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Organizational Design:
Authority Delegation and Moral Hazard*

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Abstract

We consider an organization with two projects which have productive spillovers. Three individuals are active in this organization: two agents, each specialized in one project, and the CEO, who is a generalist. The owner of the organization allocates authority over each project to these three individuals. This allocation determines the organizational design and aims to maximize profits subject to incentive constraints. The main constraints arise from non-contractible choices: in decision-making, to exploit the gains from spillovers, and in providing incentives to address moral hazard in effort. We show that the optimal organizational design can take one of the following forms: centralization, decentralization, hierarchical delegation, or cross-authority. Two forces drive the optimal organizational design: (i) the CEO's productivity relative to the agents' in exerting effort, and (ii) the value of spillovers relative to profits in the project over which an individual has authority. We illustrate the practical relevance of our model by analyzing the emergence of hierarchical delegation in Facebook's major 2018 reorganization.

JEL Classification: C70, D23, L22.

Keywords: decision rights, authority, moral hazard, hierarchies, incentives.

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I Introduction

Large organizations frequently face a dual challenge: how to allocate authority to guide decision-making and how to motivate agent's effort across multiple interdependent projects. Allocating decision-making authority to one individual provides additional incentives to make effort since he is more involved in the project, but deteriorates others individuals' incentives to exert effort. This tension becomes more pronounced as organizations grow and decision-making authority must be distributed across a larger number of interconnected projects. Centralizing authority in one individual may improve coordination but risks undermining the motivation of others. In contrast, distributing authority across different tiers can enhance overall effort incentives but may lead to coordination failures. This trade-off helps explain the widespread reliance on hierarchical structures in organizations (Foss and Klein, 2023). This paper examines how an organization should allocate decision-making authority across tiers when delegated authority is non-contractible and leads to self-motivated decisions, effort provision is subject to moral hazard and influenced by authority and decisions, and projects exhibit technological spillovers.

We develop a model with three active individuals—a CEO and two agents—and an owner, who serves as the principal in the organization. The organization consists of two divisions, each with a project that generates spillovers to the other division. Each division produces profits based on a observable decision and hidden effort, both of which are non-contractible. The key difference between the CEO and the agents is that the CEO is a generalist, exerting effort that equally affects the probability of success of both projects, while the agents are specialists who exert effort that affects only the probability of success of their own projects.

The owner's problem is to choose an organizational design that allocates decision-making authority across agents to maximize profits, subject to individuals' incentive constraints in both decision-making and effort provision. In this setting, decisions are binary and can either prioritize the profits of the division where the decision is made (a selfish decision) or the spillovers to the other division (a cooperative decision). Each of the three active individuals receives a share of the profits from the project they exert effort in, and another share from the project over which they have decision-making authority. We identify four optimal organizational designs, which we analyze in detail: (i) full centralization, where the CEO makes both decisions; (ii) decentralization, where agents make decisions in the projects they are specialized in; (iii) cross-authority, where agents make decisions in the projects they are not specialized in; and (iv) hierarchical delegation, where the CEO makes the decision for one project, and an agent makes the decision for the project he is not specialized in.[1]

The key trade-off in the allocation of authority lies in balancing the provision of incentives to exert effort with the decisions that best capture the spillovers in the organization. The decision, selfish or cooperative, affects profits in two ways: a direct effect on a project's benefits, prioritizing the project own's returns or taking advantage of the spillovers, and an indirect effect on effort provision, reducing or exacerbating the moral hazard problem. The allocation of authority to the CEO or to the agents not only impacts the incentives to make selfish or

[1]The optimal organizational design is obtained by comparing each alternative, one by one, in terms of the profits it generates.

cooperative decisions, but also allows the decision maker to appropriate an extra share of the profits affecting incentives both (i) to exert effort and (ii) to make decisions.

The optimal organizational design depends on two main factors: (a) the (relative) productivity of the CEO and the agents in exerting effort, and (b) the magnitude of the spillovers between projects. We classify spillovers into three categories: *minimal*, when spillovers are small and unlikely to justify coordination; *moderate*, when they are significant but could generate disagreement about their relevance; and *substantial*, when they are large enough to be broadly recognized as a primary source of gains.

We study organizational design as a way to solve this trade-off under a fixed payment scheme. When the CEO is less productive than the agents, delegating decisions to the agents is the best way to deal with the trade-off between effort and coordination. In this case, decentralization is optimal unless spillovers are substantial. As agents are making decisions in the projects they exert effort on, they have strong incentives to choose selfish decisions, which support the indirect effect on effort provision. However, when spillovers are substantial, the owner switches to a cross-authority organization, where each agent decides for the other project. This weakens effort incentives -indirect effect- but improves the direct effect of internatlizing spillovers. In both designs, decentralization and cross-authority, agents' incentives are aligned with the owner's preferences.

When the CEO is more productive than the agents, centralization becomes a natural way to address the trade-off between decision making and moral hazard. The CEO makes selfish decisions, which align with strong effort incentives, unless spillovers are substantial. However, a misalignment between the CEO and the owner arises when spillovers are moderate: the owner prefers cooperative decisions, but the expected benefits from cooperation relies heavily on the CEO's incentives to exert effort, which increases projects' successful probability. That is, in this case, the CEO would bear the main cost of effort of making cooperative decisions. As the owner cannot control the decision-making, the CEO still chooses selfish decisions.

In response, the owner considers three alternatives to deal with this problem. First, the owner retains centralization, accepting CEO's selfish decisions and its consequences. Second, the owner adopts a cross-authority design, allocating authority to the agents in order to ensure cooperative decisions. This sacrifices some effort provision from the more productive CEO. Third, the owner implements hierarchical delegation, assigning the CEO authority over one project and giving one agent authority over the project he is not specialized in. In this case, the CEO continues to choose selfishly, preserving effort incentives, while the agent is inclined to make a cooperative decision, ensuring that spillovers are captured in at least one project. This design has the property that organization is focus on one projects by exploiting its own projects incentives and the spillovers that the other project generates.

The choice between cross-authority and hierarchical delegation hinges on the relative importance of the direct and indirect effects of decision making. When the direct effect (on project benefits) dominates, cross-authority is optimal. When the indirect effect (on effort provision) is more important, hierarchical delegation is preferred.[2]

[2]To disentangle these effects, we compare the main results of the model with two reference points: a *first best* scenario, where the owner controls both decision-making and effort provision by each individual; and a *benchmark*

We extend the analysis to show that our results are robust to flexible payment schemes.[3] We conduct a comparative statics analysis on the two profit shares that individuals receive. The greater the share tied to the project in which an individual exerts effort, the more pronounced the moral hazard problem becomes—that is, the conflict between the owner and the CEO intensifies, and the optimal organizational design tends to shift away from centralization. In this setting, cross-authority is more frequently implemented than hierarchical delegation. Conversely, when the share of profits associated with decision-making authority increases, the conflict between the CEO and the owner narrows. In this case, hierarchical delegation becomes more likely than cross-authority.

We extend the model to allow the owner not only to choose the organizational design but also to determine the share of profits individuals receive from the projects in which they exert effort. In this framework, the owner faces an additional trade-off among providing higher-powered incentives for effort implementation, optimal decision-making, and appropriating a larger share of the profits generated by these incentives. Our analysis confirms that hierarchical delegation and cross-authority continue to serve as second-best solutions in this more flexible setting. In this extension, the owner addresses an incentive compatibility constraint for decision-making using two tools: the actual share of profits from the projects individuals put effort into, and the organizational design. For simplicity, we focus on the relevant scenario where the CEO is more productive than the agents. To implement cooperative decisions, the owner can either reduce the profit share associated with effort (weakening effort incentives) or shift to a non-centralized design- either hierarchical delegation or cross-authority- while maintaining high-powered effort incentives. When spillovers are moderate, the owner's choice departs from pure centralization.

Our results help shed light on Facebook's 2018 restructuring, for which we have gathered valuable anecdotal evidence that has not been previously discussed.[4] In 2018, Facebook shifted from a more decentralized organizational structure to a more hierarchical one. We interpret this change as an attempt to improve coordination between the Facebook app and the other apps in its ecosystem, without significantly compromising the self-motivation and autonomy within the Facebook app itself. We study the evolution from the acquisitions of Instagram in 2012 and WhatsApp in 2014 to the reorganization in 2018. Both acquisitions were driven by the recognition of strong spillovers among these apps. However, Instagram and WhatsApp were led by their founders and operated independently from the Facebook app until 2018.

After the reorganization, the Facebook app became the central node of the company's ecosys-

scenario, where the owner controls organizational decisions and decision-making, but individuals control their own effort provision.

[3]We maintain the assumption of incomplete contracting, as in key papers within this literature such as Dessein (2002), Alonso et al. (2008), and Choe and Ishiguro (2008), whose work is closely related. Incomplete contracting means that the owner cannot specify a contract based on any potential signal of effort produced by the individuals. Under complete contracting on effort signals, as in Kräkel (2017), the main trade-off we identify does not arise, and authority allocation serves primarily as an additional payment for effort implementation. Our paper clarifies how and when such constraints are critical for the trade-off to emerge.

[4]There is ample evidence of structural reorganizations in other major firms as well. Companies like *Google* (2015), *Tesla* (2018), and *Disney* (2018) have undergone similar changes. In Google's case, Larry Page stated in his announcement that the new holding company would allow for "...more management scale, as we can run things independently that aren't very related." Available at `https://www.cnet.com/tech/tech-industry/googles-larry-page-explains-the-new-alphabet/`.

tem. The CEO, Mark Zuckerberg, oversaw strategic decisions for the main app and led the development of advertising technology (e.g., algorithms) used to monetize all apps. However, the manager responsible for the Facebook app also began to exert control over Instagram and WhatsApp, a shift that became evident in three key ways. First, the leaders of Instagram and WhatsApp were replaced by former Facebook executives, and all apps were consolidated into a single large unit. This restructuring enhanced coordination and gave the Facebook app greater influence over the others. Second, at that time, the Facebook app was the most effective platform for monetizing advertising, owing to its social networking features and high traffic volume.[5] Finally, Facebook took control of WhatsApp's core messaging product and restructured its interaction with Instagram by introducing a simple, one-way cross-posting system designed to channel traffic toward the Facebook app.[6] These shifts aligned the functioning of both platforms more closely with Facebook's strategic priorities. By bringing all apps under the umbrella of the Facebook ecosystem, the company's leadership enabled tighter coordination while maintaining direct control of the Facebook app in the hands of the CEO. This reorganization contributed to sustained profit growth, driven largely by the performance of the Facebook app and the traffic spillovers it absorbed from WhatsApp and Instagram.

This paper makes the following contributions. First, it shows that organizational design is a powerful tool for addressing two distinct incentive problems that arise when spillovers are substantial and contracts are incomplete: moral hazard in effort provision and misaligned incentives in decision-making. It reinforces existing findings that centralization and decentralization are optimal organizational structures. It also builds on Choe and Ishiguro (2012) by demonstrating the optimality of hierarchical delegation and cross-authority, while contributing a novel theoretical mechanism behind this result: the CEO's lack of commitment to making the owner's preferred decision. Second, the paper offers a sharp characterization of how different payment schemes shape the trade-off between motivating effort and guiding decision-making, and how this affects the optimal organizational design. Finally, it applies the theoretical framework to interpret—for the first time, to our knowledge—Facebook's 2018 reorganization, providing new anecdotal evidence from a highly relevant and dynamic industry.

The remainder of the paper is organized as follows. Section II summarizes the related literature. Section III introduces the model as well as the first best and benchmark scenarios. Section IV describes all possible organizational designs. Section V shows the optimal organizational designs in the benchmark and model scenarios. Section VI analyzes an alternative flexible payment schemes. Section VII discuss some of the main assumptions. Section VIII shows a case of study. Finally, Section IX concludes.

[5]WhatsApp posed monetization challenges due to its messaging-based nature, and Instagram had considerably less traffic than Facebook at the time.

[6]This policy allowed content posted on one app, particularly Instagram, to be automatically mirrored on another, specifically Facebook.

II Related literature

Organizational design and firm hierarchies have long traditions in the literature of economics (Coase, 1937; Williamson, 1975; Grossman and Hart, 1986). The study of organizational design has different approaches: its use as an incentive approach to reveal private information or elicit a desired hidden action, a way of solving communication problems and information flows, and a way of optimally allocating heterogeneous agents with different abilities to different tasks.[7]

Our paper contributes to the literature of organizational design as an incentive device to elicit hidden or non contractible desired actions. In that sense, is related to the literature on economic organizations as an incentive device (Itoh, 1994; Aghion and Tirole, 1997; Baker et al., 1999; Harris and Raviv, 2005; Mookherjee, 2006; Bester and Krähmer, 2008; Choe and Park, 2011; Choe and Ishiguro, 2012; Kräkel, 2017; Choe and Ishiguro, 2022).[8]

In particular, our paper is complementary to Choe and Ishiguro (2012) and Kräkel (2017) with three main new insights. We differ from this previous work by (i) imposing a sequential timing between decisions and effort instead of a simultaneous one, and (ii) allowing the owner to simultaneously choose the organizational design and a flexible payment scheme.[9] In this environment the set of optimal organizations differ: only centralization, decentralization, cross-authority and hierarchical delegation are optimal designs under non contractible decision-making and efforts. Second, we are able to characterize the mechanism that drives these results. Finally, we show that these results are robust to a flexible payment scheme, to consider heterogeneous agents and that the trade-off between spillovers coordination and effort provision is sensitive to the choice of the modeling strategy of the payment scheme. This last aspect strongly relates

[7]A general survey of these results are proposed in Gibbons et al. (2013).

[8]Itoh (1994) studies optimal delegation of agents effort to tasks under complete contracts. While Aghion and Tirole (1997) states that delegation is optimal given that the *real* authority relies on the individual who has better information, Baker et al. (1999) states that there might be commitment problems inherent to delegation. Even when it might be optimal ex-ante, the individual with the formal authority (the one who is entitled with the authority) will renege from the commitment ex-post. Bester and Krähmer (2008) and Harris and Raviv (2005) consider the case where a principal decides to either delegate decision-making authority or to keep it. In the first paper, they consider a moral hazard problem whereas in the second one the principal deals with an adverse selection problem. Choe and Ishiguro (2022) analyzes the existence of hierarchies in a dynamic setting, while in our paper we consider a static setting. Choe and Park (2011) analyzes the existence of hierarchies in an organization with three individuals, a principal and two heterogeneous agents, one of these agents is a worker who provides effort and the other one is a manager who can acquire valuable information for the principal. Also, Laffont and Martimort (1998) shows that hierarchies as an organizational design can be implemented to solve collusion problems in an organization with two agents with hidden information. Some other papers show effects of gaming incentives under delegation, such as Englmaier et al. (2010); Kräkel and Schöttner (2020); Kräkel (2021).

[9]This modeling decision is crucial to recover the main mechanism of optimality of the organizational designs: the direct and indirect effect of decision making which turns out to indicate the lack of commitment of the CEO to make the owner's desired choice. In that sense our paper relates to the literature of sequential hidden actions Schmitz (2005, 2013). Importantly, Schmitz (2005) shows how the sequential timing between hidden actions opens up two interesting effects. On the one hand, since actions are related, there might be a way to save rent left to an individual to make an action. On the other hand, if the second action is considerably valued by the principal, the agent might shirk at the first hidden action since he will be offered enough rent at the second stage. This tension, opens up the possibility to either offering the two tasks to one agent or to separate it into different agents. If the principal wants to encourage the high action at the second stage regardless the result at the first stage, it is better to hire two agents. On the other hand, if the principal chooses an all or nothing scheme, where either it motivates effort in both tasks or none of them, it is better to allocate both tasks to one agent. Schmitz (2013) extends this problem to the case where tasks are correlated. Our paper complements these results by studying sequential correlated hidden actions motivated by incomplete contracts depending on the organizational design.

our paper to Kräkel (2017) which proposes complete contracting on efforts' signals on top of authority allocation. The introduction of these complete contracts on efforts' signals changes the trade-off of the problem. The main optimization problem in Kräkel's paper is to minimize the cost of incentivizing effort and the trade-off lies between hiring/motivating *specialist* and *generalists* individuals

Our paper is also related to the literature that studies organizational design as a means of optimally assigning agents with different productivities to tasks with different requirements (Hart and Moore, 2005).[10] In our paper, this is one of the main forces determining the optimal organizational design. In this sense, our paper also connects to the literature on multitasking and job design (Itoh, 1991, 1992; Prasad, 2009). However, rather than focusing on the choice of an optimal incentive scheme, study the optimal allocation of decision-making authority within the organization.[11]

Our work is also related to papers that study organizational design—especially hierarchies—as a way to address communication problems or to aggregate information flows (Dessein, 2002; Rantakari, 2008; Alonso and Matouschek, 2008; Alonso et al., 2008; Coleff, 2011; Deimen and Szalay, 2019; Celik et al., 2023). While these aspects are undoubtedly important, our paper abstracts from communication frictions. Instead, our results offer a complementary explanation for the use of hierarchical delegation as an optimal organizational design. In particular, we show that delegation may be optimal to different individuals within the organization (Migrow, 2021; Deimen, 2023; Arve and Honryo, 2025).

III The model

In this section we state the model. We consider a framework similar to Choe and Ishiguro (2012). We define (A) the basics of the technology, describing the individuals and the productive activities developed in the organization that generate rents. (B) The utilities of each individual and the organization; we explain the distribution of rents among agents and how utilities are related to the decision making process that leads to different organizational designs. (C) The timing and the problem of each individual. Additionally, we introduce two reference points: the first best and a benchmark case.

[10] Hart and Moore (2005) state a seminal contribution with problem-solver perspective of hierarchies differentiating between general and specialized tasks, in which those agents at the top of the organization are in charge of general tasks and these ones at the bottom deal with specialized tasks. The main contributions of this last strand of the literature are surveyed in Garicano and Van Zandt (2012).

[11] Itoh (1991) studies how to optimally design contracts to incentivize cooperation among agents who can choose the intensity of their effort to work on their own specialized tasks or to help others. Itoh (1992) studies optimal task allocation in hierarchical organizations. Prasad (2009) considers a problem of job allocation irrespective of the organizational design with complete contracts. Unlike the papers on hierarchical organizations, he finds that what matters for allocation is not the absolute productivity level in each task, but the relative productivity across tasks. Agents who are relatively more productive in a single task are considered specialists, while those with similar productivity across all tasks are allocated to general roles.

Technology

We consider an organization with two divisions where each division $j \in \{A, B\}$ has one project j.[12] There are four relevant parties, the owner (she), a CEO (named M from Manager), and two agents, Ari and Bob (named A and B).[13] The owner can be considered a representative shareholder who is interested in maximizing profits of the overall organization.[14] By contrast, the other members of the organization perceive monetary concerns about the projects through their own utility.

Each project j may or may not be successful, and the probability of success of each of them depends on the effort of both the agent involved in it (a specialist) and the CEO (general manager). Given the effort choice $e := (e_A, e_B, e_M)$, project j succeeds with probability $P_j = P(e_M, e_j) \in (0, 1)$. Each effort $e_i \in \{e_A, e_B, e_M\}$ has an associated cost given by $g(e_i) = \frac{1}{2c_i}\, e_i^2$, where $c_i > 0$ and $e_i \in [0, 1]$. We assume $c_M = k$ and $c_A = c_B = c$, where the manager may be more or less efficient in exerting effort than the (symmetric) agents, i.e., $k \gtreqless c$. Note that the CEO's effort denoted by $e_M \in [0, 1]$ has an impact in both projects, representing a general effort or an extreme case where the efforts of the CEO in both projects are perfect complements.[15]

The success of a project affects the profits of both projects. It has an impact on its project while simultaneously creating a spillover effect on the other project. However, the magnitude of each effect depends on the decision made. For example, a project can prioritize its own project's benefits or spillovers to the other project. To simplify we are going to assume that there are two types of possible decisions for each project: a "Selfish" one (S) which has a stronger impact on its own profits and a "Cooperative" one (C) which generates more spillovers. Decisions in project j are denoted by d_j where $d_j \in \{S, C\}$. We assume that there are no direct costs to make any decision and that an unsuccessful project has no profits.

Let's denote an intrinsic concern for a project or, in other words, its own profit as h and the spillover or cooperative profit as q. As mentioned, the profit generated by a successful project j has two parts which depend on the decision made d_j, its own profit denoted by $h(d_j)$, and a spillover or cooperative profit to the other project j' defined as $q(d_{j'})$, with $j \neq j'$. Projects are symmetric in their benefits for the same decision, then there are four values to be defined $\{(h(S), q(S)), (h(C), q(C))\}$; we require that $h(S) > h(C)$ and $q(S) < q(C)$, a selfish decision increases h but reduces q compared to a cooperative decision. Hence, given a pair of decisions $d := (d_A, d_B)$ and efforts e, the profit of two successful projects A and B are:

$$\pi_A(d, e) = h(d_A) + q(d_B), \quad \pi_B(d, e) = h(d_B) + q(d_A). \tag{1}$$

[12] Along the paper we use organization and firm indistinctly, and we emphasize the results in a firm context. However, the analysis applies to every organization that fulfils the assumptions.

[13] For simplicity, throughout the paper we refer directly to 'projects' instead of 'divisions'.

[14] In a more complex organization, the owner could also be interpreted as a General Manager that delegates a task to a Regional Manager, M and two divisional managers A and B.

[15] The importance of this assumption lies in the fact that the incentives to exert efforts on different projects are closely interrelated; that is, improving one project becomes easier or more cost-effective when another project has been improved. Alternatively, the CEO may exert effort to successfully implement cross-sectional services that impact the entire organization, such as communication services and infrastructure design. It is essential to note that this serves as an additional link between projects, appart from the spillovers.

Notice that effort e only affects the probability of being successful. In the case that only project A has succeed, the certain benefits for project A and B are:

$$\pi_A(d,e) = h(d_A), \quad \pi_B(d,e) = q(d_A). \tag{2}$$

An analogous situation is derived when only the project B succeeds. Finally, if both projects fail both projects benefits become zero. Given efforts, projects' success are independent events.

To summarize, the expected profits of each project depend on the efforts and types of decisions made. The expected profits are built up of two aspects, the ex-post profit and the probability of success. Given the pair of decisions d and the triple of effort choices e, the expected profits of projects A and B are:

$$\begin{aligned} E(\pi_A(d,e)) &= P_A(e_M,e_A)\,h(d_A) + P_B(e_M,e_B)\,q(d_B), \\ E(\pi_B(d,e)) &= P_B(e_M,e_B)\,h(d_B) + P_A(e_M,e_A)\,q(d_A). \end{aligned}$$

For simplicity, we write $E(\pi_A) = E(\pi_A(d,e))$ and $E(\pi_B) = E(\pi_B(d,e))$. So far, we assume:

(a) $h(S) = h > h(C) = 0, q(C) = q > q(S) = 0$.

(b) Probabilities of success are linear on efforts, $P(e_M,e_j) = e_M + e_j$.

The first assumption simplifies the consequences of the decision into a discrete binary option for each type of payoff. If a selfish decision is made $h(S) = h$ while $q(S) = 0$; but if a cooperative decision is made $q(C) = q$ and $h(C) = 0$. One may interpret these parameters (h,q) as the incremental benefit of a successful project (for a given decision). The second assumption helps to simplify the analysis by ruling out complementarities between efforts. Later, assumption (c) establishes boundaries that ensure a closed form solution for equilibrium in each organizational design.

First Best

In the First Best scenario, a social planner chooses efforts and decisions that maximize the total surplus; i.e., expected profits minus effort costs. As a consequence, the social planner problem is:

$$\max_{d,e}\; W(d,e) = E(\pi_A) + \; E(\pi_B) - g(e_M) - g(e_A) - g(e_B) \tag{3}$$

where $d = (d_A,d_B) \in \{(S,S),(S,C),(C,S),(C,C)\}$ and $e = (e_A,e_B,e_M) \in [0,1]^3$. We will incorporate assumptions that guarantee probabilities of success to be in $(0,1)$; for simplicity, we assume that probabilities never exceed one.

Proposition 1: When $q < h$ the social planner chooses both decisions $d^{FB} = (S,S)$ and efforts level are $e^{FB} = (ch,ch,2kh)$. Otherwise, a social planner chooses both decisions $d^{FB} = (C,C)$

and effort levels are $e^{FB} = (cq, cq, 2kq)$. Hence, the social surplus is:

$$W(d^{FB}, e^{FB}) = \begin{cases} 2(2k+c)\ h^2 \text{ if } q < h, \\ 2(2k+c)\ q^2 \text{ if } q \geq h. \end{cases} \tag{4}$$

To maximize the overall surplus, the social planner opts for cooperative decisions when they prove to be more profitable than self-motivated decisions, and self-motivated decisions otherwise. Given decisions, the social planner then determines the optimal efforts for the CEO and agents.[16]

Utilities and Organization

The payment scheme defines how the profits of project j are shared among individuals. An exogenous share $\alpha > 0$ is delivered to each individual that exerts an effort on project j. This means that individual j and M each receive a share $\alpha > 0$ of the profit π_j. Additionally, the individual in charge of making a decision in project j receives an exogenous share $\lambda > 0$ of the realized profit π_j, representing the value for authority. Organizations sometimes reward the responsibility of decision-making; however, individuals may also take advantage of decision power to engage in empire-building activities. As mentioned next, this decision right is endogenous. The remaining share, i.e., $1 - 2\alpha - \lambda$, goes to the owner.

An exogenous fixed payment scheme is justified from an incomplete contracts perspective. In this context, the ex-post profits of the organizations are the only observable source which is related to both actions: efforts and decisions. Thus, share α represents an incentive device to encourage effort and share λ indicates the private benefits of decision making. These private benefits of decision making can be interpreted as empire-building actions, managers connections, other monetary concerns not related to their compensation, etc.[17] A detailed discussion over the effects of this assumption on the results is provided in section VII and section VI shows that results are robust to relaxing the assumption that α is fixed.

The only contractible variable is the decision right over each project j, defining the structure (i.e., organizational design) of the organization and the number of tiers of the hierarchy. We describe an allocation of decision rights for project A by $Y_A := (X_{MA}, X_{AA}, X_{BA}) \subset \{0,1\}^3$ where the first subindex describes who makes the decision for project A. For example, if $(X_{MA}, X_{AA}, X_{BA}) = (1,0,0)$, the CEO is in charge of making decisions regarding project A or, in other words, the owner centralizes the decision of project A in the manager M; if $(X_{MA}, X_{AA}, X_{BA}) = (0,1,0)$, Ari is in charge of making decisions regarding project A (the owner decentralizes project A to Ari); finally, if $(X_{MA}, X_{AA}, X_{BA}) = (0,0,1)$, Bob is in charge of making decisions regarding project A (the owner decentralizes project A to Bob like a cross-delegation). Similarly for project B, $Y_B := (X_{MB}, X_{AB}, X_{BB})$, where the second subindex is changed to B. Let $Y = (Y_A, Y_B) \in \mathcal{Y}$ define the organizational design, and $\mathcal{Y}$ be the set that

[16]Alternatively, the owner maximizes total profits subject to participation constraints. I.e., in order to participate, each agent (agents and CEO) receives a fixed payment equal to the effort cost implemented after a given decision.

[17]We thank an anonymous referee to point out that an alternative interpretation is that all the project's returns are not contractible and the parties split these returns via ex-post negotiation. Then the parties obtain ex-post payoffs according to the constant shares of the project returns, which reflect their bargaining powers.

defines the organizational design, which comprises the allocation of two decision rights over both projects to three individuals. Therefore, there are nine possible organizational designs, $\#\mathcal{Y} = 9$.

The owner chooses Y to maximize the total expected profits of the organization. That is, her objective function is $V(d, e) = E(\pi_A) + E(\pi_B)$.[18] Next, we introduce manager M and agent j's utility functions. First, the manager utility function is:

$$U_M^Y(d, e) = \alpha\Big(E(\pi_A) + E(\pi_B)\Big) + \lambda\Big(X_{MA}E(\pi_A) + X_{MB}E(\pi_B)\Big) - g(e_M). \qquad (5)$$

The first term indicates the profits due to the effort exerted; as the manager makes an effort for both projects her intrinsic concerns depend on the sum of the expected profits of both projects. The second term presents the benefits of decision making which depends on the allocation of the decision rights chosen by the owner. Finally, the last term is the cost of effort for the manager. Similarly, the agent j's utility function is:

$$U_j^Y(d, e) = \alpha E(\pi_j) + \lambda\Big(X_{jA}E(\pi_A) + X_{jB}E(\pi_B)\Big) - g(e_j). \qquad (6)$$

Again, the first term indicates the profits due to the effort exerted in project j. As each agent could be considered a specialist, they make effort just for one project, so their effort's profits come from only one project. The second term considers the benefits of decision making and works exactly in the same way as for the manager. The last term is the effort cost.

Timing

The timing for the model is presented in figure . At date 0, the owner chooses a specific organizational design or governance structure $Y := \{Y_A, Y_B\}$. At date 1, the individual with the decision right j makes the decision for that project j, defining $d = (d_A, d_B)$. At date 2, observing d both agents and the manager choose their efforts, defining $e = (e_A, e_B, e_M)$. Finally, at date 3 nature defines which projects are successful and payoffs are delivered.[19]

Figure 1: Timing

[18] Actually, it is appropriate to define the objective function as $\tilde{V}(d, e) = (1 - 2\alpha - \lambda)\,(E(\pi_A) + E(\pi_B))$; we analyze this case in section VI when we endogeneize the payment scheme. Until that section, the payment scheme is exogenous, and it is equivalent to write his gross profits V, instead of his net profits $\tilde{V}$, as her objective function.

[19] The timing of the model is different from Choe and Ishiguro (2012). We are considering that efforts' choices are taken after observing decision making over the projects - in a sequential game (instead of considering a bayesian game). This modeling decision has two main reasons. First, from an applied perspective, we focus on cases where important strategic decisions are made prior to workers' effort choices, enabling workers to adjust or manipulate the intensity of their effort in response to the firm's observed direction. Second, a theoretical reason, the sequential timing determines two main effects of the decision-making: (i) a direct effect which is prioritizing the own benefit of a project or the spillovers, (ii) the indirect effect which is the impact on effort provision. Thus, in the way we obtain the main mechanism that characterizes the optimal organizational structures and it is related to other papers that study sequential hidden action problems (Schmitz, 2005, 2013).

This timing is essential to clearly identify the mechanism that makes hierarchical delegation and cross-authority emerge as the optimal organizational structure and to simplify the comparative static analysis. The dynamic timing between individual actions, decisions and effort, simplifies the trade-off that exist between cooperative decisions and effort implementation. By modeling the timing in a dynamic way, we show not only how cooperative decisions can lead to underprovision of effort, but also we show how differently each individual contributes to the effort implementation, which causes the main source of conflict.

Organizational design problem

The model described above considers the owner's problem of selecting an organizational design Y that maximizes the overall organization value (his own payoff) but considering that the only contractible variable is the decision right over each project, without being able to enforce a cooperative or selfish decision nor an effort choice. The participation constraints are guaranteed by the assumptions.[20] To put it bluntly, the owner's problem is to maximize the organization's value V subject to agents' and CEO's incentive compatibility constraints on efforts and decisions. So, the owner's maximization problem is: [21]

$$\begin{aligned} \max_{Y \in \mathcal{Y}} \quad & V(d,e) = E(\pi_A) \ + \ E(\pi_B); \\ s.t: IC_d: \quad & d_j^*(Y) := \arg \max_{d_j} \ U_i^Y(d_j, d_{-j}, e^*(d,Y)) \quad \forall (i,j) \in \{(i,j) \,|X_{ij} = 1\}, j = A, B. \\ IC_e: \quad & e_i^*(d,Y) := \arg \max_{e_i} \ U_i^Y(d, e_i, e_{-i}), \ \forall i = A, B, M. \end{aligned} \tag{7}$$

While IC_e is relevant for the CEO and both agents, IC_d is only relevant for the decision maker in project j, i.e., $X_{ij} = 1$.

Assumptions

For tractability, we require that parameters c, k, h are small. Additionally to Assumption (a) and (b) throughout this article we assume:

(c) $q < Z := \frac{1}{2k\alpha + max\{2k\lambda, (k+c)\lambda\}}$.

(d) The only contractible variable is the decision over a project due to incomplete contracts.

Assumption (c) complements assumption (b)[22]. Assumption (c) enables the model to have a closed form solution for equilibrium in each organizational design. It is a sufficient condition under which equilibrium effort satisfies $e_M + e_j = P_j < 1, \ j = A, B$ (no corner solution). The

[20]Note that participation constraints are guaranteed by $e_i = 0$ for $i = A, B, M$; e.g., given $e' := (e_M, 0, e_B) \in [0,1]^2$, $U_A^Y(d, e') \geq 0 \ \forall d, Y, e'$. Additionally, note that since $\alpha, \lambda > 0$ and profits are non-negative, this implies a limited liability constraint for the owner and the standard trade-off between effort implementation and rent extraction.

[21]We consider the case where $2\alpha + \lambda = 1$ since the solutions of both problems are the same, but it simplifies the algebra for some steps of the proofs.

[22]For the case of the first best problem the condition is the following c, k, h small enough and $q < Z' := \frac{1}{2k+c}$.

incomplete contracts assumption states that it is impossible to build a contingent contract for each possible combination of states of nature in the organization.

Now in order to compare our results we develop a specific benchmark analysis.

Benchmark

In the *Benchmark case*, we assume that the owner is in charge of decision-making but can neither observe nor, evidently, contract on individual efforts. That is, the owner selects the organizational design and makes decisions (or enforceable recommendations) to maximize the firm's expected profits, subject to an incentive compatibility constraint on each individual effort choice.[23] Formally, the owner's maximization problem is:[24]

$$\begin{aligned} &\max_{Y,d}\ V_B(d,e) = E(\pi_A)\ +\ E(\pi_B), \\ &s.t:\ IC_e:\ \ e_i^B(d,Y) := \arg\ \max_{e_i}\ U_i^Y(d,e_i,e_{-i}),\ \forall i = A,B,M. \end{aligned} \tag{8}$$

Regardless of decision d, the design Y matters because the value of authority provides additional incentives to exert effort.[25]

IV Organizational design

In this section we present each organizational designs. For the sake of clarity, we provide a name to each organizational design in $\mathcal{Y}$. There are nine possible organizational designs, that we classify in six: centralization (CE), decentralization (DE), cross authority (CA), partial delegation (PD), hierarchical delegation (HD), and concentrated delegation (CD). The last three has two possible symmetric organizational designs. Hence, the set $\mathcal{Y}$ is also summarized in $\mathcal{Y} := \{CE, DE, CA, PD, HD, CD\}$.

Partial Delegation implies that the manager has the decision authority over one project, say project A, whereas Bob has decision authority over project B. This is different from what we call hierarchical delegation, which will be described in one of the next subsections. *Concentrated Delegation* consists of delegating the decision rights over both projects to one agent, Ari or Bob. In out model, these two organizational designs, *Partial Delegation* and *Concentrated delegation*, are always dominated by other organizational designs (for the proof see the *Appendix A*). Therefore, the relevant set is $\mathcal{Y} := \{CE, DE, CA, HD\}$.

1. **Centralization**: the manager has the decision authority over both projects. Payoffs are $U_M^{CE}(d,e) = (\alpha+\lambda)\ (E(\pi_A)+E(\pi_B))\ - g(e_M)$ and $U_j^{CE}(d,e) = \alpha\ E(\pi_j) - g(e_j)$ for the manager and agent $j \in \{A,B\}$, respectively.

2. **Decentralization**: each agent has decision authority over his own project. Payoffs are $U_M^{DE}(d,e) = \alpha(E(\pi_A)+E(\pi_B)) - g(e_M)$ and $U_j^{DE}(d,e) = (\alpha+\lambda)\ E(\pi_j) - g(e_j)$ for the

[23]Since the problem is defined in a way that guarantees the participation constraint of the CEO and agents, the owner ignores them.

[24]Subscript B indicates that this value is computed under the benchmark framework.

[25]This problem can also be understood as the owner suggests decision d that is contractible or easy to monitor.

manager and agent $j \in \{A, B\}$, respectively.

3. **Cross Authority**: each agent has decision authority over the other project. Payoffs are $U_M^{CA}(d,e) = \alpha(E(\pi_A) + E(\pi_B)) - g(e_M)$ and $U_j^{CA}(d,e) = \alpha\ E(\pi_j) + \lambda\ E(\pi_{j'}) - g(e_j)$ for the manager and agent $j \in \{A, B\}$, respectively.

4. **Hierarchical Delegation**: The manager has the authority over one project, say project A, and the agent working on that project, Ari in this case, has the authority over project B. Payoffs, for this case, are $U_M^{HD}(d,e) = (\alpha + \lambda)\ E(\pi_A) + \alpha\ E(\pi_B) - g(e_M)$, $U_A^{HD}(d,e) = \alpha\ E(\pi_A) + \lambda\ E(\pi_B) - g(e_A)$, and $U_B^{HD}(d,e) = \alpha\ E(\pi_B) - g(e_B)$, for the manager, Ari, and Bob, respectively. We call this the $M - A - B$ hierarchy (a symmetric $M - B - A$ hierarchy can be defined). In this case, a three-tier hierarchy is characterized by successive allocation of decision authority where Ari plays the role of a "middleman". The three-tier hierarchy can be best understood as a chain of command where the party in the upper tier exercises authority over the party in the immediately lower tier.[26]

V Optimal Organizational Design

In this section, we determine the optimal organizational design by analyzing the performance of each structure under the benchmark and the model cases, respectively. In both cases, the optimal structure depends on two main factors: the relative importance of cooperative versus motivation decisions, measured by q/h, and the relative productivity of the CEO versus both agents in exerting effort, calculated by comparing k and $c/2$.[27]

A cooperative decision is preferable to a selfish one if the spillovers from cooperation, q, are sufficiently large. This principle holds across all scenarios—the first-best allocation, the benchmark case, and the main model—and applies to each organizational design (centralization, decentralization, cross-authority, and hierarchical delegation). However, the threshold for what constitutes "sufficiently large" may vary depending on the specific context. We identify three regions of spillovers to explain the main results, ordered by their relevance in *minimal*, *moderate*, and *substantial*, that we explain below.

The organizational design (decision rights), the decision-making process, and the moral hazard in effort exertion interact to balance the trade-off between control and incentives. Decision-making influences the moral hazard in effort choice in two key ways. First, the right to make decisions is often linked to a share of the project's profits, providing a direct incentive for greater effort. Second, selfish decisions typically offer agents stronger incentives to exert effort than cooperative decisions, as they more closely align individual payoffs with effort.

[26]Hierarchical delegation is different from partial delegation in that the latter does not have such a chain of command. In partial delegation, one agent has authority over his own project, whereas the manager has authority over the other project; then, the link between the delegated agent and the other project is absent in partial delegation.

[27]Note that while e/k is the CEO's marginal cost of effort and e/c represents the marginal cost of effort for each agent, we can compare $1/k$ and $1/c$ as the relative productivity of the manager and one agent for a given effort value e. Thus, we could interpret the condition $k = c/2$ as the CEO being as efficient as both agents. This is because the CEO's effort affects the probability of success of both projects, whereas each agent's effort affects the probability of success of his own project only. Therefore, if $k > c/2$, the effort cost for the manager is smaller than the cost of both agents combined given the same level of effort for all of them. Analogously, if $k < c/2$.

Benchmark case

In the benchmark case, the owner seeks to maximize V_B by choosing (Y, d), while taking into account the incentive compatibility constraint in the effort choice, as stated in (8). The following proposition characterizes the main result for this case.

Proposition 2: Given $k/c \geq 1/2$, that is the CEO is more productive than both agents, the organizational design is centralization, with $d = (S, S)$ if $q/h < \tilde{q}_{B1}$ and with $d = (C, C)$ if $q/h \geq \tilde{q}_{B1}$. Given $k/c < 1/2$, the organizational design is decentralization with $d = (S, S)$ when $q/h < \tilde{q}_{B2}$ or cross-authority with $d = (C, C)$ if $q/h \geq \tilde{q}_{B2}$. Thresholds $\tilde{q}_{B1}$ and $\tilde{q}_{B2}$ are values of q/h defined as a function of parameters k, c, α and λ.

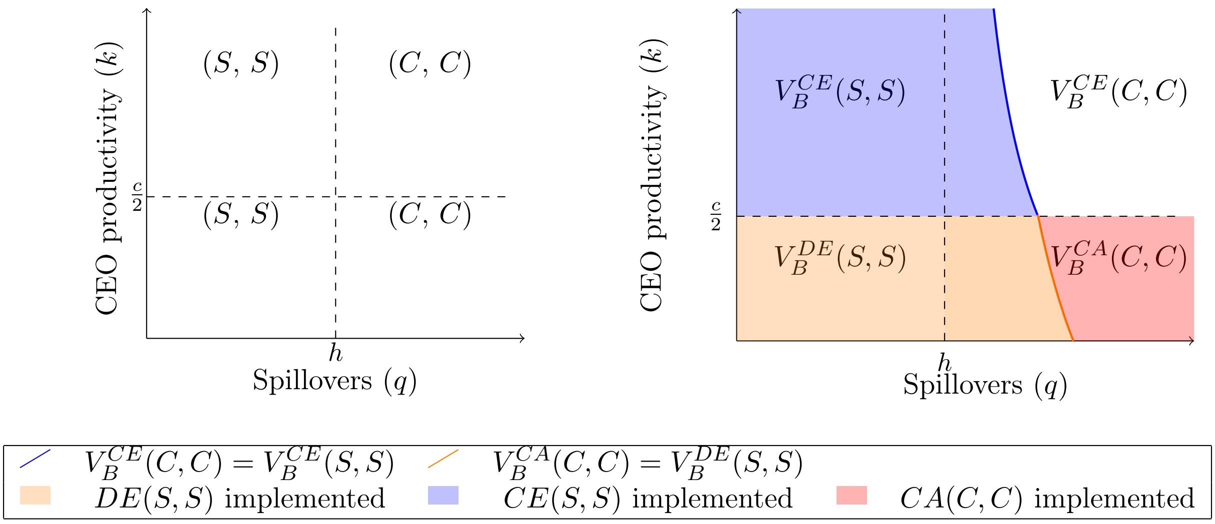
The expression of these thresholds $\tilde{q}_{B1}$ and $\tilde{q}_{B2}$, and the values of the efforts are relegated to the section B of the appendix. Proposition 2 indicates that when selecting the organizational design, the owner considers the impact of both the allocation of decision rights and the decisions themselves on the moral hazard problem; that is, the impact on incentivizing effort. Note that centralization is the organizational design that provides more incentives to the manager; on the contrast, decentralization and cross-authority provides more incentives to the agents. If the CEO is more productive than the agents, centralization becomes the optimal organizational design, where decisions can be either selfish or cooperative depending on the relative returns q and the incentives they generate for effort; i.e., (S, S) if $q/h < \tilde{q}_{B1}$ and (C, C) if $q/h \geq \tilde{q}_{B1}$. If the CEO is less productive than the agents, the agents are given decision-making authority, and the owner decides between decentralization with selfish decisions when cooperation is not so profitable, and cross-authority with cooperative decisions when the benefits of cooperation are substantial.

We can illustrate these concepts with a numerical example, shown in Figures 2a and 2b. In the First Best scenario (shown in Figure 2a) the effort is contractible, then there is no moral hazard problem. Decisions are cooperative when their returns are above a small threshold, represented by $h = 0.5$. Organizational design is meaningless in the first best. In the benchmark case, effort is not contractible and the moral hazard problem arises; both the CEO and the agents' incentives to exert effort depend on the payment schemes, the allocation of decision rights, and the decision made. To provide greater incentives for effort, selfish decisions are now more preferable; this is represented by the blue area that depicts threshold $\tilde{q}_{B1}$ (in the case of centralization) and the yellow area that represents threshold $\tilde{q}_{B2}$ (in the case of decentralization) in Figure 2b. Notice that both thresholds $\tilde{q}_{B1}$ and $\tilde{q}_{B2}$ are greater than h.

In summary, the moral hazard problem generates a cost to the owner, reducing the profitability of the firm in every organizational design and for all decisions. However, the moral hazard problem is relatively better handled with selfish decisions than with cooperative decisions, making organizational designs that complement selfish decisions more favorable. When cooperation is moderate for the profitability of the organization, the owner tolerates the effects of the moral hazard problem.

Figure 2: First best and benchmark case

(a) First Best (b) Benchmark



Note: This figure considers that the parameters $\alpha = \lambda = 1/3$ and $h = c = \frac{1}{2}$ as an example.

The model case

In the main model, the owner chooses (Y) to maximize V subject to incentive compatibility constraints in decision making and in the choice of effort, as given in equation (7). The absence of owner control over decision-making introduces a new dimension in the allocation of decision rights, shaping the organizational design. The following proposition states the main result of the paper.

Proposition 3: Given $k/c < 1/2$, the results of the benchmark case remains without modifications. Given $k/c \geq 1/2$, the owner chooses centralization with $d = (S, S)$ when $q/h < \hat{q}_{M1}$. When $\hat{q}_{M1} < q/h < \hat{q}_{M2}$, he chooses either hierarchical delegation with $d = (S, C)$ if $q/h < \hat{q}_{M1'}$ or cross-authority with $d = (C, C)$ otherwise. Finally, when $q/h \geq \hat{q}_{M2}$ he chooses centralization with $d = (C, C)$. Thresholds $\hat{q}_{M1}(k, c, \alpha, \lambda), \hat{q}_{M1'}(k, c, \alpha, \lambda)$ and $\hat{q}_{M2}(k, c, \alpha, \lambda)$, with $\hat{q}_{M1} < \hat{q}_{M1'} < \hat{q}_{M2}$ are defined in the proof.

The model shows that the optimal design depends, as in the benchmark case, on the relative profitability of selfish *vs.* cooperative decisions, as well as the relative productivity of the CEO and agents in exerting effort. Given $k/c < 1/2$, i.e., the agents are more productive than the CEO, results on the optimal organizational design, decisions, and efforts in the model replicate those in the benchmark case. In this case, the agents implement the decision that the owner would choose. Overall, the alignment of incentives, in this case, simplifies the organizational design with decentralization or cross-authority. When the CEO is more productive than both agents (i.e., $k/c \geq 1/2$) two cases deserves attention. When the CEO is highly productive, centralization is the preferred organizational design, as in the benchmark scenario when $q \leq \hat{q}_{B1}$ (minimal) or when $q \geq \hat{q}_{M2}$ (substantial). In these cases, the CEO implements selfish decisions if $q \leq \hat{q}_{B1}$ or cooperative decisions if $q \geq \hat{q}_{M2}$. These decisions coincide with the owner's best decisions.

A new result arises when the CEO is more productive than both agents (i.e., $k/c \geq 1/2$) and $q \in (\hat{q}_{B1}, \hat{q}_{M2})$ (moderate spillovers). Surprisingly, hierarchical delegation or cross-authority may emerge as the optimal design. In this context, a cooperative decision leads to both a reduction in the overall level of effort and an unequal redistribution of effort provision. While it significantly reduces the agents' incentives to exert effort, it still preserves strong incentives for the CEO to contribute to project success. The owner values the large spillovers, which more than compensate for the expected losses from reduced total effort—and thus, the lower probability of success. However, it is the CEO who bears the cost of shifting from selfish to cooperative decisions. As a result, the CEO may prefer selfish decisions which —although they reduce her own incentives-effectively motivate both agents (Ari and Bob) to exert effort. This divergence gives rise to a misalignment between the CEO's preferences and the owner's optimal organizational goals.

The owner has two alternatives to deal with this situation. First, the owner can absorb the cost associated with the misalignment of incentives. When $q/h \in (\hat{q}_{B1}, \hat{q}_{M1})$, the owner recognizes that selfish decisions are just slightly less profitable than cooperative decisions and she preserves a centralized organization, anticipating that the CEO chooses selfish decisions. Second, the owner can modify the organizational design. When the benefits of cooperation are moderate (i.e., $\hat{q}_{M1} \leq q/h < \hat{q}_{M2}$) the owner shifts the organizational design to capture the value from cooperation with one of two organizational designs.

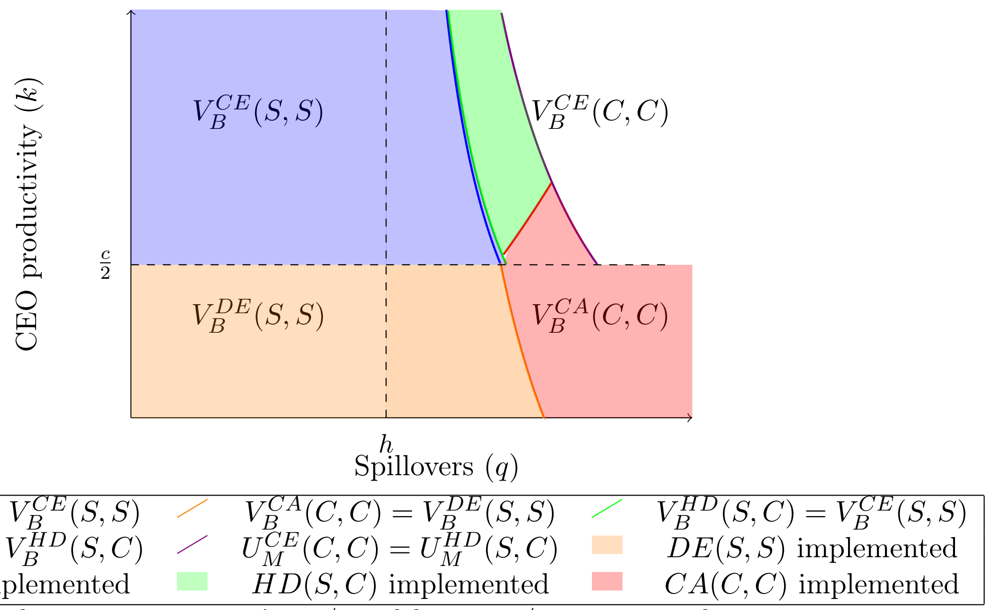
There are two possible organizational designs that help to solve this problem. First, if the CEO's productivity is only slightly higher than that of the agents, the second-best solution involves transitioning from a centralized design to a cross-authority design. By shifting decision-making authority from the CEO to the agents, the CEO's incentives to exert effort are reduced, but the cross-authority design promotes cooperation, which partially offsets the reduction in effort. As a result, efforts may be somewhat diminished due to the lower productivity of the agents relative to the CEO, but the owner can still benefit from the spillover effects of cooperation. Second, if the CEO is much more efficient than the agents, the second-best solution involves shifting to a hierarchical delegation design. In this design, the CEO retains decision-making authority over one project (say Project A), while the agent involved in that project (Ari) is granted decision-making authority over the other project (Project B). Similar to the previous scenario, the CEO still prefers selfish decisions to motivate the agent (Ari). However, the agent (Ari) chooses cooperative decisions anticipating the positive effect of spillovers on the CEO's effort. In summary, the agent with no decision-making authority has less incentive to exert effort, the agent with one decision-making right has some incentives to exert effort, and the CEO has high-powered incentives to exert effort. Consequently, the hierarchical delegation balances high-powered incentives to the most productive worker (the CEO) with some cooperative decisions that generate spillovers.

Notice that the new results are primarily driven by the fact that the agents are specialized in one project, having low-powered incentives to exert effort when cooperation is substantial.

As the CEO works on both projects, he always preserves, at least, moderate incentives to exert effort. As agents are specialized in one project, the CEO and owner may differ when it may be worthy to motivate the agents to exert effort with selfish decisions, which ultimately motivates changes in the organizational design. By modifying the structure, the owner can reduce conflicts of interest and improve overall firm performance. This high performance results from focusing on one project, which motivates effort and captures spillovers from the other.[28]

Figure 3 provides the example in figure 2b, with the new result (new thresholds and areas) of the model. When $k < c/2$ in figure 3, the results remain the same as in the benchmark case. We focus on $k \geq c/2$, where the thresholds define some new areas: The blue area is the one where $V_B^{CE}(S,S)$ is the highest, to the left of threshold $\tilde{q}_{B1}$. This area expands until the green line, close to the blue line, and depicts $\hat{q}_{M1}$. When $q \in (\tilde{q}_{B1}, \hat{q}_{M1})$, the owner prefers cooperative decisions but, due to the loss of control, she led the CEO to choose selfish decisions. The white area, to the right of threshold $\hat{q}_{M2}$, (when q is substantial) is the area where both the CEO and the owner prefer cooperative decisions and the profits are maximized with $V_B^{CE}(C,C)$. The red curve represents $\hat{q}_{M1'}$ and the red area now is greater than in the benchmark case, showing that when the CEO is slightly more productive than the agents, the owner may prefer cross authority. This cross-authority guarantees cooperative decisions at the expense of a reduction in the effort level. The green area is the main new area of figure 3. In this area, the CEO is quite productive, but spillovers are moderate; then a hierarchical delegation is the best organizational design balancing the coordination in decision-making and the motivation of individuals to exert effort. That is, generating the spillovers of coordination in some decisions and providing high-powered incentives in the effort choice of the most productive person (the CEO).

Figure 3: Model results



Note: This figure considers parameters $\alpha = \lambda = 1/3$ and $h = c = 1/2$ as an example.

[28] Actually, we connect these results with Facebook reorganization in 2018. After this reorganization to a the company focuses on the profits delivered by the Facebook app, e.g., improving ad-algorithms in this app, and promotes the spillovers from the other apps, like Whatsapp and Instagram with one-way cross links.

Finally, note that the conflict between the owner and the CEO intensifies as α increases. When a larger share of profits is tied to the individuals exerting effort on the projects, the likelihood that the CEO's preferred decisions diverge from those of the owner increases. As a result, centralization may be replaced by alternative organizational designs, such as cross-authority or hierarchical delegation. The choice between these designs depends on the value of authority, denoted by λ: cross-authority is more likely to prevail when λ is low, while hierarchical delegation becomes more favorable as λ increases. Appendix D complements the analysis with numerical simulations and graphical illustrations.

VI Flexible payment scheme (endogenous α)

In this section, we study an extension to show that our results are robust to flexible compensation schemes. We have assumed the owner could not adjust the payment scheme but only the organizational design. We now show that the results are robust to the case where the owner chooses α, the share of the profits distributed to individuals to motivate efforts, jointly with the organizational design. Some clarifications must be made. First, the objective function of the owner must be corrected to $\tilde{V} = (1 - 2\alpha - \lambda)V$ as mentioned in the footnote 18:

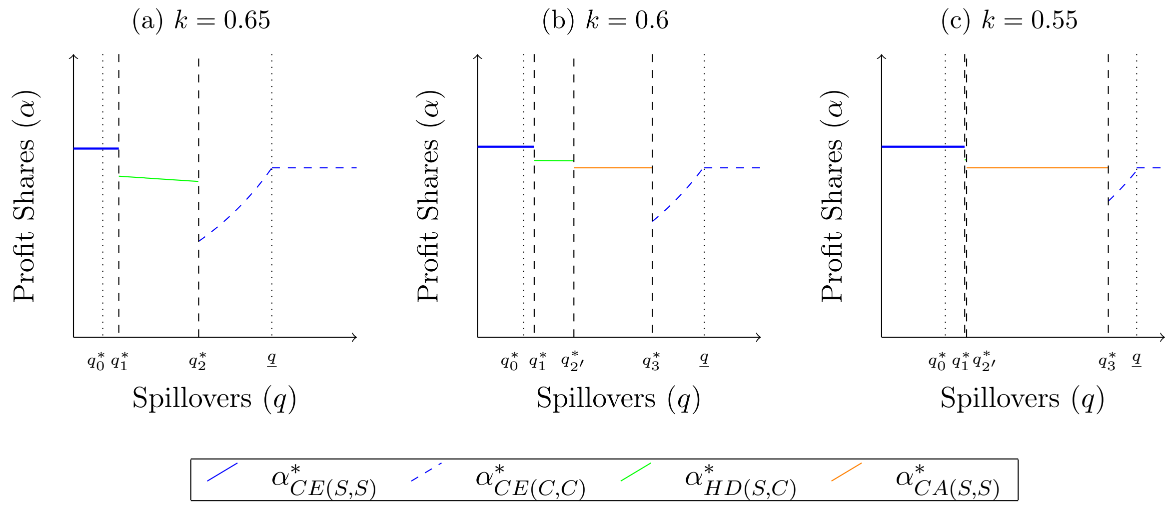
$$\tilde{V} = (1 - 2\alpha - \lambda) \sum_{j \in \{A,B\}} E(\pi_j). \tag{9}$$

The owner faces a trade-off when increasing α: on the one hand, it motivates efforts, raising the probability of a project to succeed, and decreases the proportion the owner gets from the profits generated; on the other hand, it increases the manager's returns from selfish decisions, as he can appropriate some benefits from higher agents' effort. Second, we leave λ fixed, then $\alpha \in [0, (1 - \lambda)/2]$. Third, although the owner chooses α, it cannot be made contingent on the specific decisions made, thus preserving the incomplete contracting setting.

In a benchmark case, the owner chooses the organization, the payment scheme (α), and each project's decision. As in the scenario with a fixed α, there is also a cutoff value $\frac{\hat{q}}{h} := f(k, c, \lambda)$ below which the owner chooses a centralized organization with selfish decisions. Above the threshold $\frac{\hat{q}}{h} := f(k, c, \lambda)$, the owner changes to a centralized organization with cooperative decisions. In any case, the owner chooses α (i.e., $\alpha^B_{CE(S,S)}$ or $\alpha^B_{CE(C,C)}$) with high-powered incentives to exert efforts to both the CEO and the agents; that is, the values of α are relatively high. Since the optimal $\alpha^B_{CE(C,C)}$ provides incentives mainly (or only) to the CEO to exert effort, then $\alpha^B_{CE(C,C)} < \alpha^B_{CE(S,S)}$.

In the main model, the owner chooses the organizational design and the payment scheme considering the incentive compatibility constraints in decisions and efforts. This means that choosing α affects the effort exerted by the individuals and the decision to be made in each organizational design; consequently, it also affects the allocation of decision rights. In particular, the higher the α, the more incentives a CEO has to choose selfish decisions. Consequently, the results with a fixed α replicates in the following way: for $\frac{q}{h} > \frac{\hat{q}}{h}$ the CEO prefers to choose (S, S) instead of (C, C) given $\alpha^B_{CE(C,C)}$; i.e., the CEO makes profits from the agents' effort rather than choosing (C, C) where mainly he exerts a high effort. The owner has three alternatives. First, she can let the CEO choose (S, S) with the optimal $\alpha^B_{CE(S,S)}$. Second, she can reduce α below a threshold $\overline{\alpha}(q, k, \lambda)$ to promote cooperation (C, C). When effort incentives are reduced, the misalignment between the owner and the CEO is also diminished. However, since $\overline{\alpha} < \alpha^B_{CE(C,C)}$, the resulting decline in effort incentives for all individuals may be considerable. Third, the owner can opt to change the organizational design to promote both cooperative decisions and efforts with a hierarchical delegation or cross-authority design. When k is high, a hierarchical delegation design is chosen with high α. The agent in charge of a delegated decision chooses C, and (S, C) is implemented. Anticipating these decisions, the owner can increase α, motivating the CEO and one agent to exert effort. As in the main model, hierarchical delegation with the corresponding payment scheme is the second-best alternative for the owner when spillovers are substantial. When k is moderate, cross-authority with high-powered incentives is chosen.

Figure 4: Optimal α (and organization) as a function of spillover q



Notes: in all cases we consider parameters $\lambda = 1/10$, $h = c = 1$, $\alpha^s* \in (0, 0.3)$ and thresholds $\underline{q}$ varies in $(1.2, 1.6)$. Each q^* represents the indifference cutoff between the value $\tilde{V}$ of the two organizational structures plotted under the optimal decisions, q^*_0 is the indifference between $CE(S, S)$ and $CE(C, C)$ in the benchmark scenario, q^*_1 is the indifference between $CE(S, S)$ and $HD(S, C)$, q^*_2 is the indifference between $HD(S, C)$ and $CE(C, C)$, $q^*_{2'}$ is the indifference between $HD(S, C)$ and $CA(C, C)$, and q^*_3 is the indifference between $CA(C, C)$ and $CE(C, C)$. Finally, and $\underline{q}$ is the value under which the incentive compatibility of the CEO for $CE(C, C)$ is not binding anymore. In panel (c), between q^*_1 and $q^*_{2'}$ there two dashed lines that almost overlap one with each other, inside there is the are where $HD(S, C)$ is preferred to $CE(S, S)$.

Figure 4 shows the optimal α and organizational design as a function of q; in parenthesis is indicated the decisions chosen by decision-makers.[29] Panel (4a) represents the numerical example with $k = 0.65$, where HD turns out to be optimal for intermediate values of q with high α; i.e., with high-powered incentives. For low values of q, solid blue line corresponds to the α where the owner centralizes decisions to the CEO (CE), and the CEO chooses (S, S). The dashed green line corresponds to the α with HD where decisions are (S, C), the dashed blue line corresponds

[29] q^*_0 is the threshold above which the owner prefers $CE(C, C)$ instead of $CE(S, S)$ for the benchmark case (controlling α, decisions, and organizational design).

to the α with CE where decisions are (C, C). Note that α changes both with the organizational design and with the incentives that q generates; i.e., an increase in q relaxes the compatibility constraint to motivate the CEO to choose (C, C). This explains the increasing function $\alpha(q)$ in the dashed blue line. Panel (4b) shows the numerical example for $k = 0.60$, where both HD and CA are optimal for some values of q; and panel (4c) for $k = 0.55$, where CA is optimal for intermediate values of q. Consequently, it replicates the results in figure 3, and, thus, the main results do not depend qualitatively on the assumption of exogenous payment schemes.

VII Discussion

In this section, we explore several extensions and alternative modeling approaches. In particular, we examine two alternative compensation schemes and consider the case of heterogeneous agents. We find that the two alternative compensation schemes represent extreme approaches: (i) a profit-sharing scheme across both projects that optimally incentivizes cooperation but undermines individual effort provision, and (ii) complete contracts on effort outcomes that strongly incentivize effort but severely hinder cooperation across projects. These modeling approaches fail to capture the core trade-off identified in this paper and therefore lead to different optimal organizational designs. We next summarize the key insights, and provide details in an online appendix

VII.1 Profit Sharing Across Both Projects

A natural alternative to the fixed payment scheme we propose is to offer each individual a share of the profits from both projects, rather than from the project they personally contribute effort to.

This payment scheme results in identical ex-ante compensation for all individuals: both agents and the CEO receive monetary returns from both projects, regardless of whether they hold decision-making authority. Thus, unlike the model presented in Section III, agents never provide extremely low effort regardless of which decision is implemented. However, this scheme introduces an additional feature: each project allocates a share of profits to a third party. Consequently, the incentive power of each share is diluted compared to the scheme in Section III. These effects yield two key results. First, optimal decisions correspond to the *first-best* allocation: (C, C) when $q \geq h$, and (S, S) otherwise. Second, the optimal organizational designs mirror those of the *benchmark* model under the same condition.

As discussed, this compensation scheme facilitates better coordination of cooperative decisions than the model in Section III, but lacks the incentives needed to elicit effort provision—unless spillovers are significantly higher than the direct profits from each project. Therefore, while this scheme eliminates the central trade-off of the original model, it introduces significant moral hazard issues when spillovers are minimal.

VII.2 Complete Contracts on Effort Outcomes

A second natural alternative to the fixed payment scheme is to introduce complete contracts on agents' effort outcomes, as in Kräkel (2017).

Two key insights emerge. First, complete contracts on effort outcomes eliminate the main trade-off in the model of Section III. This is because the owner no longer needs to sacrifice effort provision to achieve cooperative decisions; desired levels of effort can be contractually specified. In this setting, the owner has full control over effort incentives. However, allocating authority through profit-sharing does not facilitate coordination of decisions. In fact, the share λ simply serves as an additional payment for effort, layered on top of the contractual incentive, and provides no direct coordination mechanism. As a result, while this compensation scheme is optimal for incentivizing effort, it fails to coordinate decisions effectively. The trade-off in this case shifts from cooperation versus effort to a trade-off between employing *specialists* versus *generalists*, as in Hart and Moore (2005); Prasad (2009); Garicano and Van Zandt (2012) and Kräkel (2017). Second, the main results of Kräkel (2017) hold under the sequential timing structure used in our paper, indicating that the timing of decision-making and effort choices does not alter the fundamental trade-offs focused on specialists vs. generalists.

VII.3 Heterogeneous Agents

In this extension, we show that when agents are heterogeneous, the more productive individual should be assigned the role of middleman. This expands the region in which hierarchical delegation is optimal, and conversely, contracts the region where it is optimal to assign the less productive agent. These findings provide insight into the mechanisms driving the main results.

To analyze this, we rely on the propositions from the previous section, assuming $c_A > c_B$ to represent that productivity of Agent A is greather than the one of Agent B, respectively. Figure 7a presents the organizational design when the owner delegates to the more productive agent A, and Figure 7b shows the case of delegation to the less productive agent B.[30]

VIII Case of study

In this section we describe how our theory can shed some light on some examples of reorganizations of companies. In particular, we discuss the case of Facebook when acquiring Instagram and Whatsapp, but several other cases have been pointed out in the literature before, such as the reorganization of IBM, Procter & Gamble, and Sony.

[30] The only thresholds that are affected are those related to hierarchical delegation. Additionally, in the less relevant region $k < \frac{c_A+c_B}{4}$, concentrated delegation could be optimal under certain conditions. However, partial delegation remains dominated for any values of c_A and c_B satisfying the other assumptions of the model. Since our main results lie in the region where $\frac{q^2}{h^2} > 1$ and $k > \frac{c_A+c_B}{4}$, we do not focus on the concentrated delegation case. For the symmetric organizational structures—centralization, decentralization, and cross-authority—the optimal decisions and thresholds remain unchanged unless productivity differences are extreme enough to render one agent's effort negligible.

Facebook

Facebook, renamed Meta in 2022, is a digital company whose main product is the Facebook app, a social network. In the Facebook app each user has a personal profile with a net of social contacts (friends, family, coworkers, etc.); users post stories with pictures and videos on which friends can comment. With various configurations, the social media industry has experienced exponential growth since its appearance at the beginning of the twenty-first century. While several projects quickly gained traction, significant acquisitions also occurred early on.

Facebook acquired Instagram in 2012 for 1 billion dollars. Instagram, founded in 2010, was a rapidly emerging social network specialized in posting pictures; popular among young generations.[31] Despite both companies' significant profit complementarities, Facebook emphasized the importance of maintaining independent management for both firms.[32] Two years later, in 2014, Facebook acquired WhatsApp, another major big tech company, for nearly 20 billion dollars. WhatsApp was a messaging app that performed exceptionally well on cellphones and smartphones, with a strong global presence established by 2014. Similar to the Instagram acquisition, Facebook asserted that WhatsApp's management would remain independent. In fact, the CEO and co-founder of WhatsApp continued to lead the company and was appointed to Facebook's board.[33]

A common pattern in Facebook's acquisitions was the importance of strategic complementarities among Facebook, Instagram, Messenger, and WhatsApp. Many of these strategic complementarities became evident later on. On the supply or technological side, there were significant economies of scale in research and development, allowing them to coordinate the development of similar features across all platforms, such as instant messaging. The networks within each app also allowed for spillovers or economies of scope; for instance, the network of phone contacts in one application may enable the company to find people in others, generating a richer database. WhatsApp also brought to Facebook the potential to make messaging applications accessible on more affordable mobile phones with fewer technological requirements. Additionally, the acquisition increased the user base and helped to segment the market.[34] On the demand side, users often value the ability to seamlessly transition from one application to another when these apps are interconnected. For example, interconnecting the apps allows users to log in to one application using another app's account information. It also enables the interconnection of different devices, facilitating simpler and faster cross-linking between apps and devices. These conveniences reduced users' entry and usage costs.

In 2018, however, Facebook shifted away from its initial concept of having each app operate

[31]Instagram started as a minimalist app for photo sharing. As it grew, the platform added various features, such as stories and filters for these stories, which gained high adoption among younger generations.

[32]There could also be alternative and complementary reasons for the acquisition, such as the threat that another giant company could acquire Instagram. We abstract from this possible market strategy behind the acquisition.

[33]The fact that he was part of Facebook's board and the management of WhatsApp was seen as a positive aspect of the acquisition: in that way, Facebook was acquiring his capabilities and not only the company. `https://www.theguardian.com/media-network/media-network-blog/2014/feb/21/zuckerberg-facebook-whatsapp-mobile`.

[34]We checked different websites for the statistics of use of each application: Facebook, Instagram, and WhatsApp; we described this use in table 1. In 2018 Facebook was the most used application of the company and had control over three of the five most used social networks (Facebook, Facebook Messenger, and WhatsApp) and four over six (with Instagram in the 6th place).

independently and transitioned to a more hierarchical organizational design. While Instagram and WhatsApp were experiencing growth in user traffic, Facebook's growth (in activity and incorporating new users) was slowing down. The Facebook app, however, was responsible for most of the company's revenues and profits. On a larger scale, the company restructured its apps, placing the Facebook App at the core of this new structure.[35] Formally, a new division called the 'Family of Social Networks' was established, encompassing Facebook, Instagram, WhatsApp, and Messenger. In practice, all apps collaborated with Facebook to enhance the activity and ensure the successful monetization of Facebook's potential through advertising. While the cooperation and coordination were more noticeable in the case of WhatsApp, the other apps were also collaborating to benefit Facebook. We will now describe several facts that validate this conclusion.

The leadership of the new sector was in the hands of experienced Facebook veterans.[36] Christopher Cox, a software engineer who joined Facebook in 2005, was named the new Chief Product Officer (CPO) of the Social Network Family division, overseeing Facebook, WhatsApp, Instagram, and Messenger. Simultaneously, Chris Daniels, a former Facebook executive, replaced Jan Koum, the former CEO and co-founder of WhatsApp. In the case of Instagram, Adam Mosseri, former Facebook executive who started as Product Designer in 2008, was named president of Instagram.[37] Some press articles suggested that this reorganization implied for the Facebook app to gain more control over WhatsApp and Instagram.[38] The same press release provides an explanation for this decision: *'The reorg could prevent Facebook from haphazardly tripping over itself in an attempt to seize on emerging trends. As visual communication becomes the new Facebook mandate, the company could similarly align its efforts in augmented reality, ephemeral and encrypted messaging, and e-commerce tools. Mosseri and Daniels can implement the Facebook strategy and shield their apps from the same old pitfalls. Instagram and WhatsApp have instituted themselves in their respective markets, and now have the leaders to make them well-oiled cogs in the Facebook machine'.*

The Facebook App was the most effective at monetizing its traffic. WhatsApp had little tools to monetize its traffic whereas Instagram had significantly less traffic than Facebook. However, both apps were crucial tools for enhancing Facebook's potential benefits. This quote reveals that, as of 2023, WhatsApp can still not monetize through ads, while the Facebook App remains

[35] Other reasons also motivated the reorganization: (1) the fast rise of new product lines: Artificial Intelligence, Virtual Reality, and Blockchains. (2) the Cambridge Analytica scandal following Trump's presidential election in 2016. The reorganization of the company moved from five to three main areas shuffling completely the leadership of its products: 1) New platforms and infrastructure; 2) ads, personnel, security, and growth; and 3) the family of social networks. https://techcrunch.com/2018/05/08/one-family-under-cox/.

[36] This movement was particularly striking for Instagram. Kevin Systrom, founder and removed leader of Instagram, was offered a job from Facebook company before founding Instagram. Systrom did not take the offer at this point and founded Instagram. Facebook's acquisition of Instagram was viewed as the possibility not only to acquire the company but also the services provided by Systrom. The decision to remove him was a neat picture of the trade-off. To prioritize Facebook's benefits was necessary to remove the people pushing Instagram self profits.

[37] Adam Mosseri was first named vice-president of Instagram. After four months, he took over the lead of the app replacing Kevin Systrom, ex-CEO and co-founder of Instagram.

[38] "These changes could reduce the autonomy of Instagram and WhatsApp, at least in philosophy if not in formal hierarchy. That might make them less appealing places to work, after WhatsApp veterans like Nikesh Arora were passed over in favor of an installed Facebook exec." https://techcrunch.com/2018/05/08/one-family-under-cox/

the primary advertising channel: *"The latest numbers reported in Facebook's self-service tools indicate that the company's portfolio of platforms now enables advertisers to reach a combined potential audience of more than 3 billion distinct users. That might not sound like 'news', because Facebook Inc.'s investor earnings reports indicate that the company's Family Monthly Active People (FMAP) figure exceeded 3 billion in Q2 2020. However, that FMAP figure also includes WhatsApp's 2 billion-plus users, and WhatsApp doesn't currently offer advertising placements. Furthermore, our analysis suggests that total potential advertising reach on Facebook only equates to about 78 percent of the platform's monthly active users."* Note that this pertains specifically to the Facebook platform, not the company's entire portfolio of platforms.[39] In the case of Instagram, the situation is different. In 2018, Instagram reached 0.85 billion people through its ads. However, with more than 2 billion users, Facebook App accounted for approximately 80% of the company's total revenue. In 2018 each user, on average, makes one post, writes four comments, likes ten posts, and clicks eight times on Facebook Ads every month. These numbers positioned Facebook at the core of the organization.[40] Consequently, any coordination that helps to increase user activity would have a much bigger impact on Facebook App than on Instagram.

The other apps focused on increasing cooperation with the Facebook app, while the same emphasis was not necessarily placed on the reverse.[41] WhatsApp ceded control of its primary product, the messaging system, which came under the management of Facebook within the Family of Apps unit and had a positive impact on Facebook's business model. Having access to the messaging systems of every app, including WhatsApp's primary product, enabled Facebook to enhance and better target consumers on its platform by feeding data into their algorithms. In that way, Facebook improved its consumer targeting which allowed it to exploit its two-sided benefits: i.e., offering more dedicated products for consumers, and selling better allocation advertisements for sellers. This reorganization also affected Instagram and Messenger, compelling these products to cooperate and coordinate certain features to address issues arising from product overlap.[42] For example, Instagram implemented a cross-posting feature for stories from Instagram to Facebook. If a user made a story post on Instagram, it could be posted automatically on Facebook instantaneously. However, the reverse was not allowed, at least not at that time.[43]

In summary, we interpret this restructuring as a shift from a decentralized organization, where each app operated independently, to a more hierarchical structure. This reorganization prominently positioned the Facebook App at the forefront of the company. In alignment with

[39]Check `https://datareportal.com/essential-facebook-stats` for a more detailed analysis.

[40]By 2022, these numbers had increased to twelve clicks on Facebook ads per user per month.

[41]We claim that even though WhatsApp, Instagram and Messenger might have benefited from Facebook's cooperation as well we do not see any strategic decision that Facebook made, affecting its own business only to increase complementarities in the other apps.

[42]"Facebook was a mess. The independence it dangled to close acquisition deals with Instagram and WhatsApp turned the company into a tangle of overlapping products. Every app had its own messaging and Stories options. Economies of scale were squandered. Top innovators led mature products already bursting at the seams with features while new opportunities went unseized." `https://techcrunch.com/2018/05/08/one-family-under-cox/`.

[43]For more detail check `https://techcrunch.com/2017/10/04/instaface/`. These one-way developments, coupled with the decision to remove Systrom, illustrate the company's primary focus on the externalities of Instagram on the Facebook app.

our model, the Facebook App project, referred to as 'Project A,' received top priority with motivational decisions on that app. The board entrusted Chris Cox, the CPO of the new division, with orchestrating and executing this initiative. His primary objective was to enhance Facebook's engagement levels. To achieve this goal, Cox implemented effective decisions in the other apps, referred to as 'projects B,' ensuring their collaboration and coordination with the Facebook App. Meanwhile, Mark Zuckerberg, the CEO, directed his primary efforts toward improving the advertising business.

We believe that this reorganization is based on the idea that Zuckerberg would have faced challenges in realizing strategic synergies between WhatsApp and Instagram within the framework of a hypothetical centralized organization. Furthermore, this could explain the delay in reorganization, which occurred four years after the acquisition of WhatsApp. To address this challenge, the company decided to adopt a hierarchical design. Under this new structure, Zuckerberg retained decision-making authority for the Facebook App (putting it at the forefront), while Chris Cox assumed responsibility for (cooperative) decisions pertaining to all other apps.

IX Conclusion

One of the central issues in organizational design is to find the optimum way to coordinate organizational activities while motivating different parties within the organization. The literature has mainly relied on a binary centralization-decentralization design. This article finds that when coordination to exploit spillovers are moderate and the CEO's effort is the more convenient to be motivated, other organization designs can emerge as optimal when contracts are incomplete. These optimal organization designs are cross authority and hierarchical delegation. The latter design comprises more than two levels of hierarchy. They show to be optimal when spillovers are moderate and the owner cannot enforce the CEO to bear the main costs of effort. This result is robust to allow flexible payment schemes.

The model developed provides a useful framework for analyzing Facebook's 2018 reorganization. The company's business model relies on monetizing user activity through advertising, and its ad algorithm performed particularly well within the Facebook app. However, user growth on the Facebook app was slowing. To stimulate growth and enhance the algorithm's targeting capabilities, the company adopted a hierarchical delegation structure. The CEO retained authority to keep the Facebook app at the core of the organization's strategy, while the manager overseeing the family of apps was responsible for ensuring that WhatsApp and Instagram coordinated in ways that directed traffic toward Facebook. This reorganization proved effective for several years.

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Appendix

A. Auxiliary proofs

Proof of Propositions 1: First Best

In First Best analysis the owner maximizes the Welfare function W under each set of decisions in order to obtain the optimum efforts in each case. Solving by backward induction, at time 2 the CEO and each agent make an effort that maximizes the welfare after observing the decisions $d = (d_A, d_B)$, i.e., $e^{FB}(d)$. If $d = (C, C)$, then $e^{FB} = (cq, cq, 2kq)$. If both decisions are selfish $d = (S, S)$, then $e^{FB} = (ch, ch, 2kh)$. Finally, if $d = (C, S)$ (analogously for the other asymmetric case), then $e^{FB} = (cq, ch, k(h + q))$.

Anticipating those efforts $e^{FB}(d)$, the owner chooses $d \in \{(S, S), (S, C), (C, S), (C, C)\}$ to maximize $V_B^{CE}(d, e^*(d))$:

$$
\begin{aligned}
W((C, C), e^{FB}(C, C)) &= \quad (2k + c)q^2. \\
W((S, S), e^{FB}(S, S)) &= \quad (2k + c)h^2. \\
W((C, S), e^{FB}(C, S)) &= \quad \tfrac{k(h+q)^2+c(h^2+q^2)}{2}.
\end{aligned}
$$

Notice that $W((C, S), e^{FB}(C, S)) = W((S, C), e^{FB}(S, C))$. As in *proposition 2* the key parameter that defines the best decision is the ratio of cooperative profits over motivation incentives of projects. We next define some relevant cutoff in this dimension q/h:

- First Case: $W((C, C), e^{FB}(C, C)) \geq W((S, S), e^{FB}(S, S)) \;\Leftrightarrow\; q/h \geq 1$.
- Second Case: $W((C, C), e^{FB}(C, C)) \geq W((C, S), e^{FB}(C, S)) \;\Leftrightarrow\; q/h \geq 1$.
- Last Case: $W((C, S), e^{FB}(C, S)) \geq W((S, S), e^{FB}(S, S)) \;\Leftrightarrow\; q/h \geq 1$.

As it can be seen, $W((C, S), e^{FB}(C, S))$ is never going to be implementable, because $W((C, S), e^{FB}(C, S))$ is greater than $W((S, S), e^{FB}(S, S))$ when $q/h \geq 1$, but at the same time when

$q/h \geq 1$, $W((C,C), e^{FB}(C,C))$ is greater than $W((C,S), e^{FB}(C,S))$. As a consequence, the social planner implements $W((C,C), e^{FB}(C,C))$ when $q/h \geq 1$ and $W((S,S), e^{FB}(S,S))$ otherwise.

□

Partial Delegation

Under Partial Delegation (PD) $Y = \{PD\} = \{(1,0,0),(0,0,1)\}$ (or $\{(0,1,0),(1,0,0)\}$); i.e., the manager has the decision authority over one project, say project A, whereas Bob has decision authority over project B: $X_{MA} = X_{BB} = 1$. This is different from what we call hierarchical delegation, which will be described in the next subsection. In partial delegation, Bob has decision authority over his own project and, therefore, his expected payoff is the same as that in decentralization. The manager's and agents' expected payoff in partial delegation is given by:

$$\begin{aligned} U_M^{PD}(d,e) &= (\alpha+\lambda)\ E(\pi_A) + \alpha\ E(\pi_B) - g(e_M), \\ U_A^{PD}(d,e) &= \alpha\ E(\pi_A) - g(e_A), \\ U_B^{PD}(d,e) &= (\alpha+\lambda)\ E(\pi_B) - g(e_B). \end{aligned} \tag{10}$$

Define a cutoff $\tilde{q}^{PD} := \sqrt{1+\frac{c}{2k}}$. When $q/h < \tilde{q}^{PD}$ the CEO and Bob make decisions $d^B = (S,S)$ and the efforts are $e^B = (c\alpha h, c(\lambda+\alpha)h, k(2\alpha+\lambda)h)$. When $q/h \geq \tilde{q}^{PD}$ the CEO and Bob make a cooperative decision $d^B = (C,C)$ and the efforts are $e^B = (0,0,k(2\alpha+\lambda)q)$. Hence the overall value of the firm is:[44]

$$V_B^{PD}(d^*, e^B) = \begin{cases} (2k(2\alpha+\lambda) + c(2\alpha+\lambda))\,h^2 & \text{if } q/h < \tilde{q}^{PD}, \\ 2k(2\alpha+\lambda)q^2 & \text{if } q/h \geq \tilde{q}^{PD}. \end{cases} \tag{11}$$

The main insights of the proof come as follows. When $k/c < 1/2$ partial delegation is strictly dominated by decentralization when q/h is sufficiently small and by cross-authority otherwise. Since when $k/c < 1/2$ there is no misalignment between the decision preferred by the owner and those chosen by any other decision maker this is enough to discard it. On the other hand, when $k/c > 1/2$ Partial Delegation is always dominated by either Decentralization or Centralization from the owner perspective:

$$\begin{aligned} V_B^{DE}((S,S), e^B(S,S)) \geq V_B^{PD}((S,S), e^B(S,S)) \ \Leftrightarrow\ 2c\lambda h^2 \geq 0, \ \text{when } q/h \leq \tilde{q}^{PD}, \\ V_B^{CE}((C,C), e^B(C,C)) \geq V_B^{PD}((C,C), e^B(C,C)) \ \Leftrightarrow\ 2k\lambda q^2 \geq 0, \ \text{when } q/h > \tilde{q}^{PD}. \end{aligned}$$

Therefore, we should check whether Partial Delegation may arise as optimal when decisions are not contractible. We focus on cases where $k/c > 1/2$ as mentioned before. It is simple to check that there are some values, $\lambda \geq c$, for which Partial Delegation with decisions (C,C) is higher than

[44]The effort levels and optimal decisions are obtained in the same way as in propositions 2-5

Cross Authority (C,C). Additionally, there are values PD (C,C) gives a higher payoff, V, than HD(S,S). Therefore, the owner could be interested to implement Partial Delegtion in this area. However, note that the CEO and the agent in charge of decision making will require considerably more cooperation to move from (S,S) to (C,C) even than Centralization.[45] Therefore, Partial Delegation is dominated.

□

Concentrated Delegation

Under Concentrated Delegation (CD) $Y = \{CD\} = \{(0,1,0),(0,1,0)\}$ (or $\{(0,0,1),(0,0,1)\}$); i.e., Ari has the decision authority over both projects. The manager's and agents' expected payoff in partial delegation is given by:

$$\begin{aligned} U_M^{CD}(d,e) &= \alpha\ E(\pi_A) + \alpha\ E(\pi_B) - g(e_M), \\ U_A^{CD}(d,e) &= (\alpha+\lambda)\ E(\pi_A) + \lambda\ E(\pi_B) - g(e_A), \\ U_B^{CD}(d,e) &= \alpha\ E(\pi_B) - g(e_B). \end{aligned} \tag{12}$$

Define a cutoff $\tilde{q}^{CD} := \sqrt{1 + \frac{2c\alpha}{4k\alpha + c\lambda}}$. When $q/h < \tilde{q}^{CD}$ the CEO and Bob make decisions $d^B = (S,S)$ and the efforts are $e^B = (c(\alpha+\lambda)h, c\alpha h, 2k\alpha h)$. When $q/h \geq \tilde{q}^{CD}$ the CEO and Bob make a cooperative decision $d^B = (C,C)$ and the efforts are $e^B = (c\lambda q, 0, 2k\alpha q)$. Hence the overall value of the firm is:[46]

$$V_B^{CD}(d^B, e^B) = \begin{cases} \big(4k\alpha + c(2\alpha+\lambda)\big)h^2 & \text{if } q/h < \tilde{q}^{CD}, \\ \big(4k\alpha + c\lambda\big)q^2 & \text{if } q/h \geq \tilde{q}^{CD}. \end{cases} \tag{13}$$

The main insights of the proof come as follows. When $k/c \geq 1/2$ concentrated delegation as other forms of complete delegation (decentralization and cross authority) are dominated by other organizational designs that give higher incentives to the CEO. On the other hand, when $k/c < 1/2$ it is convenient to split the incentives into the two agents since their cost functions of effort are strictly convex. As a consequence, the joint effort is greater when it is split equally between both agents because the cost of effort does not increase as fast as if it were not so. The incentive value for the most motivated agent will not produce an effort increase capable to cover the other agent decrease of effort due to the shape of the cost effort function and, therefore, the joint effort will decrease.

Note that concentrated delegation is never preferred to other forms of dominated organization designs, so it is not a valuable alternative. Comparing with decentralization when

[45] From the utility of the CEO and agent in charge of decision making we obtain the threshold $\hat{q}^{PD} := -1 + \sqrt{4 + \frac{2c}{\alpha k} + \frac{4\alpha\lambda + \alpha^2}{\alpha^2}}$ which is considerable higher than $\hat{q}^{CE}$.

[46] The effort levels and optimal decisions are obtained in the same way as in propositions 2-5

$q/h < \sqrt{1 + \frac{2c\alpha}{4k\alpha + c\lambda}}$ is small for all k/c:

$$V_B^{DE}((S,S), e^B(S,S)) \geq V_B^{CD}((S,S), e^B(S,S)) \;\Leftrightarrow\; 2c\lambda h^2 \geq 0.$$

Since c, λ and h are greater than 0, decentralization with $d = (S,S)$ always dominates concentrated delegation with the same decision set. Comparing also with cross-authority when $q/h \geq \sqrt{1 + \frac{2c\alpha}{4k\alpha + c\lambda}}$ for all $k, c > 0$:

$$V_B^{CA}((C,C), e^{FB}(C,C)) \geq V_B^{CD}((C,C), e^{FB}(C,C)) \;\Leftrightarrow\; 2c\lambda q^2 \geq 0.$$

Since concentrated delegation is always dominated by alternative organizational designs and it does not appear in the relevant region where moral hazard in efforts and moral hazard in decisions coexist it is not considered in the analysis.

□

Lemma (Bound for closed form solution)

Consider values of c, k and h small enough to ensure that none probability is higher than one when selfish decisions are made, then we consider a bound for $q > h$. From proposition A4, the equilibrium success probability in centralization is $P_j = 2k(\alpha + \lambda)q$ for $j = A, B$ if $q/h \geq \hat{q}^{CE}$ and $P_j = [c\alpha + 2k(\alpha + \lambda)]h$ for $j = A, B$ otherwise. The latter probability does not depend on q and can be made less than one by making c, k and h small enough. Also the former probability is less than one if:

$$q < \frac{1}{2k\alpha + 2k\lambda}. \tag{L1}$$

From proposition A5, the equilibrium success probability in decentralization, when it is optimal, is $P_j = [2k\alpha + c(\alpha + \lambda)]h$ for $j = A, B$. Again this can be made less than one by choosing small enough c and k.

In cross-authority delegation, proposition A6 shows that the equilibrium success probability is $P_j = (c\lambda + 2k\alpha)q$ for $j = A, B$ when $q/h \geq \hat{q}^{CA}$, and $P_j = (c\alpha + 2k\alpha)h$ for $j = A, B$ otherwise. For the latter which does not depend on q, the same argument applies as in the previous cases. Also, the former is less than one if $q < 1/(c\lambda + 2k\alpha)$, which is satisfied if L2 is.

$$q < \frac{1}{2k\alpha + c\lambda}. \tag{L2}$$

From Proposition A7, the equilibrium success probabilities in hierarchical delegation are such that $\max\{P_A; P_B\} = [k(2\alpha + \lambda) + c\lambda]q$ if $q/h \geq \hat{q}_1^{HD}$, $\max\{P_A; P_B\} = k(\alpha + \lambda)(h + q) + c\alpha h$ if $\hat{q}_0^{HD} \leq q/h < \hat{q}_1^{HD} = \overline{q}$, and $\max\{P_A; P_B\} = [k(2\alpha + \lambda) + c\alpha]h$ if $q/h < \hat{q}_0^{HD}$. The last probability can be made less than one for small values of c and k. Note that the second probability is automatically smaller than one if $q \leq \frac{\alpha}{\alpha+\lambda}h$, for h that fulfils the condition in the first probability. Therefore, we can consider the case where $q > \frac{\alpha}{\alpha+\lambda}h$. However, since q is intermediate, cannot be bigger than $h + \frac{\alpha}{\alpha+\lambda}\frac{c}{k}$. Hence, this probability again can be made less than one for small values of c, k and h. Finally, the first probability is less than one if

$$q < \frac{1}{2k\alpha + \lambda(c+k)}. \tag{L3}$$

Thus L1-L3 are sufficient conditions for equilibrium success probabilities to be less than one in any organization if k and c are small enough. Combining L1-L3 proves the Lemma.

□

B. Benchmark Framework Equilibria

Proposition A1: (Centralization) Assume $Y = \{(1,0,0),(1,0,0)\}$. Define a cutoff $\tilde{q}^{CE} := \sqrt{1 + \frac{c}{2k}\frac{\alpha}{(\alpha+\lambda)}}$. When $q/h < \tilde{q}^{CE}$ both decisions are $d^B = (S,S)$ and the efforts are $e^B = (c\alpha h, c\alpha h, 2k(\alpha+\lambda)h)$. When $q/h \geq \tilde{q}^{CE}$ both decisions are $d^B = (C,C)$ and the efforts are $e^B = (0,0,2k(\alpha+\lambda)q)$. Hence the overall value of the firm is:

$$V_B^{CE}(d^B, e^B) = \begin{cases} \big(4k(\alpha+\lambda) + 2c\alpha\big)\ h^2 & \text{if } q/h < \tilde{q}^{CE}, \\ 4k(\alpha+\lambda)\ q^2 & \text{if } q/h \geq \tilde{q}^{CE}. \end{cases} \tag{L4}$$

Proof

Solving by backward induction, the CEO and each agent maximize their utility after observing the decisions $d = (d_A, d_B)$, i.e., $e^B(d)$. If $d = (C,C)$, then $e^B = (0,0,2k(\alpha+\lambda)q)$. If $d = (S,S)$, then $e^B = (c\alpha h, c\alpha h, 2k(\alpha+\lambda)h)$. If $d = (C,S)$, $e^B = (0, c\alpha(h+q), k(\alpha+\lambda)(q+h))$; and the symmetric case $d = (S,C)$.

Anticipating those efforts $e^B(d)$, the owner chooses $d \in \{(S,S),(S,C),(C,S),(C,C)\}$ to maximize $V_B^{CE}(d, e^B(d))$:

$$\begin{aligned} V_B^{CE}((C,C), e^B(C,C)) &= 4k(\alpha+\lambda)\ q^2, \\ V_B^{CE}((S,S), e^B(S,S)) &= (4k(\alpha+\lambda) + 2c\alpha)\ h^2, \\ V_B^{CE}((C,S), e^B(C,S)) &= k(\alpha+\lambda)\ (q+h)^2 + c\alpha h^2. \end{aligned}$$

Notice that $V_B^{CE}((C,S), e^B(C,S)) = V_B^{CE}((S,C), e^B(S,C))$. The key parameter that defines the best decision in any organizational design, in this case centralization, is the ratio of cooperative profits over motivation incentives of projects, i.e., q/h. We next define some relevant cutoff in this dimension q/h:

- First Case: $V_B^{CE}((C,C), e^B(C,C)) \geq V_B^{CE}((S,S), e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_1 = \sqrt{1 + \frac{c}{2k}\frac{\alpha}{(\alpha+\lambda)}}$.

- Second Case: $V_B^{CE}((C,C), e^B(C,C)) \geq V_B^{CE}((C,S), e^B(C,S)) \Leftrightarrow q/h \geq \tilde{q}_2 = \frac{1+\sqrt{4+3\frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}}{3}$, *considering only the positive root.*

- Last Case: $V_B^{CE}((C,S),e^B(C,S)) \geq V_B^{CE}((S,S),e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_3 = -1 + \sqrt{4+\frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}$, *considering only the positive root.*

Given our assumptions, it is not difficult (but it may take some time) to check that $\tilde{q}_2 \leq \tilde{q}_1 \leq \tilde{q}_3$. Consequently the main cutoff is $\tilde{q}_1$: if $q/h > \tilde{q}_1$, then $q/h > \tilde{q}_2$; consequently, $d = (C,C)$ is preferred to both $d = (S,S)$ and $d = (C,S)$ (and $d = (S,C)$ too). If $q/h < \tilde{q}_1$, then $q/h < \tilde{q}_3$; consequently, $d = (S,S)$ is preferred to both $d = (C,C)$ and $d = (C,S)$ (and $d = (S,C)$ too). Finally, we can obtain equation (L4), taking $\tilde{q}_1$ as the threshold $\tilde{q}^{CE}$ in q/h dimension.

□

Proposition A2: (Decentralization) Assume $Y = \{(0,1,0),(0,0,1)\}$. Define a cutoff $\tilde{q}^{DE} := \sqrt{\frac{1}{2}(2+\frac{c}{k}\frac{(\alpha+\lambda)}{\alpha})}$. When $q/h < \tilde{q}^{DE}$ both decisions are $d^B = (S,S)$ and the efforts are $e^B = (c(\alpha+\lambda)h, c(\alpha+\lambda)h, 2k\alpha h)$. When $q/h \geq \tilde{q}^{DE}$ both decisions are $d^B = (C,C)$ and the efforts are $e^B = (0,0,2k\alpha q)$. Hence the overall value of the firm is:

$$V_B^{DE}(d^B,e^B) = \begin{cases} 2\big(c(\alpha+\lambda)+2k\alpha\big)h^2 & \text{if } q/h < \tilde{q}^{DE}, \\ 4k\alpha q^2 & \text{if } q/h \geq \tilde{q}^{DE}. \end{cases} \tag{L5}$$

In decentralization, each agent has the decision right over his own project: $X_{MA} = X_{MB} = 0$ and $X_{AA} = X_{BB} = 1$. And the utility functions are those stated in Equation **??**.

Proof

Solving by backward induction, at time 2 the CEO and each agent maximize their utility after observing the decisions $d = (d_A, d_B)$, i.e., $e^B(d)$. If $d = (C,C)$, then $e^B = (0,0,2k\alpha q)$. If $d = (S,S)$, then $e^B = (c(\alpha+\lambda)h, c(\alpha+\lambda)h, 2k\alpha h)$. If $d = (C,S)$ (analogous solution for $d = (S,C)$), $e^B = (0, c(\alpha+\lambda)h, e_M = k\alpha(q+h))$.

Anticipating those efforts $e^B(d)$, the owner chooses $d \in \{(S,S),(S,C),(C,S),(C,C)\}$ to maximize $V_B^{DE}(d, e^*(d))$:

$$\begin{aligned} V_B^{DE}((C,C),e^B(C,C)) &= \ 4k\alpha q^2. \\ V_B^{DE}((S,S),e^B(S,S)) &= \ 2\big(c(\alpha+\lambda)+2k\alpha\big)h^2. \\ V_B^{DE}((C,S),e^B(C,S)) &= \ k\alpha\ (q+h)^2 + c(\alpha+\lambda)h^2. \end{aligned}$$

Notice that $V_B^{DE}((C,S),e^B(C,S)) = V_B^{DE}((S,C),e^B(S,C))$. The key parameter that defines the best decision in any organizational design is the ratio of cooperative profits over motivation incentives of projects, i.e., q/h. We next define some relevant cutoff in this dimension q/h:

- First Case: $V_B^{DE}((C,C),e^B(C,C)) \geq V_B^{DE}((S,S),e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_1 = \sqrt{\frac{1}{2}(2+\frac{c}{k}\frac{(\alpha+\lambda)}{\alpha})}$.
- Second Case: $V_B^{DE}((C,C),e^B(C,C)) \geq V_B^{DE}((C,S),e^B(C,S)) \Leftrightarrow q/h \geq \tilde{q}_2 = \frac{1}{3} + \sqrt{\frac{1}{3}(\frac{1}{3}+\frac{c}{k}\frac{\alpha+\lambda}{\alpha})}$, *considering only the positive root.*

- Last Case: $V_B^{DE}((C,S), e^B(C,S)) \geq (S,S), e^B(S,S) \;\Leftrightarrow\; q/h \geq \tilde{q}_3 = -1 + \sqrt{4 + \frac{c}{k}\frac{\alpha+\lambda}{\alpha}}$, *considering only the positive root.*

Notice that $\tilde{q}_1, \tilde{q}_2$ and $\tilde{q}_3$ are represented in the q/h dimension. Given our assumptions, it is not difficult (but it may take some time) to check that $\tilde{q}_2 \leq \tilde{q}_1 \leq \tilde{q}_3$. Consequently the main cutoff is $\tilde{q}_1$: if $q/h > \tilde{q}_1$, then $q/h > \tilde{q}_2$; consequently, $d = (C,C)$ is preferred to both $d = (S,S)$ and $d = (C,S)$ (and $d = (S,C)$ too). If $q/h < \tilde{q}_1$, then $q/h < \tilde{q}_3$; consequently, $d = (S,S)$ is preferred to both $d = (C,C)$ and $d = (C,S)$ (and $d = (S,C)$ too).

Finally, we can obtain equation (L5), taking $\tilde{q}_1$ as the threshold $\tilde{q}^{DE}$ in q/h dimension.

□

Proposition A3: (Cross-authority) Assume $Y = \{(0,0,1),(0,1,0)\}$. Define a cutoff $\tilde{q}^{CA} := \sqrt{\frac{2k\alpha+c\alpha}{2k\alpha+c\lambda}}$. When $q/h < \tilde{q}^{CA}$ both decisions are $d^B = (S,S)$ and the efforts are $e^B = (c\alpha h, c\alpha h, 2k\alpha h)$. When $q/h \geq \tilde{q}^{CA}$ both decisions are $d^B = (C,C)$ and the efforts are $e^B = (c\lambda q, c\lambda q, 2k\alpha q)$. Hence the overall value of the firm is:

$$V_B^{CA}(d^B, e^B) = \begin{cases} 2(2k\alpha + c\alpha)\ h^2 & \text{if } q/h < \tilde{q}^{CA}, \\ 2(2k\alpha + c\lambda)\ q^2 & \text{if } q/h \geq \tilde{q}^{CA}. \end{cases} \tag{L6}$$

In cross-authority, each agent has the decision right over the other project: $X_{MA} = X_{MB} = 0$ and $X_{AB} = X_{BA} = 1$. And the utility functions are those stated in Equation **??**.

Proof

Solving by backward induction, at time 2 the CEO and each agent maximize their utility after observing the decisions $d = (d_A, d_B)$, i.e., $e^B(d)$. If $d = (C,C)$, then $e^B = (c\lambda q, c\lambda q, 2k\alpha q)$. If $d = (S,S)$, then $e^B = (c\alpha h, c\alpha h, e_M = 2k\alpha h)$. If $d = (C,S)$ (analogous solution for $d = (S,C)$), $e^B = (c\lambda q, c\alpha h, k\alpha(q+h))$.

Anticipating those efforts $e^B(d)$, the owner chooses $d \in \{(S,S),(S,C),(C,S),(C,C)\}$ to maximize $V_B^{CA}(d, e^*(d))$:

$$\begin{aligned} V_B^{CA}((C,C), e^B(C,C)) = &\quad 2(2k\alpha + c\lambda)\ q^2. \\ V_B^{CA}((S,S), e^B(S,S)) = &\quad 2(2k\alpha + c\alpha)\ h^2. \\ V_B^{CA}((C,S), e^B(C,S)) = &\quad k\alpha\ (h+q)^2 + c(\alpha h^2 + \lambda q^2). \end{aligned}$$

- First Case: $V_B^{CA}((C,C), e^B(C,C)) \geq V_B^{CA}((S,S), e^B(S,S)) \;\Leftrightarrow\; q/h \geq \tilde{q}_1 = \sqrt{\frac{2k\alpha+c\alpha}{2k\alpha+c\lambda}}$.
- Second Case: $V_B^{CA}((C,C), e^B(C,C)) \geq V_B^{CA}((C,S), e^B(C,S)) \;\Leftrightarrow\; q/h \geq \tilde{q}_2 = \frac{1}{3k\alpha+c\lambda}\big(k\alpha + \sqrt{7k^2\alpha^2 + c^2\alpha\lambda + k\alpha c\lambda}\big)$, *considering only the positive root.*
- Last Case: $V_B^{CA}((C,S), e^B(C,S)) \geq V_B^{CA}((S,S), e^B(S,S)) \;\Leftrightarrow\; q/h \geq \tilde{q}_3 = -1 + \sqrt{\frac{1}{(k\alpha+c\lambda)^2} + \frac{3k\alpha+c\lambda}{k\alpha+c\lambda}}$, *considering only the positive root.*

Notice that $\tilde{q}_1, \tilde{q}_2$ and $\tilde{q}_3$ are represented in the q/h dimension. Given our assumptions, it is not difficult (but it may take some time) to check that $\tilde{q}_2 \leq \tilde{q}_1 \leq \tilde{q}_3$. Consequently the main cutoff is $\tilde{q}_1$: if $q/h > \tilde{q}_1$, then $q/h > \tilde{q}_2$; consequently, $d = (C, C)$ is preferred to both $d = (S, S)$ and $d = (C, S)$ (and $d = (S, C)$ too). If $q/h < \tilde{q}_1$, then $q/h < \tilde{q}_3$; consequently, $d = (S, S)$ is preferred to both $d = (C, C)$ and $d = (C, S)$ (and $d = (S, C)$ too).

Finally, we can obtain equation (L6), taking $\tilde{q}_1$ as the threshold $\tilde{q}^{CA}$ in q/h dimension.

□

Proposition A4: (Hierarchical delegation) Assume $Y = \{(1, 0, 0), (0, 1, 0)\}$. Define cutoffs $\tilde{q}_1^{HD} := \frac{1}{k(1+\alpha)+c\lambda}\big((k(\alpha+\lambda) + \sqrt{k^2(\alpha+\lambda)^2 + [k(\alpha+\lambda)+c\alpha][k(1+\alpha)+c\lambda]}\big)$ and $\tilde{q}_0^{HD} := -1 + \sqrt{2 + \frac{2\alpha}{\alpha+\lambda} + \frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$. When $q/h < \tilde{q}_0^{HD}$, both decisions are $d^B = (S, S)$ and efforts are $e^B = (c\alpha h, c\alpha h, k(2\alpha+\lambda)h)$. If $\tilde{q}_0^{HD} \leq q/h < \tilde{q}_1^{HD}$, decisions are $d^B = (S, C)$ and efforts are $e^B = (c\alpha h, 0, k(\alpha+\lambda)(h+q))$. Finally, when $q/h \geq \tilde{q}_1^{HD}$ both decisions are $d^B = (C, C)$ and efforts are $e^B = (c\lambda q, 0, k(2\alpha+\lambda)q)$. Hence the overall value of the firm is:

$$V_B^{HD}(d^B, e^B) = \begin{cases} (2k(2\alpha+\lambda) + 2c\alpha)\, h^2 & \text{if } q/h < \tilde{q}_0^{HD}, \\ k(\alpha+\lambda)(h+q)^2 + c\alpha h^2 & \text{if } \tilde{q}_0^{HD} < q/h \leq \tilde{q}_1^{HD}, \\ (2k(2\alpha+\lambda) + c\lambda)\, q^2 & \text{if } q/h > \tilde{q}_1^{HD}. \end{cases} \tag{L7}$$

In hierarchical delegation, the CEO has the decision over project A and Ari over project B (it could be the other way around symmetrically): $X_{MA} = 1$, $X_{MB} = 0$ and $X_{AB} = 1$. And the utility functions are those stated in Equation **??**.

Proof

Solving by backward induction, at time 2 the CEO and each agent maximize their utility after observing the decisions $d = (d_A, d_B)$, i.e., $e^B(d)$. If $d = (C, C)$, then $e^B = (c\lambda q, 0, k(2\alpha+\lambda)q)$. If $d = (C, C)$, then $e^B = (c\alpha h, c\alpha h, k(2\alpha+\lambda)h)$. If $d = (C, S)$, $e^B = (0, c\alpha h, k\alpha(h+q))$. If $d = (C, S)$, $e^B = (c\alpha h, 0, k(\alpha+\lambda)(h+q))$.

Anticipating those efforts $e^B(d)$, the owner chooses $d \in \{(S, S), (S, C), (C, S), (C, C)\}$ to maximize $V_B^{HD}(d, e^*(d))$:

$$\begin{aligned} V_B^{HD}((C,C), e^B(C,C)) = &\ \big(2k(2\alpha+\lambda) + c\lambda\big)q^2. \\ V_B^{HD}((C,S), e^B(C,S)) = &\ k\alpha(h+q)^2 + c\alpha h^2 + c\lambda q^2. \\ V_B^{HD}((S,C), e^B(S,C)) = &\ k(\alpha+\lambda)(h+q)^2 + c\alpha h^2. \\ V_B^{HD}((S,S), e^B(S,S)) = &\ \big(2k(2\alpha+\lambda) + 2c\alpha\big)h^2. \end{aligned}$$

- First Case: $V_B^{HD}((C,C), e^B(C,C)) \geq V_B^{HD}((S,S), e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_1 = \sqrt{\frac{2k(2\alpha+\lambda)+2c\alpha}{2k(2\alpha+\lambda)+c\lambda}}$.
- Second Case: $V_B^{HD}((C,S), e^B(C,S)) \geq V_B^{HD}((S,S), e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_2 = -\frac{-\alpha k}{k\alpha+c\lambda} + \sqrt{\left(\frac{\alpha k}{k\alpha+c\lambda}\right)^2 + \frac{k(3\alpha+\lambda+c\alpha)}{k\alpha+c\lambda}}$, *considering only the positive root.*

- Third Case: $V_B^{HD}((S,C),e^B(S,C)) \geq V_B^{HD}((S,S),e^B(S,S)) \Leftrightarrow q/h \geq \tilde{q}_3 = -1 + \sqrt{2+\frac{2\alpha}{\alpha+\lambda}+\frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$, *considering only the positive root.*
- Last Case: $V_B^{HD}((C,C),e^B(C,C)) \geq V_B^{HD}((S,C),e^B(S,C)) \Leftrightarrow q/h \geq \tilde{q}_4 =$
  $= \frac{1}{k(1+\alpha)+c\lambda}\big((k(\alpha+\lambda)+\sqrt{k^2(\alpha+\lambda)^2+[k(\alpha+\lambda)+c\alpha][k(1+\alpha)+c\lambda]}\big)$, *considering only the positive root.*

Notice that $\tilde{q}_1, \tilde{q}_2, \tilde{q}_3$ and $\tilde{q}_4$ are represented in the q/h dimension. Given our assumptions, it is not difficult (but it may take some time) to check that $\tilde{q}_3 \leq \tilde{q}_1 \leq \tilde{q}_4 \leq \tilde{q}_2$. Note that the two relevant thresholds are $\tilde{q}_3$ and $\tilde{q}_1$. In other words, $d=(S,C)$ are preferred to $d=(S,S)$ for $q/h \in (\tilde{q}_3,\tilde{q}_1)$, but $d=(C,C)$ is the optimal for $q/h > \tilde{q}_1$ which makes $\tilde{q}_4$ and $\tilde{q}_2$ irrelevant. $d=(S,S)$ is optimal for $q/h < \tilde{q}_3$.

Finally, we can obtain equation (L7), taking $\tilde{q}_3$ and $\tilde{q}_1$ as the threshold $\tilde{q}_0^{HD}$ and $\tilde{q}_1^{HD}$ in q/h dimension.

□

Proof of Proposition 2

Before start, for the sake of simplicity let's put aside for a while the notation of the efforts in the value of the organization, i.e. $V_B^{CE}((C,C),e^B(C,C)$ we directly denote it as $V_B^{CE}(C,C)$ and equivalently for every organizational design. We partition the range of $q/h \in (0, Z/h)$ further into three regions: (i) $q/h \in [0,1]$ where the cooperative returns are lower or equal to motivational returns, (ii) $q/h \in (1, \sqrt{1+\frac{c}{2k}\frac{\alpha}{(\alpha+\lambda)}})$ where the upper limit is the threshold under which $V_B^{CE}(C,C) > V_B^{CE}(S,S)$, and (iii) $q/h \in [\sqrt{1+\frac{c}{2k}\frac{\alpha}{(\alpha+\lambda)}}, Z)$.

Consider case (i) first. From the equilibrium total expected profits derived above, we have $V_B^{CE}(S,S) - V_B^{PD}(S,S) = V_B^{PD}(S,S) - V_B^{DE}(S,S) = (2k-c)\lambda h^2 > 0$ if and only if $k/c > 1/2$. It is also easy to see $V_B^{DE}(S,S) > V_B^{CA}(S,S)$ and $V_B^{PD}(S,S) > V_B^{HD}(S,S)$. It follows that centralization is optimal if $k > c/2$ and decentralization is optimal otherwise.

Consider next case (ii). The only organizational designs which change their decisions are hierarchical delegation and cross-authority, so they are the only ones that need to be compared with decentralization and centralization. Suppose first that $k/c \geq 1/2$, $V_B^{CE}(S,S) > V_B^{CA}(C,C)$ if and only if $q/h < \sqrt{\frac{2k(\alpha+\lambda)+c\alpha}{2k\alpha+c\lambda}}$, note that this ratio is greater than the limit of the case considered. Additionally, $V_B^{CE}(S,S) > V_B^{HD}(S,C)$ if and only if $q/h < -1+\sqrt{4+\frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$, that is greater than the limit also. As a consequence, $V_B^{CE}(S,S)$ still being optimum if $k/c \geq 1/2$. Now suppose that $k/c < 1/2$, $V_B^{CA}(C,C) > V_B^{DE}(S,S)$ if and only if $q/h \geq \sqrt{1+\frac{c\alpha}{c\lambda+2k\alpha}}$ and $V_B^{HD}(S,C) > V_B^{DE}(S,S)$ if and only if $q/h \geq -1+\sqrt{1+\frac{c}{k}\frac{(\alpha+2\lambda)}{(\alpha+\lambda)}+\frac{(3\alpha-\lambda)}{(\alpha+\lambda)}}$. Notice that cross-authority needs less cooperative returns over motivational returns than hierarchical delegation. Finally, $V_B^{CA}(C,C) > V_B^{HD}(S,C)$ if and only if $q/h \geq \frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda}+\sqrt{\big(\frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda}\big)^2+\frac{k(\alpha+\lambda)+c\alpha}{k(3\alpha-\lambda)+2c\lambda}}$, that is lower than the threshold q/h for $V_B^{HD}(S,C) > V_B^{DE}(S,S)$. As a consequence, decentralization is optimum if $q/h < \tilde{q}_{B2} := \sqrt{1+\frac{c\alpha}{c\lambda+2k\alpha}}$ and cross-authority otherwise.

Finally, consider case (iii). The lower limit is the threshold under which $V_B^{CE}(S,S)$ change to $V_B^{CE}(C,C)$, we call this ratio $\tilde{q}_{B1} := \sqrt{1+\frac{c}{2k}\frac{\alpha}{(\alpha+\lambda)}}$. The other organizational designs in which decisions are changed are hierarchical delegation, partial delegation and decentralization, the three of them decide cooperative decisions for both projects. It is straightforward that $V_B^{HD}(C,C) > V_B^{PD}(C,C) > V_B^{DE}(C,C)$. Hence, partial delegation and decentralization with both cooperative decisions are dominated. Additionally, $V_B^{CE}(C,C) - V_B^{HD}(C,C) = V_B^{HD}(C,C) - V_B^{CA}(C,C) = (2k-c)\lambda q^2$. Then if $k/c \geq 1/2$, centralization with both decisions cooperative is optimum while cross authority with both decisions cooperative is optimum otherwise.

It follows that when $k/c \geq 1/2$, there is only one optimum organizational design: centralization (in which the CEO can choose $d = (C,C)$ when $q/h > \tilde{q}_{B1}$ or $d = (S,S)$ otherwise). When $k/c < 1/2$, decentralization with $d = (S,S)$ will be chosen when $q/h < \tilde{q}_{B2}$ or cross-authority with $d = (C,C)$ otherwise.

□

C. Model Framework Equilibria

In this subsection the only step that changes in comparison to each *benchmark* equilibrium is the step in t_1 in which the individual in charge of decision making decides to choose the decision that is convenient for him/her according to his/her utility. The effort levels are identical as those calculated for each organizational design in the *benchmark case*.

Proposition A5: (Centralization) Assume $Y = \{(1,0,0),(1,0,0)\}$. Define a cutoff $\hat{q}^{CE} := \sqrt{1+\frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$ When $q/h < \hat{q}^{CE}$, the CEO makes both decisions $d = (S,S)$ and each agent chooses $e^* = (c\alpha h, c\alpha h, 2k(\alpha+\lambda)h)$. When $q/h \geq \hat{q}^{CE}$ the CEO makes both decisions $d = (C,C)$ and the efforts are $e^* = (0,0,2k(\alpha+\lambda)q)$. Hence the overall value of the firm is:

$$V^{CE}(d^*,e^*) = \begin{cases} \big(4k(\alpha+\lambda)+2c\alpha\big)\ h^2 & \text{if} q/h < \hat{q}^{CE}, \\ 4k(\alpha+\lambda)\ q^2 & \text{if } q/h \geq \hat{q}^{CE}, \end{cases} \tag{L8}$$

Proof

Anticipating those efforts $e^*(d)$, the CEO chooses $d \in \{(S,S),(S,C),(C,S),(C,C)\}$ to maximize $U_M^{CE}(d,e^*(d))$:

$$\begin{aligned} U_M^{CE}((C,C),e^*(C,C)) = &\quad 2k(\alpha+\lambda)^2\ q^2. \\ U_M^{CE}((S,S),e^*(S,S)) = &\quad 2k(\alpha+\lambda)^2\ h^2 + 2c\alpha(\alpha+\lambda)h^2. \\ U_M^{CE}((C,S),e^*(C,S)) = &\quad \tfrac{k(\alpha+\lambda)^2\ (h+q)^2}{2} + c\alpha(\alpha+\lambda)h^2. \end{aligned}$$

- First Case: $U_M^{CE}(C,C|e^*) \geq U_M^{CE}(S,S|e^*) \ \Leftrightarrow\ q/h \geq \hat{q}_1 = \sqrt{1+\frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$.

- Second Case: $U_M^{CE}(C,C|e^*) \geq U_M^{CE}(C,S|e^*) \Leftrightarrow q/h \geq \hat{q}_2 = \frac{1}{3}+\sqrt{\frac{1}{9}+\frac{2}{3}\frac{c}{k}\frac{\alpha}{\alpha+\lambda}}$, *considering only the positive root.*
- Last Case: $U_M^{CE}(C,S|e^*) \geq U_M^{CE}(S,S|e^*) \Leftrightarrow (q/h) \geq \hat{q}_3 = -1+\sqrt{4+\frac{2c}{k}\frac{\alpha}{\alpha+\lambda}}$, *considering only the positive root.*

By using exactly the same argument as in previous propositions, we can note that the only relevant threshold is $\hat{q}_1$. Therefore, we denote $\hat{q}^{CE} = \hat{q}_1$ the relevant cutoff for equation (L8). Note that the actual value for the model for a given d and e^* is the same as in the *benchmark* (since efforts are the same), the only relevant change is the cutoff.

□

Proposition A6: (Decentralization) Assume $Y = \{(0,1,0),(0,0,1)\}$. Define a cutoff $\hat{q}^{DE} := \sqrt{1+\frac{1}{4}\frac{c}{k}\frac{(\alpha+\lambda)}{\alpha}}$. When $q/h < \hat{q}^{DE}$ each agent j chooses $d_j = S$, then $d^* = (S,S)$ and $e^* = (c(\alpha+\lambda)h, c(\alpha+\lambda)h, 2k\alpha h)$. When $q/h \geq \hat{q}^{DE}$ each agent decides both cooperative $d^* = (C,C)$ and the efforts are $e^* = (0,0,2k\alpha q)$. Hence the overall value of the firm is:

$$V^{DE}(d^*,e^*) = \begin{cases} 2\big(c(\alpha+\lambda)+2k\alpha\big)h^2 & \text{if} q/h < \hat{q}^{DE}, \\ 4k\alpha q^2 & \text{if } q/h \geq \hat{q}^{DE}. \end{cases} \tag{L9}$$

Proof

Anticipating those efforts $e^*(d)$, each agent chooses the decision in his own project. Consider agent j, he chooses d_j given the decision of agent $-j$ regarding d_{-j} in order to maximize $U_j^{DE}(d, e^*(d))$:

$$\begin{aligned} U_A^{DE}((C,C),e^*(C,C)) = &\ (\alpha+\lambda)\ 2k\alpha q^2. \\ U_A^{DE}((S,S),e^*(S,S)) = &\ (\alpha+\lambda)\ 2k\alpha h^2 + \tfrac{c(\alpha+\lambda)^2h^2}{2}. \\ U_A^{DE}((S,C),e^*(S,C)) = &\ (\alpha+\lambda)\ k\alpha(h+q)^2 + \tfrac{c(\alpha+\lambda)^2h^2}{2}. \\ U_A^{DE}((C,S),e^*(C,S)) = &\ 0. \end{aligned}$$

We can compute the same for Bob. Note that agent A never makes $d_A = C$ when Bob makes $d_B = S$ because it brings utility of zero. Equivalently, since agents are symmetric, Bob never makes $d_B = C$ when Bob makes $d_A = S$. They make cooperative decisions, when they are sure that it will enforce joint cooperative decisions. Therefore, the only relevant comparison is:

$$U_j^{DE}((C,C),e^*(C,C)) \geq U_j^{DE}((S,S),e^*(S,S)) \Leftrightarrow q/h \geq \hat{q}^{DE} := \sqrt{1+\frac{1}{4}\frac{c}{k}\frac{(\alpha+\lambda)}{\alpha}}.$$

Therefore, $\hat{q}^{DE}$ is the relevant cutoff for equation (L9).

□

Proposition A7: (Cross-authority) Assume $Y = \{(0,0,1),(0,1,0)\}$. Let's define $\hat{q}^{CA} = \sqrt{\frac{(\alpha+\lambda)(2\alpha k+c\alpha)-\frac{c\alpha^2}{2}}{(\alpha+\lambda)(2\alpha k+c\lambda)-\frac{c\lambda^2}{2}}}$. When $q/h < \hat{q}^{CA}$, $d^* = (S,S)$ and $e^* = (c\alpha h, c\alpha h, 2k\alpha h)$. When $q/h \geq \hat{q}^{CA}$, $d^* = (C,C)$ and $e^* = (c\lambda q, c\lambda q, 2k\alpha q)$. Hence the overall value of the firm is:

$$V^{CA}(d^*,e^*) = \begin{cases} 2(2k\alpha + c\alpha)\ h^2 & \text{if} q/h < \hat{q}^{CA}, \\ 2(2k\alpha + c\lambda)\ q^2 & \text{if } q/h \geq \hat{q}^{CA}. \end{cases} \tag{L10}$$

Proof

Anticipating those efforts $e^*(d)$, each agent chooses the decision in the other project. Consider agent j, he chooses d_j given the decision of agent $-j$ regarding d_{-j} in order to maximize $U_j^{CA}(d, e^*(d))$. By exactly the same argument as in the previous proposition, there are only two important utilities to consider:

$$\begin{aligned} U_j^{CA}((C,C), e^*(C,C)) = & \quad [(\alpha+\lambda)(2\alpha k + c\lambda) - \tfrac{c\lambda^2}{2}]\ q^2. \\ U_j^{CA}((S,S), e^*(S,S)) = & \quad [(\alpha+\lambda)(2\alpha k + c\alpha) - \tfrac{c\alpha^2}{2}]\ h^2. \end{aligned}$$

As a consequence:

$$U_j^{CA}((C,C), e^*(C,C)) \geq U_j^{CA}((S,S), e^*(S,S)) \ \Leftrightarrow\ q/h \geq \hat{q}^{CA} := \sqrt{\frac{(\alpha+\lambda)(2\alpha k + c\alpha) - \frac{c\alpha^2}{2}}{(\alpha+\lambda)(2\alpha k + c\lambda) - \frac{c\lambda^2}{2}}}.$$

Therefore, $\hat{q}^{CA}$ is the relevant cutoff for equation (L10).

□

Proposition A8: (Hierarchical Delegation) Assume $Y = \{(1,0,0),(0,1,0)\}$. Let's define $\hat{q}_1^{HD} = \frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]} + \sqrt{\left(\frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]}\right)^2 + \frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]} + \frac{2c(\alpha+\lambda)}{k(3\alpha+2\lambda)+2c\lambda}}$ and $\hat{q}_0^{HD} = \sqrt{2 + \frac{\lambda}{\alpha} + \frac{c}{k}\frac{\alpha\lambda}{\alpha(\alpha+\lambda)}} - 1$. When $q/h < \hat{q}_0^{HD}$, $d^* = (S,S)$ and $e^* = (c\alpha h, c\alpha h, k(2\alpha+\lambda)h)$. $\hat{q}_0^{HD} \leq q/h < \hat{q}_1^{HD}$, CEO makes a selfish decision while Ari a cooperative one, i.e., $d^* = (S,C)$ and efforts are $e^* = (c\alpha h, 0, k(\alpha+\lambda)(h+q))$. When $q/h \geq \hat{q}_1^{HD}$, $d^* = (C,C)$ and $e^* = (c\lambda q, 0, k(2\alpha+\lambda)q)$. Hence the overall value of the firm is:

$$V^{HD}(d^*,e^*) = \begin{cases} (2k(2\alpha+\lambda) + 2c\alpha)\, h^2 & \text{if } q/h < \hat{q}_0^{HD}, \\ k(\alpha+\lambda)(h+q)^2 + c\alpha h^2 & \text{if } \hat{q}_0^{HD} \leq q/h < \hat{q}_1^{HD}, \\ (2k(2\alpha+\lambda) + 2c\lambda)\, q^2 & \text{if } \hat{q}_1^{HD} \leq q/h. \end{cases} \tag{L11}$$

Proof

Anticipating those efforts $e^*(d)$, the CEO makes the decision in project A and the Ari in project B. The utility function for the CEO in each case is:

$$
\begin{aligned}
U_M^{HD}((C,C),e^*(C,C)) = & \ \tfrac{k(2\alpha+\lambda)^2\ q^2}{2} + c\alpha\lambda q^2. \\
U_M^{HD}((C,S),e^*(C,S)) = & \ \tfrac{k\alpha^2(h+q)^2}{2} + c\alpha^2 h^2. \\
U_M^{HD}((S,C),e^*(S,C)) = & \ \tfrac{k(\alpha+\lambda)^2(h+q)^2}{2} + c\alpha(\alpha+\lambda)h^2. \\
U_M^{HD}((S,S),e^*(S,S)) = & \ \tfrac{k(2\alpha+\lambda)^2\ h^2}{2} + c\alpha(2\alpha+\lambda)h^2.
\end{aligned}
$$

The utility function for Ari in each case is:

$$
\begin{aligned}
U_A^{HD}((C,C),e^*(C,C)) = & \ k(\alpha+\lambda)(2\alpha+\lambda)\ q^2 + \tfrac{c\lambda^2 q^2}{2}. \\
U_A^{HD}((C,S),e^*(C,S)) = & \ k\alpha\lambda(h+q)^2 + \tfrac{c\lambda^2 q^2}{2} + c\lambda\alpha h^2. \\
U_A^{HD}((S,C),e^*(S,C)) = & \ k\alpha(\alpha+\lambda)(h+q)^2 + \tfrac{c\alpha^2 h^2}{2}. \\
U_A^{HD}((S,S),e^*(S,S)) = & \ k(\alpha+\lambda)(2\alpha+\lambda)\ h^2 + c\alpha\lambda h^2 + \tfrac{c\alpha^2 h^2}{2}.
\end{aligned}
$$

Since the CEO controls only d_A, she has two comparisons to make:

- First Case: $U_M^{HD}((C,S),e^*(C,S)) \geq U_M^{HD}((S,S),e^*(S,S)) \Leftrightarrow q/h \geq \hat{q}_1 := -1 + \sqrt{4 + \frac{4\alpha\lambda+\lambda^2}{\alpha^2} + \frac{2c}{k}\frac{\alpha+\lambda}{\alpha}}$.
- Second Case: $U_M^{HD}((C,C),e^*(C,C)) \geq U_M^{HD}((S,C),e^*(S,C)) \Leftrightarrow q/h \geq \hat{q}_2 := \frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]} + \sqrt{\left(\frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]}\right)^2 + \frac{k(\alpha+\lambda)^2}{\alpha[k(3\alpha+2\lambda)+2c\lambda]} + \frac{2c(\alpha+\lambda)}{k(3\alpha+2\lambda)+2c\lambda}}$, *considering only the positive root.*

Ari controls d_B, he has two comparisons to make. However, note that it is simple to see that $d_B = S$ is dominated when $d_A = C$[47]. Therefore, the only relevant comparison is

- Third Case: $U_A^{HD}((S,C),e^*(S,C)) \geq U_A^{HD}((S,S),e^*(S,S)) \Leftrightarrow q/h \geq \hat{q}_3 = -1 + \sqrt{2 + \frac{\lambda}{\alpha} + \frac{c}{k}\frac{\alpha\lambda}{\alpha(\alpha+\lambda)}}$, *considering only the positive root.*

Note that $\hat{q}_1 > \hat{q}_3$ so Ari requires less relative cooperative returns to implement $d_B = C$ than the CEO. As a consequence, Ari makes $d_A = C$ when $q/h \geq \hat{q}_3$ and the CEO makes $d_A = C$ when $q/h \geq \hat{q}_2$, and there are three implementable decision sets, $d = (S,S)$, $d = (S,C)$ and $d = (C,C)$.

Therefore, the relevant cutoffs for equation (L11) are $\hat{q}_0^{HD} = \hat{q}_3$ and $\hat{q}_1^{HD} = \hat{q}_2$.

□

Proof of Proposition 3

In this proof we are going to use the same strategy as in proposition 2. We partition the range of $q/h \in (0, Z/h)$ further into three regions: (i) $q/h \in [0,1]$ where the cooperative returns are lower or equal to motivational returns, (ii) $q/h \in (1, \sqrt{1 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}})$ where upper limits is the

[47]Assume that $q = h$, which makes $d = (C,C)$ less profitable than $d = (S,C)$ and in any case the utilities for Ari are higher under $d = (C,C)$.

threshold under which centralization with $d = (C, C)$ is implemented over centralization with $d = (S, S)$, and (iii) $q/h \in [\sqrt{1 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}, Z/h)$.

Note that the first case (i), still being the same since the V^y values of the firms have not change in spite of the fact that their decision thresholds have changed. It follows that centralization is optimal if $k > c/2$ and decentralization is optimal otherwise.

Consider next case (ii). As in Benchmark the only organizational designs which change their decisions are hierarchical delegation and cross-authority, so they are the only ones that need to be compared with decentralization and centralization. Note that when $k/c < 1/2$, $V^{CA}(C, C) > V^{DE}(S, S)$ if and only if $q/h \geq \sqrt{1 + \frac{c\alpha}{c\lambda+2k\alpha}}$ and $V^{HD}(S, C) > V^{DE}(S, S)$ if and only if $q/h \geq -1 + \sqrt{1 + \frac{c}{k}\frac{(\alpha+2\lambda)}{(\alpha+\lambda)} + \frac{(3\alpha-\lambda)}{(\alpha+\lambda)}}$. Notice that cross-authority needs less cooperative returns over motivational returns than hierarchical delegation[48]. Finally, $V^{CA}(C, C) > V^{HD}(S, C)$ if and only if $q/h \geq \frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda} + \sqrt{\left(\frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda}\right)^2 + \frac{k(\alpha+\lambda)+c\alpha}{k(3\alpha-\lambda)+2c\lambda}}$, that is lower than the threshold q/h for $V^{HD}(S, C) > V^{DE}(S, S)$. As a consequence, decentralization is optimum if $\hat{q}_{B2} = q/h < \sqrt{1 + \frac{c\alpha}{c\lambda+2k\alpha}}$ and cross-authority otherwise, as in the benchmark case.

Suppose $k/c \geq 1/2$, $V^{HD}(S, C) > V^{CE}(S, S)$ if and only if $-1 + \sqrt{4 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}} =: \hat{q}_{M1} \leq q/h < \sqrt{1 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}$. Additionally, $V^{CA}(C, C) > V^{HD}(S, C)$ if and only if $q/h \geq \hat{q}_{M1'} := \frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda} + \sqrt{\left(\frac{k(\alpha+\lambda)}{k(3\alpha-\lambda)+2c\lambda}\right)^2 + \frac{k(\alpha+\lambda)+c\alpha}{k(3\alpha-\lambda)+2c\lambda}}$. As a consequence, $V_B^{CE}(S, S)$ still being optimum until $q/h < -1 + \sqrt{4 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}$ if $k/c \geq 1/2$, but hierarchical delegation shows up as an optimum organizational design when $\hat{q}_{M1} \leq q/h < \hat{q}_{M1'}$ and cross-authority becomes optimal for $\hat{q}_{M1'} \leq q/h \leq \sqrt{1 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}$.

Finally, consider case (iii). The lower limit is the threshold under which the CEO chooses $d = (C, C)$ over $d = (S, S)$, we call this ratio $\hat{q}_{M2} = \sqrt{1 + \frac{c}{k}\frac{\alpha}{(\alpha+\lambda)}}$. The results in this region remain equal to that of benchmark proof. Then, centralization with both decisions cooperative is optimum if $k/c \geq 1/2$ while cross authority with both decisions cooperative is optimum otherwise.

It follows that when $k/c < 1/2$, the results of benchmark remain without modifications. When $k/c \geq 1/2$, the owner chooses centralization with $d = (S, S)$ when $q/h < \hat{q}_{M1}$. When $\hat{q}_{M1} < q/h < \hat{q}_{M2}$, he chooses either hierarchical delegation with $d = (S, C)$ if $q/h < \hat{q}_{M1'}$ or cross-authority with $d = (C, C)$ otherwise. Finally, when $q/h \geq \hat{q}_{M2}$ he chooses centralization with $d = (C, C)$.

□

D. Comparative statics

We now analyze how results are modified by the impact of the importance of authority, and the share of profits allocated to each individual, represented by λ and α respectively.

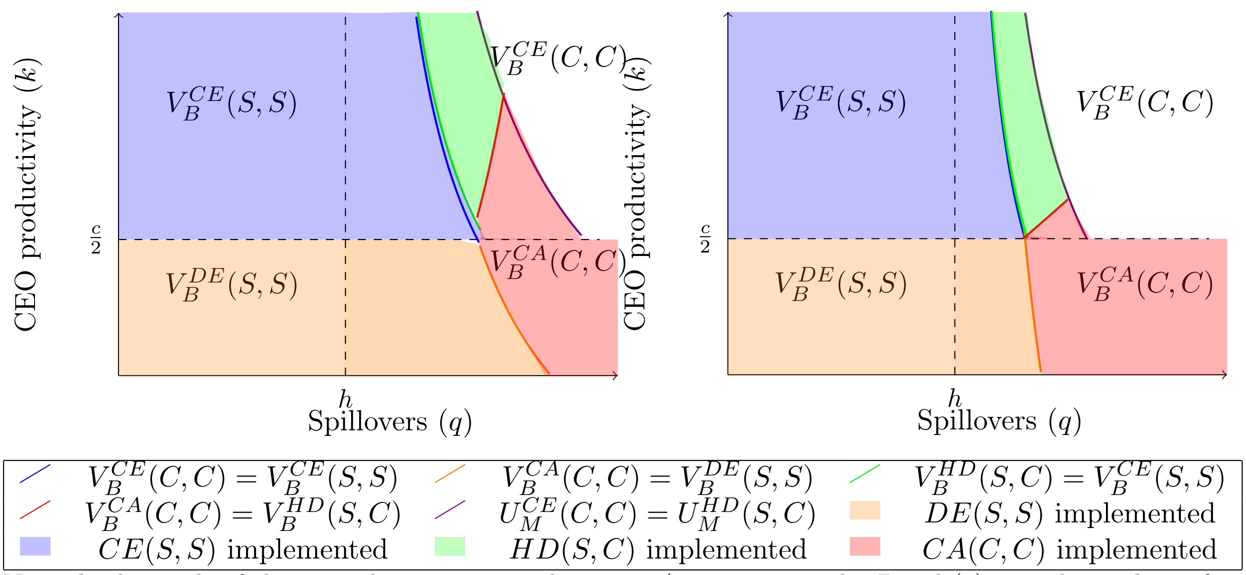
[48] We are considering that the ratio q/h needed in decentralization to change the decision set from $d = (S, S)$ to $d = (C, C)$ is greater than the upper limit of this region. So, implicitly, we are considering that $3\alpha^2 - 2\alpha\lambda - \lambda^2 > 0$. However, note that if we consider the comparison between $V^{CA}(C, C)$ and $V^{DE}(C, C)$, $V^{CA}(C, C) > V^{DE}(C, C), \forall q/h \geq 1$

First, centralization is more likely to be dominated as the benefits associated with motivation become more important. That is, our results are more relevant as α increases because the moral hazard problem in the effort choice is more relevant. In contrast, if $\alpha \to 0$, no individual has intrinsic motivation (incentives) to exert effort; then the decision rights (and thus λ) are allocated to the most productive individual because there is no conflict of interest with the owner. Thus, the double moral hazard problem disappears which overrides the possibility of having hierarchical delegation or cross-authority. Centralization is always optimal as long as the CEO is more productive than agents (i.e., $k \geq c/2$). Consequently, motivation is crucial for our results to hold.

Second, the value of authority is relevant to understanding which organization, hierarchical delegation or cross-authority, is the best to replace centralization. Recall that the value of authority is important both in decision-making and also in the extra incentives to exert effort. Then, cross-authority provides better incentives to make good decisions at the cost of reducing the incentives to exert efforts due to authority. Hierarchical delegation provides better incentives to exert efforts relegating the accuracy of decisions over some projects. If $\lambda \to 0$, the value of authority to incentivize effort is reduced. Then, cross-authority becomes more important.

Therefore, the incentives to replace centralization depend on the parameters λ and α. Graphical examples complement this analysis. Recall that figure 3 illustrated the results for $(\alpha, \lambda) = (1/3, 1/3)$. Figures 5a and 5b, available in Appendix D, show the results for $(\alpha, \lambda) = (2/5, 1/5)$, increasing the share to the effort choice and decreasing the share due to decision rights, and $(\alpha, \lambda) = (1/2, 1/4)$, reducing the share to the effort choice and increasing the share due to decision rights, respectively. These examples emphasize the importance of α, as the area where hierarchical delegation and cross-authority have become optimal increases in this motivation parameter. This provides insight into the results discussed in the next section.

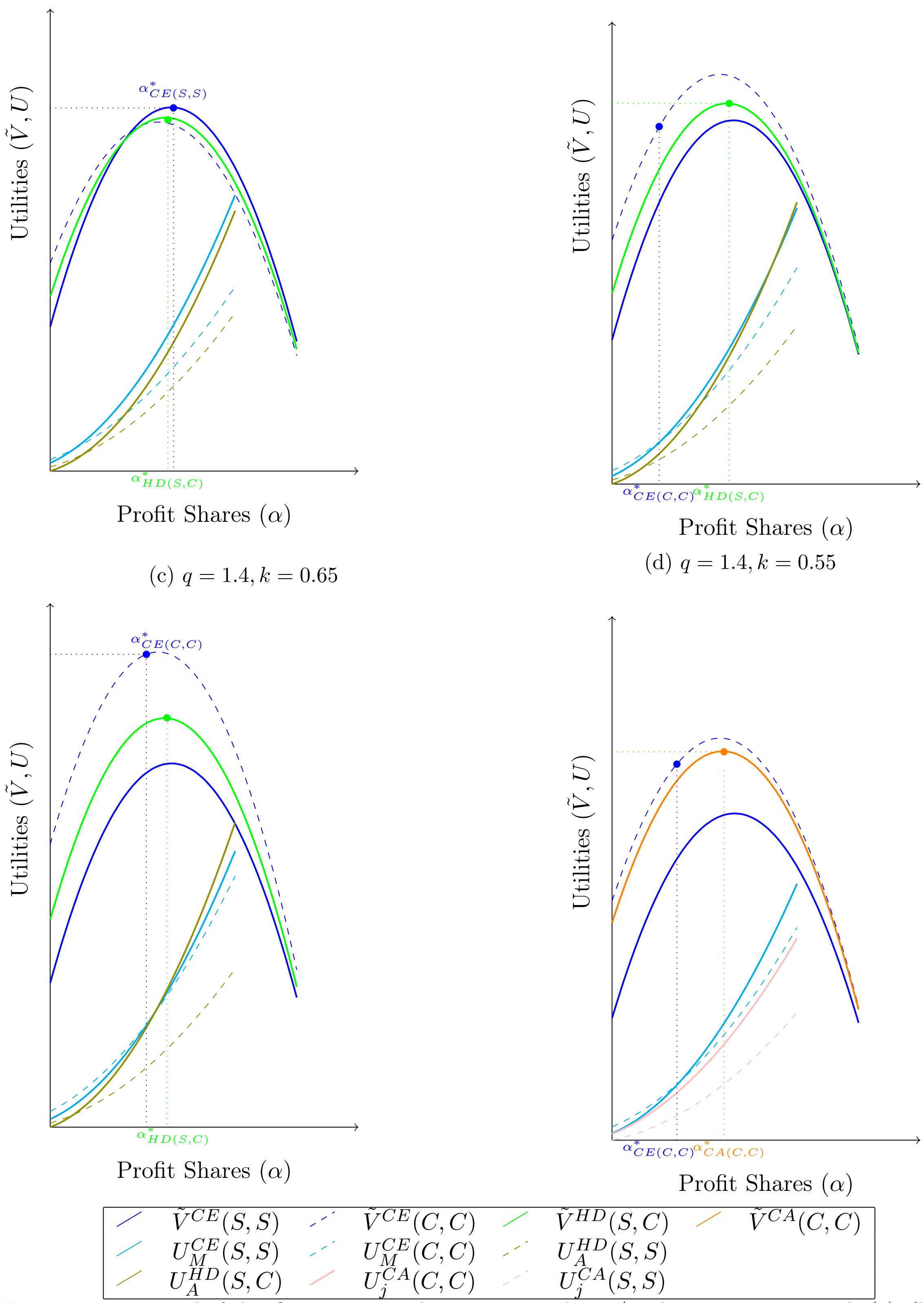
(a) Example 1 (b) Example 2



Note: both panels of this consider parameters $h = c = 1/2$ as an example. Panel (a) considers values of $\alpha = 2/5$ and $\lambda = 1/5$ while panel (b) considers values of $\alpha = 1/4$ and $\lambda = 1/2$.

E. Robustness

Figure 6: Payoffs as a function of α. Endogenous α



(a) $q = 1.2, k = 0.65$

(b) $q = 1.3, k = 0.65$

(c) $q = 1.4, k = 0.65$

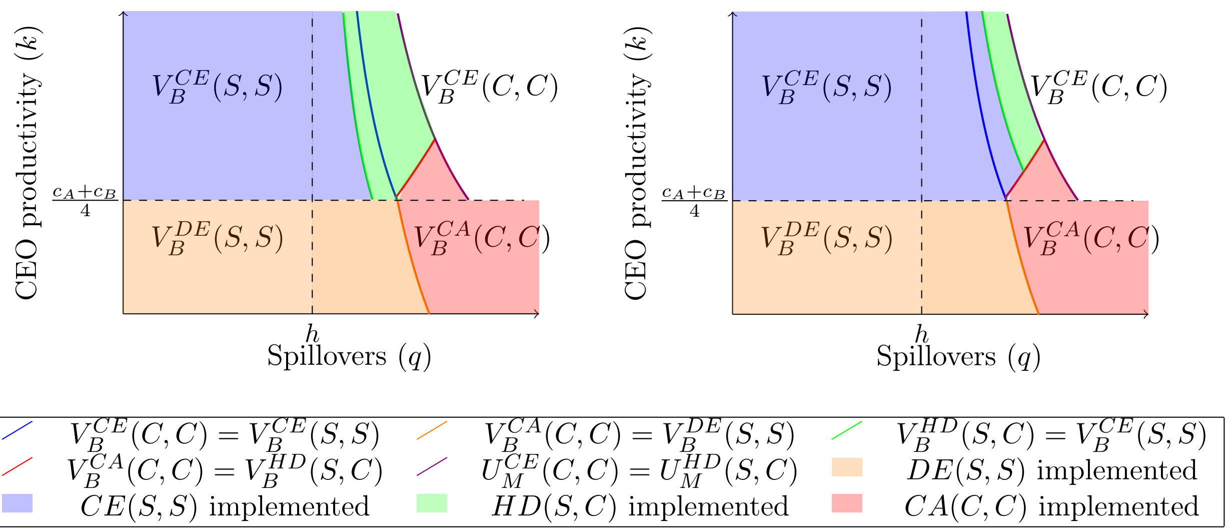
(d) $q = 1.4, k = 0.55$

Notes: in every panel of this figure we consider parameters $\lambda = 1/10, h = c = 1$. For panels (a), (b) and (c) we take $k = 0.65$ and $q \in \{1.2, 1.3, 1.4\}$. Finally, panel (d) considers $k = 0.55$ and $q = 1.4$.

Hetereogenous Agents

Figure 7: Heterogeneous agents

(a) Delegation to the most productive agent (b) Delegation to the less productive agent



Note: This figure considers that the parameters $\alpha = \lambda = \frac{1}{3}$, $h = \frac{1}{2}$ and $c_A = \frac{2}{3}$ and $c_B = \frac{1}{3}$ as an example. The green line also depicts $V_B^{CE}(S,C) = V_B^{CE}(S,S)$.

F. Case of study

Table 1: Statistics of users by App

App	2010	2014	2018
Facebook	608 mill. -	1,400 mill. (130%)	2,300 mill. (64%)
Whatsapp	10 mill. -	600 mill. (590%)	1,500 mill. (159%)
Instagram	-	200 mill. -	1000 mill. (400%)

Note: the number of users in millions are available at `statista.com`, `datareportal.com` *and* `demandsage.com`. *Instagram was founded in 2010. In parenthesis we report the increasing rate with respect to the previous period.*

Online Appendix

Share of profits over both projects

Assume that instead of offering a share α of the profit in the project the individual puts effort in, each individual gets a share α of the profits from both projects, $1 \geq 3\alpha + \lambda$. In that way, equation (6) becomes:

$$U_j^Y(d,e) = \alpha\Big(E(\pi_A) + E(\pi_B)\Big) + \lambda\Big(X_{MA}E(\pi_A) + X_{MB}E(\pi_B)\Big) - g(e_j). \tag{L12}$$

Note that in this case the CEO and the agents have the same incentives to make efforts and decisions. We replicate propositions 2, 3 and from A1-A8. We summarize these results in the next table.

Table 2: Summary of the results

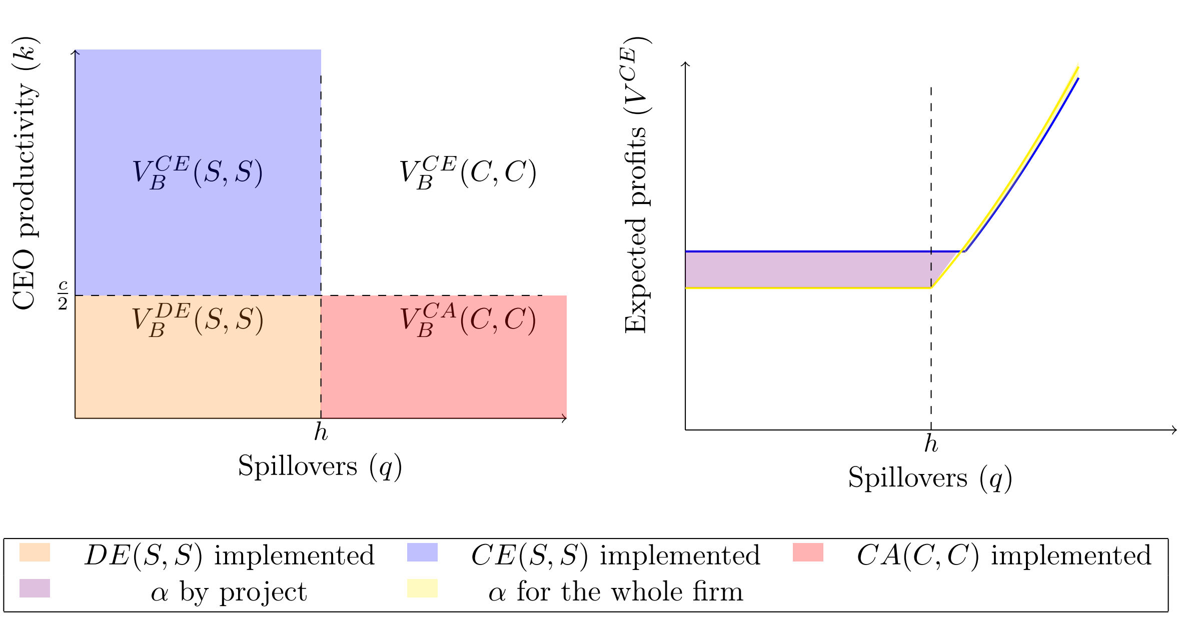
	CE (S,S)	C(C,C)	DE(S,S)	CA(C,C)	HD(S,C)
e_M^*	$2k(\alpha+\lambda)h$	$2k(\alpha+\lambda)q$	$2k\alpha h$	$2k\alpha q$	$k(\alpha+\lambda)(h+q)$
e_j^*	$c\alpha h$	$c\alpha q$	$c(\alpha+\lambda)h$	$c(\alpha+\lambda)q$	$e_A = c\alpha h$, $e_B = c\alpha q$
U_M^*	$(2k(\alpha+\lambda)^2$ $+2c(\alpha+\lambda)\alpha)h^2$	$(2k(\alpha+\lambda)^2$ $+2c(\alpha+\lambda)\alpha)q^2$	$(2k\alpha^2$ $+2c\alpha(\alpha+\lambda))h^2$	$(2k\alpha^2$ $+2c\alpha(\alpha+\lambda))q^2$	$(\frac{k(\alpha+\lambda)^2}{2}$ $+c\alpha(\alpha+\lambda))(h^2+q^2)$
U_A^*	$(4k(\alpha+\lambda)\alpha$ $+c\alpha^2)h^2$	$(4k(\alpha+\lambda)\alpha$ $+c\alpha^2)q^2$	$(4k(\alpha+\lambda)\alpha$ $c(\alpha+\lambda)^2)h^2$	$(4k(\alpha+\lambda)\alpha$ $c(\alpha+\lambda)^2)q^2$	$(k(\alpha+\lambda)\alpha$ $+c\alpha)(\frac{h^2}{2}+q^2)$
U_B^*	$(4k(\alpha+\lambda)\alpha$ $+c\alpha^2)h^2$	$(4k(\alpha+\lambda)\alpha$ $+c\alpha^2)q^2$	$(4k(\alpha+\lambda)\alpha$ $c(\alpha+\lambda)^2)h^2$	$(4k(\alpha+\lambda)\alpha$ $c(\alpha+\lambda)^2)q^2$	$(k(\alpha+\lambda)\alpha$ $+c\alpha)(h^2+\frac{q^2}{2})$
V^*	$(4k(\alpha+\lambda)$ $+2c\alpha)h^2$	$(4k(\alpha+\lambda)$ $+2c\alpha)q^2$	$(4k\alpha$ $+2c(\alpha+\lambda))h^2$	$(4k\alpha$ $+2c(\alpha+\lambda))q^2$	$(k(\alpha+\lambda)$ $+c\alpha)(h^2+q^2)$

From the last row of Table 2, we can clearly see that, in the benchmark scenario, the owner prefers centralization with two cooperative decisions over centralization with two selfish decisions when $2k \geq c$ and $q \geq h$. Additionally, the owner prefers centralization with two selfish decisions to decentralization with two selfish decisions when $2k \geq c$, and the reverse holds otherwise. Finally, he prefers centralization with two cooperative decisions over cross-authority with two cooperative decisions when $2k \geq c$, and cross-authority with two cooperative decisions over decentralization with two selfish decisions when $q \geq h$ and $2k < c$. The same analysis can be applied using utilities rather than profits, and in this context, hierarchical delegation is never optimal, as the payment scheme always coordinates the first-best decisions. These results are illustrated in panel 8a.

An important feature of this payment scheme is that it is efficient at coordinating decisions, and therefore particularly valuable when spillover returns are high. However, as soon as motivation returns become more important (i.e., $h > q$), it becomes relatively inefficient at motivating effort. We illustrate this in panel 8b, where we compare the optimal value under centralization (with the owner's optimal decisions) in the regular model (shown in blue) and in this model (shown in yellow). We observe that when $q \geq h$, the regular model performs significantly better. The violet-shaded area indicates the additional value that this per-project share α contributes to the organization. Conversely, once $q > h$ exceeds a certain threshold, the firm-wide α payment scheme starts to outperform, primarily by coordinating decisions correctly and also by providing stronger incentives under those coordinated decisions.

Figure 8: Share of profits over both projects

(a) Optimal Organizational Design (b) Comparison of firm profits



Note: panel (a) considers that the parameters $\alpha = \lambda = 1/3$ and $h = c = \frac{1}{2}$ as an example. Panel (b) considers additionally to the previous values, $k = 0.42$ and that the $\alpha = \frac{2}{9}$ for the model stated in the online appendix.

Contingent contracts on efforts' outcome

In this section we consider the case where the owner can offer a contract that conditions payments on each combination of projects' outcome, as in Kräkel (2017). That is, the owner observes a signal $R_j \in \{0, 1\}$ indicating whether project j is successful or not; i.e., 1 or 0, respectively. In particular, we denote the stochastic relationship between efforts and outcomes as $P_j = P(R_j = 1|e_M, e_j) = e_M + e_j$ and $P(R_A = 1, R_B = 1|e_M, e_A, e_B) = P_A P_B$; this means that signals realization, as projects, are independently distributed.

The payment scheme defines a payment w^i to agent i conditioning on (R_A, R_B). After choosing the organizational design y, the owner offers agent $i \in \{M, A, B\}$ a collection of payments $\mathcal{W}(Y) := \{w^i_{11}, w^i_{10}, w^i_{01}, w^i_{00}\}$ conditional on outcomes; e.g., w^A_{11} is the payment to Ari when both projects succeed. To keep the model close to our previous assumptions we assume that agents are protected by limited liability and, therefore, $w \geq 0, \forall w \in \mathcal{W}$. Still, a share λ of profits in project i is appropriated by the decision maker of project i.[49]

The preferences of every member are modified as follows. The Owner utility is denoted as:

$$V(d,e) = (1-\lambda)\Big(E(\pi_A) \ + \ E(\pi_B)\Big) - 2E\Big(\sum_{i=A,B,M} w^i\Big) \tag{L13}$$

The utility of the CEO is denoted by:

$$\begin{aligned} U_M^Y(d,e) = P_A P_B w_{11}^M + P_A(1-P_B)w_{10}^M + (1-P_A)P_B w_{01}^M \\ (1-P_A)(1-P_B)w_{00}^M + \lambda\Big(X_{MA}E(\pi_A) + X_{MB}E(\pi_B)\Big) - g(e_M). \end{aligned} \tag{L14}$$

Each agent utility is expressed as follows:

$$\begin{aligned} U_j^Y(d,e) = P_A P_B w_{11}^j + P_A(1-P_B)w_{10}^j + (1-P_A)P_B w_{01}^j \\ (1-P_A)(1-P_B)w_{00}^j + \lambda\Big(X_{jA}E(\pi_A) + X_{jB}E(\pi_B)\Big) - g(e_j). \end{aligned} \tag{L15}$$

The principal maximizes the same program characterized by (7), but choosing not only $Y \in \mathcal{Y}$ but also $w \in \mathcal{W}$, and considering $V(d,e)$, $U_M^Y(d,e)$ and $U_j^Y(d,e)$ in the equations (L13), (L14) and (L15) respectively.

This extension generates a model of moral hazard with limited liability in each organizational design. Laffont and Martimort (2002) and also Fleckinger et al. (2024) provides a full description of its solution, consequently we omit the proof here. The only positive contract is the one with the highest incentive efficiency, using Holmström (1979) sufficient statistics. The following lemma presents the optimal incentive schemes and efforts motivated by each organizational design y. Denote $\Lambda^M := X_{MA}\Big(h(d_A)+q(d_B)\Big)+X_{MB}\Big(h(d_B)+q(d_A)\Big)$ and $\Lambda^j := X_{jj}h(d_j)+X_{jj'}q(d_j), j \in \{A,B\}$ and $j \neq j'$, which represents the additional incentives to make effort that the individuals get by making decisions.

Lemma 1: The optimal incentive scheme for the CEO is $\{w_{11}^M, 0, 0, 0\}$ and the optimal effort is:

$$w_{SS}^M > 0, \qquad e_M^* = \frac{w_{SS}^M kc(\lambda(\Lambda^A+\Lambda^B)-\overline{w}^A-\overline{w}^B)-k\lambda\Lambda^M}{1-2kw_{SS}^M} \tag{L16}$$

and for Ari A is $\{w_{11}^A, w_{10}^A, 0, 0\}$ and for Bob is $\{w_{11}^B, 0, w_{01}^B, 0\}$ respectively. Where

$$w_{11}^A = w_{11}^A = \overline{w}^A > 0, \qquad e_A^* = c(\lambda\Lambda^A + \overline{w}^A), \tag{L17}$$

$$w_{11}^B = w_{11}^B = \overline{w}^B > 0, \qquad e_B^* = c(\lambda\Lambda^B + \overline{w}^B) \quad . \tag{L18}$$

Proof. *Omitted. Comparison of the incentive efficiency of each contract, the one with the highest efficiency is the positive one. The optimal effort is computed through the IC_e, by maximizing the utility of each individual with respect to each effort.*

[49] Kräkel (2017) incorporates a profit of R when project i succeeds, that we eliminate in this extension.

Let's remark some aspects from *lemma* 1. First, effort reacts to both incentives form, the contingent contract and the authority value the individual has over the project he has authority. In particular, both sources of incentives are substitutes, which is exactly the opposite to the main model exposed in this paper. Second, the optimal effort increases with high productivity of the individuals. Third, the optimal incentive scheme for the manager is a team bonus (depends on the success of both projects since his effort affects both projects), while the incentive scheme for the agents is independent of the result of the other project. Moreover, the effort decision of the manager is affected by the decision made by himself and by the agents (depending on authority allocation) while the effort of the agents only depend on their own decision choice.

Lemma 2: Optimal decisions.

- When an individual is allocated one decision right, he always makes selfish decisions.
- When an individual is allocated both decision rights, he makes selfish decisions when $h > q$ and cooperative otherwise.

Proof. Consider the expression for the ex-post profits allocated to individual j:

$$\lambda\big(X_{jA}(h(a) + q(b)) + X_{jB}(h(b) + q(a))\big).$$

Assume that individual j has decision rights over project A but not over B. Then, j will act selfishly if he aims solely to maximize the ex-post profits allocated to him. Note that decisions influence the optimal effort levels, since the timing between actions is sequential. However, this influence is a second-order effect, as the authority payment is an addition on top of the optimal incentive contract.

Because of this, the increase in effort by the other agent is never sufficient to offset the loss in ex-post profits caused by switching from selfish to cooperative decisions. The proof is straightforward: one simply needs to incorporate the optimal effort levels e^*_M, e^*_A, e^*_B into the IC_d constraint and verify that the required spillover benefits q to sustain cooperation lie outside the admissible range we have set for q.

Now assume that individual j holds decision rights over both projects. In this case, to maximize his allocated ex-post profits, he will choose action C if $q \geq h$, and S otherwise. The second-order effect on effort discussed above still applies. □

From this *lemma*, we derive two important observations: (i) Cross-authority, partial, and hierarchical delegation cannot implement any form of cooperation; (ii) Only centralization and concentrated delegation can sustain cooperative behavior.

Another key implication is that the sequential timing in our framework does not overturn the core results of Kräkel (2017). Since the owner has access to an optimal contract that targets effort directly, any additional incentive created by the assignment of authority affects effort only at the second order. Furthermore, the structure of the payment scheme implies that authority cannot be used to incentivize cooperative decisions—only to restrict the feasible organizational forms.

As a result, only centralization and concentrated delegation enable cooperation, particularly when spillover returns are sufficiently large.

The remaining two optimal designs—partial delegation and decentralization—emerge respectively when: (i) the CEO is moderately less efficient than both agents but more efficient than one of them; or (ii) the CEO is less efficient than both agents and spillover returns are relatively low. Note that partial delegation is optimal when agents are slightly more productive than the CEO, but each influences only one project.

Thus, the core trade-off in this framework is not between motivation and cooperation, but between *specialists* and *generalists*.