

Foarta, Dana; Ting, Michael M.

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Organizational capacity and project dynamics

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Organizational Capacity and Project Dynamics

Dana Foarta

Stanford Graduate School of Business and CEPR

Michael M. Ting

Columbia University

November 2023

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Abstract:

This paper develops a dynamic theory of the interaction of organizational capacity and its institutional context. Higher capacity enables organizations to deliver projects efficiently, while institutional barriers allow opposing interests to reallocate project payoffs at the cost of delays. Projects that are small and distributionally unequal are vulnerable to revisions. Project designers avoid revisions by equalizing distributive benefits or inflating project scales to increase the cost of revisions. We show that “matched” levels of capacity and institutional barriers minimize welfare. Organizational systems with high capacity and low institutional barriers, or low capacity and high institutional barriers, generate more efficient outcomes.

Stigler Center for the Study of the Economy and the State
University of Chicago Booth School of Business
5807 S Woodlawn Ave
Chicago, IL 60637

Organizational Capacity and Project Dynamics*

Dana Foarta

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Abstract

This paper develops a dynamic theory of the interaction of organizational capacity and its institutional context. Higher capacity enables organizations to deliver projects efficiently, while institutional barriers allow opposing interests to reallocate project payoffs at the cost of delays. Projects that are small and distributionally unequal are vulnerable to revisions. Project designers avoid revisions by equalizing distributive benefits or inflating project scales to increase the cost of revisions. We show that “matched” levels of capacity and institutional barriers minimize welfare. Organizational systems with high capacity and low institutional barriers, or low capacity and high institutional barriers, generate more efficient outcomes.

Keywords: Organizational Capacity, Revisions, Power Transitions, Project Delays, Project Design.

JEL codes: D73, D82

*Foarta: Stanford Graduate School of Business and CEPR, email: ofoarta@stanford.edu. Ting: Columbia University, email: mmt2033@columbia.edu. We wish to thank Luca Bellodi, Benjamin Blumenthal, Alessandro Bonnatti, Steve Callander, Wouter Dessein, Bob Gibbons, Juan Felipe Riano, Ravideep Sethi, and numerous seminar and conference participants for useful suggestions.

1 Introduction

It is now a truism that organizations are crucial for executing major undertakings in modern society, ranging from government policies to construction to product development. Leaders or policy-makers can set objectives and promise results, but a bureaucratic machinery is inevitably needed to produce on-the-ground outcomes. Capturing organizational performance is obviously a formidable task, but practitioners and scholars have increasingly coalesced around the concept of *organizational capacity* as one of its central determinants.¹

The appeal of organizational capacity is seemingly obvious. Higher capacity — loosely speaking, a better ability to “get things done” — should produce outputs that are more timely, more efficient, or of higher quality. A wide variety of studies have shown that under-resourced or under-paid organizations produce worse results.² This perspective implicitly assumes that organizations have coherent objectives and significant latitude to achieve them. Yet the assumption is tenuous when internal or external interests can exploit institutional processes to reshape outcomes. Under the threat of contestation, the effects of capacity become less clear. To take a simple example, suppose that a legal regime grants broad standing to sue project developers on environmental grounds. A high capacity organization might invite suits that incur costly delays because victorious litigants can be confident in the quick implementation of their proposals.

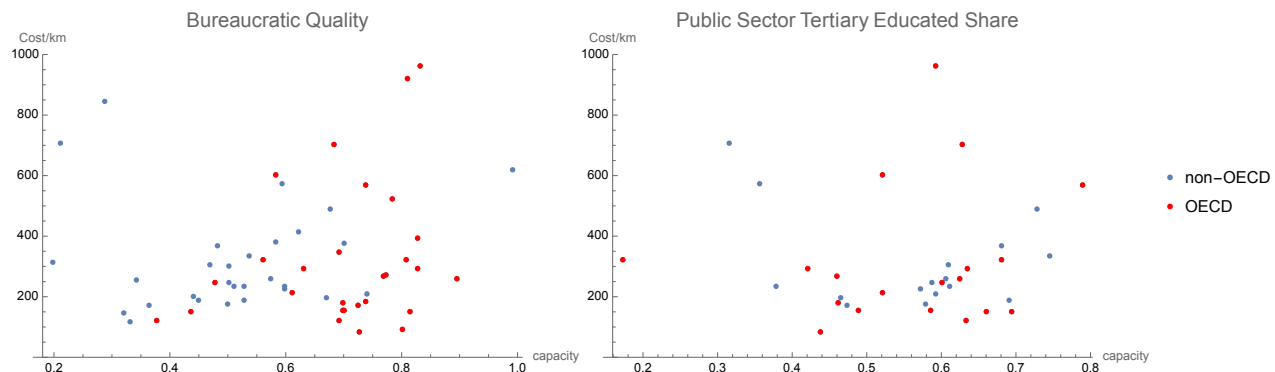
A look at aggregate data across countries highlights the lack of obvious relationships between organizational capacity and project outcomes. Figure 1 plots the average construction cost per kilometer of public infrastructure projects for 59 countries, as calculated by the New York University Transportation Costs Project ([Marron Institute of Urban Management, 2023](#)), against measures of capacity in national bureaucracies.³ The plots show no correlation between costs and World Bank data on bureaucratic quality and the education level of public sector workers, and also suggest little role for national wealth. While obviously crude, the figure implies that organizational capabilities alone cannot be the dominant

¹Bodies as varied as the UNDP, USAID, [OECD \(2011\)](#), and the European Centre for Development Policy Management ([Keijzer et al., 2011](#)) identify organizational capacity as a key developmental objective. Additionally, scholarly mentions of the term have increased sharply since the 1990s. As of October 2023, Google Scholar returned about 4,970 results for “organizational capacity” between 1990 and 1999, 16,300 between 2000 and 2009, 22,500 between 2010 and 2019, and 17,500 since 2020.

²See for example [Derthick \(1990\)](#); [Rauch and Evans \(2000\)](#); [Gorodnichenko and Peter \(2007\)](#); [Propper and Van Reenen \(2010\)](#); [Warren \(2014\)](#); [Decarolis et al. \(2020\)](#).

³The [Transportation Costs Project](#) dataset includes 588 projects that overlapped with the period 2011-2020. Costs are given in real 2021 PPP dollars. The *Bureaucratic Quality* and *Tertiary Educated Index* data come from the World Bank’s [Country-Level Institutional Assessment and Review](#) and [Worldwide Bureaucracy Indicators](#), respectively. We averaged scores over the period 2011-2020. Appendix D provides further examples and detail.

Figure 1: Transportation Costs and Bureaucratic Capacity



Note: Plots average cost per kilometer of major public transportation projects against World Bank measures of bureaucratic quality (left) and proportion of tertiary-educated public sector workers (right). Each point represents a country average for projects active between 2011 and 2020. Red data points indicate OECD countries.

driver of many important outcomes of interest.⁴

This paper develops a theory of policy-making that integrates organizational capacity and its institutional context. Its main objective is to show how these factors jointly affect the planning and execution of complex projects, in terms of scale, distribution of benefits, and delays. As a starting point, consider a politician who proposes the development of a public works project. Before the project reaches completion, the opposition may attempt to renegotiate its key features. But unlike a standard bargaining game, the politician and the opposition cannot terminate the game by agreeing to a proposal. This is because the project is administered by a bureaucratic organization, whose capacity determines its rate of progress, and hence its eventual cost and whether new opportunities for interim revisions will arise. As such, we integrate an institutional process, which governs the bargaining over the project, with an organizational process, which governs the completion of the project. While ubiquitous, this combination has not thus far been theoretically analyzed.

We formalize the organizational process with a discrete Markov process representation of projects. Completing a project requires traversing a sequence of bureaucratic stages; for example, organizational procedures often specify that research and development must be completed before construction can begin.⁵ Capacity is the probability of progressing from

⁴Liscow et al. (2023) find that higher capacity U.S. state transportation departments reduce road resurfacing costs. As the study notes, these projects tend to generate relatively little political controversy.

⁵A good example is the Federal Transit Administration (FTA) Capital Investment Grants (CIG) program, which is the US federal government’s main mechanism for supporting public transportation projects. CIG proposals must complete two stages before construction can begin: the “Project Development” stage includes environmental review, approval by local authorities, and commitments for some non-federal funds; second,

each stage to the next in a given period. If it does not progress, the project remains in the same stage to begin the next period. Each period before completion imposes costs that are increasing in the project’s scale. Thus in isolation, higher organizational capacity — due to better personnel or technology — reduces costs and variability in delivery times.

We embed the organizational process in an institutional process that allows revision of some project features. At the inception of a project, one agent, the project designer, chooses its scale and a distribution of benefits between herself and an opposing agent. The former is irreversible, while the latter is renegotiable. The distributive component corresponds to downstream decisions such as siting or contractor selection that are possible only after the scale is established.⁶ In subsequent periods, agents randomly receive opportunities to attempt revisions. Depending on the project, these could arise from a turnover in political leadership, a shift in the power balance between organizational factions, or the mobilization of NIMBY groups. Attempting a revision automatically pauses progress, and if the attempt is successful the revising agent chooses a fresh distribution of payoffs. The probability of success corresponds to the openness of the institutional environment to such interventions.⁷ The initial proposer must then take the possibility of strategic revisions into account in choosing project parameters.

The interaction between the organizational and the institutional processes has significant implications for project design and execution. We first consider projects of fixed scale, which restrict the agents to propose and possibly revise the distribution of benefits. These choices are driven primarily by the running costs that would be generated by attempted revisions. Very large projects are maximally unequal and never revised, because the costs of delay outweigh any benefit from attempting revision. Very small projects are also maximally unequal but always revised, because delays do not impose significant costs. Finally, projects of intermediate size feature a combination of revision by at most one agent and more egalitarian distributions to deter revisions.

We then ask how the initiating agent chooses scale in anticipation of these dynamics. When the opposing agent is unlikely to have revision opportunities, the optimal scale is large enough to deter revisions while allocating all benefits to the initiator. When revision

the “Engineering” stage finalizes funding sources and design details, including geotechnical and safety reports.

⁶As an example, the 1973 election of Maynard Jackson, Atlanta’s first black mayor, disrupted ongoing plans for a new international airport. Instead of proceeding with the development of a new site, Jackson pushed to expand an existing airport that was located closer to his political base, resulting in today’s Hartsfield-Jackson airport.

⁷Administrative procedures such as the US National Environmental Policy Act (NEPA) mandate reviews of government-involved projects that invite intervention by outside groups (e.g., [Mandelker, 2010](#)). As we assume, challenges can impose costly delays: the [US GAO \(2014\)](#) estimated that the 197 NEPA environmental impact statements completed in 2012 took an average of 4.6 years to finalize.

opportunities become more likely, the threat of revisions depends on relative capacity, or the difference between the probabilities of project progress and revision success. High relative capacity again allows the initiator to propose a maximally unequal project that avoids revisions. At intermediate capacity, revisions become more potent, but the initiator can forestall them by upscaling projects while maintaining high inequality. The tactic of inflating running costs becomes untenable as relative capacity declines further. Revisions then emerge as an effective threat, and reduced distributive inequality may be necessary to deter them. Both revisions and greater equality reduce the initiator’s expected payoff and thereby result in downscaled projects. Increasing capacity therefore has the overall effect of reducing revisions and increasing both scale and inequality.

The equilibrium design choices have significant welfare implications. Upscaled projects, which occur under intermediate relative capacity, cause the agents to do collectively worse than no project at all. An organizational and institutional system that features low capacity and high openness to the opposition makes upscaling impossible, while a system with high capacity and low openness makes upscaling unnecessary. Tactical upscaling is also impossible when prevented by budgets or physical limitations. Somewhat surprisingly, higher capacity can increase expected obstruction and delay in the presence of scale caps.

We finally explore the implications of allowing project cancellation. To do this, we extend the model to two phases, where the first is designated for preliminary work prior to the determination of scale and distribution, and the second is identical to our main model. During the first phase, the opposition can cancel the nascent project outright and thereby prevent some of the worst projects from proceeding. This proves to be at best a partial remedy, as cancellation itself activates the institutional barriers that affect revisions. Thus, attempts to cancel can eliminate some bad projects but increase costs and delays for others.

The main insight of our theory is that the implications of organizational capacity cannot be considered in isolation of its institutional context. Whether in the public or private sector, formal or informal channels create the potential for reallocating benefits, killing projects, and inflating costs. As a result, capacity enhancements that have the mechanical effect of improving technical execution may ultimately worsen project outcomes. In such settings, reforming institutions becomes more important than adding capacity.

Related Literature. A large literature in political economy has analyzed the dynamics of policies under transitions in political power ([Alesina and Tabellini, 1990](#); [Alesina and Drazen, 1991](#); [Battaglini and Coate, 2008](#); [Gersbach et al., 2020](#); [Gratton et al., 2021](#); [Harstad, 2023](#)). Within this literature, a main contribution of this paper is its explicit consideration of a distinct bureaucratic process that governs the production of policy outcomes. Policies and

their dynamics are not fully determined by the decision-maker in power. The bureaucratic process unfolds in parallel to the political process. It impacts the decisions of principals, and it is essential for understanding the form of long-term policies.

Our theory takes the political view of organizational systems as coalitions of individual interests, as outlined by [March \(1962\)](#) and [Cyert et al. \(1963\)](#) and surveyed in [Gibbons et al. \(2013\)](#). Work in this literature has examined on how institutions should be designed to improve project selection or collaboration between competing agents. In general, the organizational process that delivers a project is determined prior to the institutional process of selecting the winning project (e.g., [Bonatti and Rantakari, 2016](#); [Callander and Harstad, 2015](#)). The innovation of our paper is in modeling institutional and organizational processes that run simultaneously. Any bargaining between parties over claims to project output ends stochastically when the organization finishes. Previous work has also considered the issue of contested control in organizations, but from the angle of inefficient investments in order to change the transition process itself ([Skaperdas, 1992](#); [Rajan and Zingales, 2000](#)). We focus instead of the inefficiencies that emerge under a fixed institutional system for transitions, such that project design itself is altered in order to preserve claims for some members.

Theoretical efforts at modeling organizational capacity have thus far adopted widely divergent approaches. [Huber and McCarty \(2004, 2006\)](#) examine the relationship between a legislative principal and a bureaucratic agent, and represent capacity as the variance of possible outcomes following a bureaucratic policy choice. The outcome space in these models is ideological, and the outputs include delegation, compliance, and whether legislation is possible. [Ting \(2011\)](#) and [Turner \(2020\)](#) also examine this setting, but model capacity as policy valence and costs, respectively. [Foarta \(2022\)](#) formalizes capacity as agency cost structure in a dynamic electoral model. Aside from a different set of outcomes, one contribution of the present paper is a general notion of organizational capacity that generates both variance and costs. This approach is consistent with a predominant approach in empirical research, which is to treat capacity as an input into organizational production functions. Such inputs include information ([Lee and Zhang, 2017](#)) and perhaps most prominently, human capital ([Brown et al., 2009](#); [Dal Bó et al., 2013](#); [Acemoglu et al., 2015](#); [Bolton et al., 2016](#)).⁸

Finally, several theoretical models address the design of long-term policies (e.g., [Battaglini et al., 2012](#); [Callander and Raiha, 2017](#); [Chen et al., 2023](#)), with a growing literature focusing on the optimal provision of dynamic incentives for multistage projects (e.g., [Toxvaerd, 2006](#); [Green and Taylor, 2016](#); [Feng et al., 2021](#); [Foarta and Sugaya, 2021](#)). We abstract from

⁸Other lines of theoretical work have used related notions of ‘state capacity’ to explore the ability of the state to achieve macro-objectives such as tax collection and law enforcement ([Besley and Persson, 2009](#); [Johnson and Koyama, 2017](#)). One emphasis of this work is the creation of capacity in the shadow of political transitions. By contrast, we address policymaking at the organizational level, taking capacity as given.

incentive problems in order to explore project design in anticipation of transitions of control.

Paper Structure. The rest of the paper is organized as follows. Section 2 describes the model, and Section 3 analyzes it and presents the main results. Section 4 extends the model to multiple phases with cancellation. Section 5 briefly presents three examples that illustrate applied implications. Finally, Section 6 discusses several extensions and concludes. The Appendix contains all formal derivations and proofs.

2 Model

Consider an environment with discrete time periods, $t = 0, 1, 2, \dots$. There are two agents, A and B , representing two distinct constituencies. Agent A is in control of decision-making at time 0, and agent B represents an opposing interest within the same organization. Examples of agents might include politicians or division heads. Agent A initiates a long-term project at time 0. The game ends when the project is completed.

The Project. The project delivers value $v > 0$ per unit produced. It has two main characteristics: irreversible investment and renegotiable claims. We map the irreversible aspect to a scale choice $s \geq 0$, denoting the number of units to be built. We map the renegotiable claims to a division rule for how the project's output will be split, with some fraction going to agent A and the remainder going to agent B .

Once initiated, the project is run by a non-strategic bureaucracy. To be completed, the project must traverse two stages. It starts in a development stage, denoted d . Once it reaches completion, it enters the execution stage, denoted e . Progression from one stage to the next depends on the bureaucracy's organizational capacity. Higher capacity allows the bureaucracy to overcome faster the technical hurdles needed to move the project forward. We parameterize capacity by p , to capture the probability the project moves from stage d to stage e in any given period. With probability $1 - p$, the project does not progress that period. This implies that a project that is not interrupted is expected to be completed in $\frac{1}{p}$ periods. Every period the project stays in stage d costs each agent $c(s)$. This captures in reduced form the use of common organizational resources. We assume a continuously differentiable convex cost function with a constant elasticity $\varepsilon > 1$: $c(s) = s^\varepsilon$. This functional form allows us to derive closed form solutions for our results. While they facilitate the analytical solution, neither the linearity of the benefit function nor the constant elasticity of the cost function are key drivers our results. As made clear in the proofs, the main forces in the model emerge

in a setting with a concave benefit and convex cost.⁹

Transitions of Control and Revisions. In period 0, agent A initiates the project by choosing its irreversible characteristic, the scale s , and an initial, but reversible division rule that assigns fraction w^A of total benefits to A and the rest to B .

At the beginning of each period $t \geq 1$, control over the project may change. With probability $r \in (0, 1)$, agent A has control, and with probability $1 - r$, agent B has control. The transition in control captures a leadership change or simply the arrival of an opportunity for intervention by the opposition, for instance through a lawsuit. This transition opportunity is a function of the competitiveness of the institutional system and of the individual resources of the opposition. We take it as independent of the progress of the project itself.¹⁰ Notice that agent A is more likely to be in control whenever $r > \frac{1}{2}$, and agent B is more likely to be in control when $r < \frac{1}{2}$. We will refer to the agent who is more likely to be in control as *advantaged*, and to the agent less likely to be in control as *disadvantaged*.

If the project is not completed in any given period, then the agent in control may choose to trigger a revision. Doing so freezes the project for one period: it does not advance from stage d to stage e that period. With probability q , the revision is successful and the revising agent can modify the division of output between agents. The parameter q captures the openness of the institutional system, or the effective power of an agent in control.

Together, the parameters r and q describe the institutional environment. The constraints they impose on the organization are independent of its capacity to run the project. Yet, as the organization operates in the institutional environment, these constraints interact with capacity to shape the resulting project and to introduce potential delays.

Payoffs. The project's output is divided between the agents according to the division rule in place at the time it enters stage e . There is no discounting between periods. However, the running cost is paid every period the project is in stage d . Therefore, a project of scale s and with payoff share w^i to agent $i \in \{A, B\}$, which is completed after \mathbb{T} periods delivers the following payoff to agent i :

$$w^i \cdot v \cdot s - \mathbb{T} \cdot c(s). \quad (1)$$

Equilibrium Concept. We derive the Markov Perfect Equilibria of this game with state variables for periods $t \geq 1$ being the current project stage, $S \in \{d, e\}$, the agent in control

⁹The restriction to $\varepsilon > 1$ is necessary in order to ensure convexity.

¹⁰In the political context, we think of any one project as having a relatively small impact on the likelihood of a political transition. Likewise, the characteristics of the project itself determine its likelihood of facing review, not the progress made by the bureaucracy.

that period, $i \in \{A, B\}$, and the project division currently in place $(w, 1-w)$, with $w \in [0, 1]$. In period 0, the state variable is $i = A$. In each period $t \geq 1$ when $S = d$, agent i chooses a probability of revision $\sigma^i \in [0, 1]$ and a payoff share $w^i \in [0, 1]$ for agent i to maximize her own expected utility. In period 0, agent A chooses scale $s \geq 0$ and payoff share $w^A \in [0, 1]$.

3 Analysis

Our game has two parts, which we analyze separately:

1. *Project design in period 0.* Agent A sets the irreversible project characteristic, s .
2. *Transitions of control and revisions.* While the project is in stage d , the agent in control chooses whether to revise. Revising entails choosing a new payoff division rule.

We start with the revision game over the project's division, and then ask how agent A sets its scale.

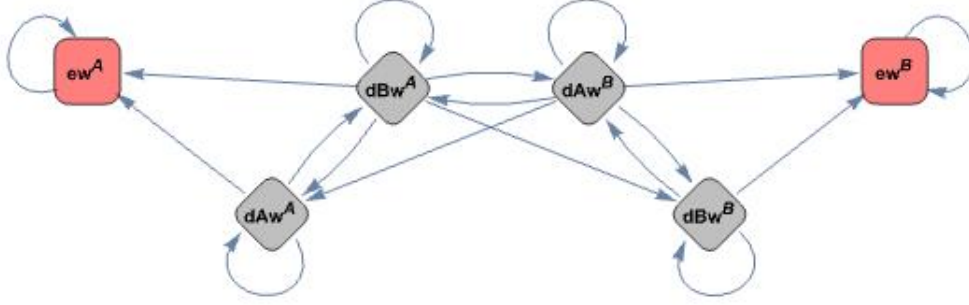
3.1 Revision Dynamics

For any ongoing project, we are interested in understanding when revisions will be triggered and how the division rule will be revised. Because of the agents' freedom to choose any division rule in a revision, the revision game has an infinite number of possible states in each period t . To make progress in the analysis, we note that the problem is in fact stationary: regardless of t , the continuation game is the same for each agent conditional on the state variable $(w, 1-w)$ which describes the division rule where agent A receives fraction $w \in [0, 1]$ of the output. As such, the agent's revision strategy will be the same given any $(w, 1-w)$. This reduces our problem to a game with only two possible division rules: a rule $(w^A, 1-w^A)$ that is chosen by agent A in a revision, or a rule $(1-w^B, w^B)$ that is chosen by agent B in a revision. With this insight, the project's evolution into the next period can be represented as a Markov chain with six states, as shown in Figure 2.

The probability of moving from stage d to any of the possible states depends on capacity, p , the institutional variables, r and q , and the revision probabilities σ^A and σ^B . The transition probabilities between states are given in Figure 3.

With this representation of the problem, we can compute $\mathbb{P}(e, w^\ell | d, i, w^k)$, the expected probability of reaching stage e with project division w^ℓ starting from state (d, i, w^k) , where $i, k, \ell \in \{A, B\}$. Also, we compute $\mathbb{T}(e, w^\ell | d, i, w^k)$, the expected number of periods for this

Figure 2: Markov Graph of Project Evolution



Note: Illustrates the Markov Process that governs the evolution of the project. Each state registers the project stage (d and e), the agent in control (A or B) and the current division rule (w^A for A or w^B for B).

transition. This allows us to express the expected utility for agent A in state (d, i, w^k) as:

$$EU^A = [\mathbb{P}(e, w^A) \cdot w^A + \mathbb{P}(e, w^B) \cdot (1 - w^B)] \cdot vs - [\mathbb{P}(e, w^A) \cdot \mathbb{T}(e, w^A) + \mathbb{P}(e, w^B) \cdot \mathbb{T}(e, w^B)] \cdot c(s). \quad (2)$$

For agent B , the expected utility is analogous, with the corresponding payoffs at each terminal state: fraction $1 - w^A$ of $v \cdot s$ at (e, w^A) and fraction w^B at (e, w^B) .

We note that the revision game differs from a classical bargaining game. One major point of departure is the independent organizational process for running the project. Whenever an agent chooses not to revise, the game does not necessarily end. The project is not completed until it reaches stage e , which depends on the organization's capacity. Agents therefore bargain over benefits in the shadow of a stochastic process for project completion.

Revision Strategies. Having expressed the problem in a form that allows us to compute expected utilities, we turn to the agents' choices of revision probabilities σ^A and σ^B . Notice that a higher choice of σ^i increases both $\mathbb{P}(e, w^i)$ and $\mathbb{T}(e, w^i)$ in the agent's expected utility. In choosing whether to trigger a revision, each agent weighs the benefit of tilting the division rule in her favor relative to the cost of increasing the expected cost of completion. The following Lemma shows that this trade-off results in a threshold value of relative cost below which a revision is triggered.

Figure 3: Project Evolution as a Markov Process

	d, A, w^A	d, A, w^B	d, B, w^A	d, B, w^B	e, w^A	e, w^B
d, A, w^A	$(1-p)r$	0	$(1-r)(1-p)$	0	p	0
d, A, w^B	$qr\sigma^A$	$(1-p)r(1-\sigma^A) + (1-q)r\sigma^A$	$q(1-r)\sigma^A$	$(1-p)(1-r)(1-\sigma^A) + (1-q)(1-r)\sigma^A$	0	$p(1-\sigma^A)$
d, B, w^A	$(1-p)r(1-\sigma^B) + (1-q)r\sigma^B$	$qr\sigma^B$	$(1-p)(1-r)(1-\sigma^B) + (1-q)(1-r)\sigma^B$	$q(1-r)\sigma^B$	$p(1-\sigma^B)$	0
d, B, w^B	0	$(1-p)r$	0	$(1-p)(1-r)$	0	p
e, w^A	0	0	0	0	1	0
e, w^B	0	0	0	0	0	1

Note: Transition matrix for the project. Each state of the Markov Process is given by the project stage (d or e), controlling agent (A or B), and project division (w^A for A or w^B for B).

Lemma 1 *Revisions follow a threshold strategy: There exist thresholds $\bar{s}_l(w^A, w^B)$ and $\bar{s}_h(w^A, w^B)$ with $\bar{s}_l \leq \bar{s}_h$ such that*

- *The disadvantaged agent (j) revises the project ($\sigma^j = 1$) if $s \leq \bar{s}_l$, and does not revise otherwise ($\sigma^j = 0$);*
- *The advantaged agent (i) revises the project ($\sigma^i = 1$) if $s \leq \bar{s}_h$, and does not revise otherwise ($\sigma^i = 0$).*

The threshold values for \bar{s}_l and \bar{s}_h are given by $\frac{c(\bar{s}_h)}{\bar{s}_h} = qv(w^A + w^B - 1)$, $\frac{c(\bar{s}_l)}{\bar{s}_l} = qv(w^A + w^B - 1) \cdot \min \left\{ \frac{pr}{pr+2q(1-r)}, \frac{p(1-r)}{p(1-r)+2qr} \right\}$. Each agent revises as long as the relative cost of doing so is not too large. The advantaged agent is more likely to be in control in the future. This agent expects a higher chance of reaching execution with her preferred payoff division in place; hence, she has a higher tolerance for costly delays from a revision.

In addition, we show in the Appendix that there exists a third threshold $\bar{s}_m(w^A, w^B)$, such that there is equilibrium multiplicity for $s \in [\bar{s}_m, \bar{s}_h]$.¹¹ Specifically, there are three possible equilibria: $(\sigma^A, \sigma^B) \in \{(1, 0), (0, 1)\}$ and a mixing equilibrium. In this region, the profitability of one agent's revision depends on the other's revision strategy. Our results are substantially unchanged by the equilibrium selected in the multiplicity region, and we therefore focus the discussion going forward on the equilibrium implied in Lemma 1. In the Appendix, we present the solution for each possible equilibrium in the multiplicity region and show how the results have a similar structure and intuition even when selection induces modest changes in project scale.

The Choice of Division Rule. We derive next the division rules chosen in revisions. Agent i 's choice of w^i will be a best response to the strategy of the other agent, j , and therefore maximizes

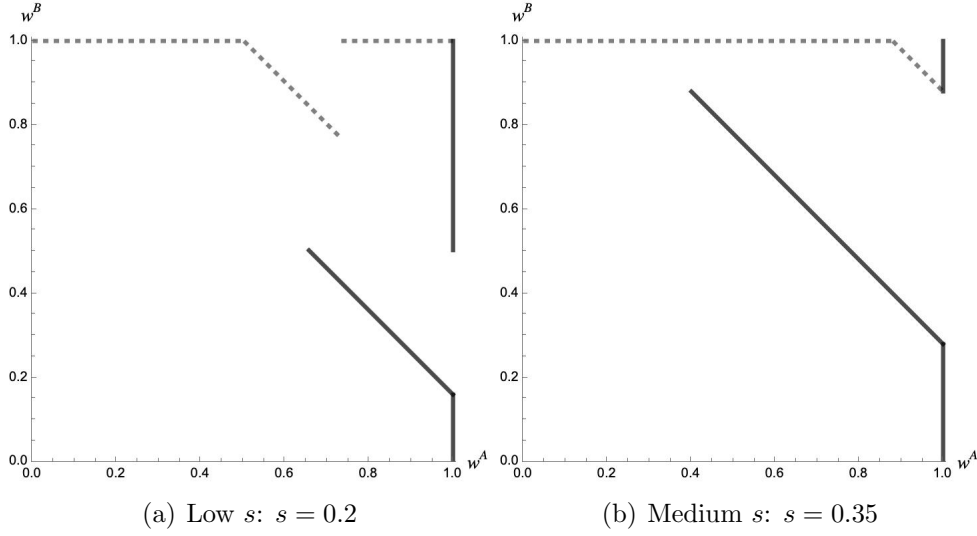
$$U^i(w^i | w^j, s) = [P_i^i(\sigma^A, \sigma^B) \cdot w^i + P_j^i(\sigma^A, \sigma^B) \cdot (1 - w^j)] \cdot vs - P_c^i(\sigma^A, \sigma^B) \cdot c(s), \quad (3)$$

where P_i^i , P_j^i and P_c^i are functions of p, q, r with expressions that depend on the equilibrium strategies σ^A, σ^B .¹² They capture, respectively, the probability of the project reaching state (e, w^i) , the probability of the project reaching state (e, w^j) , and the expected time for project

¹¹Threshold \bar{s}_m is given by $\frac{c(\bar{s}_m)}{\bar{s}_m} = qv(w^A + w^B - 1) \cdot \max \left\{ \frac{pr}{pr+2q(1-r)}, \frac{p(1-r)}{p(1-r)+2qr} \right\}$.

¹²The superscript denotes the agent in control, and the subscript the agent whose chosen project division is in place when the project enters stage e . These expressions are stated explicitly in the Appendix.

Figure 4: Revision Best Responses



Note: Depicts the payoff distribution chosen by each agent in case of a revision (dashed line for agent B and solid line for agent A), as a function of the other agent's revision strategy, given $r = 0.4$, $v = 3$, $q = 0.25$, and $p = 0.35$.

completion. This formulation shows that the expected utility for each agent i is piecewise linear in w^i whenever $\sigma^A, \sigma^B \in \{0, 1\}$.¹³

Given the threshold triggers for revisions discussed in Lemma 1, the choice for agent B reduces to two options. The first is to assign agent A just enough payoff such that she will not want to change the division rule going forward, and thus $P_B^B = 1, P_A^B = 0$. The second option is to choose a division rule that gives nothing to A , i.e., set $w^B = 1$, and face the probability of future revisions. This implies $P_B^B \leq 1$. Likewise, agent A has two options: either set $w^A < 1$ such that $P_A^A = 1$, or set $w^A = 1$ and have $P_A^A \leq 1$.

The solutions $w^B(w^A)$ and $w^A(w^B)$ are the best responses of the two agents to their respective problems. Figure 4 depicts these. The next lemma summarizes how these best responses come together to form an equilibrium.

Lemma 2 *Given p, q and r , there exists $w^{Ac}, w^{Bc} \in [0, 1]$ and a corresponding $\bar{s}_l^c \equiv \bar{s}_l(w^{Ac}, w^{Bc})$ such that along with $\bar{s}_l^n = \bar{s}_l(1, 1), \bar{s}_h^n = \bar{s}_h(1, 1)$, we have the following choices of division rules:*

- If $s \leq \bar{s}_l^c$ or $\bar{s}_h^n < s$ then each agent assigns all benefits to themselves: $w^A = w^B = 1$;

¹³For the mixed strategy equilibrium with $\sigma^A \in (0, 1)$ or $\sigma^B \in (0, 1)$, the expected utility is monotonic in w^i . This case is analyzed in the Appendix.

- If $\bar{s}_l^c < s \leq \bar{s}_l^n$ then the advantaged agent (i) sets $w^i < 1$, whereas the disadvantaged agent (j) sets $w^j = 1$;
- If $\bar{s}_l^n < s \leq \bar{s}_h^n$ then the advantaged agent sets $w^i = 1$, and the disadvantaged agent sets $w^j < 1$.

The project's scale determines the cost of attempting a revision. A very small cost makes revisions too easy to deter. A very high cost makes revisions prohibitively costly. In both cases, the agent in control assigns all project output to herself, as deterrence through a more equal payoff split is ineffective. The calculus changes if the revision cost is intermediate. If both agents would revise a rule that gives them no payoff, then the advantaged agent will revise to a more equal payoff division in order to deter future revisions by the opposition. As the revision cost increases, the advantaged agent will not revise if the division rule in place gives her enough. Therefore, a disadvantaged project initiator will compromise on the payoff division rule from the beginning to prevent future revisions.

Lemmas 1 and 2 together describe when a revision will be triggered, by which agent, and which division rule will be put in place. Figure 5 summarizes these two results, as a function of the project's scale.

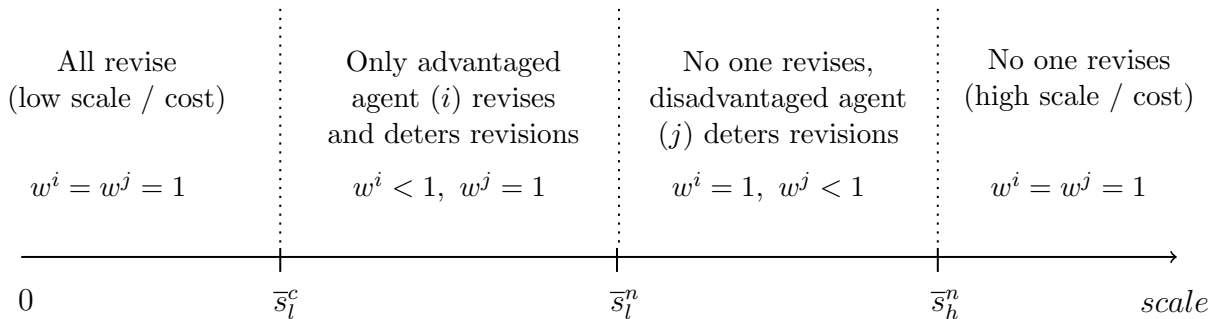
3.2 Choosing Project Scale in Period 0

The irreversible project characteristic s is set by agent A in period 0. This determines the revision game analyzed in the previous subsection. Here, we examine the choice of s .

Understanding how the revision game will unfold, agent A derives expected utility $EU^A(s) = U^A(w^A(s), w^B(s), s)$. She chooses s to solve

$$\max_{s \geq 0} EU^A(s). \quad (4)$$

Figure 5: Revision Equilibrium as a Function of Scale



Benchmark without Transitions. To clarify the importance of anticipated revisions, it is helpful to consider the benchmark case where there are no transitions of control ($r = 1$). Agent A starts in control in period 0 and remains in control until the project reaches execution. Agent A has no reason to revise her own project. She chooses $w^{NT} = 1$ and $s \geq 0$ to maximize

$$\max_s v \cdot s - \frac{c(s)}{p}, \quad (5)$$

where $\frac{1}{p}$ is the expected time to project completion. The scale s^{NT} is implicitly given by

$$c'(s^{NT}) = vp. \quad (6)$$

Design Choices under Transitions. Each scale choice made by agent A in period 0 maps to the expected revision responses depicted in Figure 5. Choosing a large scale (above \bar{s}_h^n) allows A to design the project without the prospect of a future revision of the division rule. A small scale makes future revisions unavoidable. While the per period running costs are small, delays due to revisions may significantly inflate the total project cost. Finally, an intermediate scale can induce future revisions. Yet, revisions are costly and entail compromise, and agent A can avoid them by simply inflating s . When this happens is formally shown in the next result, along with the implications for equilibrium project scale.

Proposition 1 (Capacity and Project Scaling) *There exist two thresholds $\bar{p}(\varepsilon, q, r) > \underline{p}(\varepsilon, q, r)$, with $\bar{p}(\varepsilon, q, r) \leq \varepsilon q$ such that the equilibrium scale s^* satisfies the following:*

- (Unconstrained project) *If $p \geq \bar{p}$, then s^* equals the benchmark scale under no transitions of control, $s^* = s^{NT}$.*
- (Upscaled project) *If $p \in (\underline{p}, \bar{p})$, then s^* is strictly higher than the benchmark without transitions, $s^* > s^{NT}$.*
- (Downscaled project) *If $p \leq \underline{p}$, then s^* is strictly lower than in the benchmark without transitions $s^* < s^{NT}$.*

The thresholds satisfy $\underline{p}(\varepsilon, q, r) > q$ when $r < \frac{1}{2}$ and $\underline{p}(\varepsilon, q, r) = 0$ for $r \geq \frac{1}{2}$.¹⁴ Proposition 1 shows how the strategic use of scale depends on bureaucratic capacity relative to institutional constraints. When capacity is high, the expected duration of the project is short,

¹⁴The statement of the proposition applies to the equilibrium selection implied by Lemma 1 or the mixing equilibrium in the region of multiplicity described in the analysis for that Lemma. If the equilibrium selected in the multiplicity region is the one where the disadvantaged agent revises and the advantaged agent does not, then the statement must be amended with an additional region (\bar{p}^m, \bar{p}^M) , with $\bar{p}^m > \bar{p}$ where the scale s^* is either strictly lower or strictly higher than s^{NT} . Details are given in the proof in Appendix B.3.

which keeps its implied running costs low. Then, the revision-detering benefits of a large scale outweigh the running costs. Agent A is able to choose a project scale equal to that of the benchmark without transitions of control. This alone is enough to deter revisions, without the need to compromise on payoff division.

As capacity decreases, the expected project runtime and associated costs increase. Agent A would ideally reduce the scale to adjust for these higher costs. Yet, she must keep the scale large enough to deter revisions, which results in upscaling. Finally, as capacity drops even more and the run time increases further, upscaling becomes too costly. Instead, agent A reduces scale below what she would ideally set in the absence of transitions. This is because she expects agent B to revise the project. The delay from revision attempts and a possibly unfavorable division rule make the project less appealing, which leads to downscaling.

The next result establishes the implications of the revision equilibrium for inequality in the division rule.

Proposition 2 (Payoff Inequality and Revisions) *The equilibrium project division is maximally unequal and there are no revisions if $p > \underline{p}(\varepsilon, q, r)$. Revisions occur with positive probability and both agents may receive a part of the project output and only if $p \leq \underline{p}(\varepsilon, q, r)$.*

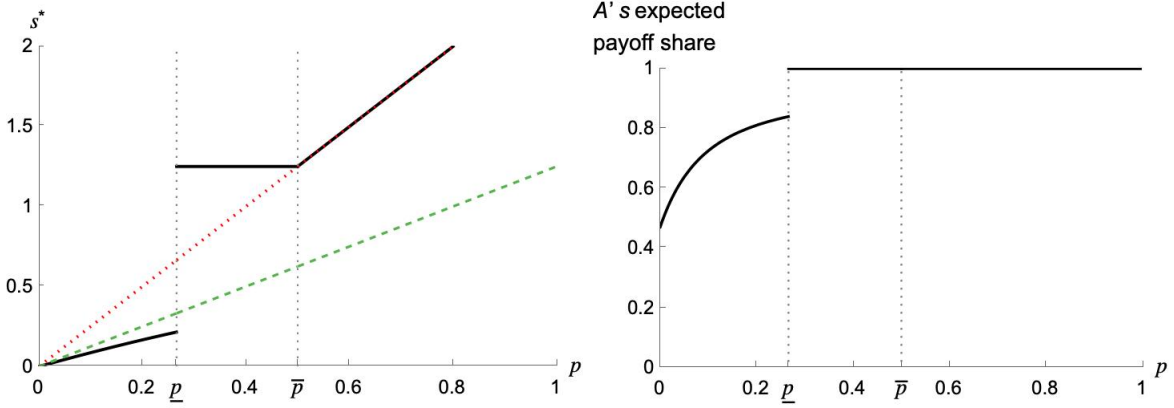
As long as capacity p is high enough relative to institutional constraints (q and r) and costs (ε), the initiating agent, A , can strategically choose the irreversible project characteristic (scale s) in order to deter revisions and assign all benefits to herself. As capacity decreases, using scale to deter revisions becomes too inefficient. The advantaged agent will revise, and if the scale is still sufficiently large, she will set a payoff division to deter further revisions by the disadvantaged agent. This reduces equilibrium payoff inequality. Otherwise, both agents will play a winner-take-all game where everyone revises whenever the opportunity arises and attempts to assign all project output to herself. We illustrate the equilibrium project scale and expected payoff division in Figure 6.

An immediate observation from Propositions 1 and 2 is that higher capacity, on average, increases project scale and inequality, but reduces the likelihood of revisions. The project initiator harnesses the shorter expected project runtime of greater capacity to her advantage: she makes projects larger, extracts greater benefits for herself, and deters future revisions.

Corollary 1 (Effect of Higher Capacity) *Higher bureaucratic capacity p is expected to increase the equilibrium scale s^* , the project initiator's payoff share w^A , and to reduce the likelihood of revisions.*

Moreover, downscaling and revisions, which can occur in equilibrium only if $\underline{p}(\varepsilon, q, r) > 0$, require a disadvantaged project initiator.

Figure 6: Equilibrium Project Characteristics



Note: Equilibrium s (left) and Agent A 's expected payoff share (right) depicted in solid black lines for $r = 0.4$, $v = 5$, and $q = 0.25$. The red dashed line shows the scale s^{NT} , and the green dashed line shows the social planner's solution (with equal weight on each agent).

Corollary 2 (Conditions for Upscaling and Revisions) *Downscaling and revising happen in equilibrium only when the project initiator (agent A) is disadvantaged ($r < \frac{1}{2}$).*

For a disadvantaged agent, a lower scale can be beneficial because it forces the advantaged agent to compromise more on payoff division in a revision in order to deter further revisions. This substitution between scale and compromise size does not emerge for the advantaged agent, as the disadvantaged agent would never be able to revise and offer enough payoff to the advantaged agent to deter further revisions.

3.3 Welfare

Our results so far show that organizational capacity has pronounced effects on project design. Higher values of capacity increase payoff inequality, while low and medium values result in downscaling or upscaling. These strategies suggest significant implications for social benefits. In particular, when capacity lies in the interval (\underline{p}, \bar{p}) , projects are both upscaled and unequally divided, and are therefore especially harmful to the non-initiating agent.

To investigate the aggregate benefits from the project, we consider the problem for a social planner who weighs the two agents equally. Given (3) and Proposition 1, the resulting social welfare function takes a relatively simple form:

$$W = vs^* - 2P_c^A c(s^*). \quad (7)$$

Proposition 3 uses expression (7) to derive the interval \mathcal{P} of capacity values under which the

resulting project produces lower welfare than no project at all; that is, where $W < 0$.

Proposition 3 (Welfare) *There exists an interval $\mathcal{P} \subset [0, 1]$ such that $W < 0$ for $p \in \mathcal{P}$ and $W \geq 0$ for $p \notin \mathcal{P}$. The interval is $\mathcal{P} = (\underline{p}, 1)$ if $\varepsilon < 2$ and $\mathcal{P} = (\underline{p}, 2q)$ if $r < \frac{1}{2}$ and $\varepsilon \geq 2$.*

Proposition 3 highlights the two drivers of welfare losses. First, a low cost elasticity ($\varepsilon < 2$) makes large scale projects more desirable. This is socially harmful given that the initiator does not internalize the cost borne by the other agent. The second driver of welfare losses is the use of strategic upscaling to deter revisions. The size of the interval \mathcal{P} is determined by institutional constraints. When agent A is advantaged ($r \geq \frac{1}{2}$), this effect is null. For the opposition, the expected gain from revisions is low if they are unlikely to stay in control. Agent A faces a low threat of revisions, and therefore does not distort the project enough to cause a welfare loss.

The calculus changes if the initiator is disadvantaged ($r < \frac{1}{2}$). In this case, the expected gains from a revision are larger. To deter revisions, agent A responds with larger distortions. The distortion is particularly costly when the project is overscaled and highly unequal. Therefore, the interval \mathcal{P} is a subset of the region (\underline{p}, \bar{p}) .

Corollary 3 *The bounds of interval \mathcal{P} are increasing in q .*

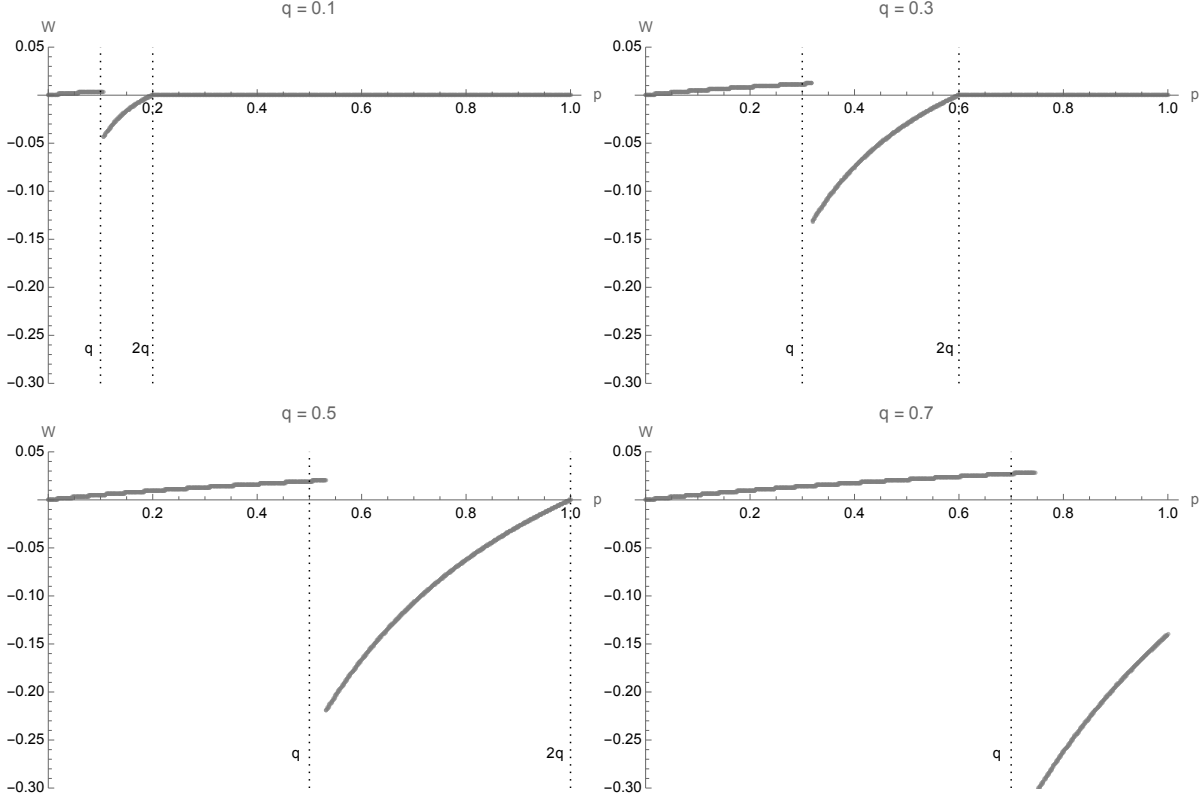
As legal or institutional challenges become more potent (i.e., q increases), the interval \mathcal{P} shifts toward higher values of p . This reflects the greater incentive to upscale as the threat of successful revisions increases. As a result, low-welfare projects are avoided only when organizational capacity is very high or very low relative to q .

Figure 7 illustrates welfare as a function of p for different values of q . Consistent with Proposition 3, it shows that the values of p and q that induce upscaling are especially bad for welfare. As these values move in tandem, the implication is that systems with high institutional barriers and high capacity are prone to producing inefficient projects. By contrast, systems with “mismatched” capacity and barriers produce higher welfare, but with some drawbacks. Under low capacity and high barriers, projects are costly and possibly too small. Under high capacity and low barriers, higher social welfare comes at the expense of high inequality in the assignment of benefits.

3.4 Scale Caps

In our model, agent A has full flexibility to choose the project scale. Yet, in practice, project designers may face hard limits that create a scale ceiling. This maximum achievable scale

Figure 7: Welfare



Note: Welfare as a function of p at different values of q when $c(s) = s^2$, $r = 0.4$, and $v = 1$.

may not be large enough to accommodate agent A 's desired upscaling. A cap on scale may therefore help to avoid upscaling and its associated welfare loss. In what follows, we show, however, that it induces more revisions in equilibrium and increases expected total cost.

Consider an exogenous ceiling on project scale, s^{\max} . This value may be set, for instance, by legal budget caps, technological limits, or bounds on physical space. If this upper bound binds, then running costs will not be high enough to induce acquiescence from agent B , and revisions cannot be avoided in equilibrium.

Proposition 4 (Scale Caps and Revisions) *If the scale cap satisfies $s^{\max} \leq \bar{s}_l^c$, then the equilibrium project inequality is maximal and each agent revises a project favorable to their opponent ($\sigma^A = \sigma^B = 1$).*

Agent A uses scale strategically to deter revisions, up to the ceiling s^{\max} . At that point, the ability to increase scale is exhausted. If the ceiling s^{\max} is low, the cost of delays is low relative to the potential gain from a revision. Compromising on how project benefits are divided remains the only tool to deter revisions. Yet, with a low s^{\max} , the needed compromise

would have to be exceedingly large. Instead, each agent prefers to enter a ‘winner-take-all’ regime ($w^A = w^B = 1$) where everyone revises.

For a fixed s^{\max} , increasing capacity p increases the likelihood of revisions. The scale needed to deter revisions rises with p . Moreover, as p increases, the expected project duration, and therefore the expected running cost, is smaller. This makes revisions more appealing and their deterrence more difficult.

Corollary 4 (Scale Caps and Higher Capacity) *With fixed $s^{\max} < \infty$, higher organizational capacity p increases, in expectation, the likelihood of project revisions and delays. However, conditional on the equilibrium with revisions, higher p reduces expected delays.*

4 Cancellation versus Revision

Thus far, revisions have been the only meaningful barrier for the project initiator. The preceding results show that this assumption gives the initiator considerable proposal power. In many settings opponents clearly have access to additional tools; in particular, institutional mechanisms such as environmental litigation can sometimes cancel projects entirely. While the threat of termination may plausibly discipline A , our theory suggests that like revisions, cancellations must also face institutional constraints. In this section we examine the implications of cancellations for project properties such as survival, welfare, and delays.

We implement cancellation by adding an initial *planning* phase to the basic model, which we refer to in this section as the *main* phase. The planning phase might represent the production of preliminary research or broad project outlines prior to a specific proposal. In the setting of US infrastructure construction, interested local governments take the initial step by formulating proposals for a Capital Improvement Grant administered by the Federal Transit Administration (FTA). Controversy and termination prior to major construction have featured prominently in domains such as American energy projects. In 2017, developers abandoned Cape Wind, which was slated to be the country’s first large offshore wind facility, after over a decade of legislative, regulatory, and judicial disputes over environmental and aesthetic issues. In 2021, the Biden administration effectively ended the Keystone XL pipeline, which would have efficiently transported “tar sands” oil from Alberta to the Gulf Coast. This decision reversed approvals granted during the Trump administration, which were themselves reversals of Obama administration policy. Thus, the two phases together capture the idea that quitting is the more natural remedy early in the life-cycle of a project, while more fine-grained modifications become feasible as concrete features become evident.

The planning phase has stages d_p and e_p that mirror the development and execution phases of the main phase, respectively. Agent A initiates a new project in period 0, and A

Figure 8: Planning Phase Markov Process

	d_p, A	d_p, B	e_p, A	q_p, B
d_p, A	$(1-p)r$	$(1-p)(1-r)$	p	0
d_p, B	$r(1-p)(1-\sigma_q^B) + r(1-q)\sigma_q^B$	$(1-r)(1-p)(1-q\sigma_q^B) + (1-r)(1-q)\sigma_q^B$	$p(1-\sigma_q^B)$	$q\sigma_q^B$
e_p	0	0	1	0
q_p	0	0	0	1

Note: Transition matrix for the planning phase. Each state of the Markov Process is given by the project stage and controlling agent.

and B gain control with probabilities r and $1-r$ in each subsequent period, respectively. A new project begins in stage d_p and progresses toward stage e_p with probability p in each period if the controlling agent chooses to continue it. Reaching e_p results in the commencement of period 0 of the main phase with A as initiator in the subsequent period.¹⁵

An attempt to quit succeeds with probability q . Success concludes the project in stage q_p ; this is equivalent to a final scale of zero. We allow only agent B to quit, as the project initiator would presumably not quit its own project. Because scale is not yet determined, the running cost per period is fixed at $c_p > 0$. Similarly, the lack of established distributional parameters implies that there can be no meaningful revisions. The planning phase produces no direct benefits for the agents. We assume that B breaks ties in favor of continuing.

Figure 8 presents the transition matrix for the equilibrium Markov chain. This allows us to derive the threshold main phase expected value, $EU^B(s^*)$, below which B quits:

$$v_q^B \equiv \left(\frac{1}{p} - \frac{1}{q} \right) c_p. \quad (8)$$

This expression conveys two important intuitions about quitting: B continues any project that produces positive expected value in the main phase if $p > q$, and attempts to quit any project with negative expected value if $p < q$.

In a stationary strategy, B either quits or continues whenever it gains control. This allows us to derive some simple measures of the consequences of quitting. Under a quitting strategy, the probability of successful termination in the planning phase is $\frac{(1-r)(1-p)q}{rp+(1-r)q}$. Quitting also produces delays. If B continues, then the planning phase will conclude in $1/p$ periods in

¹⁵We obtain similar results if the initiating agent in the main phase is randomly chosen.

expectation. Quitting increases this to $\frac{(1-r)(q-p)+1}{rp+(1-r)q}$ periods, which lengthens the completion time of the planning phase if $q < p$. Finally, conditional upon reaching the main phase, a quitting strategy will have imposed an expected $\frac{(1-r)(1-p)}{rp}$ periods of additional delay.

We use the welfare expressions from the previous section to derive the following result, which provides conditions under which B cancels projects in equilibrium.

Proposition 5 (Cancellation) *There exists an interval $\mathcal{P}^c \equiv [\underline{p}^c, \bar{p}^c]$, that is non-empty if c_p is sufficiently high and satisfies $q < \underline{p}^c \leq \varepsilon q \leq \bar{p}^c$ such that:*

(i) *For $r > 1/2$, B continues if and only if $p \in \mathcal{P}^c$ when $p > \bar{p}$; B continues only if $p \in \mathcal{P}^c$ when $p < \bar{p}$.¹⁶*

(ii) *For $r < 1/2$, B continues if and only if $p \in \mathcal{P}^c$ when $p > \underline{p}$. Additionally, B quits for p sufficiently close to 0, and continues for p in a neighborhood of q if $\varepsilon \geq 2$.*

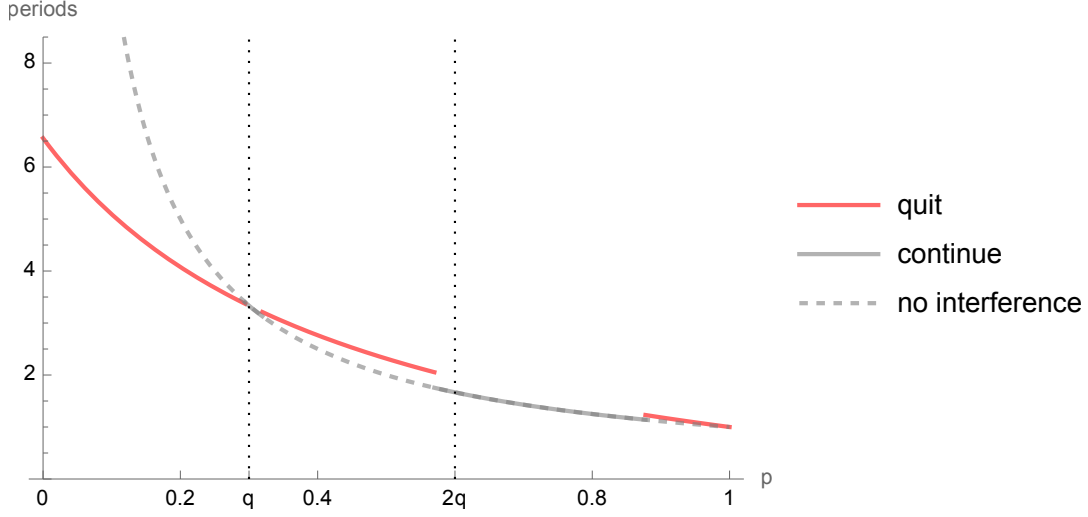
Proposition 5 first establishes a region \mathcal{P}^c of values of p where agent B has an incentive to continue. If it exists, \mathcal{P}^c contains εq , at which point $p > q$, agent A becomes able to propose her ideal scale s^{NT} , and project welfare is non-negative. One incentive to cancel arises when p is very low relative to q . As is evident from the expression for v_q^B (8), this means that cancelling is “easier” than proceeding. Agent B also cancels for values of p above \mathcal{P}^c , as these induce agent A to choose a large, unequal project in the main phase.

Part (i) of the proposition focuses on the case of B as the disadvantaged agent. In this case, cancellation only occurs for p contained within \mathcal{P}^c . In part (ii), agent B is advantaged and faces two additional considerations. When p is slightly greater than \underline{p} it faces the threat of a harmful upscaled project in the main phase. This produces an incentive to cancel the lowest-welfare projects. Next, B strictly benefits from some under-scaled projects, and therefore continues projects when p is near q . Figure 9 illustrates the resulting three cancellation regions and their implications for delay in the case of quadratic costs. Notably, the attempted cancellation of low-welfare projects (where $p > \underline{p} > q$) lengthens the expected completion time of the planning phase.

What kinds of projects survive quitting? The welfare implications of the planning phase are ambiguous. The top half of Figure 10 illustrates this by superimposing agent B ’s cancellation strategy on main phase welfare, as plotted in Figure 7. The clear implication is that cancellation does not necessarily coincide with low welfare. To avoid high delay costs due to low capacity, B cancels projects that promise positive welfare upon reaching the main phase. It also continues some moderately inefficient projects in order to avoid high delay costs from

¹⁶For quadratic costs ($\varepsilon = 2$), $\mathcal{P}^c = \left[\frac{2c_p - 2\sqrt{c_p(c_p - q^2 v^2)}}{qv^2}, \frac{2c_p + 2\sqrt{c_p(c_p - q^2 v^2)}}{qv^2} \right]$ and $p \in \mathcal{P}^c$ is necessary and sufficient for continuation for all p .

Figure 9: Planning Phase Delays



Note: Expected length of planning phase, with equilibrium cancellation (red) and continuation (gray) by agent B . Parameters are $c(s) = s^2$, $v = 1$, $q = 0.3$, $r = 0.4$, and $c_p = 0.1$. Dashed line indicates benchmark of no quitting.

obstruction. Thus, while the ability to quit gives agent B some power to prevent the worst projects from proceeding, institutional costs limit its usefulness.¹⁷

Observe finally that running costs from the planning phase could potentially dissuade agent A from even starting the project. The bottom half of Figure 10 pushes the exercise one step further by asking when agent A would wish to initiate a project at all, anticipating B 's strategy. The added delay from the planning phase causes A to hold back on projects when p is relatively low. These include some that agent B would not have cancelled. In the example, A proceeds with neither strictly positive nor strictly negative welfare projects.

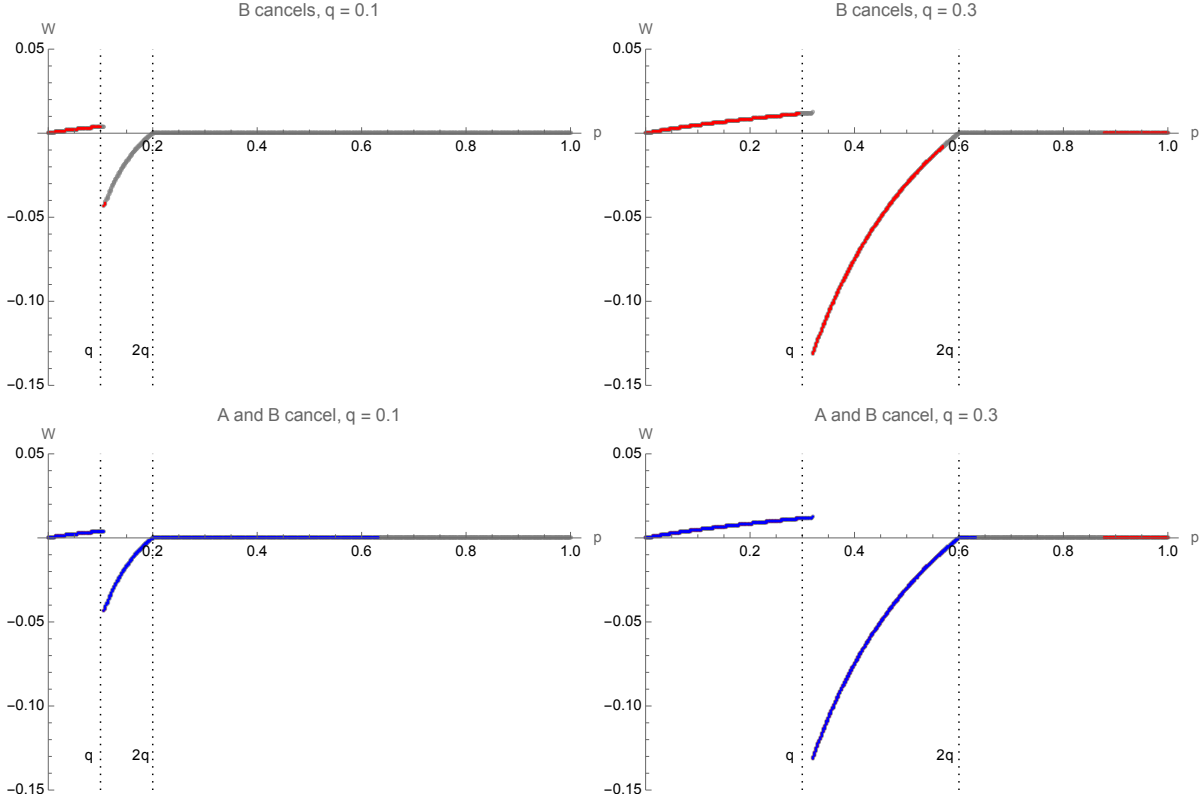
5 Applications

Our model produces a range of predictions about the implications of changes in organizational capacity (p) and the ability to exploit institutional mechanisms to revise projects (q and r). This section presents three brief applications that show how its predictions are consistent with seemingly disparate facts about key project characteristics in major organizations.

A main challenge of any application lies in measuring the exogenous parameters of inter-

¹⁷A legitimate question is what happens when cancellations and revision can happen within the same phase. We show separately that in a one-phase game where players can either revise or quit, quitting can occur in equilibrium on if $p < q$.

Figure 10: Welfare and Quitting



Note: Welfare and quitting as a function of p at different values of q . Parameters are $c(s) = s^2$, $r = 0.4$, $v = 1$, and $c_p = 0.1$. On top row, red indicates projects that agent B quits. On bottom row, blue additionally indicates projects that A does not initiate.

est. For example, many of our results depend on the relative values of p and q , and therefore require a means to draw meaningful comparisons between capacity and institutional constraints. While there have been numerous efforts at empirically measuring each in isolation (e.g., Tsebelis, 2002; Besley and Persson, 2011; Dal Bó et al., 2013; Bolton et al., 2016), we are not aware of any effort to quantify them simultaneously. Thus, the examples necessarily rest on some auxiliary assumptions about the parameters.

Subway Construction. According to the Transportation Costs Project, recent US rail construction costs have been the sixth highest in the world (Marron Institute of Urban Management, 2023). Subways in particular have faced extreme cost pressures, due to both the technical difficulty of building in high-density urban areas and the web of institutions that fund and oversee their construction.

The construction of the Washington DC Metro system in the early 1970s exemplified the confluence of institutional constraints with limited organizational capacity (Schrage, 2006).

To address the Washington Metropolitan Area Transportation Authority’s (WMATA) shortcomings in expertise, labor, and capital, General Manager Jackson Graham relied extensively on external consultants. Graham also encountered extensive resistance from local stakeholders; the National Park Service, for example, opposed the siting of stations in areas under its jurisdiction. In anticipation of widespread opposition, WMATA Deputy General Manager Warren Quenstedt adopted an upscaling strategy along with Graham:

We want to get as much under construction as we possibly can, so it would cost more to cover it up than it would to finish it. Always we wanted to give the board . . . an unacceptable alternative, so that we would take them down the road we wanted to go. If we hadn’t done that, everything would have bogged down into bureaucratic debate, and quibbling, and so forth that goes on all the time. ([Schrage, 2006](#), pp. 145-46)

More recently, the \$4.6 billion Phase 1 of the New York City Second Avenue Subway (SAS) became the most expensive subway line in the world upon its opening in 2017.¹⁸ The project, which added three stations along a three kilometer extension of an existing subway line, was first conceived in the early 20th century and saw preliminary excavations in 1972. As [Goldwyn et al. \(2023\)](#) documents, the primary agencies in charge of the SAS, the state-level Metropolitan Transportation Authority (MTA) and its New York City Transit (NYCT) agency, faced constraints from authorities responsible for parks, roads, buildings, and the environment. These included a city Department of Transportation requirement that roads remain open during construction, and a \$15 million payment to New York City Parks to occupy part of a local playground as a staging site.

Against these constraints, the MTA had limited internal resources for managing complex projects. Until 2003, NYCT had 1,600 employees dedicated to design and construction management. The MTA’s Capital Construction Company (MTACC) subsequently replaced these employees with a much smaller staff that relied instead on external consultants. In its 2007 budget, the company reported a 2006 headcount of 96 full-time equivalent (FTE) employees, with 30 categorized as MTACC-wide “Administration” and five “Engineering/Capital” staff dedicated to the SAS ([Metropolitan Transportation Authority, 2007](#)). The latter category was projected to expand to 13 after groundbreaking in 2007. By 2014, the staff had expanded to 126 FTEs, with 14 in Administration and 18 in Engineering/Capital specific to the SAS

¹⁸Funding was provided by local and federal sources, with the FTA providing \$1 billion. Phase 2 of the SAS, which will add additional track and three new stations, received FTA approval in 2023 and is slated to cost \$6.3 billion.

(Metropolitan Transportation Authority, 2015).¹⁹

The resulting SAS stations were notably large, reflecting the upscaling region of Proposition 1. Uncharacteristically for New York, the stations featured mezzanine levels and were longer than their platforms by 60% to 160% – far more than typical stations in comparable systems. The extra size gave NYCT staff and services access to exclusive working and storage spaces. Part of NYCT’s success in gaining concessions was due to its ability to withhold approvals from its parent agency. Goldwyn et al. (2023) estimate that scale alone more than doubled the cost of the SAS, and was the largest single contributor to its overall excess costs.

20th Century US Infrastructure. Proposition 1 shows that as q increases relative to p , project designers may prevent revisions by increasing scales beyond their ideal levels. If a planning phase exists, as in Proposition 5, the relative increase in q may also result in projects being canceled before breaking ground. As Altshuler and Luberoff (2003) relate, changes in the political environment that enabled interest group opposition have upended the trajectory of US infrastructure projects. In the mid-20th century, urban planners exemplified by figures such as Robert Moses operated with few constraints, often promoting automobile-centered ideas for urban renewal, supported of local business interests (Caro, 1974).

The programs operated, moreover, in relative secrecy, so that those affected often learned of projects just before the bulldozers rolled. In the early years there were no organized interest groups monitoring or learning from these experiences, much less providing potential victims with tactical assistance. Since their cause seemed hopeless, even those most adversely affected generally gave in without a fight. This tendency was accentuated by the fact that the victims were disproportionately poor and black. (Altshuler and Luberoff, 2003, p. 22)

Assisted by the national rise of civil rights and environmental movements, as well as laws such as NEPA and the Clean Air Act, conflicts over infrastructure development rose drastically starting in the late 1960s. The increasingly effective political mobilization, which might be interpreted as a decrease in r and an increase in q , affected numerous ongoing projects. For example, a 1982 court order paused construction of the New York Westway in order to protect local fish breeding grounds. The project, which was intended to replace a decaying highway along the west side of Manhattan, was eventually canceled in 1985 after over a decade of development and \$200 million in expenditures.²⁰

¹⁹Plotch (2015) reviews the roles of under-staffing and poor consultant work in accounting for infrastructure project delays.

²⁰See Sam Roberts, “The Legacy of Westway: Lessons from its Demise.” *New York Times*, 10/7/1985.

For planners, the response to more effective contestation was not to abandon large projects, but rather to expand their size.²¹ This strategy was in evidence in the construction of the Boston Central Artery/Tunnel (CA/T, better known as the “Big Dig”), which replaced an elevated highway in downtown Boston with a technologically ambitious tunnel and associated connecting structures. In addition to local interests, stakeholders in CA/T included the Massachusetts and federal governments, which provided its primary funding, as well as neighboring municipalities. The ultimate design contained over 1,500 mitigation agreements, which expanded the project to include wetlands restoration, landfill redevelopment, and the construction of an artificial reef.²² While the original highway was constructed in five years in the 1950s, the CA/T took over 20 years of planning and construction, at a cost more than double that of early projections.

Inequality in Government Procurement. By Corollary 1, the distributive consequence of increasing p is greater inequality in how benefits are distributed at the project level. Government procurement provides a natural setting for examining this implication. US federal procurement is a highly regulated process that employs hundreds of thousands of personnel.²³ As in the $r < 1/2$ case in the model, existing laws provide frequent opportunities for revisions. Losing or excluded bidders can challenge award decisions with either the contracting agency or the Government Accountability Office (GAO), and successful appeals can change awardees, re-open competition, or result in a range of intermediate steps. Between fiscal years 2018 and 2022, about half of the 2,000 or so cases per year heard by the GAO received some form of remediation (US GAO, 2022).

The Competition in Contracting Act mandates a default process of “full and open competition,” whereby prospective contractors submit competitive bids that are evaluated according to preset criteria. However, a substantial minority of contracts are awarded on a non-competitive, “sole source” basis. This process is intended for circumstances such as absence of alternate suppliers, emergencies, or one of several public interest criteria. These

²¹Altshuler and Luberoff (2003) also point out that in some cases projects also expanded their distributive reach, consistent with Proposition 2.

²²See Daniel C. Wood, “Learning From The Big Dig.” *Public Roads* 65(1), July/August 2001.

²³The stages of the federal contracting process fit well with the stage structure of our model. As DiIulio (2014) describes:

[T]he federal contracting process has three separate but related parts: (1) planning (how federal agencies decide what and how much to contract for . . . and what terms and conditions are they subject to); (2) awarding (the background market research, . . . the budgetary criteria, and the precise procedures for awarding competitive bids or making noncompetitive selections); and (3) overseeing (everything from routine reporting requirements to financial audits, field inspections, public comments, and impact studies). [p. 65]

contracts require increasing levels of justification and approval as their size grows, but observers have noted that agencies have substantial discretion to adopt them (e.g., [Dahlström et al., 2021](#)). Sole-sourcing therefore serves as a plausible proxy for high-inequality projects.

The Department of Defense (DoD) is both the largest user of sole-source contracts and one of the few recent examples of a substantial increase in organizational capacity in the federal government. In 2009, DoD began a long-term expansion its acquisition workforce, which had declined significantly since the 1990s ([Gates et al., 2022](#)). This effort, which was exempted from concurrent DoD hiring freezes, resulted in growth from about 130,000 to over 180,000 staff between fiscal years 2009 and 2021. The added personnel significantly enhanced the ability of program managers to oversee the contracting process ([DiIulio, 2014](#)). Importantly, expansion was highly uneven during this period, with no headcount change between fiscal years 2011 and 2014 and a net growth of 15,000 between 2014 and 2017.

The fiscal years 2014 through 2017 coincided with the second term of the Obama presidency, during which Democrats and Republicans split control of government. Defense spending changed only modestly during this period, but outlays from non-competitive contracts of all sizes grew far faster than those from competitive contracts. For example, among awards worth over \$1 million, outlays from competitive contracts decreased by 1.5%, compared to a 34.4% increase from non-competitive contracts.²⁴ Thus, this era saw dramatic growth in both organizational capacity and less egalitarian projects.²⁵

6 Discussion and Concluding Remarks

Within academic and policy circles, bureaucratic capacity has become a hallmark of good management and governance. In isolation, better-resourced or better-equipped organizations can naturally be expected to complete given tasks more efficiently and predictably. But organizations inevitably function within an institutional environment in which interested agents generate their tasks and opposing agents attempt to renegotiate them. In contrast with the consensus about the benefits of capacity, much less is understood about how capacity interacts with its institutional environment.

Our theory addresses this interaction, focusing on two fundamental aspects of institutional decision-making processes: transitions of control and revisions of ongoing projects. These features alone produce a rich interdependence between organizational and institutional

²⁴Data from <https://usaspending.gov>. Competitive contracts accounted for 53% of the DoD total. The disparity is somewhat higher for higher-valued contracts.

²⁵The acquisition workforce continued to grow during the Trump administration, and the level of sole source contracts remained high, but these developments also coincided with higher defense spending starting in fiscal year 2018.

processes. The overarching implication is that greater capacity does not unambiguously improve performance. High capacity relative to ease of revision maximizes execution speed but also delivers all benefits to the initiator. Exogenous limits on scale induce revisions, which reduce ex ante inequality but increase delays. When initiators cannot expect continuous managerial control, low capacity also encourages revisions, and moderate capacity gives initiators incentives to inflate scales. Inflated projects minimize welfare, and even the ability to cancel at an early phase does not entirely eliminate them. Thus, institutional reforms should target the “matched” profiles of organizational capacity and institutional constraints that encourage the inefficient project upscaling.

Our results speak to contemporary policy debates about the role of institutional and legal barriers in various domains. Such barriers have long been recognized as parts of the US regulatory landscape (Pressman and Wildavsky, 1984; Smith et al., 1999). In recent years they have attracted fresh attention as sources of delay and cost inflation in areas such as infrastructure, housing, and clean energy (Mehrotra et al., 2022; Brooks and Liscow, 2023).

To expand upon our basic ideas, we briefly discuss two other institutional features commonly observed in practice. These extensions provide additional insights without undoing our main results. Further details on each are provided in Appendix C.

Multiple Project Phases. Section 4 extended the baseline model to a more complex project completion process, where the opposing agent B could cancel in a preliminary phase. As an alternative, complex projects may present multiple opportunities for politicians to revisit basic questions of scale and distribution. Thus, the project scale parameter we took as irreversible may be modified. We extend the model to ask how the possibility of resetting program parameters mid-stream affects project scale and revisions. In particular, the project here consists of two structurally identical phases, each of which is identical to the basic model. The phases are dynamically linked through their cost functions: a higher scale in phase 1 reduces the cost of running the project in phase 2. The phase 1 and 2 projects may thereby be understood as pilot and final projects, respectively. The agent who happens to be in control when the first phase is completed becomes the initiator for the second phase. This agent chooses the second phase scale, regardless of what the scale was in phase 1. Thus, in contrast with Section 4, agent B may modify project characteristics in phase 1 and gain control as the initiator in phase 2, but cannot quit.

The additional initial phase shows how uncertainty over future control affects project design. A higher scale in the first phase lowers the threshold for upscaling in the second phase. This disincentivizes investment in scale by agent A in phase 1, reducing the phase 2 scale below that which A would choose if her continued control were assured. A may forgo

funding the project altogether by setting the phase 1 scale to zero if it anticipates a low welfare project that has the potential to penalize the non-initiating agent in phase 2.

Variable Capacity. We can also adapt the model to allow scale to impact capacity directly. Organizations may be able to handle and move forward lower scale projects easily, while larger scale projects may trigger additional compliance procedures or more specialized expertise. For instance, in hierarchical organizations, more expertise layers may be involved in larger projects (Garicano, 2000).

In our model, making p a function of scale operates akin to the budget limits described above. For instance, consider the case in which, above some $s^p > 0$, the speed of completion goes to 0. This limits any equilibrium scale choice by agent A to one that can be handled given the organization’s capacity. As a result, project scale is lower and the likelihood of revisions is higher than in a world with constant capacity.

Implications for Future Work. While the model parameterizes many features relevant to organizations, institutions, and projects, it also omits several. Consider the problem of product development with uncertain technologies. If a project has quality dimensions that are unknown at the point of initiation, then agents may seek revisions as they learn about payoff implications. Our framework may then be applied to ask how organizational capacity generates over- or under-investment in risky technologies. Other applications might usefully exploit plausible relationships between parameters. For example, the probabilities of retaining control or revising successfully may depend on scale or the rate of progress.

Finally, the implications of organizational capacity and the institutional environment raise several questions about their origins. We mention several as possibilities for further inquiry. First, agents may have incentives both to invest in the capabilities of organizations that may far outlive them, as well as to develop the institutional forums for determining project outcomes. Next, the openness of an institutional system to revisions could invite more participants, which would be better approximated by having more agents and a richer distributive space. Finally, it may be useful to unpack the capacity parameter p to reflect the realities of modern projects. For example, outside contractors often play major roles in large infrastructure construction, but whether such players ultimately enhance capacity, or are symptoms of low capacity, is not obvious.²⁶

²⁶See Ralph Vartabedian, “[How California’s faltering high-speed rail project was ‘captured’ by costly consultants.](#)” *Los Angeles Times*, April 26, 2019.

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Appendix

For Online Publication

A Preliminaries

Let $(w^A, 1 - w^A)$ denote the division of the total benefits vs between agents A and B when the division was put in place by agent A , such that agent A receives fraction w^A , and agent B receives fraction $1 - w^A$. Similarly, let $(1 - w^B, w^B)$ denote the division of the total benefits vs between agents A and B when the division was put in place by agent B , such that agent A receives fraction $1 - w^B$, and agent B receives fraction w^B . Finally, let r^A stand for the probability of agent A being in control ($r^A = r$) and r^B stand for the probability of agent B being in control ($r^B = 1 - r$).

Given the Markov transition probabilities, the expected utility for agent $i \in \{A, B\}$ starting in the next period with the payoff division in place set by agent i is

$$U^i(w^i | w^j, s, \sigma^A, \sigma^B) = sv \cdot [P_i^i \cdot w^i + P_j^i \cdot (1 - w^j)] - P_c^i \cdot c(s), \quad (9)$$

where

$$P_i^i = \left(1 + \frac{q(r^j \sigma^j (1 - r^j \sigma^j))}{p(1 - r^i \sigma^i)(1 - r^j \sigma^j) + qr^i \sigma^i (1 - r^j \sigma^j)} \right)^{-1}, \quad (10)$$

$$P_j^i = \left(1 + \frac{p(1 - r^i \sigma^i)(1 - r^j \sigma^j) + qr^i \sigma^i (1 - r^j \sigma^j)}{qr^j \sigma^j (1 - r^i \sigma^i)} \right)^{-1}, \quad (11)$$

$$P_c^i = \frac{1}{p} \left(1 - r^j \sigma^j \frac{p(1 - r^i \sigma^i) + 2qr^i \sigma^i}{p(1 - r^i \sigma^i) + q(r^i \sigma^i + r^j \sigma^j)} \right)^{-1}. \quad (12)$$

B Proofs

B.1 Proof for Lemma 1

Consider first the pure strategy equilibria, $\sigma^A, \sigma^B \in \{0, 1\}$. An equilibrium exists if each agent $i \in \{A, B\}$ prefers to follow his/her prescribed strategy given the other agent j 's strategy. For agent i , if $\sigma^i = 1$, then the ex-ante payoff from a revision is

$$U^{i,R} = q \cdot U^i(w^i) + (1 - q) \cdot U^i(1 - w^j).$$

If $\sigma^i = 0$, then the ex-ante payoff from project continuation with the division rule set by agent j is

$$U^{i,C} = p \cdot sv \cdot (1 - w^j) + (1 - p) \cdot U^i(1 - w^j).$$

Case 1: $\sigma^A = 1$ and $\sigma^B = 1$. This is an equilibrium if $U^{i,R} \geq U^{i,C}$ for $i \in \{A, B\}$. These conditions reduce to two upper bounds on $c(s)/s$, such that this equilibrium is sustainable if

$$\frac{c(s)}{s} \leq qv(w^A + w^B - 1) \cdot \min \left\{ \frac{p(1-r)}{p(1-r) + 2qr}, \frac{pr}{pr + 2q(1-r)} \right\}.$$

Case 2: $\sigma^A = 1$ and $\sigma^B = 0$. This is an equilibrium if $U^{A,R} \geq U^{A,C}$ and $U^{B,R} \leq U^{B,C}$. These conditions reduce to two thresholds:

$$\begin{aligned} \frac{c(s)}{s} &\leq qv(w^A + w^B - 1), \\ \frac{c(s)}{s} &\geq qv(w^A + w^B - 1) \frac{p(1-r)}{p(1-r) + 2qr}. \end{aligned}$$

Therefore, the equilibrium exists for

$$\frac{c(s)}{s} \in \left[qv(w^A + w^B - 1) \frac{p(1-r)}{p(1-r) + 2qr}, qv(w^A + w^B - 1) \right].$$

Case 3: $\sigma^A = 0$ and $\sigma^B = 1$. This is an equilibrium if $U^{A,R} \leq U^{A,C}$ and $U^{B,R} \geq U^{B,C}$. These conditions reduce to two thresholds:

$$\begin{aligned} \frac{c(s)}{s} &\geq qv(w^A + w^B - 1) \frac{pr}{pr + 2q(1-r)}, \\ \frac{c(s)}{s} &\leq qv(w^A + w^B - 1). \end{aligned}$$

Therefore, the equilibrium exists for

$$\frac{c(s)}{s} \in \left[qv(w^A + w^B - 1) \frac{pr}{pr + 2q(1-r)}, qv(w^A + w^B - 1) \right].$$

Case 4: $\sigma^A = 0$ and $\sigma^B = 0$. This is an equilibrium if $U^{A,R} \leq U^{A,C}$ and $U^{B,R} \leq U^{B,C}$. These conditions reduce to the same lower bound $\frac{c(s)}{s} \geq qv(w^A + w^B - 1)$.

Consider next the case of mixed strategy equilibria.

Case 5: $\sigma^A \in (0, 1)$ or $\sigma^B \in (0, 1)$. If Agent A mixes with $\sigma^A \in (0, 1)$, this requires $U^A(w^A|1, \sigma^B) = U^A(1 - w^B|0, \sigma^B)$, and thus the equilibrium σ^{B*} is

$$\sigma^{B*} = \frac{p(qsv(w^A + w^B - 1) - c(s))}{(1-r)[p(qsv(w^A + w^B - 1) - c(s)) + 2qc(s)]}. \quad (13)$$

Similarly, if Agent B mixes, then $U^B(w^B|\sigma^A, 1) = U^B(1 - w^A|\sigma^A, 0)$. Thus the equilibrium σ^{A*} is

$$\sigma^{A*} = \frac{p(qsv(w^A + w^B - 1) - c(s))}{r[p(qsv(w^A + w^B - 1) - c(s)) + 2qc(s)]}. \quad (14)$$

The mixing probabilities must satisfy $\sigma^B \in [0, 1]$ and $\sigma^A \in [0, 1]$. Given (13) and (14), this implies

$$\frac{c(s)}{s} \in \left[pqv(w^i + w^j - 1) \max \left\{ \frac{1-r}{p(1-r)+2qr}, \frac{r}{pr+2q(1-r)} \right\}, qv(w^A + w^B - 1) \right]. \quad (15)$$

Notice that the above condition allows for an equilibrium with $\sigma^A = 1, \sigma^B \in (0, 1)$ if $\frac{c(s)}{s} = \frac{1-r}{p(1-r)+2qr}$ and $\max \left\{ \frac{1-r}{p(1-r)+2qr}, \frac{r}{pr+2q(1-r)} \right\} = \frac{1-r}{p(1-r)+2qr}$. Conversely, an equilibrium with $\sigma^A \in (0, 1), \sigma^B = 1$ exists if $\frac{c(s)}{s} = \frac{r}{pr+2q(1-r)}$ and $\max \left\{ \frac{1-r}{p(1-r)+2qr}, \frac{r}{pr+2q(1-r)} \right\} = \frac{r}{pr+2q(1-r)}$.

Therefore, we have the following bounds in terms of $\frac{c(s)}{s}$ for the equilibrium regions:

$$\begin{aligned} \frac{c(\bar{s}_h)}{\bar{s}_h} &= qv(w^A + w^B - 1), \\ \frac{c(\bar{s}_m)}{\bar{s}_m} &= qv(w^A + w^B - 1) \cdot \max \left\{ \frac{pr}{pr+2q(1-r)}, \frac{p(1-r)}{p(1-r)+2qr} \right\}, \\ \frac{c(\bar{s}_l)}{\bar{s}_l} &= qv(w^A + w^B - 1) \cdot \min \left\{ \frac{pr}{pr+2q(1-r)}, \frac{p(1-r)}{p(1-r)+2qr} \right\}. \end{aligned}$$

This implies the following corresponding bounds on w^i , for $i, j \in \{A, B\}$:

$$w_1^i = 1 - w^j + \frac{c(s)}{s} \frac{1}{qv}, \quad (16)$$

$$w_2^i = 1 - w^j + \frac{c(s)}{s} \frac{1}{qv} + 2 \frac{c(s)}{s} \frac{1}{pv} \min \left\{ \frac{1-r}{r}, \frac{r}{1-r} \right\}, \quad (17)$$

$$w_3^i = 1 - w^j + \frac{c(s)}{s} \frac{1}{qv} + 2 \frac{c(s)}{s} \frac{1}{pv} \max \left\{ \frac{1-r}{r}, \frac{r}{1-r} \right\}. \quad (18)$$

B.2 Proof for Lemma 2

Denote the advantaged agent as i . That is, $i = A$ if $r \geq \frac{1}{2}$ and $i = B$ if $r < \frac{1}{2}$. Denote the disadvantaged agent as j .

Part 1: Revision strategy for agent less likely to be in control (agent j)

Given that the expected utility U^j is linear in w^j for fixed w^i and s , agent j has two possible choices for w^j :

1. $w^j < 1$ such that the equilibrium has $\sigma^i = 0$. This value is $w^j = w_1^j$ as given in (16) (given the equilibrium selection where the equilibrium selected in the multiplicity region is not $\sigma^i = 1, \sigma^j = 0$). In this case, the expected utility for agent j is

$$U^j = svw_1^j - \frac{c(s)}{p} = sv(1 - w^i) + c(s) \left(\frac{1}{q} - \frac{1}{p} \right). \quad (19)$$

Note that this case is obtained as long as $w_1^j \leq 1$, that is

$$w^i \geq \frac{c(s)}{s} \frac{1}{qv} \quad (20)$$

2. $w^j = 1$. Then, we have one of the following sub-cases:

Case 2(a): The equilibrium is $\sigma^A = \sigma^B = 1$. This happens when $w_3^j \leq 1$, that is

$$w^i \geq \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2r^i}{1-r^i}. \quad (21)$$

Then,

$$U^j = sv - sv \frac{qr^{i2}w^i}{p(1-r)r + q(1-2(1-r)r)} - \frac{c(s)}{p} \frac{pr^i + q}{p(1-r)r + q(1-2(1-r)r)}. \quad (22)$$

Case 2(b): The equilibrium is $\sigma^i = 1, \sigma^j = 0$. This happens when $w_2^j \leq 1 < w_3^j$, that is

$$\frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2(1-r^i)}{r^i} \leq w^i < \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i}. \quad (23)$$

Then,

$$U^j = sv - sv \frac{qr^i w^i}{p(1-r^i) + qr^i} - \frac{c(s)}{p} \frac{p + qr^i}{p(1-r^i) + qr^i}. \quad (24)$$

Case 2(c): The equilibrium is $\sigma^i = 0, \sigma^j = 0$. This happens when $1 < w_1^j$, that is

$$w^i < \frac{c(s)}{s} \frac{1}{qv}. \quad (25)$$

In this case, the expected utility for agent j is

$$U^j = sv - \frac{c(s)}{p}. \quad (26)$$

Best response for j . If $w^i \leq \frac{c(s)}{sqv}$, then the solution is $w^j = 1$, and the equilibrium is $\sigma^i = \sigma^j = 0$. We only need to compare Cases 1 and 2(a), (b) for the region where $w^i > \frac{c(s)}{sqv}$, so that $w_1^j < 1$. In this region, the internal solution w_1^j is chosen if and only if

$$w^i \leq \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i}. \quad (27)$$

Notice that this is exactly the condition for $w_3^j \leq 1$.

Therefore, agent j 's best response can be summarized as follows:

$$w^j(w^i, s) = \begin{cases} 1 & \text{if } w^i \leq \frac{c(s)}{sqv}, \\ w_1^j < 1 & \text{if } \frac{c(s)}{sqv} < w^i < \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i}, \\ 1 & \text{if } \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i} \leq w^i; \end{cases}$$

Part 2: Revision strategy for agent more likely to be in control (agent i)

Given that the expected utility EU^i is linear in w^i for fixed w^j and s , agent i has two possible choices for w^i :

1. $w^i < 1$ such that the equilibrium has $\sigma^j = 0$. This value is $w^i = w_3^i$ as given in (18) (given the equilibrium selection where the equilibrium selected in the multiplicity region is not $\sigma^i = 1, \sigma^j = 0$). In this case, the expected utility for agent i given $\sigma^i = 1, \sigma^j = 0$ is

$$U^i = svw_3^i - \frac{c(s)}{p} = sv(1 - w^j) + \frac{c(s)}{p} \left(\frac{p}{q} + \frac{2r^i}{1-r^i} \right) - \frac{c(s)}{p}. \quad (28)$$

Note that this case is obtained as long as $w_1^i \leq 1$, that is

$$w^j \geq \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2r^i}{1-r^i}. \quad (29)$$

2. $w^i = 1$. This happens in the following subcases:

2(a). When w_3^i the equilibrium is $\sigma^A = \sigma^B = 1$ when $w_3^i < 1$, that is

$$w^j > \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2r^i}{1-r^i}. \quad (30)$$

Then,

$$U^i = sv - svw^j \frac{q(1-r^i)^2}{pr^i(1-r^i) + q(1-r^i)^2 + qr^{i2}} - \frac{c(s)}{p} \frac{p(1-r^i) + q}{p(1-r^i)r^i + q(1-r^i)^2 + qr^{i2}}. \quad (31)$$

2(b). If $w_2^i \leq 1 < w_3^i$, then $w^i = 1$ corresponds to the equilibrium where $\sigma^j = 0$ as in Case 1.

2(c). If $1 < w_2^i$, then the solution is $w^i = 1$.

Best response for i . Comparing expected utilities from Cases 1 and 2 when $w_3^i < 1$, we find that the solution is $w^i = w_3^i$ if

$$w^j \leq \left(\frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2r^i}{1-r^i} \right) \left(1 + \frac{2q(1-r^i)^2}{pr^i(1-r^i) + qr^{i2}} \right). \quad (32)$$

Therefore, agent i 's best response can be summarized as follows:

$$w^i(w^j, s) = \begin{cases} 1 & \text{if } w^j \leq \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right), \\ w_3^i < 1 & \text{if } \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) < w^j < \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) \left(1 + \frac{2q(1-r^i)^2}{pr^i(1-r^i)+qr^{i2}} \right), \\ 1 & \text{if } \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) \left(1 + \frac{2q(1-r^i)}{p(1-r^i)+qr^i} \frac{1-r^i}{r^i} \right) \leq w^j; \end{cases}$$

Part 3: Equilibrium payoffs given s

Given the best responses derived in Parts 1 and 2, the Nash equilibrium becomes

$$\begin{cases} w^i(s) = w^j(s) = 1 & \text{if } \frac{c(s)}{s} \geq \frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \text{ or } \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} \\ w^i(s) = 1, w^j(s) = w_1^j \leq 1 & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s} < \frac{c(\bar{s}_h^n)}{\bar{s}_h^n}, \\ w^i(s) = w_3^i \leq 1, w^j(s) = 1 & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} < \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}; \end{cases}$$

$$(\sigma^{i*}(s), \sigma^{j*}(s)) = \begin{cases} (0, 0) & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s}, \\ (1, 0) & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} < \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}, \\ (1, 1) & \text{if } \frac{c(s)}{s} < \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2}. \end{cases}$$

Part 4: Other equilibrium selection in the region of multiplicity

If the equilibrium selected in the region of multiplicity is $\sigma^i = 0, \sigma^j = 1$, then the thresholds described above change in the following way. For agent j (the disadvantaged agent), the threshold needed for $w^j < 1$ is now $w_2^j \leq 1$. This means that

$$w^i \geq \frac{c(s)}{s} \frac{1}{qv} + 2 \frac{c(s)}{s} \frac{1}{pv} \frac{1-r}{r}. \quad (33)$$

The analysis for the cases when $w^j = 1$ (cases 2(a)-(c) above) is unchanged. Then, the best response for j is

$$w^j(w^i, s) = \begin{cases} 1 & \text{if } w^i \leq \frac{c(s)}{sqv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2(1-r^i)}{r^i}, \\ w_1^j < 1 & \text{if } \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2(1-r^i)}{r^i} < w^i < \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i}, \\ 1 & \text{if } \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2r^i}{1-r^i} \leq w^i; \end{cases}$$

For agent i , the threshold for $w^i < 1$ is the same, at w_3^i . An alternative threshold of w_1^i would also deter revisions, but at a higher cost for agent i . If $w^i = 1$, then cases 2(a), 2(b) do not change. If $w_1^i < 1 < w_2^i$, then the solution is w_1^i . This case requires $\frac{c(s)}{sqv} \leq w^j \leq \frac{c(s)}{sqv} + \frac{c(s)}{spv} \frac{2(1-r^i)}{r^i}$. Finally, case 2(c) requires $1 < w_1^i$. Therefore, the only difference from our previous analysis is to check when w_1^i may be the solution. We obtain that $w = w_1^i$

whenever $w^j \leq \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{spv} \frac{2(1-r^i)}{r^i} = w_2^i$. This implies

$$w^i(w^j, s) = \begin{cases} 1 & \text{if } w^j \leq \frac{c(s)}{s} \frac{1}{qv}, \\ w_1^i < 1 & \text{if } \frac{c(s)}{s} \frac{1}{qv} < w^j \leq \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2(1-r^i)}{r^i}, \\ 1 & \text{if } \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2(1-r^i)}{r^i} < w^j \leq \frac{c(s)}{s} \frac{1}{qv} + \frac{c(s)}{s} \frac{1}{pv} \frac{2r^i}{1-r^i}, \\ w_3^i < 1 & \text{if } \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) < w^j < \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) \left(1 + \frac{2q(1-r^i)^2}{pr^i(1-r^i)+qr^{i2}} \right), \\ 1 & \text{if } \frac{c(s)}{s} \left(\frac{1}{qv} + \frac{1}{pv} \frac{2r^i}{1-r^i} \right) \left(1 + \frac{2q(1-r^i)}{p(1-r^i)+qr^i} \frac{1-r^i}{r^i} \right) \leq w^j; \end{cases}$$

This results in the following Nash Equilibrium

$$\begin{cases} w^i(s) = w^j(s) = 1 & \text{if } \frac{c(s)}{s} \geq \frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \text{ or } \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} \\ w^i(s) = w_1^i \leq 1, w^j(s) = 1 & \text{if } \frac{c(\bar{s}_m^n)}{\bar{s}_m^n} \leq \frac{c(s)}{s} < \frac{c(\bar{s}_h^n)}{\bar{s}_h^n}, \\ w^i(s) = 1, w^j(s) = w_1^j \leq 1 & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s} < \frac{c(\bar{s}_m^n)}{\bar{s}_m^n}, \\ w^i(s) = w_3^i \leq 1, w^j(s) = 1 & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} < \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}; \end{cases}$$

$$(\sigma^{i*}(s), \sigma^{j*}(s)) = \begin{cases} (0, 0) & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s}, \\ (1, 0) & \text{if } \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2} < \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}, \\ (1, 1) & \text{if } \frac{c(s)}{s} < \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{r^i(p(1-r^i)+qr^i)}{r^i(p(1-r^i)+qr^i)+2q(1-r^i)^2}. \end{cases}$$

If the equilibrium in the region of multiplicity is the mixing equilibrium, then each agent must have the same expected utility given any w they select – as the mixing probabilities adjust to the selected w to ensure indifference. Therefore, the analysis is the same as in the case in which the equilibrium selection in the multiplicity region is $\sigma^i = 1, \sigma^j = 0$.

B.3 Proof for Proposition 1

We derive the equilibrium s^* chosen by Agent A in period 0. We solve the problem for the case when $r > \frac{1}{2}$ in the subsection B.3.1. We solve the problem for the case when $r < \frac{1}{2}$ in subsection B.3.2. In each subsection, the derivation is divided into three parts: (1) For each equilibrium pair (w^{A*}, w^{B*}) identified in Lemma 2, we characterize the value function for agent A at time 0, $EU^A(s)$, and the optimal s in each equilibrium region; (2) we derive the conditions for the optimal s to be in each of the four equilibrium regions; (3) we characterize the global maximizer. Then, in section B.3.3 we show the result about downscaling or upscaling.

B.3.1 The case when $r \geq \frac{1}{2}$.

Part 1: $EU^A(s)$ and the optimal s in each region

(i) If $\frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \leq \frac{c(s)}{s}$, where $\frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \equiv \frac{c(\bar{s}_h(w^A=w^B=1))}{\bar{s}_h(w^A=w^B=1)}$.

The expected utility when the equilibrium is $(\sigma^A, \sigma^B) = (0, 0)$ and $w^A = w^B = 1$ is

$$EU^A(s) = sv - \frac{c(s)}{p} \quad (34)$$

The optimal s in this region is

$$s^* = \begin{cases} c'^{-1}(vp) & \text{if } c'(\bar{s}_h^n) < vp \\ \bar{s}_h^n & \text{if } c'(\bar{s}_h^n) \geq vp \end{cases} \quad (35)$$

(ii) If $\frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s} \leq \frac{c(\bar{s}_h^n)}{\bar{s}_h^n}$, where $\frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \equiv \frac{c(\bar{s}_l(w^A=w^B=1))}{\bar{s}_l(w^A=w^B=1)}$:

The expected utility given $(\sigma^A, \sigma^B) = (0, 0)$ and $w^A = 1, w^B = \frac{c(s)}{s} \frac{1}{qv}$ is:

$$EU^A(s) = sv - \frac{c(s)}{p} \quad (36)$$

The optimal s in this region is

$$s^* = \begin{cases} \bar{s}_h^n & \text{if } c'(\bar{s}_h^n) < vp \\ c'^{-1}(vp) & \text{if } c'(\bar{s}_h^n) \geq vp \geq c'(\bar{s}_l^n) \\ \bar{s}_l^n & \text{if } c'(\bar{s}_l^n) > vp \end{cases} \quad (37)$$

(iii) If $\frac{c(\bar{s}_l^c)}{\bar{s}_l^c} \leq \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}$, where

$$\frac{c(\bar{s}_l^c)}{\bar{s}_l^c} \equiv \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \max \left\{ \frac{r(p(1-r) + qr)}{r(p(1-r) + qr) + 2q(1-r)^2}, \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} \right\}, \quad (38)$$

then $(\sigma^A, \sigma^B) = (1, 0)$ and $w^A = \frac{c(s)}{s} \frac{1}{qv} + 2\frac{c(s)}{s} \frac{1}{pv} \frac{r}{1-r}, w^B = 1$, so that

$$EU^A(s) = \frac{c(s)}{p} \left(\frac{p}{q} + \frac{3r-1}{1-r} \right). \quad (39)$$

Notice that $\frac{\partial EU^A(s)}{\partial s} > 0$ and therefore $s^* = \bar{s}_l^n$. Notice also that $\frac{\partial^2 EU^A(s)}{\partial s^2} > 0$, so $EU^A(s)$ is convex in this region.

(iv) If $\frac{c(s)}{s} \leq \frac{c(\bar{s}_l^c)}{\bar{s}_l^c}$, the expected utility given $(\sigma^A, \sigma^B) = (1, 1)$ and $w^A = w^B = 1$ is:

$$EU^A(s) = \frac{p(1-r) + qr}{pr(1-r) + qr^2 + q(1-r)^2} \left(svr - \frac{c(s)}{p} \frac{p(1-r) + q}{p(1-r) + qr} \right), \quad (40)$$

where we note that $\frac{p(1-r)+qr}{pr(1-r)+qr^2+q(1-r)^2} > 1$. Then,

$$s^* = \begin{cases} c'^{-1}\left(vpr \frac{p(1-r)+qr}{p(1-r)+q}\right) & \text{if } c'(\bar{s}_l^c) \geq vpr \frac{p(1-r)+qr}{p(1-r)+q} \\ \bar{s}_l^c & \text{if } c'(\bar{s}_l^c) < vpr \frac{p(1-r)+qr}{p(1-r)+q} \end{cases} \quad (41)$$

Part 2: Optimal s .

Claim 1h. If $p \geq q\left(\varepsilon - \frac{2r}{1-r}\right) \equiv \bar{p}^h$, then $s^* = c'^{-1}(vp)$ and $s^* \geq \bar{s}_l^n$.

Proof. Notice that for any s , $EU^A(s|\sigma^A = \sigma^B = 0) > EU^A(s|\sigma^A = \sigma^B = 1)$. Therefore, if in the region $\frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s}$ we have $s^* = c'^{-1}(vp)$, then this is the global maximizer. Given that $\varepsilon \cdot c(\bar{s}_3) = s \cdot c'(\bar{s}_3)$ and solutions (35) and (37), we have that $s^* = c'^{-1}(vp)$ iff $p \geq \bar{p}^h$.

Claim 2h. Given q, r and ε , there exists \tilde{p} such that if $\tilde{p} \leq p < \bar{p}^h$, then the solution is $s^* = \bar{s}_l^n$.

Proof. For $p < \bar{p}^h$, optimal s in the interval $s \geq \bar{s}_l^n$ is \bar{s}_l^n . Note that the expected utility is increasing in the interval $[\bar{s}_l^c, \bar{s}_l^n]$. Therefore, if EU^A is also increasing over $(0, \bar{s}_l^c)$, then the global optimum is $s^* = \bar{s}_l^n$. Solving the inequality in (41), the condition $c'(\bar{s}_l^c) < vpr \frac{p(1-r)+qr}{p(1-r)+q}$ reduces to $p \geq \tilde{p}$, where

$$\tilde{p} = \begin{cases} \frac{q}{2(1-r)r}[\varepsilon(1-r) - (1-2r)^2 - (r^2+1) + (1-r)\sqrt{\delta}], & \text{if (i) or (ii)} \\ 0, & \text{otherwise} \end{cases} \quad (42)$$

where

$$\delta = (1-r)[(3-r) - 2(1-r)((1-r)^2 + (1-2r)^2)\varepsilon + (1-r)^2\varepsilon], \quad (43)$$

and conditions (i) and (ii) are as follows:

$$(i) : 2 \frac{r(2(1-r)^2 + r^2)}{1-r} < \varepsilon \leq \frac{2-r+r^2(2r-1)}{(1-r)(2-r)}, \quad (44)$$

and

$$(ii) : \varepsilon > \frac{2-r+r^2(2r-1)}{(1-r)(2-r)} \text{ and } q < \frac{1-r}{2(4r(1-r)^2 + 2r^3 - (1-r)\varepsilon)} \cdot \left(r^2 - 2(1-r)^2 + (1-r)\varepsilon + \sqrt{(1-r)^2\varepsilon^2 - 2(1-r)((1-r)^2 + (1-2r)^2)\varepsilon + (2(1-r)^2 - r^2)} \right)$$

Claim 3h. If $p < \tilde{p}$ such that $\max_{s \in (0, \bar{s}_l^c)} EU^A(s)$ has an interior solution, then the optimal $s^* = \bar{s}_l^n$.

Proof. If $c'(\bar{s}_l^n) > vp$ and $c'(\bar{s}_l^c) > vpr \frac{p(1-r)+qr}{p(1-r)+q}$, let $s_{11}^* \in (0, \bar{s}_l^c)$ denote the maximizer for $EU^A(s|\sigma^A = \sigma^B = 1)$. Finding the global maximizer requires comparing expected utilities

$EU^A(s_{11}^*|\sigma^A = \sigma^B = 1)$ and $EU^A(\bar{s}_l^n|\sigma^A = \sigma^B = 0)$. We note that $s_{11}^*(\sigma^A = \sigma^B = 1)$ and $EU^A(s_{11}^*|\sigma^A = \sigma^B = 1)$ are increasing in r , and \bar{s}_l^n is increasing in r , meaning that $EU^A(\bar{s}_3|\sigma^A = \sigma^B = 0)$ is decreasing in r . At $r = 1$, $EU^A(s_{11}^*|\sigma^A = \sigma^B = 1) = EU^A(\bar{s}_l^n|\sigma^A = \sigma^B = 0)$. At $r \rightarrow \frac{1}{2}$, $EU^A(s_{11}^*|\sigma^A = \sigma^B = 1) = s_{11}^* v \frac{p+q}{p+2q} - 2 \frac{c(s_{11}^*)}{p} < \bar{s}_l^n v \frac{p+q}{p+2q} = EU^A(\bar{s}_l^n|\sigma^A = \sigma^B = 0)$. Moreover, for $s \in (\bar{s}_l^c, \bar{s}_l^n)$, $EU^A(s)$ is increasing and convex. Therefore, $\forall r \in (\frac{1}{2}, 1)$, given the monotonic increase in $EU^A(s^*|\sigma^A = \sigma^B = 1)$ and $EU^A(\bar{s}_l^n|\sigma^A = \sigma^B = 0)$ and the limit points, we have $EU^A(s_{11}^*|\sigma^A = \sigma^B = 1) \leq EU^A(\bar{s}_l^n|\sigma^A = \sigma^B = 0)$. This means that $s^* = \bar{s}_l^n$.

Summary: To sum up, the optimal s when $r > \frac{1}{2}$ is:

$$s^* = \begin{cases} c'^{-1}(vp) & \text{if } p > \bar{p}^h \\ \bar{s}_l^n & \text{if } p \leq \bar{p}^h \end{cases}. \quad (45)$$

B.3.2 The case when $r < \frac{1}{2}$.

Part 1: $EU^A(s)$ and the optimal s in each region

(i) If $\frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \leq \frac{c(s)}{s}$: The expected utility when the equilibrium is $(\sigma^A, \sigma^B) = (0, 0)$ and $w^A = w^B = 1$ is

$$EU^A(s) = sv - \frac{c(s)}{p}, \quad (46)$$

and so

$$s^* = \begin{cases} c'^{-1}(vp) & \text{if } c'(\bar{s}_h^n) < vp, \\ \bar{s}_h^n & \text{if } c'(\bar{s}_h^n) \geq vp. \end{cases} \quad (47)$$

(ii) If $\frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \leq \frac{c(s)}{s} \leq \frac{c(\bar{s}_h^n)}{\bar{s}_h^n}$: The expected utility is $(\sigma^A, \sigma^B) = (0, 0)$ and $w^A = \frac{c(s)}{s} \frac{1}{qv}$, $w^B = 1$:

$$EU^A(s) = c(s) \left(\frac{1}{q} - \frac{1}{p} \right), \quad (48)$$

and the optimal s is therefore at a corner:

$$s^* = \begin{cases} c'^{-1}(\bar{s}_h^n) & \text{if } q \leq p, \\ c'^{-1}(\bar{s}_l^n) & \text{if } q > p. \end{cases} \quad (49)$$

(iii) If $\frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{(1-r)(pr+q(1-r))}{(1-r)(pr+q(1-r))+2qr^2} \leq \frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n}$: The expected utility is $(\sigma^A, \sigma^B) = (0, 1)$ and $w^A = 1$, $w^B = \frac{c(s)}{s} \frac{1}{qv} + 2 \frac{c(s)}{s} \frac{1}{pv} \frac{1-r}{r}$:

$$EU^A(s) = sv - \frac{c(s)}{p} \frac{2-r}{r}. \quad (50)$$

The optimal s in this region is thus

$$s^* = \begin{cases} \bar{s}_l^n & \text{if } c'(\bar{s}_l^n) \leq vp_{\frac{r}{2-r}}, \\ c'^{-1}\left(vp_{\frac{r}{2-r}}\right) & \text{if } c'(\bar{s}_l^c) < vp_{\frac{r}{2-r}} < c'(\bar{s}_l^n), \\ \bar{s}_l^c & \text{if } c'(\bar{s}_l^c) \geq vp_{\frac{r}{2-r}}. \end{cases} \quad (51)$$

(iv) If $\frac{c(s)}{s} \leq \frac{c(\bar{s}_l^n)}{\bar{s}_l^n} \frac{(1-r)(pr+q(1-r))}{(1-r)(pr+q(1-r))+2qr^2}$: The expected utility is $(\sigma^A, \sigma^B) = (1, 1)$ and $w^A = w^B = 1$:

$$EU^A(s) = \frac{p(1-r)r + qr^2}{pr(1-r) + qr^2 + q(1-r)^2} \left(sv - \frac{c(s)}{pr} \frac{p(1-r) + q}{p(1-r) + qr} \right), \quad (52)$$

The optimal s^* in this region is thus

$$s^* = \begin{cases} c'^{-1}\left(vpr \frac{p(1-r)+qr}{p(1-r)+q}\right) & \text{if } c'(\bar{s}_l^c) \geq vpr \frac{p(1-r)+qr}{p(1-r)+q}, \\ \bar{s}_l^c & \text{if } c'(\bar{s}_l^c) < vpr \frac{p(1-r)+qr}{p(1-r)+q}. \end{cases} \quad (53)$$

Part 2: Optimal s .

Claim 11. If $p \geq \varepsilon q \equiv \bar{p}^l$, then $s^* = c'^{-1}(vp)$ and $s^* \geq \bar{s}_1$.

Proof. Notice that for any s , $EU^A(s|\sigma^A = \sigma^B = 0) > EU^A(s|\sigma^A = \sigma^B = 1)$. Therefore, if in the region $\frac{c(\bar{s}_h^n)}{\bar{s}_h^n} \leq \frac{c(s)}{s}$ we have $s^* = c'^{-1}(vp)$, then this is the global maximizer. Given that $\varepsilon \cdot c(\bar{s}_1) = s \cdot c'(\bar{s}_1)$ and solutions (35) and (37), we have that $s^* = c'^{-1}(vp)$ iff $p \geq \varepsilon q$.

Claim 21. The expected utility $EU(s)$ is discontinuous at \bar{s}_l^c : it exhibits an upwards jump.

Proof. Given (22) and (24), the difference in expected utilities at \bar{s}_l^c is:

$$EU^A(\bar{s}_l^c|\sigma^A = 0, \sigma^B = 1) - EU^A(\bar{s}_l^c|\sigma^A = \sigma^B = 1) = v\bar{s}_l^c \cdot \frac{2q^2r^2(1-r)^2}{[pr(1-r) + qr^2 + q(1-r)^2] \cdot [pr(1-r) + q(1-r)^2 + 2qr^2]} > 0. \quad (54)$$

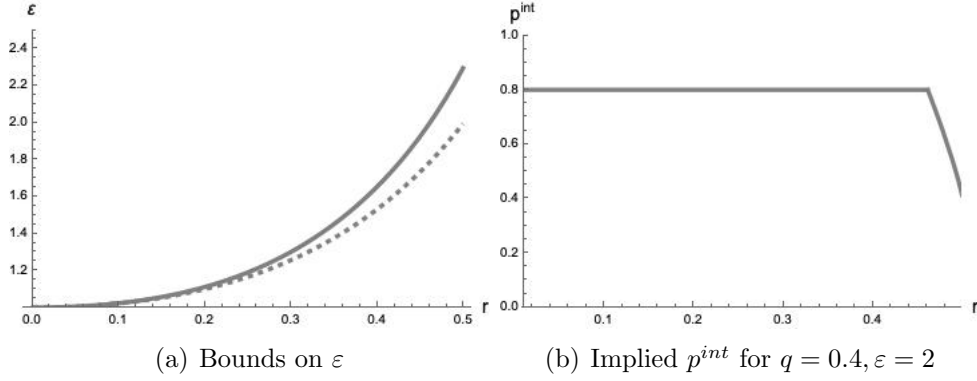
Claim 31. If $q < p < \varepsilon q$, there is a local maximum at \bar{s}_h^n and an interior local maximum for $s \in [0, \bar{s}_l^n]$.

Proof. By (49), the expected utility is convex and increasing over $(\bar{s}_l^n, \bar{s}_h^n)$. For $s \in (\bar{s}_l^c, \bar{s}_l^n)$, the expected utility $EU^A(s|\sigma^A = 0, \sigma^B = 1)$ is decreasing at \bar{s}_l^n . To show this, notice that $c'(\bar{s}_l^n) > vp_{\frac{r}{2-r}}$ whenever

$$\varepsilon q \left(\frac{2-r}{r} - \frac{2(1-r)}{r\varepsilon} \right) > p. \quad (55)$$

As $\frac{2-r}{r} - \frac{2(1-r)}{r\varepsilon} > 1$ for $r < \frac{1}{2}$, this holds for all $p \leq \varepsilon q$. Hence, $EU^A(s|\sigma^A = 0, \sigma^B = 1)$ either has an interior maximum in $(\bar{s}_l^c, \bar{s}_l^n)$, or the function achieves its maximum at the corner \bar{s}_l^c .

Figure 11: Bounds for Case a



Then, the expected utility EU^A is maximized either at \bar{s}_h^n or at some value $s < \bar{s}_l^n$.

Claim 41. There exists $\underline{p}^l > q$ such that the global maximum is at $s = \bar{s}_h^n$ for $\underline{p}^l < p < \bar{p}^l$.

Proof. There are three possible local maxima for $s < \bar{s}_l^n$: (a) The expected utility has an internal maximum for $s \in (\bar{s}_l^c, \bar{s}_l^n)$, in which case this is also higher than any maximum achieved for $s \leq \bar{s}_l^c$; (b) the expected utility is decreasing over $(\bar{s}_l^c, \bar{s}_l^n)$ and increasing over $(0, \bar{s}_l^c)$; and (c) the expected utility is decreasing over $(\bar{s}_l^c, \bar{s}_l^n)$ and it has an internal maximum in $(0, \bar{s}_l^c)$. We consider each case below.

(a). $EU^A(s|\sigma^A = 0, \sigma^B = 1)$ is increasing at \bar{s}_l^c if

$$\varepsilon \frac{q(2-r)}{pr + 2q(1-r)} \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} < 1 \quad (56)$$

which implies

$$p \geq p^{int} \equiv \begin{cases} \frac{q}{2r(1-r)} \left((1-r)^2(2\varepsilon - 3) + r^2(\varepsilon \frac{1-r}{r} - 2) + \sqrt{\delta_2} \right), & \text{if (iii)} \\ \varepsilon q, & \text{otherwise} \end{cases}, \quad (57)$$

where

$$\delta_2 = (1+r^2)^2 - 4r(1-r^2) - 2\varepsilon(r^2(1-r)^2 - r^4 + 2(1-r^2)) - \varepsilon^2(4(1-r)^3 - r^3(2-r)), \quad (58)$$

and

$$(iii) : 1 + \frac{2r^2}{1-r} < \varepsilon < \frac{3}{2} - \frac{1-r-r^2 - \sqrt{(1-2r)^2(1+2r^3) + r^2(2-4r^2-3r^2(1-r)^2)}}{2r(1-r)^2}.$$

To illustrate what these bounds imply, Figure 11 shows the bounds on ε as a function of r (Panel a) and the implied p^{int} as a function for r (Panel b) for $q = 0.4$ and $\varepsilon = 2$. Moreover, given the bounds on ε and $r \in [0, \frac{1}{2}]$, we can derive the lower bound $q \leq p^{int}$.

If $\varepsilon q > p > p^{int}$, then $EU^A(s|\sigma^A = 0, \sigma^B = 1)$ is maximized at a value $s^* \in (\bar{s}_l^c, \bar{s}_l^n)$. Moreover, notice that $EU^A(s^*|\sigma^A = 0, \sigma^B = 1) > EU^A(s|\sigma^A = \sigma^B = 1)$, since the expected utility when $\sigma^A = 0, \sigma^B = 1$ is higher than the expected utility when $\sigma^A = \sigma^B = 1$ at any s .

To find the global maximum, we compare the expected utility at s^* against the expected utility at \bar{s}_h^n :

$$EU^A(s^*) = s^* v \left(1 - \frac{1}{\varepsilon}\right) \quad (59)$$

$$EU^A(\bar{s}_h^n) = \bar{s}_h^n v \left(1 - \frac{q}{p}\right) \quad (60)$$

where

$$s^* = \left(\frac{vp}{\varepsilon} \frac{r}{2-r}\right)^{\frac{1}{\varepsilon-1}} \quad (61)$$

$$\bar{s}_h^n = (vq)^{\frac{1}{\varepsilon-1}} \quad (62)$$

Notice that $EU^A(\bar{s}_h^n) \geq EU^A(s^*)$ implies

$$q \left(1 - \frac{q}{p}\right)^{\varepsilon-1} \geq \frac{p}{\varepsilon} \frac{r}{2-r} \left(1 - \frac{1}{\varepsilon}\right)^{\varepsilon-1}. \quad (63)$$

At $p = q$, the left-hand side of (63) is 0, whereas the right-hand side of the equation is positive. At $p = \varepsilon q$, the left-hand side of (63) is positive and necessarily higher than the right-hand side, given that the expected utility achieves its global maximum at \bar{s}_h^n when $p = \varepsilon q$. The left-hand side of the inequality is decreasing in q for $q \in (\frac{p}{\varepsilon}, p)$, while the right side is constant in q . Moreover, the left-hand is concave for $q < \frac{2p}{\varepsilon}$ or $\varepsilon = 2$ and convex for $q \geq \frac{2p}{\varepsilon}$ and $\varepsilon \neq 2$. Therefore, the functions of q on each side of the inequality satisfy single-crossing for $q \in (\frac{p}{\varepsilon}, p)$. Inverting this relationship as a function of p , it follows that there exists $\underline{p}^{la} \in [q, \varepsilon q]$ such that (63) is satisfied iff $p \geq \underline{p}^{la}$; that is, the optimal s is \bar{s}_h^n for $p \geq \underline{p}^{la}$.²⁷

(b). If $q < p < p^{int}$, then $EU^A(s)$ is decreasing for s to the right of \bar{s}_l^c ; additionally, the expected utility is increasing for s to the left of \bar{s}_l^c if

$$c'(\bar{s}_l^c) \leq vpr \frac{p(1-r) + qr}{p(1-r) + q}, \quad (64)$$

that is²⁸

$$\frac{\varepsilon q}{pr + 2q(1-r)} \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} - \frac{p(1-r) + qr}{p(1-r) + q} \leq 0. \quad (65)$$

The first derivative of (65) with respect to p is strictly negative given $q \in (0, 1), r \in$

²⁷Note: if $\varepsilon = 2$, then we can have $\underline{p}^{la} > p^{int}$. For instance, if $q = 0.5, r = 0.495$; in which case $p^{int} = 0.5822$ and $\underline{p}^{la} = 0.625$.

²⁸Note that this case exists as long as $p > q$.

$(0, 0.5), \varepsilon > 1$, which means that the left-hand side of the above expression is monotonically decreasing in p . Therefore, there exists at most one value $p^{int2*} \geq q$ such that inequality (65) is satisfied for all $p \geq p^{int2*}$. A necessary condition for $p^{int2*} > q$ is that

$$\varepsilon > 1 + 2\frac{r^2}{1-r}. \quad (66)$$

Therefore, let

$$p^{int2} = \begin{cases} q & \text{if } p^{int2*} \leq q \\ p^{int2*} & \text{if } p^{int2*} \in (q, p^{int}) \\ p^{int} & \text{otherwise} \end{cases} \quad (67)$$

For $p \in (p^{int2}, p^{int})$, in the region $(0, \bar{s}_h^n)$, the expected utility $EU^A(s)$ is maximized at \bar{s}_l^c . It remains to compare $EU^A(\bar{s}_l^c | \sigma^A = 1, \sigma^B = 0)$ and $EU^A(\bar{s}_h^n | \sigma^A = 0, \sigma^B = 0)$. We have

$$EU^A(\bar{s}_l^c) = (vq)^{\frac{1}{\varepsilon-1}} v \left(\frac{pr}{pr + 2q(1-r)} \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} \right)^{\frac{1}{\varepsilon-1}} \left(1 - \frac{q(2-r)}{pr + 2q(1-r)} \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} \right), \quad (68)$$

$$EU^A(\bar{s}_h^n) = (vq)^{\frac{1}{\varepsilon-1}} v \left(1 - \frac{q}{p} \right). \quad (69)$$

Consider the function $\Delta(p, q, r, \varepsilon) \equiv [EU^A(\bar{s}_h^n) - EU^A(\bar{s}_l^c)] / (vq)^{\frac{1}{\varepsilon-1}}$. Then, $\Delta(p, q, r, \varepsilon)$ is continuous in p over (q, p^{int}) . It is also increasing in p over that interval, a result we derive through numerical methods for $q \in (0, 1), r \in (0, \frac{1}{2}), \varepsilon > 1$ (and analytically for $\varepsilon = 2$). As $p \rightarrow q$, we have $EU^A(\bar{s}_l^c) > 0 = EU^A(\bar{s}_h^n)$, and hence $\Delta(p, q, r, \varepsilon) < 0$. As $p \rightarrow p^{int}$, we have $EU^A(\bar{s}_h^n) \geq EU^A(\bar{s}_l^c)$. Hence, $\Delta(p, q, r, \varepsilon) \geq 0$. Then, there exists a unique $\underline{p}^{lb} \in [q, p^{int}]$ such that $EU^A(\bar{s}_h^n) \geq EU^A(\bar{s}_l^c)$ if and only if $p \geq \underline{p}^{lb}$. Notice also that, if $\underline{p}^{la} > p^{int}$, then by continuity we have $\underline{p}^{lb} = p^{int}$.

(c). If $q < p < p^{int2}$, then the expected utility has an interior local maximum for $s \in (0, \bar{s}_l^c]$, and it is decreasing over $(\bar{s}_l^c, \bar{s}_l^n)$. If $\underline{p}^{lb} > q$, then the global maximum is not at \bar{s}_h^n . If $\underline{p}^{lb} = q$, then for the global maximum is at \bar{s}_h^n if $EU^A(\bar{s}_h^n) \geq EU^A(s^* | \sigma^A = \sigma^B = 1)$, where

$$EU^A(s^*) = \left(\frac{vpr(p(1-r) + qr)}{\varepsilon(p(1-r) + q)} \right)^{\frac{1}{\varepsilon-1}} \frac{v(pr(1-r) + qr^2)}{pr(1-r) + q(1-r)^2 + qr^2} \left(1 - \frac{1}{\varepsilon} \right) \quad (70)$$

We have $EU^A(s^*) \leq EU^A(\bar{s}_h^n)$ if

$$\left(\frac{p(1-r) + qr}{\varepsilon(p(1-r) + q)} \right)^{\frac{1}{\varepsilon-1}} \cdot \frac{pr(1-r) + qr^2}{pr(1-r) + q(1-r)^2 + qr^2} \left(1 - \frac{1}{\varepsilon} \right) \leq q^{\frac{1}{\varepsilon-1}} v \left(1 - \frac{q}{p} \right) \quad (71)$$

At $p = q$, the right-hand side of (71) is 0, whereas the left-hand side of the equation is strictly positive. At $p = \varepsilon q$, the right-hand side of (71) is positive and necessarily higher

than the left-hand side, given that the expected utility achieves its global maximum at \bar{s}_h^n when $p = \varepsilon q$. Both sides of the inequality are increasing and convex in p for $p \in (q, \varepsilon q)$. Therefore, the functions of p on each side of the inequality (71) satisfy single-crossing. It follows that there exists $\underline{p}^{lc} \in [q, \varepsilon q]$ such that (71) is satisfied iff $p \geq \underline{p}^{lc}$.

Notice that 4(a) – 4(c) imply that there is a unique $\underline{p}^l = \max\{\underline{p}^{la}, \underline{p}^{lb}, \underline{p}^{lc}\}$ with $\underline{p}^l > q$ such that for $p \in [\underline{p}^l, \bar{p}^l]$ the expected utility is maximized at $s = \underline{s}_h^n$. Otherwise, the optimal s is in $(0, \underline{s}_l^n)$.

Claim 5l. If $p \leq q$, then $EU^A(s)$ is decreasing for $s \geq \underline{s}_l^c$.

Proof. Follows from (46) and (48) with $p \leq q$.

B.3.3 Over-/Under-scaling.

Define

$$\bar{p}(\varepsilon, q, r) = \begin{cases} \bar{p}^h & \text{if } r \geq \frac{1}{2} \\ \bar{p}^l & \text{if } r < \frac{1}{2} \end{cases} \quad (72)$$

$$\underline{p}(\varepsilon, q, r) = \begin{cases} 0 & \text{if } r \geq \frac{1}{2} \\ \underline{p}^l & \text{if } r < \frac{1}{2} \end{cases} \quad (73)$$

If $p \geq \bar{p}$, then by Claims 1h and 1l, the optimal s chosen by A is $s^* = c'^{-1}(vp)$. The benchmark without transitions of control is $s^{NT} = c'^{-1}(vp)$. Therefore, $s^* = s^{NT}$.

If $p \in (\underline{p}, \bar{p})$, then

$$c'(s^*) = \begin{cases} \varepsilon q v \frac{p(1-r)}{p(1-r)+2qr} & \text{if } r \geq \frac{1}{2} \\ \varepsilon q v & \text{if } r < \frac{1}{2} \end{cases} \quad (74)$$

Then, for $r \geq \frac{1}{2}$, $p < \bar{p}$ means $p < q \frac{\varepsilon(1-r)-2r}{1-r}$. Notice that, rearranged, this expression is $q\varepsilon \frac{p(1-r)}{p(1-r)+2qr} > p$. This is, $s^* > s^{NT}$. For $r < \frac{1}{2}$, $p < \bar{p}$ means $p < q\varepsilon$. Thus, $\varepsilon q v > vp$ and so $s^* > s^{NT}$.

If $p \leq \underline{p}$, then the only relevant case is the one where $r < \frac{1}{2}$. We have the following three sub-cases:

1. First, if s^* is the interior solution to maximizing $EU^A(s|\sigma^A = 0, \sigma^B = 1)$. In this case, $c'(s^*) = vp \frac{r}{2-r} < vp = c'(s^{NT})$. Therefore, there is downscaling relative to s^{NT} .

2. If at the optimum for A , $s = \bar{s}_l^c$, then from (65), $\frac{c'(\bar{s}_l^c)}{vpr} < \frac{p(1-r)+qr}{p(1-r)+q} < \frac{1}{r} = \frac{c'(s^{NT})}{vpr}$, which implies that $\bar{s}_l^c < s^{NT}$ and thus downscaling.

3. If s^* is the interior solution to maximizing $EU^A(s|\sigma^A = 1, \sigma^B = 1)$, then $c'(s^*) = vpr \frac{p(1-r)+qr}{p(1-r)+q} < vp = c'(s^{NT})$, and thus downscaling.

B.3.4 Other equilibrium selections in the multiplicity region

If the mixing equilibrium is played in the region of multiplicity, then the above analysis unchanged. If the other pure strategy equilibrium is played instead ($\sigma^i = 0, \sigma^j = 1$), then the analysis does not change for $r \leq 1/2$ (in the region $(\bar{s}_m^n, \bar{s}_h^n)$, the equilibrium payoff

division is $w^A = 1, w^B = w_1^B$ and no one revises; hence, for $s \in (\bar{s}_m^n, \bar{s}_h^n)$, the expected utility for agent A is the same as in the main analysis above. If $r > 1/2$ and the equilibrium played in the multiplicity region is $\sigma^i = 0, \sigma^j = 1$, where i is the advantaged agent, then for $s \in (s_m^n, s_h^n)$ the expected utility is

$$EU^A(s) = c(s)\left(\frac{1}{q} - \frac{1}{p}\right). \quad (75)$$

Then, the optimal s in this region is either $c'(\bar{s}_m^n)$ if $q > p$ or $c'(\bar{s}_h^n)$ if $q \leq p$. Notice, however, that $EU(\bar{s}_m^n | w^A = 1) > EU(\bar{s}_m^n | w_1^A)$. Hence, if $\varepsilon q > p > q(\varepsilon - 2\frac{1-r}{r}) > \bar{p}^h$, then the optimal s^* is $s^* \in \{\bar{s}_m^n, \bar{s}_h^n\}$, and there is either downscaling if $\left(\frac{pr}{pr+2q(1-r)}\right)^{\frac{1}{\varepsilon-1}} \left(1 - \frac{qr}{pr+2q(1-r)}\right) > \left(1 - \frac{q}{p}\right)$ or upscaling otherwise. Therefore, if $r > \frac{1}{2}$ and the equilibrium selection in the region of multiplicity is $(0, 1)$, then:

$$\begin{cases} \text{if } p < \bar{p}^h, \text{ upscaling} \\ \text{if } \bar{p}^h \leq p \leq q(\varepsilon - 2\frac{1-r}{r}), \text{ unconstrained} \\ \text{if } q(\varepsilon - 2\frac{1-r}{r}) < p < \varepsilon q, \text{ down-/up-scaling} \\ \text{if } \varepsilon q \leq p, \text{ unconstrained.} \end{cases} \quad (76)$$

B.4 Proof for Proposition 2

If $r \geq \frac{1}{2}$, then the equilibrium strategies are $\sigma^A = \sigma^B = 0$, and $w^A = 1, w^B = 1$. If $r < \frac{1}{2}$, then the equilibrium strategies are $\sigma^A = \sigma^B = 0$, and $w^A = 1$ if $p > \underline{p}$. For $p \leq \underline{p}$, then there are two possible equilibria: either $\sigma^A = 0, \sigma^B = 1$, or $\sigma^A = \sigma^B = 1$. In the first equilibrium, $s^* = \bar{s}_l^c$ and $w^A = 1, w^B < 1$. Therefore, given $r > 0$, with positive probability the resulting project division is $(1 - w^B, w^B)$ where $w^B < 1$. In the first equilibrium, $s^* < \bar{s}_l^c$ and $w^A = 1, w^B = 1$. Therefore, the resulting project division will allocate all benefits to only one agent.

B.5 Proof for Corollary 1

Follows directly from Proposition 1 given that s^* increases in p and the equilibrium revision strategies have $\sigma^A = 1$ or $\sigma^B = 1$ for $p \leq \underline{p}$ and $\sigma^A = \sigma^B = 0$ for $p > \underline{p}$.

B.6 Proof of Corollary 2

Follows directly from Proposition 1 given that $\underline{p} = 0$ for $r \geq \frac{1}{2}$, and the equilibrium revision strategy has $\sigma^A = 1$ or $\sigma^B = 1$ only if $p \leq \underline{p}$.

B.7 Proof for Proposition 3

The welfare function given project designer A and a social planner that places equal weight on each agent is:

$$W = s^*v - 2P_c^A \frac{c(s^*)}{p}.$$

Part 1: If $r \geq \frac{1}{2}$. If $p \geq \bar{p} = q\left(\varepsilon - \frac{2r}{1-r}\right)$, then $s^* = c'^{-1}(vp) = s^{NT}$, and ²⁹

$$W < 0 \Leftrightarrow \varepsilon < 2. \quad (77)$$

Moreover, note that if $\varepsilon < 2$, then $\bar{p} < 0$, meaning that $W < 0$ for all $p \in [0, 1]$. If $p < \bar{p}$ (note that a necessary condition is that $\varepsilon > 2$), then $s^* = \bar{s}_l^n$. Thus

$$W = v\bar{s}_l^n \left(1 - \frac{2q(1-r)}{p(1-r) + 2qr}\right) = v\bar{s}_l^n \frac{p(1-r) + 2q(2r-1)}{p(1-r) + 2qr} > 0.$$

Part 2: If $r < \frac{1}{2}$. If $p \geq \bar{p}(\varepsilon, q, r)$, then $c'(s^*) = vp$ and the condition for $W < 0$ is as in (77). If $\underline{p}(\varepsilon, q, r) < p < \bar{p}(\varepsilon, q, r)$, then $s^* = \bar{s}_h^n$, and

$$W = v\bar{s}_h^n \left(1 - 2\frac{q}{p}\right)$$

Thus,

$$W < 0 \Leftrightarrow p < 2q \text{ and } \underline{p} < p < \varepsilon q$$

If $p \leq \underline{p}(\varepsilon, q, r)$, then:

(i) if $p > p^{int}$ such that $c'(s^*) = \frac{vpr}{2-r}$, then

$$W = vs^* \left(1 - 2\frac{r}{\varepsilon(2-r)} \left(1 + \frac{p(1-r)}{pr + q(1-r)}\right)\right),$$

which means that $W > 0$ given $\varepsilon > 1$.

(ii) if $s^* = \bar{s}_l^c$, then

$$W = v\bar{s}_l^c \left(1 - \frac{(1-r)(pr + q(1-r))}{(1-r)(pr + q(1-r)) + 2qr^2} \frac{2qr}{pr + 2q(1-r)}\right) > 0.$$

(iii) if $c'(s^*) = vpr \frac{p(1-r)+qr}{p(1-r)+q}$, then

$$W = vs^* \left(1 - 2r \frac{p(1-r) + qr}{\varepsilon(p(1-r) + q)}\right) > 0.$$

²⁹Note that for $c(s) = s^2$, we have $\varepsilon = 2$, hence $W \geq 0$ when $r \geq \frac{1}{2}$.

To summarize,

$$W < 0 \text{ if } \begin{cases} \varepsilon < 2 \text{ \& } r \geq \frac{1}{2}, \\ q\varepsilon < p < 1 \text{ \& } \varepsilon < 2 \text{ \& } r < \frac{1}{2}, \\ \underline{p} < p < \min\{2q, \bar{p}\} \text{ \& } r < \frac{1}{2} \end{cases}.$$

The interval \mathcal{P} is therefore:

$$\mathcal{P} = \begin{cases} (\underline{p}, 1) \text{ if } \varepsilon < 2, \\ (\underline{p}, 2q) \text{ if } r < \frac{1}{2} \text{ and } \varepsilon \geq 2. \end{cases} \quad (78)$$

B.8 Proof for Corollary 3

Follows given the upper bound $2q$ and the lower bound q on $p(\varepsilon, q, r | r < 0.5)$.

B.9 Proof for Proposition 4

If $\frac{c(s^{\max})}{s^{\max}} \leq \frac{c(\bar{s}_l^c)}{\bar{s}_l^c}$ then as shown in Lemma 2, the equilibrium play is $\sigma^A = \sigma^B = 1$ and $w^A = w^B = 1$ for all $s \leq \bar{s}_l^c$. Therefore, the choice of s will be in the region where everyone revises and there is maximal inequality.

B.10 Proof for Corollary 4

The value \bar{s}_l^c is increasing in p . Therefore, the probability of any fixed scale cap satisfying $s^{\max} \leq \bar{s}_l^c$ increases.

B.11 Proof for Proposition 5

For both cases of r , we calculate conditions under which agent B continues whenever it has control, or:

$$v_q^B = \left(\frac{1}{p} - \frac{1}{q} \right) c_p \leq EU^B(s^*). \quad (79)$$

where v_q^B (8) is the expected cost of completing the design phase given no attempts at cancellation, and $EU^B(s^*)$ is agent B 's expected payoff in the main phase (where agent A initiates).

(i) $r > 1/2$. In this case, $s^* = s^{NT}$ if $p \geq \bar{p}$ (where $\bar{p} = q^{\frac{\varepsilon(1-r)-2r}{1-r}}$), and $s^* = \left(\frac{2qr+p-pr}{qp(1-r)} \right)^{\frac{1}{1-\varepsilon}}$ otherwise. Agent B 's expected utility in the main phase then evaluates to:

$$EU^B(s^*) = \begin{cases} -p^{\frac{1}{\varepsilon-1}} \left(\frac{v}{\varepsilon} \right)^{\frac{\varepsilon}{\varepsilon-1}} & \text{if } p \geq \bar{p} \\ -\frac{1}{p} \left(\frac{2qr+p-pr}{qp(1-r)} \right)^{\frac{\varepsilon}{1-\varepsilon}} & \text{if } p < \bar{p}. \end{cases} \quad (80)$$

Observe that $EU^B(s^*)$ and s^* are continuous at $p = \bar{p}$.

There are two subcases. First, consider the case where $p > \bar{p}$ (which is assured for all p if $\varepsilon \leq 2$).

To determine the conditions satisfying (79), it will be convenient to multiply both sides of the expression by p , which simplifies the expressions while preserving inequalities. This produces an equivalent condition for B to continue:

$$\left(1 - \frac{p}{q}\right) c_p \leq -p^{\frac{\varepsilon}{\varepsilon-1}} \left(\frac{v}{\varepsilon}\right)^{\frac{\varepsilon}{\varepsilon-1}}. \quad (81)$$

As the left-hand side is linear and decreasing in p , and the right-hand side is concave and decreasing in p , expression (81) holds iff $p \in \mathcal{P}^{c'} \equiv [\underline{p}^{c'}, \bar{p}^{c'}]$, where $\underline{p}^{c'}$ and $\bar{p}^{c'}$ satisfy (81) with equality.

To show that $\varepsilon q \in \mathcal{P}^{c'}$, we find $\arg \max_p p(EU^B(s^*) - v_q^B)$, which is assured of being in $\mathcal{P}^{c'}$ if it is non-empty. This is easily calculated as:

$$p^{c*'} = \left(\frac{c_p(\varepsilon - 1)}{q}\right)^{\varepsilon-1} \frac{\varepsilon}{v^\varepsilon}.$$

Setting $p^{c*'} = \varepsilon q$ and solving for c_p then produces a value of c_p such that $\varepsilon q \in \mathcal{P}^{c'}$:

$$c'_p = \frac{(qv)^{\frac{\varepsilon}{\varepsilon-1}}}{\varepsilon - 1}. \quad (82)$$

Substituting c'_p into $EU^B(s^*) - v_q^B$ produces a value of zero. Thus, at $c_p = c'_p$, $\underline{p}^{c'} = \bar{p}^{c'} = \varepsilon q$.

Now observe that because $EU^B(s^*)$ is independent of c_p , (79) implies that if $p \in \mathcal{P}^{c'}$ for any c'_p , then it remains so for any $c_p < c'_p$. It also implies that c'_p is the maximum value of c_p for which $\mathcal{P}^{c'}$ is non-empty. Thus $\varepsilon q \in \mathcal{P}^{c'}$ whenever it is non-empty.

To show that $q < \underline{p}^{c'}$, note that $\lim_{q \rightarrow p^+} v_q^B = 0$ and $EU^B(s^{NT})$ is negative and bounded away from zero for $p > q$. This implies that (79) cannot hold for an interval of p above q , and thus $q \notin \mathcal{P}^{c'}$.

Defining $\mathcal{P}^c = [\underline{p}^c, \bar{p}^c]$ as the interval $[\underline{p}^{c'}, \bar{p}^{c'}]$ produces the stated result.

Second, suppose that $p < \bar{p}$. It is straightforward to verify that $EU^B(s^*) < -p^{\frac{1}{\varepsilon-1}} \left(\frac{v}{\varepsilon}\right)^{\frac{\varepsilon}{\varepsilon-1}}$ for all such p ; i.e., $EU^B(s^*)$ is less than what B would receive if A chose $s = s^{NT}$ because $s^* > s^{NT}$. Consequently, $p \in [\underline{p}^{c'}, \bar{p}]$ is necessary, but no longer sufficient for B to continue.

(ii) $r < 1/2$. There are three subcases. First, for $p \geq \underline{p}$, we begin by deriving \mathcal{P}^c . In this case, $s^* = s^{NT}$ for $p \geq \varepsilon q$ and (to prevent revision) $s^* = (qv)^{\frac{1}{\varepsilon-1}}$ for $p \in (\underline{p}, \varepsilon q)$. This produces the following expressions for agent B 's expected main phase payoff:

$$EU^B(s^*) = \begin{cases} -p^{\frac{1}{\varepsilon-1}} \left(\frac{v}{\varepsilon}\right)^{\frac{\varepsilon}{\varepsilon-1}} & p \geq \varepsilon q \\ -\frac{(qv)^{\frac{\varepsilon}{\varepsilon-1}}}{p} & p \in (\underline{p}, \varepsilon q) \end{cases}$$

Note that the two expressions for $EU^B(s^*)$ are equal at $p = \varepsilon q$.

To determine the conditions satisfying (79), it will be convenient to multiply both sides

of the expression by p , which simplifies the expressions while preserving inequalities. Then, $pEU^B(s^*)$ is weakly concave and decreasing in p and pv_q^B is linear and decreasing in p . Thus B continues iff $p \in \mathcal{P}^{c''} \equiv [\underline{p}^{c''}, \bar{p}^{c''}]$, where $\underline{p}^{c''}$ and $\bar{p}^{c''}$ satisfy (79) with equality, and $\bar{p}^{c''} = \bar{p}^{c'}$ as derived in part (i). We calculate the value of $\underline{p}^{c''}$ directly by solving (79) for p , producing $q \left(1 + \frac{(qv)^{\frac{\varepsilon}{\varepsilon-1}}}{c_p} \right)$. Clearly, $\underline{p}^{c''} > q$. If $\underline{p}^{c''} < \underline{p}$, then B continues for all $p \geq \underline{p}$.

To show that $\varepsilon q \in \mathcal{P}^{c''}$, observe that $p(EU^B(s^*) - v_q^B)$ is linear and increasing in p . We may therefore apply the same argument as in part (i) to show that $\varepsilon q = \underline{p}^{c''} = \bar{p}^{c''}$ for $c_p = c'_p$ (as derived in expression (82)) and $\varepsilon q \in [\underline{p}^{c''}, \bar{p}^{c''}]$ for $c_p < c'_p$.

Defining $\mathcal{P}^c = [\underline{p}^c, \bar{p}^c]$ as the interval $[\max\{\underline{p}, \underline{p}^{c''}\}, \bar{p}^{c''}]$ produces the result for $p > \underline{p}$.

Second, consider the neighborhood around $p = q$. As $q < \underline{p}$, there are three possible values for s^* . We evaluate $EU^B(s^*)$ for each.

1. If $c'(s^*) = \frac{vpr}{2-r}$, or equivalently $s^* = \left(\frac{vpr}{(2-r)\varepsilon} \right)^{\frac{1}{\varepsilon-1}}$, then at $p = q$ we have:

$$EU^B(s^* | \sigma^A = 0, \sigma^B = 1) = \frac{(2r^2 - 5r + 2) \left(\frac{(2-r)\varepsilon}{qrv} \right)^{\frac{\varepsilon}{1-\varepsilon}}}{qr}.$$

This is positive for $r < 1/2$.

2. If $s^* = \bar{s}_l^c = \left(\frac{p^2(1-r)r^2 + pqr(5r^2 - 6r + 3) - 2q^2(3r^3 - 5r^2 + 3r - 1)}{pq(1-r)rv(pr + q(1-r))} \right)^{\frac{1}{1-\varepsilon}}$, then at $p = q$ we have:

$$EU^B(s^* | \sigma^A = 0, \sigma^B = 1) = \frac{(2r^2 - 5r + 2) \left(\frac{-2r^3 + 5r^2 - 3r + 2}{qrv(1-r)} \right)^{\frac{\varepsilon}{1-\varepsilon}}}{qr}.$$

This is positive for $r < 1/2$.

3. If $c'(s^*) = \frac{vpr(p(1-r)+qr)}{p(1-r)+q}$, or equivalently $s^* = \left(\frac{vpr(p(1-r)+qr)}{(p(1-r)+q)\varepsilon} \right)^{\frac{1}{\varepsilon-1}}$, then at $p = q$ we have:

$$EU^B(s^* | \sigma^A = 1, \sigma^B = 1) = v \left(1 - \frac{r(\varepsilon + 1)}{(r^2 - r + 1)\varepsilon} \right) \left(\frac{(2-r)\varepsilon}{qrv} \right)^{\frac{1}{1-\varepsilon}}.$$

This value is non-negative for $r < 1/2$ and $\varepsilon \geq 2$.

As $EU^B(s^*)$ is continuous in the neighborhood of $p = q$ and v_q^B is continuous and equals zero at $p = q$, we conclude that B continues in some neighborhood of $p = q$.

Third, consider the neighborhood around $p = 0$. As $EU^B(s^*)$ is clearly bounded and v_q^B increases without bound as p approaches zero, there exists a neighborhood of 0 in which $v_q^B > EU^B(s^*)$ and B quits.

C Extensions

C.1 Multiple Project Phases

Section 4 develops a two-phase model in which agent A is the initiator in both phases and agent B can kill nascent projects in the first phase. This setting might describe projects with a clear advocate (A) and a back-loaded delivery. In this extension we develop an alternative two phase project structure that gives B greater opportunity to revise basic features.

The extension captures three features that may be factors in large, complex projects. First, they may mobilize opponents to revisit scale. For example, in 2011 the Obama administration proposed the \$30 billion Gateway Program to upgrade rail links between New York and New Jersey. Despite favorable FTA reviews, the Trump administration effectively canceled the program, only to have it revived under the Biden administration.³⁰ Second, they may present opportunities for learning by doing. The early phases of such projects may therefore be investments that reduce subsequent construction or implementation costs. Finally, investments may also provide benefits in their own right, independently of the final project outcome. We examine the incentives for investment and, analogously to Section 4, the conditions that prevent projects from starting at all.

Each phase of the two-phase model is structurally similar to the basic model. Agent A has control at the start of phase 1, and has control at the start of phase 2 with probability r . Denote the parameters for scale, distribution, and valuation in phase τ by s_τ , w_τ , and v_τ , respectively. As in the basic model, the scale s_τ and benefit division w_τ are chosen by the initial incumbent in each phase, and v_τ is exogenous. To keep the analysis tractable, when there are multiple equilibria we select the one in which only the favored agent revises.

The phases are dynamically linked through their cost functions. Let the running cost of each period in phase τ be $c(s_\tau) = m_\tau s_\tau^2$, where $m_\tau > 0$ and $m_1 = 1$. In phase 2, $m_2 = 1/s_1$, so that early investments in the project reduce future marginal costs. Note that in isolation, phase 1 of the model is identical to the basic game if $s_2 = 0$ and $\varepsilon = 2$, and phase 2 of the model is identical to the basic game if $s_1 = 1$ and $\varepsilon = 2$.

Within each phase τ , actions following the choice of s_τ only affect payoffs through the division of the total project payoff $v_\tau s_\tau$. Thus, the agents' incentives following the initial period are similar to those of the one-phase game, and we can exploit the derivations of Section 2 to analyze revisions and the choice of w_τ . The second phase primarily affects agent A 's incentives in choosing the phase 1 scale, which affects phase 2 costs. Due to the simple structure of m_2 and quadratic costs, s_1 linearly scales A 's phase 2 expected payoff. Her phase 1 objective can be expressed as:

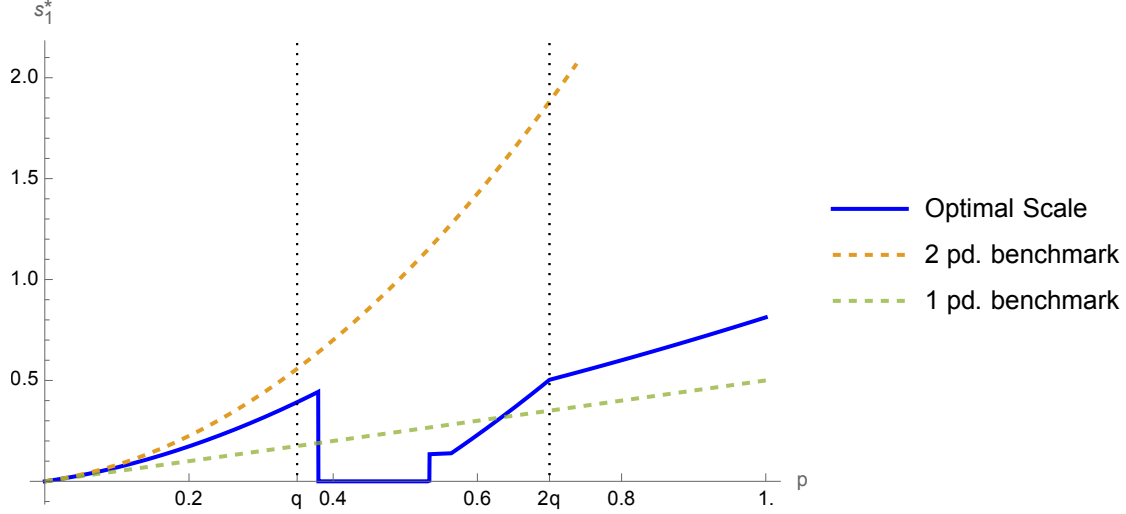
$$EU^A(s_1, w_1) + s_1 \tilde{U}^A, \quad (83)$$

where \tilde{U}^A is agent A 's phase 2 expected payoff prior to the revelation of the phase 2 initiator.

Maximizing (83) with respect to s_1 produces the optimal initial investment. Roughly speaking, the phase 1 investment is the scale of the one-phase game, s^* , adjusted to reflect \tilde{U}^A . Importantly, \tilde{U}^A is negative whenever $r < \frac{1}{2}$, as well as for some values of p between \underline{p}

³⁰See Matt Hickman, “New York and New Jersey’s long-delayed Gateway Program faces a more favorable outlook under Biden presidency.” *The Architect’s Newspaper*, November 10, 2020.

Figure 12: Investment with Two Phases



Note: Initial investment (s_1 , blue), benchmark investment (orange) in a setting with where A chooses s_2 and w_2 in phase 2, and investment in the one-phase game ($s^* = s^{NT}$, green), as a function of p . Parameters are $r = 0.55$, $v_1 = 1$, $v_2 = 5$, and $q = 0.35$. Vertical lines are located at the thresholds q and $2q$, between which upscaling may occur in the basic model.

and \bar{p} (where $\bar{p} = 2q$ under quadratic costs) when $r > \frac{1}{2}$. When this happens, the phase 1 scale s_1^* is lower than s^* . Consistent with Lemma 1, s_1^* may even be low enough to induce revisions in equilibrium. Negative values of \tilde{U}^A play a role similar to that of increasing the cost of high project scales in the one-phase model: inhibiting large scales generates projects that are insufficient to deter revisions.

Beyond merely reducing scale, the optimal scale in the initial phase may be zero, which in effect cancels the project. For a favored ($r > \frac{1}{2}$) phase 1 initiator, cancellations occur because of the potential for upscaling. As Figure 6 illustrates, under moderate capacity a disadvantaged agent B upscales to prevent revisions. This can produce a highly undesirable expected payoff for agent A , especially if she is not overwhelmingly likely to retain power. A highly competitive political environment thereby forces A to internalize in part the social benefits of the project.³¹ As Proposition 3 shows, these benefits are minimized at intermediate levels of capacity. By contrast, under low capacity, downscaled projects are relatively efficient and do not invite cancellation. And under high capacity, a favored initiator is likely to benefit from an unequal phase 2 project.

Figure 12 illustrates the role of cancellations in the $r > \frac{1}{2}$ case by comparing phase 1 investments against two benchmarks. In the first benchmark, A remains in control with certainty at the beginning of phase 2, but faces the possibility of revision in both phases. As expected, the possibility of losing control over the final project depresses investment. The second benchmark is simply the equilibrium scale s^{NT} in the one-phase game. The initial investment s_1^* may be up- or downscaled relative to this benchmark, depending on agent A 's

³¹Note, however, that public projects may provide public good benefits to actors besides agents A and B .

expected phase 2 payoffs. In this example, power transitions are likely ($r = 0.55$), so the threat of upscaling by B in phase 2 causes downscaling and cancellations when capacity is in the interval $[p, \bar{p}]$. This non-monotonicity of project scale with respect to capacity reflects in part the non-monotonicity of social benefits in the one-phase game, as illustrated in Figure 7.

C.2 Variable Capacity

In this extension, we consider the case where scale impact capacity directly. Organizations may be able to move projects ahead swiftly as long as the project size is not too large; however, once a project is too big, the capacity to handle it decreases. In the extreme case, it may completely overwhelm the organization, making it impossible to run projects beyond a certain size. To capture this idea, we allow capacity to decrease as a function of s . In the simplest case, $p(s)$ may take the form of a step function:

$$p(s) = \begin{cases} p^h & \text{if } s \leq s^p \\ p^l & \text{if } s > s^p \end{cases}, \quad (84)$$

where $p^h > p^l$, and $s^p > 0$ denotes the maximal scale at which the organization can work at capacity p^h . For projects with scale above s^p , capacity drops to p^l .

Such a step function for $p(s)$ means that solving for agent A 's optimal choice of scale requires doing the analysis of Lemmas 1 and 2 and Proposition 1 first for the case when $s \leq s^p$ and then for the case when $s > s^p$, and then choosing among the two resulting solutions the scale s that is the global maximizer. Figure 13 illustrates this case. In the benchmark case of our main model, if $p = p^h$ throughout, the optimal s^* for agent A is at the upscaling value of \bar{s}_h^n . However, if capacity drops above s^p , then the expected utility at \bar{s}_h^n also declines, so much so as to make it optimal for agent A to pick scale \bar{s}_l^c instead. The project is downscaled in order to avoid the drop in capacity at the larger scale. Clearly, if we let $p^l = 0$, then s^p acts as an effective scale cap: it's a ceiling on the scale that agent A would ever choose.

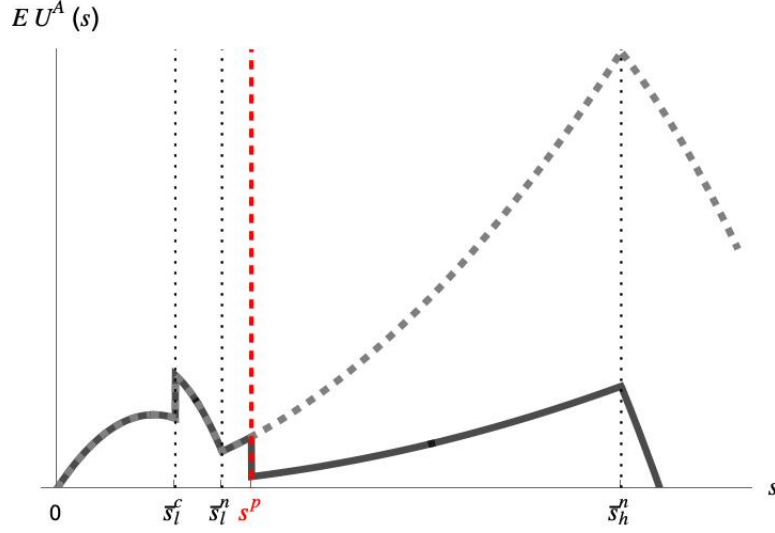
D Data on Transportation Construction Costs and Bureaucratic Capacity

Figure 1 in the paper shows that average construction costs for public transportation projects seem unrelated to measures of organizational capacity. In this section we provide additional data that are consistent this claim.

Our data on construction costs come from the [Transportation Costs Project](#) at the New York University Marron Institute of Urban Management. As of September 2023, the project had gathered full or partial cost data on over 900 projects, with cost estimates on projects in 184 cities in 59 countries.³² For each project, they report average costs per kilometer at

³²Data accessed at https://docs.google.com/spreadsheets/d/16GoHcbW-eVzHUUP_XCWXS1s_

Figure 13: Investment with Two Phases



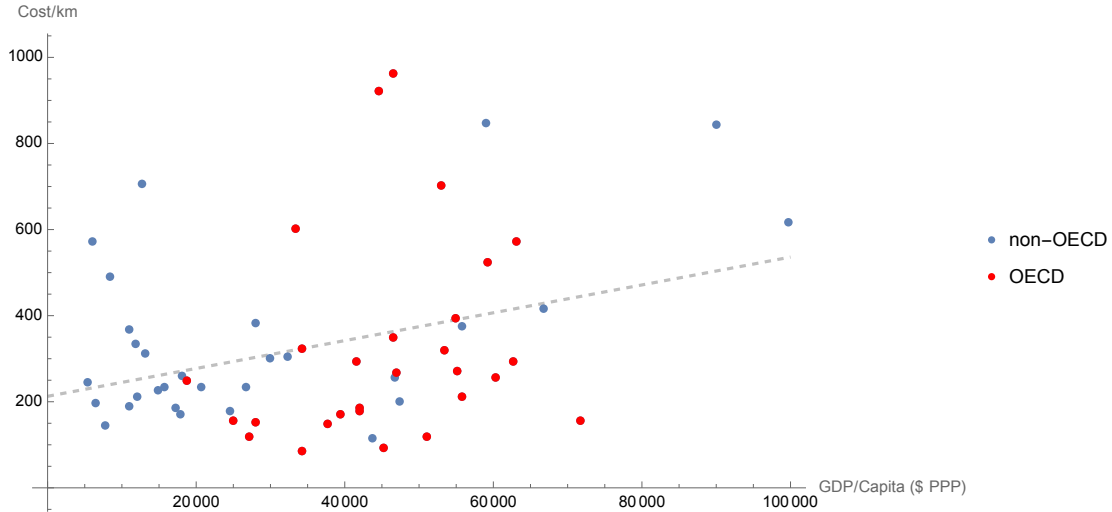
Note: Agent A 's expected utility when $q = 0.29, r = 0.375, v = 5, \varepsilon = 2$, with a step function $p(s)$ where $p^h = 0.4, p^l = 0.31, s^p = 0.5$ (solid black line). The dashed gray line shows the expected utility in the benchmark case where $p = p^h$ throughout.

2021 PPP dollars. To calculate mean costs, we restricted our analysis to projects that either started or concluded within the years 2011 to 2020. Figure 14 shows that construction vary widely at all levels of GDP per capita.

Our national-level measures of bureaucratic quality come from two World Bank sources. The first is the [World Bank Country-Level Institutional Assessment and Review](#) (CLIAR) measure of *Bureaucratic Quality*, which awards higher scores to countries where the “bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training.” We draw additional data from the [World Bank Worldwide Bureaucracy Indicators](#), which provides a more fine-grained set of indicators. From this source, we used the variables *Public Sector Employment Share* (of total national employment), *Public Sector Tertiary Educated Share*, and *Public Sector Wage Premium*. These variables capture the size and human capital levels of national bureaucracies, while also offering substantial overlap in country coverage with the Transportation Costs Project data. For all variables we calculated country averages from 2011 to 2020.

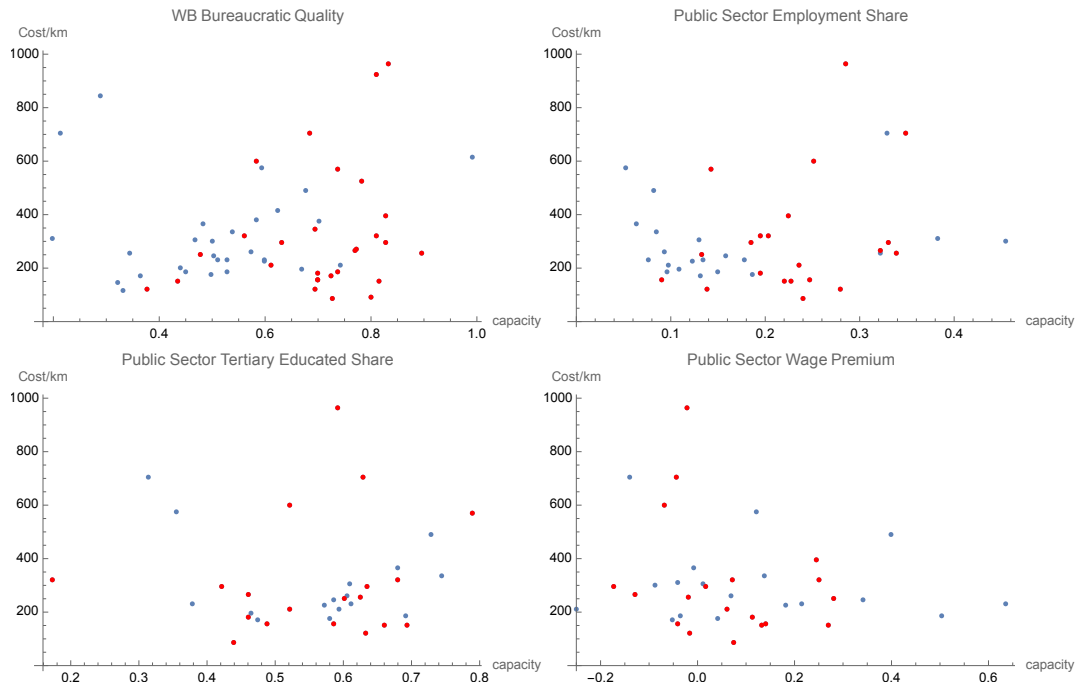
Figure 15 plots average construction costs against all four measures of bureaucratic capacity. (The CLIAR and *Public Sector Tertiary Educated Share* variables were also used in Figure 1.) None show an obvious relationship, though in some cases the variance in costs is maximized at high or low levels of capacity. The plots additionally show little relationship among the predominantly wealthy members of the Organization for Economic Cooperation and Development (OECD), as well as little difference between OECD and non-OECD members.

Figure 14: Transportation Costs and Bureaucratic Capacity



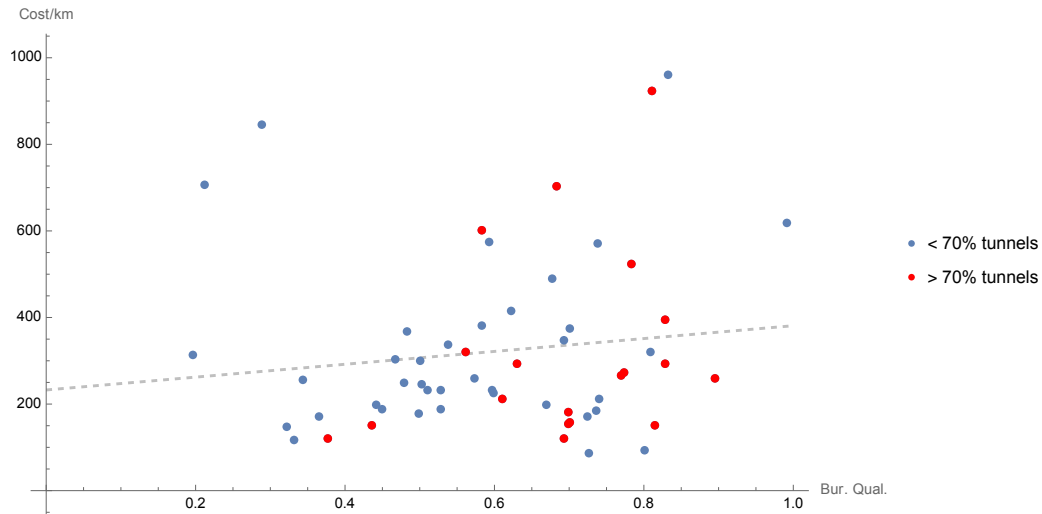
Note: Plots average cost per kilometer of major public transportation projects against 2021 GDP per capita. Each point represents a country average for projects active between 2011 and 2020. Red data points indicate OECD countries.

Figure 15: Transportation Costs and Bureaucratic Capacity



Note: Plots average cost per kilometer of major public transportation projects against World Bank CLIAR *Bureaucratic Quality* (top left), World Bank Worldwide Bureaucracy Indicator (WWBI) *Public Sector Employment Share* (top right), WWBI *Public Sector Tertiary Educated Share* (bottom left), and WWBI *Public Sector Wage Premium* (bottom right). Each point represents a country average for projects active between 2011 and 2020. Red data points indicate OECD countries.

Figure 16: Transportation Costs and Bureaucratic Capacity



Note: Plots average cost per kilometer of major public transportation projects against World Bank CLIAR Bureaucratic Quality. Each point represents a country average for projects active between 2011 and 2020. Darker data points indicate countries with greater than 70% of project miles in tunnels.

Finally, according to the Transportation Costs Project’s analysis, tunneling is a common cost driver for transportation projects.³³ Figure 16 therefore re-plots the CLIAR data to show countries with at least 70% of project-miles in tunnels. Remarkably, costs continue to vary considerably within this subgroup, especially among high-capacity bureaucracies.

³³See <https://transitcosts.com/new-data/>.