are increasing over time both before and after the first development. Furthermore, agent $-i$'s equilibrium payoff increases as soon as agent i develops his own project, and as a result, his effort level jumps down.

To summarize, the option of delaying decisions in order to foster competition induces three sources of inefficiency: (a) progressively more selfish projects are pursued; (b) any effort exerted after the first breakthrough is socially worthless; and (c) implementation decisions suffer from costly delay.

Finally, an interesting extension consists of analyzing the performance of capital-budgeting meetings when agents can keep any developments to themselves and reveal them at the meeting only. This game has a mixed-strategy equilibrium in which agents randomize over projects at time 0 and then exert a (deterministic) level of effort, which is independent of the project chosen and increasing over time. Random (inefficient) project choice is also a feature of Hirsch and Shotts (2013)'s static model of competing policy proposals. Overall, our analysis suggests that the power to generate alternatives and to commit to *dynamic* (vs. fixed-date) decision-making is a necessary condition for generating efficient compromise through delegation.

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,

$$w_i(\alpha, x) = (1 - \alpha) v_i(x) + \alpha v_{-i}(x), \tag{16}$$

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.[20] We denote each agent's favorite project (i.e. the project that maximizes $w_i(\alpha, x)$) by $x_i^*(\alpha)$.

We analyze the effect of alignment on the equilibrium choice of projects and effort levels. To keep the illustration simple, we consider a deadline for counteroffers as described in Section 5. Given the agents' preferences (16), the immediate-acceptance constraint can be written as

$$w_{-i}(\alpha, x_i) \geq u\left(w_{-i}\left(\alpha, x_{-i}^*(\alpha)\right), T\right). \tag{17}$$

The function $u(w, T)$ denotes the value of the single-agent problem defined in (9), modified with the introduction of a deadline of T. In Proposition 11, we denote by $x_i(\alpha, T)$ the project that satisfies (17) with equality.

[20] 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 (16) arises if two division managers are compensated linearly based on both their division's performance and the firm's overall performance.

Proposition 11 (Effect of Preference Alignment)

1. *Fix a deadline for counteroffers* $T \geq 0$. *There exists a threshold* $\alpha^* \in (0, 1/2)$ *such that the equilibrium project choice is given by* $x_i(\alpha, T)$ *for* $\alpha < \alpha^*$, *and by* $x_i^*(\alpha)$ *for* $\alpha \geq \alpha^*$.

2. *The distance* $\Delta(x_i(\alpha, T))$ *is increasing in* α *and decreasing in* T. *The distance* $\Delta(x_i^*(\alpha))$ *is decreasing in* α.

Part (1.) establishes that the immediate-acceptance condition (17) provides a binding constraint on the agents' choice of projects for low levels of α. Once incentives are sufficiently aligned, however, this acceptance constraint will no longer bind, because each agent's favorite project now generates sufficient value for the other agent. Part (2.) shows that, as long as (17) 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 (17) binds. If (17) does not bind, the degree of compromise is then increasing in α.

This result reinforces the basic message of our model: *preference conflict* achieves *project alignment* when implementation 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.

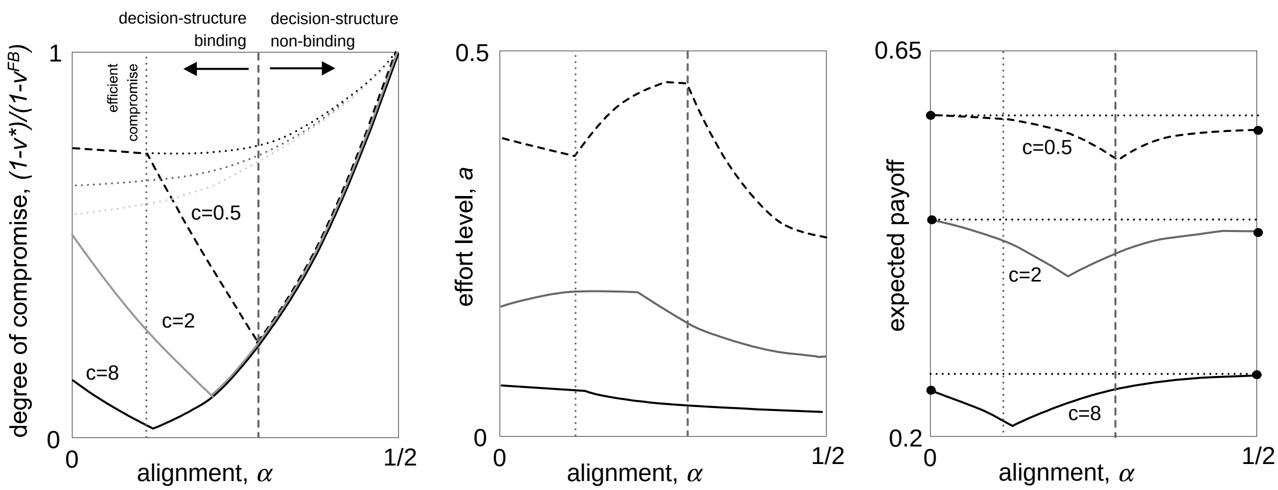
In Figure 9, we illustrate the team's performance in terms of project choices, effort levels, and payoffs.[21] For each level of α, we select the optimal deadline for counteroffers $\hat{T}$.

Panel (i) illustrates the project choices: when the agents are sufficiently efficient ($c = 0.5$) and preference alignment is sufficiently low, the efficient degree of compromise is attainable; as the level of alignment increases, the equilibrium level of compromise decreases until (17) no longer binds; for even larger values of α, the level of alignment increases again as the agents increasingly value 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 $\alpha = 0$. The immediate-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 the one hand, the divergence in projects supports stronger incentives to work; on the other hand, the increased degree of alignment exacerbates the free-riding incentives.

[21] We let $\phi(v) = \sqrt{1 - v^2}$ and $r = 0.1$.

Figure 9: Preference and Project Alignment



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

Panel (iii) shows that the agents' expected payoff is U-shaped in α. When agents are very patient or efficient, maximal conflict is beneficial because an appropriate decision-making procedure is able to harness the existing conflict to yield considerable compromise. Conversely, complete preference-alignment is preferred when the maximum degree of compromise is low, i.e. when the agents' cost of effort and discount rate are high.

Finally, note that the effect of alignment under basic governance structures may depend on the continuation equilibrium in the negotiations phase: if the continuation equilibrium leading to the constrained-efficient project choice is selected, alignment can, in fact, reduce both compromise and expected payoffs (as in Figure 9); however, if a worse continuation equilibrium is selected, e.g., the one leading to the development of each agent's favorite project, alignment constitutes a substitute means to inducing compromise. Outside of our model, alignment of interests is valuable if the organization needs to rely on strategic communication to ascertain the actual value of proposals on the table.[22] In short, we do not claim that conflict is unambiguously beneficial. What we have shown is that some decision structures 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.

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

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 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.

Monetary Payments. Some of the dynamics of our model would change if monetary payments between the two agents were allowed. At the same time, 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 will need to specify an actual bargaining protocol. 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. Finally, 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.

Appendix

Proof of Proposition 1. (1.) Each agent chooses an effort level $a_{i,t}$ to maximize (2). For any symmetric action profile $a_{i,s} = a_s$, $s \geq t$, the agent's continuation payoff at time t can be written as

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

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

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

for any symmetric action profile $a_{i,s} = a_s$. Furthermore, for all $\Delta\left(x_i\right) \geq 0$, the equilibrium payoff is strictly lower than $v_i\left(x_i\right)$.

We first look for a symmetric equilibrium with a constant value $V_{i,t} = V^*$, and therefore constant effort levels $a_{i,t}^* = a^*$. Each agent's effort level satisfies

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

The first-order condition for this problem is

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

and the expression for $a_i^*\left(x_i\right)$ given in (6) is the unique positive root to this equation. Using the first-order condition (4), each agent's symmetric equilibrium payoff is then given by

$$V_i^*\left(x_i\right) = v_i\left(x_i\right) - ca_i^*\left(x_i\right).$$

Conversely, suppose there exists an equilibrium with non-constant effort levels a_t^* and payoffs V_t^*. Because we know equilibrium effort is positive for all t, we can substitute the interior solution to first-order condition (4) into the HJB equation (3), and obtain the following ordinary differential equation for the equilibrium payoff,

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

The solution to this differential equation is given by

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

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

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

Therefore, for t large enough, we have

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

which violates the bound in (18), and contradicts the hypothesis that V_t^* is a symmetric equilibrium payoff.
(2.) The comparative statics with respect to x_i, c, and r follow immediately from differentiation of $a_{i,t}^*$ in (6). ■

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

$$a_i^{FB}(x_i) = \frac{-cr + \sqrt{c^2r^2 + 4r(v_i(x_i) + v_i(1-x_i))}}{2c}. \tag{20}$$

Setting $a_{i,t}^*$ in (6) equal to $a_{i,t}^{FB}$ in (20) 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 (7) 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 (20) is decreasing in x_i for all $\Delta(x_i) \geq 0$, while the equilibrium effort level $a_{i,t}^*$ in (6) is strictly increasing in x_i. Therefore, the expressions $a_{i,t}^* - a_{i,t}^{FB}$ and $\Delta(x_i) - \sqrt{2v_i(1-x_i)cr}$ have the same sign, and we know the latter expression is nil for the projects x_i^E defined in (7). ■

Proof of Proposition 3. (1.) If agents develop symmetric projects, let $v = v_i(x_i)$, and denote agent i's payoff from agent $-i$'s project $v_i(x_{-i})$ by $\phi(v)$. We can then write each agent's equilibrium payoff in terms of v and ρ as

$$V_i(v) = \frac{2v + \phi(v) + \rho - \sqrt{(v - \phi(v) - \rho)^2 + 6\rho v}}{3}. \tag{21}$$

Differentiate with respect to v and obtain

$$V_i'(v) \propto 2 + \phi'(v) - \frac{(v - \phi(v) - \rho)(1 - \phi'(v)) + 3\rho}{\sqrt{(v - \phi(v) - \rho)^2 + 6\rho v}}. \tag{22}$$

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 $\phi(v) = v$ and $\phi'(v) = -1$. Substituting into (22), we obtain

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

As $x \to 1$, we obtain $v = 1$ and $\phi(v) = 0$. Furthermore, by the concavity of the payoff frontier, we have $\phi'(1) < -1$. Substituting into (22), 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,

$$V^*(v) = \frac{a(v)(v + \phi(v)) - ca(v)^2/2}{r + 2a(v)}. \tag{23}$$

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

$$a(v) = \frac{v - \phi(v) - \rho + \sqrt{(v - \phi(v) - \rho)^2 + 6\rho v}}{3c}. \tag{24}$$

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 $\partial V/\partial v \propto 1 + \phi'(v) < 0$, 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 (21) and setting equal to zero, we can solve for the inverse function $\rho^*(v)$ in closed form,

$$\rho^*(v) = -\frac{1 + 2\phi'(v)}{2(2 + \phi'(v))} \frac{(v - \phi(v))^2}{v + \phi(v) + v\phi'(v)}. \tag{25}$$

Notice that (25) implies $\rho^*(v) = 0$ when $\phi(v) = v$, which corresponds to the project $x_i = 1/2$ for both agents i. This also implies $\phi'(v^*(\rho)) \to -1$ as $\rho \to 0$. Therefore, for ρ close to zero, we have $\phi'(v^*(\rho)) > -2$ and $v + \phi(v) + v\phi'(v) > 0$. Then as v increases, the first term (which is positive) increases. The numerator of second term increases, while the denominator decreases (since $\phi'(v) < -1$). As v increases, the term $v + \phi(v) + v\phi'(v)$ decreases, and $\phi'(v) > -2$ as long as $v + \phi(v) + v\phi'(v) \geq 0$. Therefore $\rho^*(v)$ is increasing in v, and grows without bound as v approaches the root of $v + \phi(v) + v\phi'(v)$, which is itself bounded away from 1. ■

Proof of Proposition 5. Fix a pair of projects $(\hat{x}_1, \hat{x}_2)$, and consider the following selection function:

$$\xi(\underline{x}, \underline{\tau}) = \begin{cases} x_i & \text{if} \quad \tau_i < \tau_{-i} \quad \text{and} \quad x_i = \hat{x}_i, \\ x_i & \text{if} \quad \tau_i > \tau_{-i} \quad \text{and} \quad x_{-i} \neq \hat{x}_{-i}, \\ x_{-i} & \text{otherwise.} \end{cases} \tag{26}$$

Under selection function (26), each agent must develop a project that will be implemented: suppose the first project developed is given by $x_i \neq \hat{x}_i$; agent $-i$ can implement x_i or pursue his favorite project and implement it immediately; however, agent $-i$'s project is worth zero to agent i. Furthermore, agent $-i$ will implement "the right project" $x_i = \hat{x}_i$ immediately, because his continuation payoff by blocking this proposal is given by

$$u(v_{-i}(\hat{x}_i)) < v_{-i}(\hat{x}_i).$$

It remains to be verified whether agent i can develop any project $x_i \neq \hat{x}_i$ and still induce agent $-i$ to implement it. Notice that agent $-i$ implements a project $x_i \neq \hat{x}_i$ if and only if

$$v_{-i}(x_i) \geq u(1) = W^*.$$

Therefore, if $v_{-i}(\hat{x}_i) > W^*$ there exists by continuity another project $x_i \neq \hat{x}_i$ with both $v_{-i}(x_i) > W^*$ and $v_i(x_i) > v(\hat{x}_i)$. Developing this project constitutes a profitable deviation for agent i. Thus, the set of equilibrium projects contains all pairs $(x_1, x_2) \in [\bar{x}_1(\rho), 1] \times [0, \bar{x}_2(\rho)]$. Finally, notice that the selection function $\xi(\underline{x}, \underline{\tau})$ in (26) maximizes the continuation payoff from blocking an off-equilibrium proposal by assigning unconditional authority to the receiver of such a proposal. Therefore, if there exists a profitable deviation $x_i \neq \hat{x}_i$ under this selection rule, this deviation is also profitable under any other selection function. This establishes that no pair $(x_1, x_2) \notin [\bar{x}_1(\rho), 1] \times [0, \bar{x}_2(\rho)]$ can be developed in equilibrium. ■

Proof of Proposition 4. (1.) Let $v_i(x_i) = v$, and denote the Pareto frontier by $\phi(v)$. The solution $\bar{v}(\rho)$ to the equation

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

where $u(1, \rho)$ is defined in (9), characterizes the maximum level of compromise (i.e. the lowest v) that can be achieved in an equilibrium. We denote the constrained-efficient projects in terms of their value for agent i by defining $v^*(\rho) := v_i(x_i^*(\rho))$. We then compare the maximum-compromise project values $\bar{v}(\rho)$ and the second-best project values $v^*(\rho)$. Writing the function $u(1, \rho)$ more explicitly, we obtain

$$\phi(v) = 1 + \rho - \sqrt{\rho(2 + \rho)}. \tag{27}$$

Solving for ρ we obtain the inverse function

$$\bar{\rho}(v) = \frac{(1 - \phi(v))^2}{2\phi(v)}. \tag{28}$$

We now compare this expression with the inverse function $\rho^*(v)$ in (25), which is given by

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

Note that both functions are strictly increasing in v. Denote the value of project $x = 1/2$ as $v_0 = \phi(v_0)$. We then know $\rho^*(v_0) = 0$ while $\bar{\rho}(v_0) > 0$.

(2.) Furthermore, we know $\bar{\rho} \to \infty$ as $v \to 1$ while $\rho^* \to \infty$ as v approaches the root of $v + \phi(v) + v\phi'(v)$, which is smaller than one. The agents' symmetric equilibrium payoffs (21) are concave in v and maximized by $v^*(\rho)$. When $v^*(\rho)$ is not attainable, the highest equilibrium total payoff is obtained by minimizing the equilibrium $v(\rho)$. Because v is decreasing in the continuation value $u(\cdot)$, it follows that the value of the best equilibrium projects is given by $\bar{v}(\rho)$.

(3.) We know from (1.) and (2.) that the function $\bar{\rho}$ must cross ρ^* from above at least once. We now show these functions cross only once under condition (13). For this purpose, define the function

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

Now consider the ratio

$$\frac{\rho^*(v)}{\hat{\rho}(v)} = -\frac{1+2\phi'(v)}{2+\phi'(v)} \frac{\phi(v)}{v+\phi(v)+v\phi'(v)}, \tag{29}$$

and rewrite it as

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

where the denominator is always positive because $\phi'(v^*(\rho)) \in (-2,-1)$. 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

$$\phi'(v) - 2v\phi''(v),$$

which is positive under condition (13). Therefore, the ratio $\rho^*(v)/\hat{\rho}(v)$ is increasing in v. Finally, notice that

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

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. ■

Proof of Proposition 6. (1.) Let x_i^{**} denote agent i's favorite project. Projects $\left(x_i^{**}, x_{-i}^{**}\right)$ are developed in the unique equilibrium under unilateral implementation. Under agent-i authority, projects $(x_i^{**}, \bar{x}_{-i})$ are developed. By Proposition 5, both projects are implemented in equilibrium under unanimity.

(2.) 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

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

where $a_i^*(1,0)$ is the equilibrium action as in (6) 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 $v_1(\bar{x}_2) = W^*$ 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 $V^A \triangleq \Sigma_i V_i^A$ satisfies

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

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 their *maximum-compromise* 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

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

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

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

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

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

Let $y \triangleq v_{-i}(\bar{x}_i)$, and solving for ρ, we obtain $\bar{\rho}(y)$, i.e. the threshold function $\bar{\rho}(\cdot)$ defined in (28). Solving $a_2^*(1, \bar{x}_2) = a_i^{FB}(\bar{x}_i)$ for v, and replacing ρ with $\bar{\rho}(y)$, we obtain

$$a_2^*(1, \bar{x}_2) > a_i^{FB}(\bar{x}_i) \iff v > \hat{v}(y), \tag{30}$$

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 (30) is satisfied. ■

Proof of Proposition 7. (1.) Suppose both agents develop the second-best project $x_i^*(\rho)$. We construct a deadline for counteroffers $\hat{T}(\rho)$ that makes the receiver of the first proposal indifferent between accepting and pursuing his favorite project under the deadline. Because the first agent who develops a project must choose one in the other agent's acceptance set (else receive a payoff of zero), this condition is sufficient to induce the second-best project choices $x^*_{-i}(\rho)$. The second agent's continuation value $V(t,T)$ 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

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

We now let $y(\rho) = v_i\left(x^*_{-i}(\rho)\right)$, and we solve the equation

$$V(0,T) = y(\rho)$$

for T. The solution is given by

$$r\hat{T}(\rho) = \sqrt{\frac{\rho}{2+\rho}}\ln\left(\frac{1-y(\rho)\left(1+\rho-\sqrt{\rho(2+\rho)}\right)}{1-y(\rho)\left(1+\rho+\sqrt{\rho(2+\rho)}\right)}\right). \tag{31}$$

(2.) The right-hand side of (31) 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 (28). Therefore, for $\rho > \bar{\rho}$, the optimal deadline in (31) (which is now infinite) induces development of the maximum-compromise projects $\bar{x}_i(\rho)$.

(3.) From the proof of Proposition 4, we know the following bound on $y'(\rho)$,

$$y'(\rho) \in \left[-\frac{(1-y(\rho))\,y(\rho)}{(1+y(\rho))\,\rho}, 0\right]. \tag{32}$$

Now let $y = y(\rho)$ in expression (31), differentiate totally with respect to ρ, and use the bound in (32). We obtain

$$(2+\rho)\frac{d(rT)}{d\rho} > \frac{-2y}{1+y} + \frac{1}{\sqrt{\rho(2+\rho)}}\ln\frac{1-y\left(1+\rho-\sqrt{\rho(2+\rho)}\right)}{1-y\left(1+\rho+\sqrt{\rho(2+\rho)}\right)}. \tag{33}$$

We then note that the right-hand side of (33) 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. ■

Proof of Proposition 8. (1.) We show that under any optimal mechanism agents pursue the constrained-efficient projects

$$x_i(\rho) = v \begin{cases} x_i^*(\rho) & \text{if} \quad \rho \leq \bar{\rho}, \\ \bar{x}(\rho) & \text{if} \quad \rho > \bar{\rho}, \end{cases}$$

and implement the first developed project without delay. We establish this result in the following steps.

We first consider a relaxed problem in which we optimize directly over the two agents' expected payoffs at the time the first project is developed. As we focus on symmetric mechanisms, let v_t denote agent i's expected payoff from developing the first project at time t. Similarly, y_t denotes agent i's expected payoff if agent $-i$ develops the first project at time t. An optimal mechanism maximizes each agent's expected payoff over all feasible paths of v_t and y_t. Each agent's expected payoff is given by

$$V_0 = \int_0^\infty e^{-\int_0^t (r+2a_s^*)\mathrm{d}s} \left(a_t^*(v_t + y_t) - c(a_t^*)\right) \mathrm{d}t, \tag{34}$$

where a_t^* is the equilibrium effort path, given payoffs v_t and y_t. We first establish a bound on the equilibrium payoffs v_t and y_t

Claim 1 *Under any mechanism, the receiver of the first proposal obtains an expected payoff*

$$y_t \leq \min\{W^*, \phi(v_t)\}, \tag{35}$$

where W^* is the value of the single-agent problem defined in (10).

Proof. Suppose agent $-i$ receives a proposal x_i at time τ_i. His continuation payoff 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 W^* defined in (10) provides a tight upper bound on his continuation payoff if the first project is never implemented. Finally, suppose agent $-i$'s expected payoff upon development of agent i's project x_i exceeds W^*. Then agent i can improve his own payoff by pursuing a more preferred project x_i' because the subsequent assignment of authority does not depend on project characteristics, and agent $-i$ implements any proposal worth at least W^* as soon as he is granted the authority to do so. ■

Thus, an optimal mechanism maximizes (34) with respect to the paths v_t and y_t, subject to (35) and to the following equilibrium restriction on the function a_t^*,

$$a_t^* = \arg\max_{\{a_t\}} \int_0^\infty e^{-\int_0^t (r + a_s + a_s^*) \mathrm{d}s} \left(a_t v_t + a_t^* y_t - c\left(a_t\right)\right) \mathrm{d}t.$$

Following the approach of Mason and Välimäki (2012), we write our maximization problem recursively, letting V_t denote each agent's continuation payoff. Furthermore, we normalize the cost parameter c to 1, and let $r = \rho$. We then obtain the following optimal-control formulation of our original problem:

$$\max_{\{v_t, y_t\}} V_0$$

$$\text{s.t.} \quad \dot{V}_t = \rho V_t + \left(a_t^*\right)^2/2 - a_t^*\left(v_t + y_t - 2V_t\right), \tag{36}$$

$$a_t^* = v_t - V_t, \tag{37}$$

$$y_t \leq \min\left\{W^*, \phi\left(v_t\right)\right\},$$

where (36) is the law of motion of V_t and (37) is the recursive formulation of the agents' best-reply in terms of effort. We can then write the Hamiltonian as

$$H_t = \lambda_t\left(\rho V_t - \left(v_t - V_t\right)\left(\left(v_t - V_t\right)/2 + y_t - V_t\right)\right) + \mu_t\left(W^* - y_t\right) + \gamma_t\left(\phi\left(v_t\right) - y_t\right). \tag{38}$$

The necessary conditions for the Maximum Principle are the following:

$$\frac{\partial H_t}{\partial v_t} = \frac{\partial H_t}{\partial y_t} = 0$$

$$\dot{\lambda}_t = -\frac{\partial H_t}{\partial V_t},$$

in addition to complementary slackness (40) and to the transversality condition (39) for infinite-horizon problems established by Michel (1982),

$$\lim_{t \to \infty} H_t = 0 \tag{39}$$

$$\mu_t\left(W^* - y_t\right) = \gamma_t\left(\phi\left(v_t\right) - y_t\right) = 0. \tag{40}$$

Because this is an autonomous problem, it is straightforward to verify that the Hamiltonian is identically zero along the optimal path (Seierstad and Sydstaeter, 1987). Finally, using the complementary slackness conditions (40), we conclude that $\dot{V}_t \equiv 0$. Because the optimal path V_t^* is constant, the optimal controls v_t^* and y_t^* are stationary. Using the fact that (36) is identically zero, the equilibrium value V^* as a function of the controls v and y is given by

$$V^*(v, y) = \frac{1}{3}\left(2v + y + \rho - \sqrt{(v - y - \rho)^2 + 6\rho v}\right). \tag{41}$$

Our original problem then reduces to maximizing (41) subject to (35). It is easy to verify that $V^*(v, y)$ is increasing in both of its arguments. Because $\phi(v)$ is strictly decreasing in v, we know the constraint $y^* \leq \phi(v^*)$ binds. This establishes that the optimal mechanism involves no dissipation on the equilibrium path. Finally, following the steps in the proof of Proposition 4, we can establish that the constraint $y^* \leq W^*$ binds depending on the value of ρ. In particular, we have the following characterization of the optimal policy v^*:

$$v^* = \begin{cases} v(x^*(\rho)) & \text{if} \quad \rho \leq \bar{\rho}, \\ \phi^{-1}(W^*(\rho)) & \text{if} \quad \rho > \bar{\rho}. \end{cases}$$

(2.) As $\rho \to 0$, the constrained efficient projects coincide with the second-best projects $x_i^*(\rho)$ (see Proposition 4). A necessary condition for these projects to be implemented without delay is that each agent i wishes to develop $x_i^*(\rho)$ and that each agent $-i$ accepts the first proposal immediately. In particular, we need

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

where W_{-i} denotes the continuation payoff of agent $-i$ upon receiving the first proposal. Now suppose the mechanism introduces no dissipation and delay (or effort) costs vanish ($\rho \to 0$). The continuation payoff $W_{-i}(x_i^*, \rho)$ converges to a weighted average of the payoffs from implementing the original proposal x_i^* and any counterproposal x_{-i}. Because the allocation of authority does not condition on project characteristics, it must be that

$$v_{-i}(x_i^*(\rho)) \geq p_i v_{-i}(x_i^*(\rho)) + (1 - p_i) \cdot 1, \tag{42}$$

where p_i is the probability of implementing the original proposal, and agent $-i$ can develop her favorite project as a counterproposal. Satisfying (42) requires $p_i \to 1$. Now consider the first agent's incentives to develop project $x_i^*(\rho)$. It must be that, for each agent i,

$$v_i(x_i^*(\rho)) \geq p_i, \tag{43}$$

because agent $-i$ would develop her favorite project as a counteroffer (which is worth nothing to agent i). However, as $\rho \to 0$ and $p_i \to 1$, condition (43) cannot hold for $v_i(x_i^*(\rho)) < 1$, which we know from Proposition (3) is true of the second-best projects, for all $\rho \geq 0$. ■

Proof of Proposition 9. 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 10. The solution to agent $-i$'s best-reply problem (14) is given by

$$V_{-i,t}(x_i) = e^{-r(T-t)}\left(v_i(x_i) - \frac{2r(v_i(x_i) - v_{-i}(x_i))}{(1 - e^{-r(T-t)})(v_i(x_i) - v_{-i}(x_i)) + 2r}\right),$$

and therefore

$$a_{-i,t}(x_i) = e^{-r(T-t)}v_{-i}(1 - x_i) - V_{-i,t} = \frac{2r(v_i(x_i) - v_{-i}(x_i))}{(e^{r(T-t)} - 1)(v_i(x_i) - v_{-i}(x_i)) + 2re^{r(T-t)}}.$$

The probability of successfully developing project $x_{-i} = 1 - x_i$ over the interval $[\tau, T]$ is given by

$$\begin{aligned}\alpha_\tau(x_i) &= 1 - e^{-\int_\tau^T a_{-i,t}(x_i)\mathrm{d}t} \\ &= \frac{\left(1 - e^{-r(T-t)}\right)(v_i(x_i) - v_{-i}(x_i))}{(1 - e^{-r(T-t)})(v_i(x_i) - v_{-i}(x_i)) + 2r}\left(1 + \frac{2r}{2r + (1 - e^{-r(T-t)})(v_i(x_i) - v_{-i}(x_i))}\right).\end{aligned}$$

Now we can turn to the agents' initial project choice. Agent i's first-stage value function $W_{i,t}$ given the effort level and project choice of agent $-i$, is given by the solution to the following problem:

$$rW_{i,t} = \max_{a,x}[a(\beta_t(x) - W_{i,t}) + a_{-i,t}(V_{i,t}(x_{-i,t}) - W_{i,t}) - c(a) + \dot{W}_{i,t}]. \tag{44}$$

The reward $\beta_t(x)$ in (44) for completing project x at time t is given by

$$\begin{aligned}\beta_t(x) &= e^{-r(T-t)}\left(v_i(x) - \alpha_t(x)\left(v_i(x) - v_{-i}(x)\right)\right), \\ &= e^{-r(T-t)}\left(v_{-i}(x) + \frac{4r^2\left(v_i(x) - v_{-i}(x)\right)}{\left(2r + \left(1 - e^{-r(T-t)}\right)\left(v_i(x) - v_{-i}(x)\right)\right)^2}\right). \qquad (45)\end{aligned}$$

We then maximize (45) with respect to x, letting $v_i(x) = v$ and $v_i(x) - v_{-i}(x) = \Delta(v)$. Differentiating (45) and setting equal to zero, one can show that agent i's optimal project choice at time $t = T - \tau$ satisfies

$$\frac{\Delta'(v) - 1}{\Delta'(v)} = 4r^2 \frac{2r - \delta(\tau, v)}{\left(2r + \delta(\tau, v)\right)^3}, \qquad (46)$$

where $\tau = T - t$ and

$$\delta(\tau, v) \triangleq \left(1 - e^{-r\tau}\right)\Delta(v).$$

Note that $\delta(\tau, v)$ is increasing in both v and τ. The right-hand side of (46) is decreasing in δ, and the left-hand side is increasing in v. Therefore, the solution v_τ is decreasing in τ. Furthermore, as $\tau \to 0$, the right-hand side of () goes to one, while the left-hand side takes values between 1/2 and 1. Therefore, if the slope of the Pareto frontier has no upper bound, $\Delta(v_\tau) \to 1$ as $\tau \to 0$. Otherwise, there exists $\bar{\tau} > 0$ such that $\Delta(v_\tau) = 1$ for all $\tau \leq \bar{\tau}$. Conversely, as $\tau \to \infty$ we have $\delta(\tau, v) \to \Delta(v)$ and the equilibrium projects satisfy

$$\frac{\Delta'(v) - 1}{\Delta'(v)} = 4r^2 \frac{2r - \Delta(v)}{\left(2r + \Delta(v)\right)^3},$$

whose solution Δ^* is strictly positive since the right-hand side is equal to 1 when $\Delta = 0$, while the left-hand side is equal to 1/2. ■

Proof of Proposition 11. (1.) Fix a deadline for counteroffers T and the degree of preference alignment α. Denote agent i's favorite project by $v_\alpha \triangleq v_i(x_i^*(\alpha))$. In other words,

$$v_\alpha = \arg\max_v \left[(1 - \alpha)v + \alpha\phi(v)\right].$$

Analogously, let $y_\alpha \triangleq v_i\left(x_{-i}^*(\alpha)\right)$ and note that if agents pursue symmetric projects then $y_\alpha = \phi(v_\alpha)$. If each agent's favorite project satisfies the immediate-acceptance constraint (17), the following inequality must hold

$$(1 - \alpha)y_\alpha + \alpha v_\alpha \geq u\left((1 - \alpha)v_\alpha + \alpha y_\alpha, T\right). \qquad (47)$$

Notice that each agent's value for his own favorite project, $(1 - \alpha)v_\alpha + \alpha y_\alpha$, is decreasing in

α by the Envelope Theorem. Furthermore, v_α satisfies the following first-order condition

$$1 - \alpha + \alpha\phi'(v_\alpha) = 0.$$

Now differentiate the left-hand side of (47) with respect to α. We obtain

$$\frac{d((1-\alpha) y_\alpha + \alpha v_\alpha)}{d\alpha} = v_\alpha - y_\alpha + \frac{\partial v_\alpha}{\partial \alpha}(1 + \phi'(v_\alpha)) > 0,$$

because $\alpha < 1/2$ implies $v_\alpha > y_\alpha$, hence $\phi'(v_\alpha) < -1$; and because

$$\frac{\partial v_\alpha}{\partial \alpha} = \frac{1 - \phi'(v_\alpha)}{\alpha\phi''(v_\alpha)} < 0.$$

Therefore, the right-hand side of (47) is decreasing and the left-hand side is increasing in α. It follows that there exists a threshold α^* such that the immediate-acceptance constraint (17) binds for $\alpha \leq \alpha^*$. Finally, the threshold α^* must be interior, because the left-hand side of (47) is nil for $\alpha = 0$, and it is equal to the first argument of $u(w, T)$ for $\alpha = 1/2$ (which implies the constraint is satisfied for all T).

(2.) For $\alpha > \alpha^*$, the comparative statics of v_α follow from part (1.). For $\alpha \leq \alpha^*$, we can rewrite (17) in terms of values v as

$$(1-\alpha)\phi(v) + \alpha v - u((1-\alpha)v + \alpha\phi(v), T) = 0. \tag{48}$$

and totally differentiate. We obtain

$$\frac{\partial v}{\partial \alpha} = \frac{(v - \phi(v))(1 + u_1((1-\alpha)v + \alpha\phi(v), T))}{(1 - \alpha + \alpha\phi'(v))(1 + u_1((1-\alpha)v + \alpha\phi(v), T)) - (1 + \phi'(v))}.$$

Notice that the numerator is positive because $\alpha < 1/2$ and $u(w, T)$ is increasing in both of its arguments. The denominator is positive because $\phi'(v) < -1$ and the marginal value of a more extreme project $1 - \alpha + \alpha\phi'(v)$ is strictly positive when (17) binds. Therefore the solution v to (48) is increasing in α. By the same arguments, it is immediate to see that

$$\frac{\partial v}{\partial T} = -\frac{u_2((1-\alpha)v + \alpha\phi(v), T)}{(1 - \alpha + \alpha\phi'(v))(1 + u_1((1-\alpha)v + \alpha\phi(v), T)) - (1 + \phi'(v))}$$

is negative, and therefore a longer deadline increases the required level of compromise. ■

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