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Strategic Resource Allocation: Top-Down, Bottom-Up, and the Value of Strategic Buckets

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When senior managers make the critical decision of whether to assign resources to a strategic initiative, they have less precise initiative-specific information than project managers who execute such initiatives. Senior management chooses between a decision process that dictates the resource level (top-down) and one that delegates the resource decision and gives up control in favor of more precise information (bottom-up). We investigate this choice and vary the amount of information asymmetry between stakeholders, the "penalty for failure" imposed upon project managers, and how challenging the initiative is for the firm. We find that no single decision process is the "best." Bottom-up processes are beneficial for more challenging initiatives. Increased organizational penalties may prompt the firm to choose a narrower scope and deter the approval of profitable initiatives. Such penalties, however, enable an effective decision process known as "strategic buckets" that holds the potential to achieve first-best resource allocation levels.

Keywords: resource allocation processes; strategic buckets; empowerment; innovation strategy; new product development strategy; corporate culture

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1. Introduction

Senior management's strategic resource allocation decision has significant implications on a firm's viability (Wheelwright and Clark 1992, Cooper et al. 2001, Chao and Kavadias 2008, Klingebiel and Rammer 2014). Specifically, senior management must decide how much funding, if any, should be assigned to a particular strategic initiative. Yet, at the time these funding decisions are made, the precise details regarding how the initiative will be executed are rarely understood. Knowledge of how to execute the initiative is dispersed throughout different layers of the firm's organizational hierarchy, which gives rise to significant information asymmetries. As a result, the decision process employed by senior management influences the scope of the initiative and the funding the initiative receives, including the possibility that the initiative is not funded. The fact that the strategic resource allocation processes shape what initiatives a firm funds is not, by itself, new (Bower 1970, Burgelman 1983, Bower and Gilbert 2005). Yet, understanding *how* the chosen processes determine *which* initiatives the firm funds is an important and underresearched operational element that determines strategy execution.

The decision process senior management employs to choose the level of resources to allocate to a strategic initiative falls within two broad categories: top-down or bottom-up. In *top-down* processes, senior management dictates a fixed resource level to middle management (e.g., project managers) to oversee. Alternatively, *bottom-up* processes grant the project manager the *decision rights* (Aghion and Tirole 1997) to determine the level of resources to assign (Maritan 2001, Chao and Kavadias 2009, Kavadias and Kovach 2010). Whereas a top-down process allows senior management to maintain explicit *control* over the resource level decision, a bottom-up process allows senior management to utilize the project manager's initiative-specific knowledge to better *tailor* the resource level decision to the needs of a particular initiative. Both methods are widely advocated and encountered in practice, yet little guidance has been offered regarding the context-specific application of either decision process.

There is, however, an additional decision process employed by practitioners known as "strategic buckets" that has received much less attention from the academic community. A strategic-buckets decision process seeks to maintain some of the control achieved through a top-down process and still utilize the specialized knowledge of the project manager, as in a bottom-up process. To achieve this, senior management defines distinct categories of initiatives (e.g., low and high risk) and assigns a specific level of resources to each specific category. Practitioner studies have observed that firms that follow a strategic-buckets decision process tend to outperform other firms, citing that a strategic-buckets process enables firms to better "earmark funding" for initiatives that are deemed particularly difficult and/or risky to execute (Cooper 2005, p. 19). We investigate whether the use of a strategic-buckets process can serve another inherently valuable purpose for the firm: serve as a simple and effective means to overcome the information asymmetry between senior management and the project manager.

Scholars have long studied the efficient implementation of top-down resource allocation (Harris et al. 1982). More recently, though, operations management scholars have incorporated decision-making processes that account for the hierarchical nature of decision making within organizations (Siemsen 2008, Chao et al. 2009, Mihm 2010, Mihm et al. 2010, Sting and Loch 2012). Primarily, these studies have emerged within the domain of new product development (NPD) as a result of the obvious fit. In other words, NPD is a highly specialized activity (Zingales and Rajan 2001) which requires expertise that is largely dispersed across numerous stakeholders at various levels within the organization. Most prior studies, however, choose to focus on the unobservable, i.e., private, effort of product development specialists. Instead, we focus on the funding of an initiative as a driver of success and argue that the level of funding is observable and verifiable, and that senior management faces a fundamental challenge with the information asymmetry that exists between the top of the organizational hierarchy and those lower down in the hierarchy, i.e., those closer to the execution of the project are more familiar with the details of what is required to complete specific tasks. Given this information asymmetry, the decision process that senior management employs to choose the level of resources for a strategic initiative is defined by the allocation of decision rights between each of the stakeholders in the process.

We seek to understand when senior management would prefer each resource allocation process and what the key implications are, given the reality of an organizational hierarchy, and the information asymmetries that exist between mid-level and senior-level management. We model the hierarchical nature of decision making through a principal–agent model; senior management (the principal) decides the *scope* of the initiative based on strategic fit, and a project manager (the agent) oversees the detailed execution of the initiative. The strategic resource allocation process defines whether the senior manager or the project manager decides on the resource level.

We capture the information asymmetry between senior management and middle management by how well they understand the *difficulty* of the initiative. We define the difficulty of an initiative as follows: for any given level of resources, the more difficult an initiative is, the lower its chance of succeeding. Said differently, more difficult projects require a greater allocation of resources to achieve the same chance of success. We acknowledge that a project manager obtains better information regarding the exact difficulty of a particular initiative. Put another way, the project manager knows the difficulty of the initiative, whereas senior management only knows the likelihood of the initiative's difficulty. Our definition of difficulty also captures the reality that more difficult initiatives may never be able to achieve as high a likelihood of success as a simpler project, regardless of the resources allocated to an initiative.

We consider a straightforward setting where the project manager would rather avoid the consequences imposed by the organization following a failed initiative. Managers of failed projects may face varying levels of organizational penalties, either explicit, i.e., forgone bonuses and/or promotions, or implicit, i.e., intraorganizational status. Such an organizational penalty constitutes an important element of a firm's corporate culture (Kreps 1990, Schein 2010, Hermalin 2013).

Our analysis reveals that there are instances where top-down decision processes yield more value to the firm than bottom-up processes, but that the reverse can also be true: a bottom-up decision process can generate more value than a top-down one. These results provide normative support regarding the need for both bottom up and top-down decision processes to coexist within an organization, as advocated early on by Burgelman's (1983) seminal work. We offer a detailed characterization of these settings.

Additionally, our results identify how the chosen resource allocation process impacts senior management's *scope* decision. Specifically, although senior management cannot decipher what the actual difficulty of an initiative is, they recognize that there is a limit to the magnitude of difficulty that the firm should undertake. Thus, senior management decides on this level and informs the project manager of such a limit, but more importantly provides incentives that are aligned with such a decision. The incentives induce the project manager to only pursue initiatives with difficulty levels that fall within the "acceptable" range. We interpret this acceptable range as the scope of the initiative. Our characterization of bottom-up and top-down strategic resource allocation details how an increased organizational penalty drives senior management to limit the scope of strategic initiatives, effectively limiting the strategic options available to the firm.

Finally, we identify and analyze how the use of strategic buckets can enhance the effectiveness of a firm's strategic resource allocation. The idea behind strategic buckets is straightforward: resource levels are defined for specific categories of initiatives, i.e., specific ranges of difficulty, without offering any sophisticated compensation contracts. Such a method of strategic resource allocation rests upon the ability to "sort" the initiatives into the appropriate category to enable the firm to capture the benefits of a bottom-up process while still maintaining some control over the resource decision, similar to a top-down process. We analyze the implementation of strategic buckets and explain how a first-best allocation of resources can be achieved and, additionally, how strategic buckets can enable the pursuit of an expanded scope for a given strategic initiative. In the end, we offer a potential explanation for why strategic buckets are commonly associated with higher performing companies.

2. Related Literature

A substantial body of research across management disciplines has addressed various challenges surrounding resource allocation decisions. The literature that is most relevant to our work comes from the disciplines of operations management, strategic management, and corporate finance.

Scholars have looked at the resource allocation problem in an effort to answer the following question: should a firm fund (or continue funding) a specific initiative (e.g., Weitzman 1979, Huchzermeier and Loch 2001, Santiago and Vakili 2005)? This stream of research builds upon a long tradition in the field of operations research and considers a decision process where the decision maker is also the executor of the project tasks. We relate to the overarching objective of these papers, as we also look at the decision process associated with resource allocation and the choice to fund a project. We take a different perspective, however, as we account for the realities of the strategic resource allocation processes in modern organizations: hierarchical decision making and the distributed nature of knowledge, which gives rise to agency and incentive challenges.

More recently, new product development scholars have begun to account for the hierarchical nature of decision making (Siemsen 2008, Chao et al. 2009, Mihm 2010). The work of Chao et al. (2009) is the closest to ours, as they study a hierarchical setting where a senior manager (the principal) chooses between *empowering* a business unit manager (the agent) to adapt the innovation budget to the division sales and *controlling* new product development activities through a fixed budget. Given the funding policy, the agent decides to optimally allocate resources to exploration (long term) or exploitation (short term) initiatives. Chao et al. (2009) compare different funding policies, but they do not characterize the optimal funding decisions for the principal in any of these settings. We extend their setting to characterize and compare the optimal funding decision across different resource allocation processes. We also note that whereas Chao et al. (2009) assume that the exact budget may not be observable by the principal, we posit that the resources allocated are in fact observable by senior management. Instead, a more suitable source of asymmetry between the stakeholders arises from their initiative-specific knowledge as opposed to cost-accounting "noise."

Our research question also echoes prior attempts to determine the optimal resource allocation from the field of capital budgeting (Harris et al. 1982, Antle and Eppen 1985, Baiman and Rajan 1995), which has flourished in the accounting and corporate finance disciplines. We share their conceptualization of the resource allocation problem, and we agree with the assumptions made in this literature: decisions are decentralized and hierarchical, there exists asymmetry of information between the stakeholders, and the compensation and incentive schemes rely on incomplete contracts. However, the context of strategic product development initiatives presents distinct challenges that are not of primary concern to this stream of literature: (i) the assumed returns on investment exhibit strong nonlinearities (Loch and Kavadias 2002), different from the additive or linear profit functions predominantly used in capital budgeting; (ii) these nonlinearities stem from strong complementarities between the resources allocated and the difficulty of tasks being executed, i.e., a disproportionate increase in the resources allocated is required for more difficult projects; (iii) the specialized know-how held by the project team is tacit and not imitable by the senior management of the firm, and therefore substitution of effort between stakeholders is rarely an option; and finally, (iv) the disutility a project manager incurs may be a result of organizational norms (i.e., penalties resulting from a failed initiative) and not solely a result of effort put toward a project. Our model formulation operationalizes the decision process associated with strategic resource allocation to account for these distinctions.

Finally, we owe special credit to the seminal work of Bower (1970) and Burgelman (1983) in the strategic management discipline. They offer substantial field evidence about the structure of the resource allocation processes found in organizations. Their insights have given way to a debate about the benefits arising from bottom-up versus top-down resource allocation processes, and they have informed many of the constructs of our model (for a thorough review, see Bower and Gilbert 2005). However, the primary research method applied in these studies has been descriptive field research (Bower and Doz 1979, Burgelman 1983, Maritan 2001). We borrow their grounded theory to develop a normative model that seeks to explain and extend their findings. In that vein, our work operationalizes the choice of resource allocation processes within a hierarchical organization.

3. Model Setup

Consider a typical organizational hierarchy: Senior management (the principal) oversees a project manager (the agent), who is responsible for executing strategic product development initiatives. The project manager represents all of the interests and knowledge of the project team, whereas senior management acts as a proxy for the firm's interests and is responsible for implementing corporate strategy through a specific initiative. Senior management defines the scope of the initiative and decides if the initiative should be funded, and thus assigned to the project manager, by maximizing the net value the initiative generates for the firm.[1]

Prior research (Bower 1970, Burgelman 1983, Coen and Maritan 2011) has identified a critical organizational factor that influences the decision to fund an initiative: the *structural context* within which the initiative is carried out, that is, the "formal organization, the way businesses are measured, and the way functional and general managers are measured and rewarded" (Bower and Gilbert 2005, p. 32). Given the specificities of the initiative and its structural context, researchers have advocated that successful execution and profitability depend on elements of the resource allocation process, i.e., which stakeholder decides what (Bower and Gilbert 2005).

To map our abstraction of a strategic resource allocation problem to a real-world setting, we consider a large bicycle company, which we refer to as "Bikes by Z," or BZ, that has just gone through their yearly strategic planning process. Senior management at BZ is considering a new initiative to pursue in support of their strategy. The process that BZ's senior management uses to evaluate the expected profitability from the initiative constitutes their strategic resource allocation process; this activity occurs prior to any actual expenditure.

In the following three subsections we detail the three constructs that are essential elements of any strategic resource allocation process: the properties of the initiative, the organizational context, and the structure of the decision process associated with strategic resource allocation. We employ these constructs to characterize the decision process that yields the maximum value for a particular initiative and firm. Throughout each of these subsections we use our example of BZ as an ongoing mapping from our model to a real managerial setting.

3.1. The Strategic New Product Development Initiative

An initiative is defined by the value it could generate if its outcome is a success and the probability that such a success occurs. We assume that the potential value v is fixed, and known by all of the stakeholders, i.e., the senior manager and the project manager. The probability of success depends on two key factors: the difficulty the initiative represents to the firm and the resources allocated to the initiative.[2] We define an initiative's difficulty in a very straightforward manner: a difficult initiative requires more resources than a simple one to have the same likelihood of success. Said differently, given the same resource allocation, a more difficult initiative has a lower chance of success. Furthermore, the firm may never be able to achieve the same likelihood of success for a more difficult initiative as it could for a simple one. As such, the initiative's difficulty also represents the maximum likelihood of success the initiative can have regardless of the resources invested. In that regard, our conceptualization of difficulty classifies initiatives into those that are difficult (i.e., more radical), with a higher chance of failure, and those that are standard (i.e., more incremental) and exhibit a greater chance of success.

Senior management at BZ has identified an initiative that supports the key growth objective. The initiative would expand their current product offering of bicycles to include a product line of off-road motorcycles. BZ has established itself through the successful design and manufacture of technologically advanced full-suspension off-road bicycles. Based on this success, BZ's senior management estimates that substantial value could be appropriated if they could extend these capabilities to include the successful development and production of an off-road motorcycle. However, such an initiative might pose a significant challenge to BZ. In fact, when BZ's senior management proposed the motorcycle initiative, it was common knowledge that, at best, the initiative would be straightforward to execute, i.e., their advanced frame design and suspension design expertise could

[1] Value can be thought of as monetary cash flow, monetary equivalents, or other outcomes, e.g., intellectual property.

[2] These assumptions are not restrictive. In the sections that follow we show that what matters is the expected value.

prove superior to that found in the off-road motorcycles. On the other hand, it is likely that the initiative turns out to be significantly more difficult, i.e., the frames and suspension associated with a much heavier, internal combustion engine powered vehicle could lead to fundamentally different engineering design challenges.

The project manager of the strategic initiative has the opportunity to learn the firm-specific difficulty that a particular initiative represents, captured by δ. The difficulty ranges from an impossible initiative, with $\delta = 1$ representing a probability of success equal to zero, to a "standard" initiative, with $\delta = 0$ representing the most straightforward type of initiative. For example, developing an off-road motorcycle likely represents a different level of difficulty for BZ than it would for an established producer of off-road motorcycles. Initially, the senior manager and the project manager hold common beliefs regarding the difficulty of the initiative, $\delta \sim g(\delta)$. Yet, after the project manager has completed his due diligence, he obtains a better understanding of the true difficulty; in a stylized manner we assume he learns the true difficulty of the initiative, δ. Lacking such knowledge, the senior manager must rely on the project manager for any refined information.

The probability that an initiative ultimately turns out to be a success is a function of the resources allocated. Let $r \in \mathbb{R}^+$ be the level of resources allocated to the initiative; then the probability of success is defined as $\mathbb{P}[\delta, r] = (1-\delta)p[r]$. We assume that $p[r]$ is concave with respect to r, $p[0] = 0$, and $\lim_{r\to\infty} p[r] = 1$. Our structural assumptions represent a set of intuitive properties: the likelihood of success is increasing in both the resources allocated to the initiative and the ease of the initiative; the likelihood of success exhibits diminishing returns with regard to the resources allocated; finally the resources allocated and the ease by which the tasks are executed are complementary inputs to the likelihood of success. Indeed, more difficult initiatives require a disproportionately higher level of resources to achieve a given likelihood of success. Furthermore, more difficult initiatives may never achieve the same likelihood of success as standard ones, regardless of the level of resources allocated.

3.2. Organizational Context

Another important aspect that impacts the decision process is the organizational context. Specifically, the organizational rules that implicitly govern how "things get done" within a firm. Such (usually non-codified) rules comprise an organization's corporate culture (Kreps 1990, Chao et al. 2009, Schein 2010, Hermalin 2013). We focus on a particularly important dimension, the consequences that project managers face when they are held accountable for the failure of an initiative. There is ample evidence that organizations differ in the consequences they impose following failed outcomes (e.g., a diminished intraorganizational status reflected in the career paths or development programs the manager is considered for). This dimension of a firm's "tolerance for failure" has recently drawn attention as an important determinant of task choice and execution (Manso 2011).

Based on field interviews with senior executives, we have found that the consequences associated with failed initiatives are strongly dependent on the magnitude of resources, r, allocated to an initiative. Even in a harsh corporate environment, an initiative that fails, yet consumes negligible resources, would not warrant detrimental consequences for the project manager's career. However, when an initiative consumes an egregious amount of organizational resources and fails, then the consequences are, ceteris paribus, proportionally much greater.

We capture the relationship between the organizational penalty and the resource level through a linear parametrization: $k_p r$, where $k_p > 0$ is fixed for a specific organization as a dimension of its corporate culture. Although the resulting penalty the project manager faces is a linear parametrization, we make the assumption that the expected penalty, $k_p r(1-(1-\delta)p[r])$, is quasi-concave in the resource allocation, r, for the initiative. Furthermore, we fix k_p to reflect the relative rigidity (or stability) of the implicit policies and accepted routines within an organization. Changes to such organizational traits occur over longer periods of time, and therefore lie outside the scope of this model.

To effectively allocate strategic resources, senior management must ensure that the compensation structure, W, provides adequate incentives to induce the project manager to make the "right" (i.e., most profitable for the firm) decision. Let $W = w + k_s(v - r)$ represent a generic form of compensation offered to the agent. Compensation may be a combination of a fixed wage, w, and an *output-contingent* profit sharing contract, $k_s(v-r)$. Through our analysis we determine which parts of the generic compensation are rendered inactive, i.e., when w or k_s equals zero to effectively implement the specific process.

Two important observations, rooted in field studies, are subsumed in our characterization of the resource allocation processes. First, the project manager has *formal authority*[3] to recommend that an initiative be rejected (Aghion and Tirole 1997). Second, senior management cannot determine (or verify) the true underlying difficulty of the initiative, that is, δ is not

[3] Aghion and Tirole (1997, p. 1) define *formal authority* as "the right to decide" and *real authority* as "the effective control over decisions."

directly contractible. In this sense, the contract senior management offers is incomplete.

Independent of the process that senior management employs to allocate resources, the project manager must receive sufficient compensation so that he does not expect to suffer a loss simply from taking part in the initiative. In other words, his expected utility should at least be equal to his "opportunity cost" ($\underline{U}$) (Baiman and Rajan 1995). In the analysis that follows, we normalize $\underline{U}$ to zero and assume that the project manager's opportunity cost is common knowledge. The interpretation is intuitive: embedded in the opportunity cost is the benefit the project manager can receive, net of switching costs, if they were to choose alternate employment. This captures the reality that a project manager would rather seek out alternative opportunities than risk having their career prospects severely impacted when their exposure to harsh penalties is substantially high.

3.3. The Scope of An Initiative and Decision Rights

When senior management decides to fund an initiative, it does so with a specific scope in mind. The scope for the initiative sets boundaries on what types of initiatives (i.e., difficulty levels) should and should not be pursued. In other words, regardless of which strategic resource allocation process senior managers employ, they always dictate their desired scope for the initiative, i.e., the set of difficulty types, $\mathcal{D}$, for which the firm would like the project manager to proceed with the initiative. This means that the decision to fund an initiative does not always translate into the initiative's full execution; if the project manager recognizes that the difficulty of the initiative is outside the scope set by senior management, they have the authority to recommend that it be abandoned. Yet, because senior managers do not have the detailed knowledge to be able to enforce their desired scope, they must do more than simply request that the project manager recommend abandonment if they recognize the initiative is outside of their desired scope. Instead, senior managers must design the incentives so that they induce the project manager to only accept the initiative if it is within the desired scope, i.e., when $\delta \in \mathcal{D} \subset [0, 1]$. When such incentives are put in place, the project manager recommends the initiative be rejected whenever the initiative turns out to be outside of the desired scope.

Our general conceptualization of the resource allocation decision process allows us to present three specific processes encountered in practice. Two of these have received a great deal of attention, whereas the third has not. First, in a top-down process, the resource decision rests with senior managers, who must make their decision based solely on the distribution of the initiative's difficulty. In our example, BZ's senior management, e.g., the vice president (VP) of research and development (R&D), would decide the level of resources she felt would be appropriate given the capabilities held within the firm. When making her resource decision, she has a specific (desired) scope in mind for the initiative. For example, if the initiative requires a substantial retooling of the current manufacturing process and new design capabilities acquired through additional engineers, then she may not want the initiative to be pursued. However, if the initiative only requires minor retooling of the manufacturing process, i.e., purchasing minimal new tooling, but no additional labor, then she may want the initiative to be pursued.

In a top-down decision process, the senior manager sets the incentive compensation and the resource level, so that the project manager recommends abandoning the initiative if the initiative when the true difficulty falls outside of senior management's desired scope. More specifically, incentives are set so that the project manager only expects to receive utility equal to his opportunity cost when the difficulty of the initiative turns out to be the highest level of difficulty allowed by the scope, i.e., when δ is the greatest element in $\mathcal{D}$. Critically, the senior manager relies upon the project manager to recommend these initiatives be abandoned in to implement their desired scope, i.e., formal authority resides with senior management although real authority resides with the project manager (Aghion and Tirole 1997).

A bottom-up resource allocation process differs in that the resource allocation decision rests with the project manager. Similar to a top-down process, however, the senior manager still has a preferred scope, $\mathcal{D}$, which must be implemented through the discretion of the project manager. Yet, whereas a top-down process allows senior management to influence the project manager through the resource level and compensation decision, a bottom-up process only affords senior management the ability to alter the incentives. Thus, the incentives alone must balance two objectives: inducing the project manager to decide on the most appropriate resource level, i.e., bringing the project manager's utility (or career objectives) more in line with those of the firm, and ensuring that the project manager recommends abandonment of any initiative that falls outside the initiative's scope.

To illustrate the key differences between these two processes, consider the VP of R&D at BZ, who must ultimately decide whether the company should pursue (fund) the proposed off-road motorcycle initiative and, if so, what their desired scope should be and the level of resources such an initiative might require. If a top-down process is employed, the VP of R&D, makes all of these decisions herself. Specifically, she evaluates the scope of the initiative, the project manager's compensation plan, and the resource level in concert with one another to ultimately decide whether to fund the initiative, albeit with limited knowledge of the details of the initiative. If she decides to fund the initiative, she dictates a fixed level of resources that, in tandem with the compensation offered, supports the firm's desired scope. Note, however, that the fixed resource level is allocated independent of the actual difficulty, and there still is the chance that the project manager will recommend abandonment of the initiative once he learns the true difficulty.

A bottom-up process differs, though, in that the VP of R&D involves the project manager beyond using him to implement her desired scope and execute the initiative. In a bottom-up process, the project manager is intimately involved in the resource level decision. Whereas the VP of R&D made the scope, compensation, and resource level decisions followed by the project manager's scope enforcement and initiative execution, now the VP leaves the resource level decision to the project manager. Thus, the VP decides the scope and incentive compensation, and the project manager enforces the scope (i.e., recommends abandonment or not), chooses the appropriate resource level, and executes the initiative (assuming it is within the desired and enforced scope). Critically different from the top-down process, the bottom-up process allows the resources to be tailored to the knowledge the project manager has been able to learn about the initiative. However, there is an important distinction: resource levels are tailored toward the project manager's interests. Under a bottom-up process, if the VP of R&D decides to move forward with the initiative, she solely dictates the incentives offered, keeping in mind that the incentives must induce the project manager to enforce the desired scope while at the same time encouraging him to make the right resource level decision. In the end, although the resource level is tailored to the actual difficulty of the initiative, it is tailored by the project manager, to his preferences.

Although these first two processes are more ubiquitous, we note another process known as strategic buckets (Cooper 2005, Chao and Kavadias 2008, Terwiesch and Ulrich 2009), where senior management determines specific "buckets," i.e., predetermined resource levels tailored to distinct subsets of initiatives, and the project manager determines the appropriate bucket for the initiative.

As an example, BZ could apply the strategic-buckets decision process to the proposed off-road motorcycle initiative as follows: First, assume that BZ has already defined a fixed number of strategic buckets (categories of strategic initiatives). We will assume that BZ has two buckets that are broadly categorized by the risk associated with the initiative: a low-risk bucket (initiatives where a high success probability can be attained if substantial resources are allocated, i.e., low difficulty initiatives) and a high-risk bucket (initiatives where a significant probability of failure remains, even if substantial resources are allocated, i.e., high difficulty initiatives). It follows that low-risk initiatives receive different levels of support (funding) than do high-risk initiatives.

Importantly, a strategic-buckets process combines the positive aspects of a top-down process with those of a bottom-up process. Similar to a top-down process, a strategic-buckets process dictates the funding levels to the project manager. Yet, instead of only one level of resources to accommodate all possible difficulty levels, senior management dictates a resource level for each category of initiatives (i.e., each unique set of difficulty levels), which effectively maps the difficulty levels into distinct buckets. However, reminiscent of a bottom-up decision process, it is the project manager's responsibility to decide which bucket the initiative belongs to. Thus, although senior management retains control over the resource level decision, the ability to correctly tailor the resource allocation to the difficulty of the initiative critically rests upon the project manager. This means that the effectiveness of a strategic-buckets process critically rests upon senior management's ability to provide the proper incentives to the project manager so that the appropriate bucket is chosen.

In our example, BZ's senior management has implemented two buckets. The resource levels for each bucket are designed to induce the project manager to categorize the off-road motorcycle initiative as low risk if it would only require minor tooling and categorize it as high risk if it would require a major retooling and additional labor. Senior management induces the project manager to choose the right bucket through their understanding of the interplay between the penalty for failure and the resource level. Specifically, the same level of resources applied to a more difficult initiative yields a higher chance of failure than when applied to a less difficult initiative, which results in a higher expected penalty. In the end, the penalty for failure acts as an implicit lever that complements the explicit compensation to ultimately induce the project manager to choose the right bucket. Thus, if the project manager at BZ believed the off-road motorcycle initiative to be low risk, but instead assigned it to the high-risk bucket, the utility he would expect from such a decision would be less than if he chose the low-risk bucket.

Table 1 formally presents the optimization programs that senior management faces under a top-down and a bottom-up resource allocation process. As expected, the scope of the project is strongly tied to which decision process is chosen. We summarize

Table 1 Senior Management's Optimization Program for a Top-Down and a Bottom-Up Resource Allocation Process

Top-down	Bottom-up
$\max_{\mathcal{D},r,W} \; \mathbb{E}_{\delta\in\mathcal{D}}[(1-\delta)p[r]v - r - W]$	$\max_{\mathcal{D},W} \; \mathbb{E}_{\delta\in\mathcal{D}}[(1-\delta)p[r]v - r - W]$
s.t. $W-(1-(1-\delta)p[r])k_p r \geq \underline{U}, \quad \forall\,\delta\in\mathcal{D}$	s.t. $r = \arg\max_r W-(1-(1-\delta)p[r])k_p r$
$\mathbb{E}[\Pi]\geq 0$	$W-(1-(1-\delta)p[r])k_p r \geq \underline{U}, \quad \forall\,\delta\in\mathcal{D}$
	$\mathbb{E}[\Pi]\geq 0$

the prior sections and present the sequence of decisions and the timing of information in Figure A.1 in the appendix. This sequence reflects our own anecdotal evidence, but also rests upon the extensive volume of field studies conducted by researchers of strategic management (Bower and Gilbert 2005).

4. Analytic Results

In this section we present the results of our analysis. We adopt a simple and analytically tractable setting where $g(\cdot)$ is a two-point distribution[4] such that $\delta = \bar{\delta} \in (0,1)$ with probability q, and $\delta = 0$ with probability $1-q$. By assigning a two-point distribution to the initiative's difficulty level, we get a straightforward interpretation of senior management's choice of scope (the set of project difficulties that they would like the project manager to pursue). Senior management has two choices for the scope of the initiative: a narrow scope, in which case the set of difficulty levels is simply the singleton, $\mathcal{D}^n = \{0\}$, or a broad scope, in which case the set of difficulty levels includes both difficulty levels, $\mathcal{D}^b = \{0, \bar{\delta}\}$. Under a narrow scope, senior management only wants the initiative to be executed if it turns out to be a *standard difficulty* level, i.e., $\delta = 0$, whereas under a broad scope senior management would prefer the initiative to be executed whether it turns out to be of standard difficulty ($\delta = 0$) or of high difficulty ($\delta = \bar{\delta}$). Using this interpretation of scope, we analyze each of the strategic resource allocation processes to determine what difficulty level drives senior management to switch from a broad scope to a narrow scope, i.e., how high of a difficulty level senior management will allow before excluding it from the scope of the initiative.[5]

We begin our analysis with the canonical, and most widely cited, resource allocation processes: the top-down and bottom-up strategic resource allocation process. We characterize the maximum level of difficulty that senior management will accommodate under a broad scope for each process, present the optimal resource level decision made by either the senior management or the project manager depending on the chosen process, and outline the associated compensation.

4.1. A Top-Down Strategic Resource Allocation Process

When resources are allocated in a top-down manner, senior management can only tailor the resource decision to the scope of the initiative and not the true difficulty level. Because senior management decides on the resource level without ever learning the true difficulty level, their decision must accommodate all possible difficulty realizations for the initiative. As a result, when senior management chooses a broad scope, the same resource level gets used for both standard and high difficulty initiatives. Alternatively, when a narrow scope is chosen, senior management chooses a resource level that is only appropriate for standard difficulty level initiatives. Thus, even when resources are allocated in a top-down manner, senior management may still rely on the project manager (and his detailed knowledge) to allocate the proper level of resources by inducing the project manager to recommend the initiative be abandoned if a high difficulty level is realized and senior management desires a narrow scope.

It is worthwhile to explicitly define the first-best resource allocation as a benchmark for our setting. Senior management has two key limiting factors: their knowledge of the true difficulty and their need to ensure that the project manager does not abandon a project that should be pursued or pursue a project that should be abandoned. The first-best allocation defines the resource level that senior management assigns to the initiative if they are able to deduce the true difficulty. When senior management decides on a broad scope for the initiative, the first-best resource allocation must still account for the fact that the project manager's compensation was set prior to learning the true difficulty. More specifically, the first-best allocation does not guarantee the senior manager the ability to extract the full surplus from the project manager. When an initiative is broadly scoped and it

[4] Numerically, we have verified that our insights still hold if the difficulty is a continuously distributed random variable (results available from the authors upon request).

[5] For expositional clarity, we fix the difficulty level of a standard difficulty initiative to be $\delta = 0$. All of our results still hold if we allow the difficulty of the standard initiative to assume a nonzero difficulty level, i.e., $\delta > 0$.

turns out to be of standard difficulty, even the first-best leaves surplus on the table for the project manager. A narrow scope, however, implies that the set of difficulty realizations senior management accommodates is a singleton. Thus, so long as a narrow scope is enforced by the project manager, senior management has effectively eliminated all uncertainty and can deduce that the difficulty level is standard, regardless of the resource allocation process. As such, a narrow scope translates into a first-best resource allocation for a standard initiative.

Prior to delving into the results, we describe our notation in detail. We use the subscript $i \in \{td, bu, sb, fb\}$ to denote the decision process employed (top-down, bottom-up, strategic buckets, and first best). When it is applicable, we denote the true difficulty level with the subscript $j \in \{d, e\}$, where d represents a high difficulty level, and e represents a standard level of difficulty. Additionally, we use the superscripts n and b to denote whether the scope is narrow or broad, respectively. Last, wherever possible, we suppress any "$*$" notation that denotes optimality. For example, $\pi_{fb,d}$ denotes the first-best expected profit for an initiative with a high difficulty level, and $r_{fb,e}$ denotes the first-best resource allocation for an initiative with a standard difficulty level. We provide a table outlining all of the notation used throughout this study in the appendix (Table A.1).

Proposition 1 (First-Best Solutions and the Scope of the Initiative). (a) *First-best expected profits under a narrow and broad scope are as follows*: $\pi^n = (1-q)p[r^n]v - r^n - k_p r^n(1-p[r^n])$ (*narrow*) *and* $\pi^b_{fb} = q\pi_{fb,d} + (1-q)\pi_{fb,e}$ (*broad*).

(b) *Compensation is offered as follows*: $w^n = k_p r^n \cdot (1-p[r^n])$ *or, equivalently*, $k^n_s = k_p r^n(1-p[r^n])/((v-r^n)p[r^n])$ (*narrow*), *and* $w^b_{fb} = k_p r_{fb,d}(1-(1-\bar{\delta})\cdot p[r_{fb,d}])$ (*broad*), *where* $w^n < w^b_{fb}$.

(c) *The most difficult initiative the firm can pursue and still expect nonnegative profits is* $\delta^{\max}_{fb}$.

(d) *The most difficult initiative that the firm can pursue and still expect nonnegative profits under a broad scope is* $\hat{\bar{\delta}}_{fb}$ *and* $0 < \hat{\bar{\delta}}_{fb} < \delta^{\max}_{fb} < 1$.

Proposition 1 serves two purposes: it explicitly characterizes the first-best resource allocation under a narrow scope and a broad scope, and it sets the baseline for evaluating the breadth of scope that can be achieved. As noted, a narrow-scoped initiative is equivalent to the first-best resource allocation since we have adopted a two-point distribution for the difficulty. Senior management can reliably implement the first-best level of resources through an initiative with a narrow scope, r^n, as follows: offer the appropriate incentives so that the project manager only proceeds with the initiative when a standard level of difficulty is realized. If the initiative turns out to be more difficult, the project manager recommends that the initiative be abandoned.

The first-best solution under a broad scope allows senior management to tailor the resource allocation to the true difficulty level of the initiative. Specifically, the baseline objective for senior management is to be able to achieve a tailored resource allocation based on the firm's interests while ensuring that the project manager is still willing to execute the initiative regardless of the true difficulty level. Delineating the first best allows us to set a benchmark for the maximum level of difficulty that senior management would ever knowingly accommodate.

The highest difficulty level that $\bar{\delta}$ can assume and still have senior management choose a broad scope is $\hat{\bar{\delta}}_{fb}$. Importantly, this value is always less than the highest difficulty level that $\bar{\delta}$ could assume and still have a nonnegative expected profit to the firm, $\delta^{\max}_{fb}$. The rationale stems from the way in which the scope is implemented through the project manager's incentives and compensation. To implement a narrow scope, there must be a disincentive to adopt the initiative if it turns out to have a high difficulty level. It follows that the compensation offered under a broad scope must be greater than the compensation offered under a narrow scope. Said differently, the project manager receives a surplus when a standard difficulty level occurs under a broad scope, whereas the firm extracts all of the surplus when a narrow scope is implemented. This difference in compensation implies that if senior management is to switch from a narrow to a broad scope, the profitability that senior management expects from the initiative when it has a high difficulty level must at least offset the difference in compensation. Since the difference in compensation is nonzero, an initiative with a high difficulty level must yield more than a nonnegative expected profit; it is a necessary condition that an initiative with a high difficulty level yield positive expected profit. The fact that this insight emerges under a first-best scenario sets the groundwork for our subsequent analysis.

Whereas a narrow scope allows for any fixed wage contract to be replicated by an equivalent profit sharing agreement, this does not hold true when the scope is broadly set. When a broad scope is chosen, it is suboptimal to offer the project manager compensation based on the realized profit (an output-contingent incentive), even in a first-best setting. A broad scope implies that the initiative may take on multiple difficulty levels. Since the compensation must provide adequate incentive for the project manager to execute the initiative, regardless of its true difficulty level, senior management can only extract the full surplus from the highest difficulty level. This means that if the true difficulty level is a standard level, senior management has no choice but to leave some surplus for the project manager. When the initiative turns out to have a high difficulty level, a fixed wage contract and a profit sharing contract have the same effect on the project manager's actions. However, this is not the case when the initiative turns out to have a standard difficulty level. If the project manager received an output-contingent incentive, i.e., $k_s > 0$, and a standard difficulty initiative were realized, the project manager would receive a greater surplus than a fixed wage would provide, an outcome that senior management would rather avoid.

Corollary 1 (Exchanging Information). *A rational project manager has no incentive to truthfully disclose the actual difficulty of an initiative.*

Corollary 1 outlines an important aspect of the information asymmetry that is at the heart of the tension between senior management and the project manager for all strategic resource allocation processes: the project manager has no incentive to truthfully reveal the true difficulty of an initiative. The intuition driving this result is as follows. When a narrow scope is chosen, there is no information to exchange since when the project manager does not recommend abandonment of the initiative, senior management can deduce that the initiative has a standard difficulty level. Armed with this information, senior management extracts the full surplus, leaving the project manager to expect to receive a utility equivalent to his opportunity cost. However, when a broad scope is chosen, the project manager does have an opportunity to receive an expected utility greater than his opportunity cost when the initiative turns out to have a standard difficulty level. If the project manager were to inform senior management that the initiative has a standard difficulty level, it would only induce senior management to extract the full surplus, which is not in the project manager's interest. Furthermore, if the senior management were to learn that the initiative had a standard difficulty level, she would increase the resource level, which would only increase the penalty the project manager would incur if it did indeed fail. In the end, sharing information does not offer a benefit to the project manager.

Although the first-best solution is informative, rarely does senior management have full knowledge of the true difficulty level of an initiative. Yet, this does not preclude senior management from maintaining the decision rights and deciding on the resource level in a top-down manner. When this happens, senior management accounts for both possible difficulty levels without the ability to tailor the resource level to a specific difficulty level. We evaluate a top-down resource allocation process to ensure that the structural insights generated by Proposition 1 persist, and to explicitly define the difficulty level that induces senior management to switch from a narrow scope to a broad scope.

Proposition 2 (Top-Down Resource Allocation and the Breadth of Scope). *When strategic resource allocation occurs though a top-down process,*

(a) *the most difficult initiative the firm can pursue and still expect nonnegative profits is* $\delta_{td}^{\max}$;

(b) *the most difficult initiative the firm will pursue under a broad scope and still expect nonnegative profits is* $\hat{\delta}_{td}$, *and* $0 < \hat{\delta}_{td} < \delta_{td}^{\max} < \delta_{fb}^{\max}$ *and* $\hat{\delta}_{td} < \hat{\delta}_{fb}$;

(c) *compensation is offered as follows*: $k_s = 0$ *and* $w_{td} = k_p r_{td}(1-(1-\bar{\delta})p[r_{td}])$.

The insights generated in Proposition 1 extend to Proposition 2. Despite the fact that senior management expects nonnegative profits from an initiative that has a $\delta_{td}^{\max}$ difficulty level, senior management will not include it in the scope of the initiative. Instead senior management induces the project manager to recommend abandonment of an initiative that has a $\delta_{td}^{\max}$ difficulty level. A narrow scope, as outlined in Proposition 1, allows the firm to allocate the first-best level of resources as long as the initiative realizes a standard difficulty level. Senior management requires that the difficulty level of the initiative be less than $\delta_{td}^{\max}$ before they are willing to accommodate a broad scope. The explanation provided for Proposition 1 still holds under a top-down process: when a standard difficulty level is realized, a higher expected profit can be achieved under a narrow scope than under a broad scope, which means that a necessary condition for senior management to choose a broad scope is that the expected profit from a high difficulty level must be strictly positive.

Furthermore, under a top-down process, the point at which senior management switches from a narrow scope to a broad scope requires that the high difficulty level be less difficult than that which is required under a first-best scenario. Specifically, the prospect of including a high difficulty level initiative in the set of "allowable" difficulty levels that defines the scope must offset two key factors. The first one is analogous to a first-best setting; the expected profit from a high difficulty initiative must offset the loss incurred from the additional compensation that is required to induce the project manager to execute such an initiative. The second factor, however, stems from the fact that senior management's resource allocation decision under a broad scope is guaranteed to be inefficient, regardless of whether a standard or a high difficulty level occurs. Under a broad scope, a single resource level must account for the possibility of either difficulty level. As such, it is certain that a first-best resource allocation cannot be achieved for either level of difficulty. When we combine both of these factors, we are guaranteed that the switching point between a broad and a narrow scope that results from a top-down process has a lower difficulty level than the first-best switching point.

Similar to the first-best setting, a profit sharing contract is inefficient whenever a top-down process is employed. The intuition is analogous to that of Proposition 1. Senior management must offer a compensation scheme that applies regardless of what the initiative's true difficulty turns out to be. Compensating the project manager through a profit sharing agreement is more costly for the firm compared to using a fixed wage.

4.2. A Bottom-Up Resource Allocation Process

A bottom-up resource allocation process differs from a top-down one in that the project manager decides on the resource level to allocate to the strategic initiative. However, similar to a top-down process, senior management decides on the scope of the initiative and aims to induce the project manager to enforce it through an appropriately designed compensation plan. The distinguishing factor of a bottom-up decision process, i.e., the ability to tailor the resource allocation to the exact (true) difficulty level of the initiative, stems from the fact that the project manager is able to learn critical information about the initiative prior to committing to the resource level decision. The following proposition characterizes bottom-up resource allocation.

Proposition 3 (Bottom-Up Processes and the Breadth of Scope). *When strategic resource allocation occurs though a top-down process,*

(a) *the most difficult initiative the firm can pursue and still expect nonnegative profits is* $\delta_{bu}^{\max}$;

(b) *the most difficult initiative the firm will pursue under a broad scope is* $\hat{\delta}_{bu}$, *and* $0 < \hat{\delta}_{bu} < \delta_{bu}^{\max} < \delta_{fb}^{\max}$ *and* $\hat{\delta}_{bu} < \hat{\delta}_{fb}$;

(c) *compensation is offered as follows*: $w = 0$, $k_s^* = k_p r_d(1 - (1 - \bar{\delta})p[r_d])/((v - r_d)(1 - \bar{\delta})p[r_d])$, *and* $k_s^* < k_p/(1 + k_p)$.

Similar to the discussion of Proposition 2, $\delta_{bu}^{\max}$ represents the maximum difficulty level that the firm pursues under a broad scope where they still expect a nonnegative profit if the initiative turns out to be difficult. Yet, because senior management retains the option to choose a narrow scope, the difficulty required for senior management to choose a broad scope needs to be strictly less than $\delta_{bu}^{\max}$. For senior management to optimally choose a broad scope, the high difficulty level for the initiative must be no more difficult than $\hat{\delta}_{bu}$.

Bottom-up resource allocation processes shift the authority for the resource decision from a senior manager with incomplete information to a project manager with full information. Just as with a top-down process, when it is optimal to pursue a broad scope in a bottom-up process, the incentives offered must be substantial enough so that the project manager does not reject a difficult initiative. Yet even though the project manager is better informed regarding the difficulty of the initiative, this may not always translate into a resource decision that is better for the firm due to the differing objectives of the stakeholders. Specifically, when the initiative succeeds, the firm and the project manager each receive a portion of the profits equal to $(1 - k_s)$ and k_s, respectively, and when it fails the firm incurs the full cost, r, and the project manager incurs a penalty equivalent to $k_p r$. Thus, for all $k_s \neq k_p/(1 + k_p)$, the objectives between the two stakeholders differ. It should not go unnoticed that it *is* within senior management's control to perfectly align the interests of the project manager with those of the firm, i.e., set $k_s = k_p/(1 + k_p)$. Yet, in many instances senior management chooses not to do so because ultimately aligning the project manager's objectives is viewed as too costly.

In contrast to a top-down resource allocation process, the firm is strictly better off using output-contingent compensation, i.e., a profit sharing contract, for a bottom-up process. Fixed wages work in a top-down process since the resource level is decided upon by senior management, and thus the project manager wants to avoid the penalty associated with a failed outcome, or "wasting" these valuable resources. Thus, in a top-down setting, senior management's resource level decision determines the magnitude of the penalty, and this is then offset through a fixed wage. A bottom-up process differs in that since the resource level is decided upon by the project manager, the magnitude of the penalty is also determined by the project manager. Thus, the project manager has no incentive to increase their penalty to offset a fixed wage; to the contrary, they would rather minimize the penalty through a minimal resource allocation so that they maximize their utility, the result being that a fixed wage provides inadequate incentive for the project manager to assign any meaningful level of resources. Said differently, a fixed wage is an appropriate incentive when the resources are assigned *to* the project manager, but not when they are assigned *by* the project manager.

5. Top-Down vs. Bottom-Up: Choosing the Right Process

So far we have characterized the optimal decisions corresponding to each particular resource allocation process. These decisions directly impact the scope of the initiative, the resources that get committed, and consequently the likelihood the initiative succeeds and generates profits for the firm. The differences between each of these processes prompt a natural question: when does one process yield more profitable results for the firm than another? Moreover, this question has enticed scholars over the years because of its managerial importance (Bower 1970, Burgelman 1983, Bower and Gilbert 2005). In this section we address this question by comparing the optimal profits obtained under each decision process to determine when each one is most profitable for the firm.

First, we characterize when senior management finds it more profitable to employ a bottom-up versus a top-down process. We need to recognize, though, that the decision between a bottom-up and top-down process only comes into play when the initiative is broadly scoped.

Proposition 4 (Scope for Top-Down and Bottom-Up Processes). (a) *Let* $\hat{\delta} = \max\{\hat{\delta}_{td}, \hat{\delta}_{bu}\}$; *then if* $\bar{\delta} \leq \hat{\delta}$, *senior management chooses a broad scope, and otherwise senior management chooses a narrow scope.*

(b) *The maximum difficulty level that senior management will tolerate for the initiative under a broad scope is decreasing in the organizational penalty* (k_p).

Proposition 4 sheds light on senior management's optimal scope for the initiative. As noted already, when the initiative is narrowly scoped, the choice of process is inconsequential. A narrow scope implies that the exact difficulty of the initiative is known, and therefore resources can be optimally set by senior management. Thus, only when a broad scope appears to be more profitable than a narrow scope is the choice between the two decision processes meaningful. As discussed, a broad or a narrow scope can only be effectively implemented through the proper incentives. The cost of providing such incentives increases in the penalty for failure. The implications of an increased organizational penalty for failure become clear: the larger a penalty an organization imparts on its project managers, the more limited the breadth of scope becomes.

Proposition 5 outlines the optimal process choice. As explained, if the initiative faces the possibility of being prohibitively difficult ($\bar{\delta} > \hat{\delta}$), senior management forgoes a broad scope and instead only pursues standard initiatives. However, for the interesting cases where the initiative faces the possibility that it could be highly difficult but still tolerable ($\bar{\delta} \leq \hat{\delta}$), senior management faces a critical decision between two potential resource allocation processes.

Proposition 5 (A Top-Down vs. a Bottom-Up Process). *When it is optimal to choose a broad scope for an initiative, there exists a threshold difficulty level*, Δ *such that*

(a) *for* $\bar{\delta} \leq \Delta$ *it is optimal to allocate resources through a top-down process, i.e.*, $\pi_{td} \geq \pi_{bu}$ *for all* $q \in (0, 1)$;

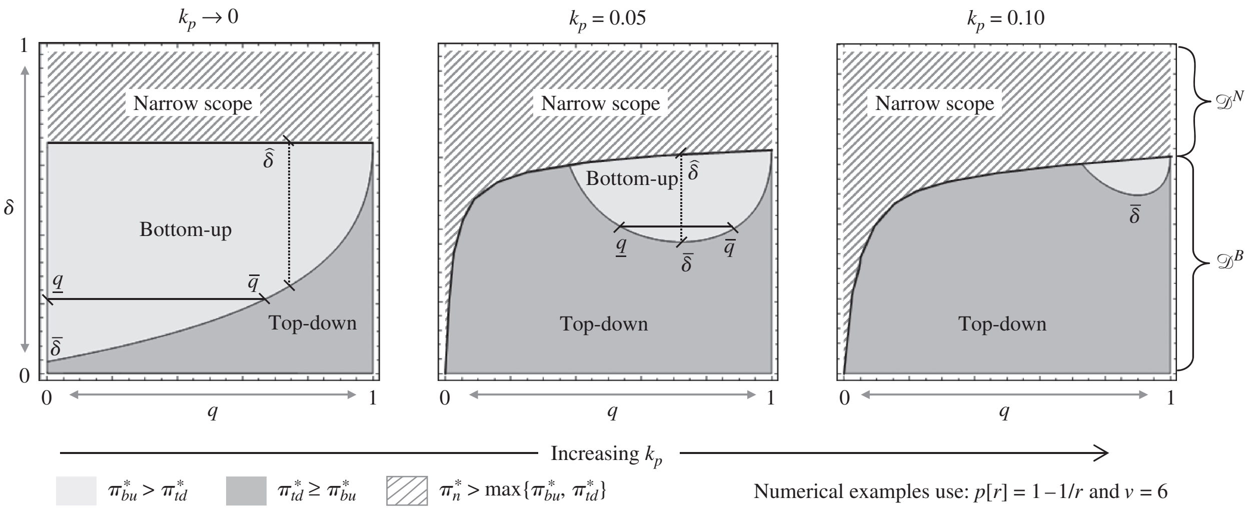
(b) *for* $\bar{\delta} > \Delta$ *there exists an interval* $q \in (\underline{q}, \bar{q})$, *with* $0 \leq \underline{q} < q < \bar{q} \leq 1$, *such that a bottom-up process is optimal, i.e.*, $\pi_{bu} > \pi_{td}$

Proposition 5 provides a normative foundation for a documented reality in many organizations: one single process cannot accommodate all types of initiatives. Instead, Proposition 5 supports the observed coexistence of both top-down and bottom-up resource allocation processes in firms and the need to tailor these processes to the difficulty level of the strategic initiative (alternatively, the riskiness of the initiative). This is an observation noted in prior field-based research (Burgelman 1983). Yet we provide further insight beyond just the need for this coexistence. Our results suggest that only through such coexistence can the firm achieve both the maximum profit *and* the maximum breadth of scope. In other words, senior management benefits from choosing an allocation process that fits the characteristics of the strategic initiative. To this end, our proposition characterizes the conditions under which senior management should consider implementing a bottom-up process in favor of a top-down process.

Our results reveal an interesting relationship among the potential difficulty level, $\bar{\delta}$, the likelihood that such a difficulty level occurs, q, and the way in which decision rights are distributed between the stakeholders to achieve the best strategic resource allocation. The disparity among the potential difficulty levels needs to be large enough, otherwise the firm should employ a top-down process to better serve their own interests. Intuitively, senior management maintains control over the resource decision when the potential difficulty associated with the initiative does not appear much more difficult than a standard initiative. Figure 1 depicts our results through a numerical example.

Provided there exists sufficient disparity between the initiative's potential difficulty levels, the process choice is dependent on the likelihood that the true difficulty level is high. Specifically, when the uncertainty falls within an interval, $q \in (\underline{q}, \bar{q})$, the firm benefits from employing a bottom-up process. Thus, if it is highly likely that a standard difficulty level occurs ($q < \underline{q}$) or it is highly likely that a high difficulty level occurs ($q > \bar{q}$), then the firm benefits from a top-down process. The intuition is as follows: if senior management is fairly certain of the actual difficulty of the initiative, then they are better off dictating the resource level because the loss in value due to incomplete information is less than the cost that would be

Figure 1 A Numerical Example Showing the Regions Where a Broad Scope Is Chosen (Solid Shaded Regions), as Opposed to a Narrow Scope (Cross-Hatched Region), and How the Penalty for Failure, k_p, Affects the Region Where $\pi_{bu} > \pi_{td}$ (Light Gray Region)



required to induce the project manager to choose a more appropriate resource allocation.

Our analysis thus far suggests an interesting managerial message regarding the value of either controlling the resource decision via a top-down process or delegating it via a bottom-up process. Control allows senior management to make decisions directly in line with the firm's objectives, thus mitigating the cost of providing an incentive for the project manager to make decisions in line with the firm's interests. Yet senior management's decision is made with less detailed information and results in less flexibility for the project manager to adapt to the true difficulty. Delegation, however, offers value through the ability to tailor the project funding to the true difficulty level of the initiative. Thus, it provides a level of flexibility not evident in the top-down process. Since both decision processes are valuable to the organization, it is worthwhile to explore whether a process exists where both of these benefits can be exploited.

Specifically, we seek to identify whether a process exists that meets the following criteria: (i) resource allocations are defined by senior management according to the initiative's specific difficulty level, (ii) the project manager's detailed knowledge is used to tailor the resource decision to the initiative's true difficulty, and (iii) the project manager's compensation plan is independent of the true difficulty level. Interestingly, there exists such a strategic resource allocation process, which is known as strategic buckets. We explore this process in the next section.

6. A Strategic-Buckets Resource Allocation Process

Recent fieldwork reveals that a strategic resource allocation process known as strategic buckets has gained momentum in practice. Strategic buckets, although not ubiquitous, seem to be associated with the best performing companies: on average, only 26.9% of businesses employ strategic buckets, yet 41.4% of the best performing companies employ strategic buckets, whereas only 15.4% of the worst performing companies employ it (Cooper 2005). The predominant rationale for the use of strategic buckets is based on the need to protect resources for the long term when faced with difficult and more uncertain initiatives (Cooper et al. 2001, Chao and Kavadias 2008, Terwiesch and Ulrich 2009). In this section we analyze a strategic-buckets process to analyze whether they can offer additional value as an information revelation mechanism, beyond the procedural benefit of protecting resources for specific initiatives.

Resource allocation through strategic buckets is a decision process whereby fixed levels of resources are "earmarked" for unique categories (sets) of initiatives. In our case of a two-point distribution, the "category" translates to a single difficulty type (standard, low-risk initiatives or high difficulty, higher-risk initiatives), such that there are two unique sets of initiatives, namely, two singletons. The two-point distribution also allows us to avoid having to decide on how to partition the full set of difficulty levels, or even how many buckets there should be. We leave these important questions for future research.[6] As examples, it is well documented that firms such as Google and 3M expect that their employees spend a certain percentage of their time working on projects that are not explicitly assigned to them. Such practices seek to

[6] A more general case, however, would include an ordered partitioning of the full set of all difficulty levels into categories, where different resource levels would be assigned to each of these categories.

allocate a small portion of the resources toward what could be deemed low probability of success (high-risk) novel projects.

Consider the case where BZ uses strategic buckets for their strategic resource allocation. The senior management at BZ has already come up with guidelines for what they term Horizon I and Horizon II (henceforth, H1 and H2) initiatives. Their H1 initiatives represent projects that can be completed within 100 days. As such, these initiatives are standard efforts that can be completed with their current capabilities and labor force. On the other hand, H2 initiatives are considered to be much more involved because they are associated with higher degrees of difficulty and uncertainty. Although the VP of R&D has communicated BZ's intentions to enter the off-road motorcycle market, she allows the project manager to decide whether BZ's eventual project should be classified as an H1 or an H2 initiative. Once a project manager has completed due diligence on the initiative (effectively determining the relationship between the likelihood of success and resources), he will evaluate the resources that the VP of R&D has assigned to an H1 or an H2 initiative, translate this into a likelihood of success (and failure), and ultimately decide which bucket the initiative belongs to.

In our model, each bucket has predetermined resource levels r_d or r_e that correspond to the initiative's difficulty. Thus, despite the fact that senior managers determine the resource level for each category, they are unable to determine which is the right bucket for the specific initiative. As such, strategic buckets maintain aspects of both bottom-up and top-down resource allocations. The choice of the appropriate bucket is delegated to the project manager, which requires senior management to offer the project manager adequate incentives to choose the correct bucket. We formally state senior management's optimization program below when a strategic-buckets process is employed, where constraints (i) and (ii) represent the participation constraints and (iii) and (iv) ensure incentive compatibility:

Strategic buckets

$$\max_{w,\mathcal{D},r_e,r_d} \left\{q((1-\bar{\delta})p[r_d]v-r_d)+(1-q)(p[r_e]v-r_e)-w\right\}$$

$$\begin{aligned}\text{s.t. (i)}\ & w-(1-(1-\bar{\delta})p[r_d])k_p r_d \geq 0;\\ \text{(ii)}\ & w-(1-(1-\bar{\delta})p[r_e])k_p r_e \geq 0;\\ \text{(iii)}\ & (1-p(r_e))r_e \geq (1-p[r_d])r_d;\\ \text{(iv)}\ & (1-(1-\bar{\delta})p[r_d])r_d \geq (1-(1-\bar{\delta})p[r_e])r_e.\end{aligned}$$

As before, an initiative with a narrow scope is a special case of a top-down process, without any information asymmetry. The resource allocation is dictated, but only for a single difficulty level. Similarly, a top-down process can be viewed as a degenerate case of a strategic-buckets process where only a single bucket is defined. Our use of the term "buckets" implies that there exists more than a single bucket; otherwise we refer to the process as top-down. Below we elaborate on the optimal decisions taken under a strategic-buckets process.

Proposition 6 (Implementing Strategic Buckets). *Define the following*: $\phi_e \doteq r_e(1-p[r_e])$ (*standard*), $\phi_d \doteq r_d(1-(1-\bar{\delta})p[r_d])$ (*high difficulty*), $r^h = \arg\max_r \phi_e[r]$, *and* r^l *satisfies* $\phi_e[r^l] = \phi_e[r_{fb,e}]$ *and* $r^l \leq r_{fb,e}$. *Then, strategic resources are tailored to the difficulty level of the initiative as follows*:

$$\text{If}\ \begin{cases} r_{fb,e} > r^h \text{ and } r_{fb,d} > r^l, & \text{then } r_{sb,d} = r_{fb,d} \text{ and}\\ & r_{sb,e} = r_{fb,e};\\ r_{fb,e} > r^h \text{ and } r_{fb,d} < r^l, & \text{then } r_{sb,d} > r_{fb,d};\\ r_{fb,e} \leq r^h, & \text{then } r_{sb,d} = r_{sb,e} = r_{td}.\end{cases}$$

Senior management's ability to implement strategic buckets is critically linked to the expected failure cost, ϕ_j. From the project manager's perspective, this is directly proportional to the organizational penalty they expect to incur following a failed initiative. Given that the project manager knows the true difficulty of the initiative and is aware that the resource level impacts his expected utility, i.e., the wages less the expected organizational penalty, he has the incentive to self select the appropriate resource level (bucket) for the initiative. A defining property of an initiative's difficulty is that, given the same resource level, a high difficulty initiative is more likely to fail, resulting in a higher expected penalty for the project manager. Keenly aware of this property, senior management can effectively use the predetermined resource levels to accomplish two things: maximize firm profitability and ensure incentive compatibility. Senior management sets each bucket's resource level so that the project manager's expected penalty from choosing the wrong bucket is higher than if he chooses the right one. Interestingly, the incentive to assign the initiative to the right bucket comes from the penalty, as dictated by the resource level, as opposed to the wage.

Proposition 6 outlines the possible outcomes of employing a strategic-buckets process. The best-case scenario is when the first-best resource allocation for each difficulty level falls within the region of incentive compatibility. In such a case it is possible that strategic resource allocation through the use of strategic buckets achieves first-best profits by effectively distinguishing the difficulty level of an initiative. Achieving first-best profits under a strategic-buckets process clearly surpasses the profits obtained from a top-down or bottom-up process, because strategic buckets combine the best aspects from both top-down and bottom-up decision processes. However, achieving first-best allocations for both levels of difficulty may not always be possible. For instance, if the value of the initiative is not substantial enough, the resource level will be lower, potentially resulting in $r_{fb,e} < r^h$, in which case separation between the two categories of initiative will not be possible, resulting in a single bucket (a top-down decision process).

Alternatively, separation may be possible, but it may be that only one, or neither, of the resource allocations is first best. Such cases come about when the initiative's value is substantial enough to meet the criteria that $r_{fb,e} > r^h$. However, the first-best allocation for a difficult initiative may be too low, $r_{fb,d} < r^l$, i.e., inadequate to provide incentive compatibility when the initiative has a standard difficulty level. In such instances, the resources allocated to the difficult initiative are greater than the first-best allocation. This may require an increase, decrease, or no change at all to the resource allocation assigned to the standard initiatives, depending on the properties of the expected failure cost. What can be shown, however, is that the increase from first-best levels for difficult initiatives is minimized when the resources assigned to a standard initiative are less than the first-best allocation. Likewise, the overinvestment (compared to first-best levels) for difficult initiatives is greatest when the allocation to standard initiatives is greater than the first-best levels. Regardless, our results show that there are significant opportunities for the firm to employ strategic buckets and credibly sort the proper initiatives to the appropriate resource allocations. In fact, the following corollary provides the case when strategic buckets are in fact the optimal mechanism to allocate resources.

Corollary 2. *If ϕ_d is linear in r_d and ϕ_e is constant, then a strategic-buckets process is the optimal mechanism.*

For the special case noted in Corollary 2, the expected organizational penalty of the project manager for a standard initiative is held constant, i.e., as a reference, and the expected organizational penalty for a difficult initiative is a linear function of the resource allocation, r_d. When this is the case, a strategic-buckets process is the optimal mechanism. This special case can be interpreted as the organization being characterized by the way it treats managers following a failed initiative that was considered more routine. All other initiatives will incur a penalty less than that incurred on the standard initiatives, but proportionate to the magnitude of resources consumed.

Importantly, we note that because strategic buckets are able to invoke elements of a bottom-up process while also maintaining considerable top-down control, they are able to perform at least as well as a pure bottom-up process. Likewise, because a top-down process is a degenerate case of strategic buckets, strategic buckets can always perform at least as well as a top-down process. These observations offer robust justification for the broad use and applicability of strategic buckets as an effective strategic resource allocation process.

7. Discussion and Conclusions

In this paper we explore the effectiveness of different strategic resource allocation processes. Thus, we contribute to an ongoing debate regarding the relative dominance of top-down versus bottom-up resource allocation decisions. The former advocates control over the exact level of resources, whereas the latter aims at tailoring the resource level to the nuances of a specific initiative. Since Bower's (1970) early work on resource allocation processes in organizations, numerous field studies have confirmed the prevalence of different approaches. Surprisingly, few studies have looked at when and how these different processes should (and could) be most valuable. Beyond this, our analysis explores a practitioner-driven process known as strategic buckets that represents a middle ground between a top-down and a bottom-up process, while appearing to accomplish efficient resource allocation without sophisticated incentive schemes. Our analysis offers insights as to why strategic buckets are so valuable for companies to employ, beyond the oft-cited need to protect resources for more difficult and risky initiatives.

We conceptualize a problem setting where the senior management of a firm aims to implement a key strategic NPD initiative. Building upon prior literature, we recognize that certain organizations allocate resources in a top-down fashion (i.e., scope and resource decisions are made at senior levels within the organization), whereas others follow a bottom-up resource allocation process (i.e., the scope of initiatives are set at senior levels but resource decisions are made by the project managers who ultimately execute the initiative). Senior management rarely understands the initiative's specific difficulty, or "what it takes" to successfully execute the initiative. It is more common that a project manager, who is familiar with such tasks, understands this aspect better (in a stylized manner, the project manager knows the initiative's true difficulty). We represent the initiative's difficulty in a concrete and distinct manner: for any fixed resource allocation, the more difficult an initiative is, the less chance of success it has, and the more difficult an initiative is, the lower the maximum probability of success possible.

This information asymmetry between the senior manager and the project manager prompts a distinct agency setting where the firm and the project manager face different consequences should the initiative fail. The firm incurs the full cost of the resources for the initiative, whereas the project manager faces organizational penalties, such as lack of promotions, lower status, or potentially even lowered bonuses or raises. However, it is important to note that we do not explicitly impose any misalignment between senior management and the project manager. In other words, senior management can choose to perfectly align the interests of the project manager with those of the firm. As such, the misalignment that results comes about endogenously.

Our analysis adds an operational perspective to Burgelman's (1983) early observation that no single resource allocation process, top-down or bottom-up, is appropriate for all firms and all initiatives. Instead, even within a single firm, senior management may want to employ multiple resource allocation processes. This stands in contrast to traditional notions of standardization within firms that advocate a single all-encompassing process. The use of a single process means the firm may forgo initiatives that would otherwise be perceived favorably by another process. This is clearly illustrated through our analysis of the scope senior management chooses to induce with either a top-down or a bottom-up process. As an example, a firm with a low penalty for failure may find that a bottom-up process allows the organization to profitably pursue more risky and difficult initiatives than would a top-down process, yet this same organization may find it more profitable to employ a top-down process for initiatives that are standard and do not represent a lot of risk. Were this organization to employ just one process they would certainly sell themselves short on either the profitability of standard initiatives or the ability to pursue more challenging and risky strategic initiatives, thus effectively reducing the opportunity space (Kornish and Ulrich 2011) the firm can explore.

We also find that the culture of a firm, specifically the organizational penalty imposed on managers of failed initiatives, can have a significant effect on the scope that a firm chooses for strategic initiatives. Higher penalties drive firms to forgo more open-ended (broadly scoped) initiatives even when they represent a positive contribution to the profit of the firm. Thus, so long as there is a positive penalty for failure, there are initiatives with difficulty realizations that the firm will not include within the scope of the initiative, despite the fact that they offer a positive expected profit. Instead, the firm would rather choose a narrow scope, simply because the incentives that the firm must offer to overcome the organizational penalty render an initiative whose scope included such difficult realizations inferior to an otherwise narrowly scoped initiative.

Beyond the dilemma between a top-down and a bottom-up decision process, we discuss how and when a process known as strategic buckets is associated with the most successful businesses (Cooper 2005). We characterize when the use of such a decision process can achieve first-best resource allocation decisions. More specifically, we show that a strategic-buckets process, by appropriately sorting initiatives into resource buckets, holds the potential to mitigate the information asymmetry between senior management and project managers. One of the key insights that emerges from our analysis is the critical role that the penalty for failure plays. We show that the ability to efficiently sort initiatives rests on two aspects: the project manager's knowledge of the likelihood of failure for a given resource level and the fact that the resulting organizational penalty is proportional to the level of resources consumed should the initiative fail. Interestingly, the conclusion we draw is that *some* penalty for failure (i.e., $k_p > 0$) is necessary to enable the senior management to induce the project manager to choose the correct resource bucket. A complete absence of consequences renders the implementation of strategic buckets infeasible. However, the penalty for failure should be relatively low to keep the cost of incentives low and, ultimately, increase the firm's ability to pursue more difficult or more risky initiatives, i.e., broaden the scope.

In conclusion, our work places emphasis on the need for senior management to account for operational details of NPD initiatives when determining the firm's resource allocation process. As a first step toward this direction, we bear limitations that open up potential avenues for future research. Future work needs to shed additional light on the potential to delegate the definition of strategy (i.e., which initiatives to pursue) and account for the effects of competition. Furthermore, future work should also establish how certain organizational norms, i.e., the organizational penalty for failure, come to fruition, thus adding detail to such an intertemporal process. Finally the effects of the collaborative and cross-functional nature of innovation should come under scrutiny.

Appendix

A.1. Notation and Definitions

In Table A.1 we present all of the notation used throughout this study.

A.2. Sequence of Events

In Figure A.1 we present the sequence of events that summarizes the model setup of §3.

A.3. Proof of Proposition 1: First-Best Solutions and the Scope of the Initiative

When a narrow scope is employed, senior management provides incentives such that the project manager only accepts initiatives when $\delta = 0$. Thus, the participation constraint is not met when $\delta = 1 - \theta$ and is met when $\delta = 0$, i.e.,

Table A.1 Notation and Definitions

Notation	Type	Description
$r_{i,j}$	Decision variable	Resource level, where i defines the process and j defines the difficulty level
$\mathscr{D}^k$, Θ^k	Decision variable	The scope of the initiative, where $k \in \{n, b\}$ is either a narrow scope or broad scope, respectively, and $\mathscr{D}^k$ represents the set in terms of δ notation and Θ^k in terms of θ notation
k_s	Decision variable	Incentive parameter that determines the profit sharing contract offered to the project manager
w	Decision variable	Fixed wages given to the project manager
$\bar{\delta}$, θ	Parameter	The high difficulty level of the initiative, $\bar{\delta}$ (equivalently, θ), where we make use of the transformation $\theta = 1 - \bar{\delta}$ for the proofs, i.e., proofs utilize θ notation for expositional clarity; θ defines the maximum probability of success for an initiative regardless of the quantity of resources allocated
v	Parameter	Gross value the initiative yields if it is successful
k_p	Parameter	Parameterizes the magnitude of the organizational penalty imposed on the project manager should the initiative fail (proportional to the resources consumed)
q	Parameter	The probability that the initiative has a difficulty level equal to $\bar{\delta} = 1 - \theta$, where $1 - q$ is the probability that the initiative has a difficulty level of 0
td, bu, sb, fb	Subscript i	Defines the process, either a top-down (td), bottom-up (bu), strategic buckets (sb), or first best (fb) (the true value of θ is known by senior management)
d, e	Subscript j	Defines the level of difficulty the project manager observes, where d implies that $\delta = 1 - \theta$, and e implies that $\delta = 0$ (note that the subscript j is redundant when $i = n$, since whenever $i = n$ it implies that $j = e$)
n, b	Superscript k	When applicable, denotes whether senior management would like to employ a narrow scope (i.e., only allow standard initiatives, $\delta = 0$) or a broad scope (i.e., pursue the project regardless of whether $\delta = 0$ or $\delta = \bar{\delta}$)
$p[r]$		Probability of success as determined by the resource decision
$u_{i,j}$		The project manager's expected utility
$\pi^k_{i,j}$		The firm's expected profit for the chosen process, difficulty level (if the subscript j is dropped, it denotes the unconditional expected profit for the process), and the chosen scope (if the superscript k is dropped it is to because it is redundant, i.e., $\pi_{fb,d}$ is the first-best expected profit of a high difficulty initiative, which is only applicable for a broad scoped initiative; thus, the superscript b is suppressed)

Definition	Description
$\delta_i^{\max}$ ($\theta_i^{\min}$)	The difficulty level where, if realized, the expected profit of the initiative is zero
$\hat{\delta}_i(\hat{\theta}_i)$	The difficulty level where the expected profit from choosing a broad scope is equivalent to that of an initiative with a narrow scope
$\Delta(\bar{\theta})$	The maximum difficulty level, beyond which a bottom-up process will never be preferred, regardless of q
$\bar{\delta}_{sb}(\bar{\theta}_{sb})$	The difficulty level below which separation is no longer possible under a strategic-buckets process
$\bar{k}_p$	The value of k_p such that the expected profit of a narrowly scoped initiative is zero
ϕ_j	The expected cost to the firm.
r^h	The resource level that achieves the maximum expected cost for a $\delta = 0$ initiative
r^l	The resource level less than r^h that yields the same expected cost as $r_{fb,e}$, given that $r_{fb,e} > r^h$

$w - k_p r(1 - \theta p[r]) < 0$ and $w - k_p r(1 - p[r]) = 0$. Since $\delta = 0$ only occurs with a $1 - q$ probability, the expected profit of the firm under a narrow scope becomes $\pi^n = (1 - q)p[r]v - r - k_p r(1 - p[r])$. Clearly, the resource level that maximizes the firm's profit is $r^{n*} = \arg\max_r \pi^n[r]$ and $w = k_p r^{n*}(1 - p[r^{n*}])$ so that r^n solves $\partial p[r]/\partial r = (1 + k_p(1 - p[r]))/(k_p r + v(1 - q))$. Last, we show, because it will be useful for further proofs, that π^n is monotonically decreasing ink_p, which is a straightforward application of the envelope theorem, where $\partial \pi^n[r^n, k_p]/\partial k_p = k_p - r^n(1 - p[r^n]) < 0$. When θ is known, $\pi_{fb,d}|_{\theta=0} < 0$ and $\pi_{fb,e}|_{\theta=1} = \pi^n > 0$ so that $\theta_{fb}^{\min} \in (0, 1)$ exists, and likewise for $\hat{\theta}_{fb} > \theta_{fb}^{\min}$.

It is worth noting the distinction we make between the subscript denoting the first-best (fb) and a narrow scope (n). A narrow scope is also a first-best solution to the senior manager's problem since only $\delta = 0$ difficulty initiatives are accepted; the uncertainty surrounding the resource decision is nullified. However, we reserve the first-best notation for the situations where the senior manager chooses to employ a broad scope, i.e., when the choice between processes is meaningful. Each of the potential processes requires that the wage (and/or incentive parameter) must be set prior to the realization of the difficulty level. Furthermore, the compensation must meet a minimum level for the project manager to accept the initiative regardless of the difficulty realization. Given such conditions, senior management's first-best solution is the resource allocation that would be made if the difficulty were known and the wages promised ex ante were still honored. This is where the first-best solution for a $\delta = 0$ difficulty initiative will differ from the allocation under a narrow scope, provided that $k_p > 0$ and $q > 0$ (so that the wages differ). Note that $\pi_{fb}|_{\theta=1} = \pi_n$ (equivalently, $q = 0$); however, owing to the required incentives to enable a broad scope when $\theta \neq 1$ and/or $q \neq 0$, $\pi_{fb,e} < \pi^n$.

A.4. Proof of Proposition 2: Top-Down Resource Allocation and the Breadth of Scope

We claim that if $q > 0$ and $0 < k_p < \bar{k}_p$, where $\bar{k}_p \doteq k_p$: $\pi^n = 0$, then $\theta_{td}^{\min}$, $\hat{\theta}_{td}$, $\theta_{fb}^{\min}$, $\hat{\theta}_{fb} \in (0, 1)$ all exist. We first show that $\theta_{td}^{\min} > 0$. The ex post expected profit when $\theta = 0$ has a negative expected value, i.e., $\pi_{td,d}|_{\theta=0} = -r(1 + k_p) < 0$, since

Figure A.1 The Sequence of Events and Related Decisions

1. Senior management and the project manager:
   (a) Hold common beliefs that the initiative is of a standard level of difficulty, $\delta = 0$, with probability q and realizes a higher level of difficulty, $\delta = \bar{\delta}$, with probability $(1-q)$.
   (b) Have common knowledge that the project manager of a failed initiative incurs an organizational penalty equivalent to $k_p\, r$.
2. Senior management evaluates the profitability of the initiative. If $\pi_i > 0$, $i \in \{td, bu\}$ they proceed otherwise the initiative is abandoned.
3. Senior management chooses whether the initiative should have a narrow scope, $\mathscr{D}^N = \delta \in \{0\}$, or a broad scope, $\mathscr{D}^B = \delta \in \{0, \bar{\delta}\}$.
4. Nature determines the true difficulty of the initiative, δ, and the agent observes this difficulty realization.
5. If a narrow scope is chosen, then senior management decides on the optimal resource allocation, r_n, that only satisfies the participation constraint of the project manager when a standard difficulty realization occurs. When a nonstandard difficulty realization occurs, the project manager abandons (rejects) the initiative.
6. If a broad scope is chosen, then senior management decides which resource allocation process to employ. They employ the process that yields max $\{\pi_{td}, \pi_{bu}\}$.
   (a) If a top-down process is chosen, then senior management determines the optimal resource allocation, r_{td}; and wages and incentives, w^*, k_s^*.
   (b) If the principal chooses a bottom-up process, then senior management decides on the wages and incentives w^*, k_s^* to offer.
7. The agent accepts or rejects the contract.
8. If a bottom-up process is employed, then the agent chooses $r_{bu,\,j}$, $j \in \{d, e\}$ to maximize their utility based on the observed difficulty realization.
9. Eventually, uncertainty is realized for the initiative and either value is appropriated, or losses and penalties are incurred.

$r, k_p > 0$. Applying the envelope theorem yields $\partial\pi_{td,\,d}/\partial\theta = p[r_{td}^*](k_p r_{td}^* + qv) > 0$, which implies that $\theta_{td}^{\min} > 0$.

Next we show that $\theta_{td}^{\min} < 1$. By the definition of $\bar{k}_p$ and the monotonicity of π_n with respect to k_p, $k_p < \bar{k}_p \Rightarrow \pi_n > 0$. Clearly $\pi_n > 0 \Rightarrow \pi_{td,\,d}|_{\theta=1} > 0$, which implies that $\theta_{td}^{\min} < 1$. Based on the monotonicity of $\pi_{td,\,d}$ with respect to θ implied by the envelope theorem and the continuity of the profit function, there must exist some $\theta \in (0,1)$ such that $\pi_{td,\,d} = 0$, which implies that $\theta_{td}^{\min} \in (0,1)$ exists.

Next we show that $\hat{\theta}_{td} > \theta_{td}^{\min}$. Suppose the contrary that $\hat{\theta}_{td} \le \theta_{td}^{\min}$. We can show π_{td} is increasing in θ based on the envelope theorem as follows: $\partial\pi_{td}[r_{td}, \theta]/\partial\theta = p[r_{td}](k_p r_{td} + qv) > 0$, so $\hat{\theta}_{td} \le \theta_{td}^{\min}$ can be restated as $\pi_{td}|_{\theta=\theta_{td}^{\min}} \ge \pi^n$, which expands to $(q\pi_{td,\,d} + (1-q)\pi_{td,\,e})|_{\theta=\theta_{td}^{\min}} = (1-q)\pi_{td,\,e} > \pi_n$, which contradicts our supposition since π_n is the first-best when only $\delta = 0$ difficulty initiatives are allowed.

Next we show by contradiction that $\hat{\theta}_{td} < 1$. Suppose that $\hat{\theta}_{td} \ge 1$.

Then $\pi_{td}|_{\theta=1-\epsilon} < \pi^n$, which expands to $q\pi_{td,\,d}|_{\theta=1-\epsilon} + (1-q)\pi_{td,\,e} < \pi^n$. Note that $\pi^n = (1-q)\pi_{td,\,e}|_{\theta=1} = (1-q)\pi_{td,\,d}|_{\theta=1}$. So, in the limit as $\theta \to 1$ we have that $\lim_{\epsilon\to 0}[q\pi_{td,\,d} + (1-q)\pi_{td,\,e}]_{\theta=1-\epsilon} = q\pi_{td,\,e}|_{\theta=1} + (1-q)\pi_{td,\,e}|_{\theta=1} = \pi^n/(1-q)$, which is clearly greater than π^n, which contradicts our supposition for any $q > 0$.

We have left to show that $\theta_{fb}^{\min} < \theta_{td}^{\min}$ and that $\hat{\theta}_{fb} < \hat{\theta}_{td}$.

We begin with the claim that $\theta_{fb}^{\min} < \theta_{td}^{\min}$.

Suppose the contrary that $\theta_{fb}^{\min} \ge \theta_{td}^{\min}$. This implies that $\pi_{fb,\,d}|_{\theta=\theta_{td}^{\min}} \le \pi_{td,\,d}|_{\theta=\theta_{td}^{\min}} = 0$; however, by definition the first-best solution must be greater than the top-down solution, where the difficulty is uncertain (so long as $q > 0$, as we have assumed), so this is a contradiction.

Similar logic supports the claim that $\hat{\theta}_{fb} < \hat{\theta}_{td}$.

Suppose instead that $\hat{\theta}_{fb} \ge \hat{\theta}_{td}$.

This implies that $[q\pi_{fb,\,d} + (1-q)\pi_{fb,\,e}]_{\theta=\hat{\theta}_{td}} \le [q\pi_{td,\,d} + (1-q)\pi_{td,\,e}]_{\theta=\hat{\theta}_{td}} = \pi_n$, but the definition of the first-best requires that if $q > 0$, then $\pi_{fb,\,d} > \pi_{td,\,d}$ and $\pi_{fb,\,e} > \pi_{td,\,e}$, which means that $[q\pi_{fb,\,d} + (1-q)\pi_{fb,\,e}]_{\theta=\hat{\theta}_{td}}$ must be greater than $[q\pi_{td,\,d} + (1-q)\pi_{td,\,e}]_{\theta=\hat{\theta}_{td}} = \pi^n$, which contradicts our supposition.

The optimal resource allocation for a top-down decision process follows directly from the first-order conditions on the respective objective function when the participation constraint (i.e., $w \ge k_p r_{td}(1 - \theta p[r_{td}])$) is binding at equality.

Thus, $(\partial/\partial r)\pi_{td} = (\partial p[r]/\partial r)((q\theta + 1 - q)v + k_p r\theta) - 1 - k_p(1 - \theta p[r])$ implies that r_{td}^*, senior management's optimal resource allocation, solves $(\partial p[r]/\partial r)((q\theta + 1 - q)v + k_p r\theta) - 1 - k_p(1 - \theta p[r]) = 0$.

Regarding compensation, senior management has two levers, or any combination of them, with which they can provide compensation and incentives to the project manager: w and k_s. The senior manager must meet the participation constraint of the project manager, which is binding when a difficulty realization of $\delta = 1 - \theta$ occurs.

To meet this constraint under a fixed wage, w, senior management offers $w = k_p r_{td}^*(1 - \theta p[r_{td}^*])$.

Alternatively, if senior management were to use a profit sharing contract, a k_s share of the profits would be offered, where k_s must satisfy $k_s\theta p[r^*_{td}](v-r^*_{td})-k_p r^*_{td}(1-\theta p[r^*_{td}])=0$, or $k_s=k_p r^*_{td}(1-\theta p[r^*_{td}])/(\theta p[r^*_{td}](v-r^*_{td}))$. When a difficulty realization of $\delta=1-\theta$ occurs and $\theta\neq 1$, the two forms of compensation yield the same ex post expected profit, i.e., $\pi_{td,d}$ is equivalent under both forms of compensation. However, when $\theta\neq 1$, and a standard difficulty realization occurs, $\delta=0$, both forms of compensation are not equal, as shown below.

Under a fixed wage, the ex post expected profit is $\pi_{td,e}=p[r]v-r-k_p r(1-\theta p[r])$, and profit sharing yields ex post expected profit of $\pi_{td,e}=(1-(k_p r(1-\theta p[r]))/(\theta p[r](v-r)))\cdot p[r](v-r)-r(1-p[r])$.

Subtracting the ex post expected profit under a profit sharing contract from the ex post expected profit under a fixed wage yields $(rk_p(1-\theta p[r])(p[r]-\theta p[r]))/(\theta p[r])>0$. Thus, it is always more profitable for senior management to implement a fixed wage.

As clarified in the proof of Proposition 1, a narrow scope is the senior manager's first-best solution when the participation constraint is met for a difficulty realization of $\delta=0$ but not a realization of $\delta=1-\theta$. In other words, senior management screens out more difficult projects. Then profit is maximized when the participation constraint for a $\delta=0$ initiative is binding so that senior management maximizes the objective $\pi^n=(1-q)p[r]v-r-k_p r(1-p[r])$ with respect to r, which results in the first-order condition $(k_p r+v-qv)(\partial p[r]/\partial r)-1-k_p(1-p[r])$ or the implicit solution for r^{n*}, where r solves $\partial p[r]/\partial r=(1+k_p(1-p[r]))/(k_p r+v(1-q))$.

A.5. Proof of Proposition 3: Bottom-Up Processes and the Breadth of Scope

This proof follows similar logic to the proof of Proposition 2. We claim that if $q>0$ and $0<k_p<\bar{k}_p$, then $\theta^{\min}_{bu}$, $\hat{\theta}_{bu}\in(0,1)$ both exist.

First, we show that $\theta^{\min}_{bu}>0$. The ex post expected profit when a difficulty of $\delta=1-\theta$ is realized is $\pi_{bu,d}=(1-k_s)\theta p[r_d](v-r_d)-r_d(1-\theta p[r_d])$. When $\theta=0$, this translates into $\pi_{bu,d}=-r_d$, which clearly has a negative expected value. From the envelope theorem, $\partial\pi_{bu,d}/\partial\theta=p[r^*_{bu}](v-k_s(v-r_d))>0$, so that $\theta^{\min}_{bu}>0$.

Next we show that $\theta^{\min}_{bu}<1$, which follows the same argument as in Proposition 2, where the definition of $\bar{k}_p$ requires that $\pi^n>0$. Clearly $\pi^n>0\Rightarrow\pi_{bu,d}|_{\theta=1}>0$, which implies that $\theta^{\min}_{bu}<1$. Based on the monotonicity of $\pi_{bu,d}$ with respect to θ (by the envelope theorem) and the continuity of the profit function, there must exist some $\theta\in(0,1)$ such that $\pi_{bu,d}=0$ so that $\theta^{\min}_{bu}\in(0,1)$ exists.

Next we claim that $\hat{\theta}_{bu}>\theta^{\min}_{bu}$.

Suppose the contrary. This implies that $\hat{\theta}_{bu}\leq\theta^{\min}_{bu}$. But, we know that π_{bu} is increasing in θ, so our supposition implies that $\pi_{bu}|_{\theta=\theta^{\min}_{bu}}\geq\pi^n$, which expands to $q\pi_{bu,d}+(1-q)\pi_{bu,e}|_{\theta=\theta^{\min}_{bu}}=[(1-q)\pi_{bu,e}]_{\theta=\theta^{\min}_{bu}}\geq\pi^n$, which is a contradiction since π^n is the first-best when only $\delta=0$ difficulty initiatives are allowed.

Finally, we claim that $\hat{\theta}_{bu}<1$.

Suppose the contrary. This would imply that $\hat{\theta}_{bu}\geq 1$. Then, $\pi_{bu}|_{\theta=1-\epsilon}<\pi^n$. In the limit as $\epsilon\to 0$, this equates to

$$\begin{aligned}&\lim_{\epsilon\to 0}[q\pi_{bu,d}+(1-q)\pi_{bu,e}]_{\theta=1-\epsilon}\\&\quad=q\pi_{bu,e}|_{\theta=1}+(1-q)[\pi_{bu,e}]_{\theta=1}=\pi_n/(1-q),\end{aligned}$$

which is clearly greater than π^n, which contradicts our supposition.

The optimal resource allocation when a bottom-up process is chosen follows directly from the first-order conditions on the respective objective function when the participation constraint is binding for the project manager, i.e., the constraint $k_s(v-r_{bu,d})\geq k_p r_{bu,d}(1-\theta p[r_{bu,d}])$.

The participation constraint is binding when $k_s\theta p[r_d]\cdot(v-r_d)-k_p r_d(1-\theta p[r_d])=0$ at equality. Solving for k_s yields $k^*_s=k_p r^*_d(1-\theta p[r^*_d])/(\theta p[r^*_d](v-r^*_d))$. It follows that when the project manager maximizes their utility to arrive at their optimal resource allocation, given the incentive k_s we arrive at the following:

$$\left.\frac{\partial u_{bu,d}[r_d]}{\partial r_d}\right|_{k_s=k^*_s}=\frac{k_p\left(\frac{\partial p[r_d]}{\partial r_d}r_d(v-r_d)-p[r_d]v(1-\theta p[r_d])\right)}{(v-r_d)p[r_d]}$$

so that r^*_d solves

$$\frac{\partial p[r_d]}{\partial r_d}r_d(v-r_d)-p[r_d]v(1-\theta p[r_d])=0,$$

or equivalently, r^*_d solves

$$\frac{\partial p[r_d]}{\partial r_d}=\frac{vp[r](1-\theta p[r])}{r(v-r)}.$$

We do the same for r^*_e, where

$$\begin{aligned}&\left.\frac{\partial u_{bu,e}[r_e]}{\partial r_e}\right|_{k_s=k^*_s}\\&=\left[k_p\left(r_d\left((v-r_e)\frac{\partial p[r_e]}{\partial r_e}-p[r_e]\right)\right.\right.\\&\qquad\left.\left.+\theta p[r_d]\left(p[r_e]v+v\frac{\partial p[r_e]}{\partial r_e}(r_e-r_d)-(v-r_d)\right)\right)\right]\Big/\\&\qquad\theta p[r_d](v-r_d)\end{aligned}$$

so that r^*_e solves

$$\begin{aligned}&r_d\left((v-r_e)\frac{\partial p[r_e]}{\partial r_e}-p[r_e]\right)\\&\quad+\theta p[r_d]\left(p[r_e]v+v\frac{\partial p[r_e]}{\partial r_e}(r_e-r_d)-(v-r_d)\right)=0,\end{aligned}$$

or equivalently,

$$\begin{aligned}\frac{\partial p[r_e]}{\partial r_e}&=[p[r_e](p[r^*_d]v\theta-r^*_d)-p[r^*_d]\theta(v-r^*_d)]\\&\quad\cdot\left[r^*_d(v(1-p[r^*_d]\theta)-r_e)vp[r^*_d]\theta r_e\right]^{-1}.\end{aligned}$$

With regard to the use of a fixed wage or a profit sharing contract (or any combination thereof), we claim that a profit sharing contract is necessary to induce the project manager to allocate resources.

Suppose a fixed wage were employed. The project manager chooses the resource allocation $r_j=\arg\max_{r_j}\{w-k_p r_j(1-\theta p[r_j])\}$. But this is maximized when the argument r is 0. Thus, to induce a nonzero resource allocation, r_j, senior management must employ a profit sharing contract with an incentive parameter k_s.

A.6. Proof of Proposition 4: Scope for Top-Down and Bottom-Up Processes

We claim that for any $\theta > \hat{\theta} = \min\{\hat{\theta}_{bu}, \hat{\theta}_{td}\}$, the optimal scope for the firm is Θ^b.

Suppose the contrary. This would imply that $\theta > \hat{\theta} \Rightarrow \Theta^n$, which further implies that $\pi^n > \max\{\pi_{bu}, \pi_{td}\}$. However, if $\theta > \hat{\theta}$, then the definition of $\hat{\theta}$ implies that $\max\{\pi_{bu}, \pi_{td}\} > \pi^n$, which is a contradiction.

The claim that $\partial\hat{\theta}/\partial k_p > 0$ follows directly from both $\hat{\theta}_{bu}$ and $\hat{\theta}_{td}$. Next, we claim that $\partial\hat{\theta}_{td}/\partial k_p > 0$.

This implies that $(\partial\pi_{td}/\partial k_p)|_{\hat{\theta}_{td}} < \partial\pi^n/\partial k_p$. It is sufficient to show that $\partial\pi_{td}/\partial k_p < \partial\pi^n/\partial k_p$, which equates to $-(q\theta + 1-q)r_{td}(1-\theta p[r_{td}]) < -(1-q)r_n(1-p[r_n])$, for which a sufficient condition is $r_{td}(1-\theta p[r_{td}]) > r^n(1-p[r^n]) \Rightarrow (1/k_p)w_{td} > (1/k_p)w^n$, which is clearly satisfied by the participation constraints, since $w_{td} > w^n$, which is required for a narrow scope to be implemented.

The same argument for a bottom-up process supports the claim that $\partial\hat{\theta}_{bu}/\partial k_p > 0$. It follows that so long as both $\partial\hat{\theta}_{td}/\partial k_p > 0$ and $\partial\hat{\theta}_{bu}/\partial k_p > 0$, and because $\hat{\theta} = \min\{\hat{\theta}_{bu}, \hat{\theta}_{td}\}$, it must be true that $\partial\hat{\theta}/\partial k_p > 0$.

A.7. Proof of Proposition 5: A Top-Down vs. a Bottom-Up Process

We begin by evaluating the limiting case when $k_p \to 0$ and $\theta = \hat{\theta}_{bu}$. Note that $k_p \to 0$ implies that $\hat{\theta}_{td} \to \theta_{td}^{\min}$, $\hat{\theta}_{bu} \to \theta_{bu}^{\min}$, which further implies that $\theta_{td}^{\min} = \theta_{bu}^{\min}$, which we will define as $\underline{\theta}$. Next, note that π_{bu} is linearly decreasing in q. This is because the project manager observes the realization prior to making the resource decision and thus $\pi_{bu,d}$ and $\pi_{bu,e}$ are each independent of q. Instead, q just determines the weights of the linear combination of the two that the firm expects to receive. Note, however, that π_{td} is convex decreasing in q, specifically because it is senior management that makes this decision, *without any knowledge of the actual difficulty*, so that the resource decision *is* dependent on q. To show convexity we employ the envelope theorem: $[\partial\pi_{td}/\partial q]_{r_{td}^*} = -(1-\theta)p[r_{td}^*]v$, where $-[p[r_{td}^*]v]_{q=q_L} < -[p[r_{td}^*]v]_{q=q_H}$ for $q_L < q_H$. We evaluate the endpoints on the interval $q \in [0,1]$ to find that when $q = 0$, optimal allocations for either process, r_{td} and r_{bu}, both solve $\partial p[r]/\partial r = 1/v$, and likewise when $q = 1$, r_{bu} and r_{bu} both solve $\partial p[r]/\partial r = 1/\theta v$. When $k_p \to 0$ both processes thus have the same profit for $q = 0$ and $q = 1$. As a result of the strict convexity of π_{td} with respect to q, we have the result that $\pi_{bu} > \pi_{td}$ for all $q \in (0,1)$.

Next, we evaluate the behavior when $k_p > 0$ while maintaining $\theta = \theta_{bu}^{\min}$. We solve the simultaneous equations $(\partial\pi_{td}/\partial r)|_{q=1} = 0$ and $\pi_{td} = 0|_{q=1}$, resulting in $\theta_{td}^{\min} = (1+k_p)r_{td}/((k_p r_{td} + v)p[r_{td}])$ and r_{td} that solves $\partial p[r]/\partial r = vp[r]/(r(k_p r + v))$. Likewise we do the same for the bottom-up process solving the simultaneous equations, where the first-order conditions are taken on the project manager's utility as opposed to the firm's profits, $(\partial u_{bu,d}/\partial r)|_{q=1} = 0$ and $\pi_{bu} = 0|_{q=1}$ yielding $\theta_{bu}^{\min} = (1+k_p)r_{bu,d}/((k_p r_{bu,d} + v)\, p[r_{bu,d}])$ and $r_{bu,d}$ that solves $\partial p[r]/\partial r = vp[r]/(r(k_p r + v))$; thus, $\pi_{td} = \pi_{bu}$ for $q = 1$ and $k_p > 0$. For $q = 1$, bottom-up and top-down processes yield the same profits (albeit no positive profit is achieved for the firm in either case).

When $q = 0$, we know from the proof of Proposition 3 that the resulting induced allocation level $r_{bu,e}$ is independent of k_p so that $r_{bu,e}$ still solves $\partial p[r]/\partial r = 1/v$, the same as when $k_p \to 0$, but when we solve for the optimal allocation levels for top-down when $q = 1$, we get that r_{td} solves $\partial p[r]/\partial r = (1+k_p)vp[r]/(k_p r^2 + k_p^2 r^2 + k_p rvp[r] + v^2 p[r])$ such that $r_{td} \neq r_{bu,e}$ for $k_p > 0$, and since the top-down is the first-best allocation (note that at the endpoints $q = 0$, $q = 1$ π_{td} yield the first-best solutions since there is no asymmetry), $\pi_{td} > \pi_{bu}$ for $q = 0$ and $k_p > 0$.

We claim that there exists a value of $k_p \doteq k_p^{\max}$ such that any $k_p > k_p^{\max}$ implies that $\pi_{td} > \pi_{bu}$. When $\pi_{bu,e} = 0$ it is clear that $\pi_{bu} = 0$. Thus, let k_p' be the value of k_p such that $\pi_{bu,e} = 0$, and note that, as we just showed, $\pi_{td}|_{q=0} > \pi_{bu,e} = \pi_{bu}|_{q=0}$ so that for any $k_p^{\max} \geq k_p'$ $\pi_{td} > \pi_{bu}$, which represents an upper bound for $k_p^{\max}$ so that $k_p^{\max} \leq k_p'$.

For $\theta = \theta_{bu}^{\min}$ and $0 < k_p < k_p^{\max}$ we claim there is a lower threshold $\underline{q}$ such that if $q \in [0, \underline{q})$, then $\pi_{td} > \pi_{bu}$, and if $q \in [\underline{q}, 1)$, then $\pi_{bu} > \pi_{td}$.

Suppose the contrary that $k_p > 0$ implies that for all $q \in [0,1)$, a top-down process is more profitable, $\pi_{td} > \pi_{bu}$.

However, both the top-down and the bottom-up profit functions are continuous and continuously differentiable, π_{td} is strictly convex in q, and because $k_p \to 0$ we know that $\pi_{td} < \pi_{bu}$ for all $q \in (0,1)$ and that $\pi_{td} = \pi_{bu}$ for $q = 1$ and $k_p > 0$. But our supposition only holds when a discontinuity is present in $(\pi_{bu} - \pi_{td})|_q$, which by definition is not possible.

In a similar manner we evaluate the profit functions while $k_p \to 0$ and $\theta > \theta_{bu}^{\min}$. In such a case when $q = 0$, $\pi_{td}|_{q=0} = \pi_{bu}|_{q=0}$ (the same result as when $k_p \to 0$ and $\theta = \theta_{bu}^{\min}$ since when $q = 0$, θ plays no role, and for $k_p \to 0$ the wages for the standard type initiatives are equal between the two processes). However, evaluating the allocation when $q = 1$ reveals that the resulting allocation is not the same for both processes. Top-down yields r_{td}, which solves $\partial p[r]/\partial r = 1/(\theta v)$, whereas $r_{bu,d}$ solves $\partial p[r]/\partial r = (p[r] \cdot v(1-\theta p[r]))/(r(v-r))$. We know that r_{td} is the first-best allocation, and thus when $q = 1$ for $k_p \to 0$ and $\theta > \theta_{bu}^{\min}$, the top-down process results in greater profits as $k_p \to 0$.

Next, we claim there exists a threshold $\Delta = 1 - \bar{\theta}$ such that if $\theta > \bar{\theta}$, then $\pi_{td}[\theta] > \pi_{bu}[\theta]$ for all $q \in (0,1)$. The profit under a top-down process, π_{td}, is convex decreasing in q, because senior management makes the resource decision *without any knowledge of the actual difficulty*, so that the resource decision *is* dependent on q. To show convexity we employ the envelope theorem: $[\partial\pi_{td}/\partial q]_{r_{td}^*} = -(1-\theta)p[r_{td}^*]v$, where $-[p[r_{td}^*]v]_{q=q_L} < -[p[r_{td}^*]v]_{q=q_H}$ for $q_L < q_H$.

Given that π_{bu} is linear decreasing and π_{td} is convex decreasing, then $\pi_{bu} - \pi_{td}$ is strictly a concave function with respect to q.

If a θ exists such that $[\partial\pi_{bu}/\partial q]_{q=0} < [\partial\pi_{td}/\partial q]_{q=0}$, then because of the convexity of π_{td} with respect to q, $\pi_{td} > \pi_{bu}$ for all $q > 0$.

To see if such a θ exists, we need to establish that there is a $\theta < 1$ such that $[\partial\pi_{bu}/\partial q]_{k_p\to 0} > [\partial\pi_{td}/\partial q]_{k_p,\, q\to 0}$, and furthermore see whether there exists a threshold level of θ, $\bar{\theta}$ where $[\partial\pi_{bu}/\partial q]_{k_p\to 0} < [\partial\pi_{td}/\partial q]_{k_p,\, q\to 0}$ such that $\pi_{td} > \pi_{bu}$ for all $\theta > \bar{\theta}$ regardless of the parameters.

Note that $[\partial\pi_{td}/\partial q]_{k_p\to 0,\, q=0} = -(1-\theta)p[r_{td}[q=0]]v$ and $[\partial\pi_{bu}/\partial q]_{k_p\to 0,\, q=0} = r_{bu,e} - r_{bu,d} - v(p[r_{bu,e}] - p[r_{bu,d}])$, and since $r_{td} = r_{bu,e}$ for $q = 0$ we substitute $r_{td} = r_{bu,e}$ to obtain the following relationship: $\theta v(p[r_{bu,e}] - p[r_{bu,d}]) > r_{bu,e} - r_{bu,d}$ or $\theta > (r_{bu,e} - r_{bu,d})/(v(p[r_{bu,e}] - p[r_{bu,d}]))$. Clearly the right-hand side of the inequality is positive. So, we only have left to establish that the right-hand side is less than 1, or, equivalently, $r_{bu,e} - r_{bu,d} < v(p[r_{bu,e}] - p[r_{bu,d}])$. This can be restated as $(p[r_{bu,e}]v - r_{bu,e}) - (p[r_{bu,d}]v - r_{bu,d}) > 0$. However, because $r_{bu,e}$ is the optimal solution to $(p[r_{bu,e}]v - r_{bu,e})$, and by definition $(p[r_{bu,e}]v - r_{bu,e}) - (p[r_{bu,d}]v - r_{bu,d}) > 0$, so long as $p[r_{bu,e}]v - r_{bu,e} > 0$, there does exist a threshold θ above which $\pi_{td} > \pi_{bu}$ for all $q \in (0, 1)$.

Thus, when $k_p \to 0$ and $0 < \theta < \bar{\theta}$, there exists a threshold value $\bar{q}$ such that for $q \in (0, \bar{q})$ a bottom-up process yields greater profits and for $q \in (\bar{q}, 1]$ a top-down process yields greater profits.

Next we claim that for $\theta < \bar{\theta}$ there exists an interval where $\pi_{bu} > \pi_{td}$ for $q \in (\underline{q}, \bar{q})$, where $0 \leq \underline{q} < q < \bar{q} \leq 1$. We have shown that for $k_p < k_p^{\max}$ and $\theta = \theta_{bu}^{\min}$ there exists a threshold for q such that $\pi_{bu} > \pi_{td}$ for $q \in (0, \underline{q})$. Similarly, we showed that for $\theta < \bar{\theta}$ and $k_p \to 0$ there exists a threshold for q such that $\pi_{bu} > \pi_{td}$ for $q \in (\bar{q}, 1)$. Then given that both profit functions are continuous and continuously differentiable, and monotonic in k_p, q, and θ, any supposition that such an interval does not exist results in a contradiction because it requires a discontinuity.

A.8. Proof of Proposition 6: Implementing Strategic Buckets

We point out that a top-down process is a special case (a degenerate one) of strategic buckets where only one bucket exists. Thus, from Proposition 2, $\hat{\theta}_{td} \in (0, 1)$ and $\hat{\theta}_{fb} \in (0, \hat{\theta}_{td})$, which implies that $\hat{\theta}_{sb} \in [\hat{\theta}_{fb}, \hat{\theta}_{td}]$.

We elaborate on the definitions provided in Proposition 6. Although a top-down process is a special case of strategic buckets with a single bucket, we draw a distinction between the two by restricting the strategic-bucket process to have greater than a single resource level. We note that the following definitions apply when $\Theta^* = \Theta^b$: $\phi_e \doteq r_e(1 - p[r_e])$, $\phi_d \doteq r_d(1 - \theta p[r_d])$, $r^h = \arg\max_r \phi_e[r]$, $r^l = r$: $\phi_e[r] = \phi_e[r_{fb,e}]$, and $r^l < r_{fb,e}$.

These definitions of the expected cost to the firm (directly proportional to the expected penalty of the project manager) help us to understand when the various constraints of the senior manager's problem are binding. We assume that the expected cost is quasi-concave in r over the interval $[0, r^*_{fb,e}]$ (a property that is readily evident for distributions that meet the properties of the problem, i.e., $p[r] = 1 - \exp^{-r}$, $p[r] = 1 - 1/r$, or $p[r] = \sqrt{r}$).

Recall that the senior manager faces the following problem: $\max_{w, r_{sb,d}, r_{sb,e}} \{q\pi_{sb,d}[w, r_{sb,d}] + (1 - q)\pi_{sb,e}[w, r_{sb,e}]\}$ subject to the constraints that (i) $u_{sb,d}[w, r_{sb,d}] \geq 0$, (ii) $u_{sb,e}[w, r_{sb,e}] \geq 0$, (iii) $u_{sb,d}[w, r_{sb,d}] \geq u_{sb,d}[w, r_{sb,e}]$, and (iv) $u_{sb,e}[w, r_{sb,e}] \geq u_{sb,e}[w, r_{sb,d}]$ (and that all decision variables are nonnegative $w, r_{sb,d}, r_{sb,e} \geq 0$), which translates into the Lagrangian

$$\begin{aligned}
&\mathcal{L}[w, r_{sb,d}, r_{sb,d}, \lambda_d, \lambda_e, \mu_d, \mu_e] \\
&\quad = q\pi_{sb,d}[w, r_{sb,d}] + (1 - q)\pi_{sb,e}[w, r_{sb,e}] + \lambda_d u_{sb,d}[w, r_{sb,d}] \\
&\qquad + \lambda_e u_{sb,e}[w, r_{sb,e}] + \mu_d(u_{sb,d}[w, r_{sb,d}] - u_{sb,d}[w, r_{sb,e}]) \\
&\qquad + \mu_e(u_{sb,e}[w, r_{sb,e}] - u_{sb,e}[w, r_{sb,d}]).
\end{aligned}$$

It is straightforward to see that λ_e will always be 0 and $\lambda_d > 0$. However the remaining constraints, the incentive compatibility constraints are at the heart of understanding how the strategic buckets can work without employing multiple levels of wages. It is for this reason that we introduced ϕ_e, Φ_d, r^l, and r^h. Note that by expanding constraints (iii) and (iv) we get, for (iii), $w - k_p r_{sb,d}(1 - \theta p[r_{sb,d}]) \geq w - k_p r_{sb,e}(1 - \theta p[r_{sb,e}])$, which reduces to $r_{sb,d}(1 - \theta p[r_{sb,d}]) \leq r_{sb,e}(1 - \theta p[r_{sb,e}])$ and, likewise for (iv), $w - k_p r_{sb,e}(1 - p[r_{sb,e}]) \geq w - k_p r_{sb,d}(1 - p[r_{sb,d}])$, which reduces to $r_{sb,e}(1 - p[r_{sb,e}]) \leq r_{sb,d}(1 - p[r_{sb,d}])$. Importantly, the penalty for failure (k_p) does not play a direct role in determining when the constraints are binding; instead the properties of $\phi_.$ are critical determinants of the applicability of the process. What enables the separation is the fact that the project manager is more aware of the expected loss than the senior manager, and since the expected loss is directly related to the resources allocated, the project manager self-selects the appropriate resource level. Given the concavity of ϕ and π, we expand the prior definitions as follows: Let $r^h_{\phi,d} = \arg\max_r \phi_d[r]$ and $r^h_{\phi,e} = \arg\max_r \phi_e[r]$, which represents the maximum expected cost given that either a more difficult or a standard initiative is realized, and $r^l_{\phi,e} = r$: $\phi_e[r] = \phi_e[r_{fb,e}]$, $r < r_{fb,e}$, which represents the resource level that is less than the optimal resource level that yields the same expected cost. In other words, if the optimal allocation lies on the decreasing portion of the penalty curve, then there is an equivalent resource level less than the optimal resource allocation that results in the same expected cost (the cost is less, but the chances of failure are higher). Then the conditions for separation are as follows: If $r^h_{\phi,d} \geq r_{fb,e} > r^h_{\phi,e}$ and $r_{fb,d} \geq r^l_{\phi,e}$, then first-best resource allocations can be achieved, $r_{sb,d} = r_{fb,d}$ and $r_{sb,e} = r_{fb,e}$.

When $r^h_{\phi,d} \geq r_{fb,e}$, incentive compatibility for a $\delta = 1 - \theta$ initiative, i.e., constraint (iii), is satisfied as $r_{fb,e} > r_{fb,d}$, which means that if the project manager chooses $r_{fb,e}$ when the preferred allocation is $r_{fb,d}$, they increase their expected penalty. However, since the wage is fixed a priori, an increased expected penalty means a lower expected utility. Similarly, $r_{fb,e} > r^h_{\phi,e}$ implies that there is an interval $[r^l_{\phi,e}, r_{fb,e})$ within which incentive compatibility for a $\delta = 0$ initiative is satisfied, i.e., constraint (iv). In other words, for any $r_{fb,d} \in [r^l_{\phi,e}, r_{fb,e})$, when a standard difficulty level is realized, choosing $r_{fb,d}$ within this interval only increases the expected penalty over choosing $r_{fb,e}$ and reduces the expected utility of the project manager given that the wage is fixed ex ante of the realization. Note that $r_{fb,e}$ is solely dependent on the value of the initiative as $r_{fb,e} = \arg\max_r p[r]v - r - w$, where w satisfies the participation constraint given a $\delta = 1 - \theta$ difficulty realization and thus $w = k_p r_{sb,d}(1 - \theta p[r_{sb,d}])$, which is clearly independent of $r_{fb,d}$. When we solve the first-order conditions for $r_{fb,e}$, we find that $r_{fb,e}$ solves $\partial p[r]/\partial r = 1/v$. Note that $r_{fb,d} = \arg\max_r \theta p[r]v - r - k_p r(1 - \theta p[r])$, so that $r_{fb,d}$ solves

$$\frac{\partial p[r]}{\partial r} = \frac{1 + k_p(1 - \theta p[r])}{\theta(k_p r + v)}.$$

Since $r_{fb,d}$ is decreasing in θ,

$$\frac{\partial u_{sb,d}[r]}{\partial r} = \frac{\partial p[r]}{\partial r}\theta(v + k_p r) - 1 - k_p(1 - \theta p[r]).$$

When we implicitly solve for $\partial r_{fb,d}/\partial\theta$, we get

$$\frac{\partial r_{fb,d}}{\partial\theta} = -\frac{k_p p[r] + \frac{\partial p[r]}{\partial r}(v + k_p r)}{\theta\left(2\frac{\partial p[r]}{\partial r}k_p + \frac{\partial^2 p[r]}{\partial r^2}(v + k_p r)\right)}.$$

The second-order conditions satisfy concavity

$$\frac{\partial^2 u_{sb,d}[r]}{\partial r^2} = \theta\left(2\frac{\partial p[r]}{\partial r}k_p + \frac{\partial^2 p[r]}{\partial r^2}(v + k_p r)\right) < 0.$$

Noting that this is the denominator of $\partial r_{fb,d}/\partial\theta$, it implies that $\partial r_{fb,d}/\partial\theta < 0$. So there exists a θ and some v where strategic buckets can achieve first-best resource allocations.

However, if the above conditions are not met, it is still possible to sort the initiatives as follows. If, as before, the first-best resource allocation is $r^h_{\phi,d} \geq r_{fb,e} > r^h_{\phi,e}$ (so that incentive compatibility for $\delta = 1-\theta$ initiatives is met), yet instead of $r_{fb,d} \geq r^l_{\phi,e}$ we have that $r_{fb,d} < r^l_{\phi,e}$, then incentive compatibility no longer exists for first-best resource allocations. In such an instance, we can have multiple different scenarios. The simplest of which is that $\mu_e = 0$, leaving $r_{sb,e} = r_{fb,e}$ and increasing $r_{sb,d}$ beyond $r_{fb,d}$ until $r_{sb,e} = r^l_{\phi,e}$, at which point incentive compatibility for $\delta = 1-\theta$ initiatives is satisfied. However, it may be the case that as μ_d is increased from 0, incentive compatibility for the $\delta = 0$ initiative is no longer slack. If $r^l_{\phi,e}$ is much greater than $r_{fb,d}$, then increasing $r_{sb,e} > r_{fb,e}$ reduces the difference $r^l_{\phi,e} - r_{fb,d}$, which results in $\mu_d > 0$ and $\mu_e > 0$, and $r_{sb,d} < r^l_{\phi,e}$ and $r_{sb,e} > r_{fb,e}$. Similarly, it is possible that an increase in $r_{sb,d}$ renders $r_{fb,e}$ suboptimal such that it is an overinvestment to the point where $r_{sb,e} < r_{fb,e}$ and $r_{fb,d} < r_{sb,d} < r^l_{\phi,e}$. All three cases are possible, where the commonality between them is the overinvestment in a $\delta = 1-\theta$ initiative.

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