Resource Allocation Processes for New Product Development: Empowerment, Control...or Both? The Value of Strategic Buckets

Jeremy Hutchison-Krupat
College of Management, Georgia Institute of Technology, Atlanta, GA 30308, jhk@gatech.edu
Stylianos Kavadias
College of Management, Georgia Institute of Technology, Atlanta, GA 30308, stelios@gatech.edu

Few decisions carry the weight that funding choices do within organizations. The decision to fund a particular new product development (NPD) initiative may have substantial implications for a firm's viability. Yet, at the time such decisions take place they are not well defined, and are critically dependent on specialized knowledge that resides at different levels within the organization. As a result, firms try to allocate resources through either top-down processes that emphasize control over budgeting, or bottom-up processes that aim to exploit the specialized knowledge held by stakeholders lower down in the organizational hierarchy. In this manuscript we address the challenges associated with choosing the "right" resource allocation process, given the hierarchical context and two important factors: (i) the asymmetry of information between the stakeholders (senior management and the project manager) regarding the difficulty to execute the initiative, and (ii) the organizational norms that affect managerial choices, namely the tolerance for failure that an organization exhibits towards those project managers associated with failed initiatives. We develop a normative model that accounts for the agency setting that arises in such a context, and seek to determine the features associated with the right resource allocation process, namely how decision rights are distributed among the stakeholders, and the associated compensation schemes that are employed. We find that no dominant process exists for all organizations and all initiatives, when choosing between a top-down and a bottom-up process. The firm benefits from delegation (bottom-up) when the initiative is more difficult, whereas initiatives associated with standard (incremental) tasks can do better when resource levels are dictated in a top-down process. We extend our analysis to account for optimal hybrid processes and we find that a process based on *strategic buckets* (a commonly observed practice in industry) offers the firm better results than either the top-down or bottom-up process. Our results offer an alternative justification for the use of strategic buckets, while also providing an interesting side effect of the organizational norms that impose penalties on managers of failed initiatives: they may enable the firm to implement processes such as strategic buckets, that might otherwise not be possible. We discuss the implications of our results towards the firm's overall ability to add new initiatives to the portfolio.

Key words: Resource Allocation Process, Strategic buckets, Empowerment, Resource bundles, New Product Development Strategy.

1. Introduction

The decision of whether or not to fund a particular strategic initiative can have substantial implications for the firm's viability (Wheelwright and Clark 1992, Cooper et al. 2001, Chao and Kavadias 2009). At the time such a decision is made, the initiative may not be fully defined, or precisely understood. Knowledge regarding what it takes to execute a specific initiative is dispersed across different levels of the firm's hierarchy, creating significant asymmetries of information. As a result, the decision process (i.e which decisions are made by whom) that senior management implements, ultimately influences the decision whether to fund an initiative, and how much funding should be allocated. The fact that resource allocation processes (RAP) 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 affect *which* initiatives the firm funds, is an important operational element that determines strategy execution.

The resource allocation processes employed in practice fall within two broad categories. In a *top-down* process, senior management dictates fixed levels of resources for middle management (i.e. a project manager) to oversee, whereas in *bottom-up* processes project managers are granted *decision rights* (Aghion and Tirole, 1997) to determine the right level of resources (Maritan 2001, Chao and Kavadias 2010, Kavadias and Kovach 2010). As such, top-down processes aim to establish the efficient use of resources by maintaining *control*. In contrast, bottom-up processes aim to leverage the effective use of resources, by *empowering* managers who tailor resource allocation through their expert knowledge of the challenges associated with the execution of the initiative. Since both types of processes are encountered in practice, a natural question is: when is it best to employ a top-down process as opposed to a bottom-up one? Moreover, there is a more general question regarding the existence of processes that could combine the best elements of both approaches. Could such an "optimal" process be operationalized?

Scholars have long studied efficient implementation of top-down resource allocation (Harris et al. 1982). More recently the Operations Management literature has explored decision making processes that account for the hierarchical nature of decision making within organizations (Siemsen 2008, Chao et al. 2009, Loch and Sting 2009, Mihm 2010, Mihm et al. 2010). These studies have primarily emerged within the new product development (NPD) domain due to the obvious fit, NPD is highly specialized (Zingales and Rajan, 2001), NPD activities imply decentralized expertise, and are central to the growth and livelihood of the firm, and as such require substantial resources. However, most of these studies have focused on the private effort undertaken by NPD specialists and have not accounted for the existence of bottom-up resource decisions, i.e. budgets that are shaped by middle management.

In this study we seek to understand the drivers of resource allocation. We account for both the hierarchical nature of the organization, and the asymmetries that exist between stakeholders, i.e. the middle management (PM) and senior management (the VP, acting as a proxy for the executive level of decision making within the firm). We capture the hierarchical nature of decision making through the use of a principal-agent model where, the PM (agent) must oversee the execution of the initiative, and the VP (principal) must decide whether or not the initiative should even be funded. We distinguish between the resource allocation processes based on which stakeholder (the PM or VP) chooses the level of resources (budget) to allocate to the initiative. Our model captures an important asymmetry between the VP and the PM, regarding their respective knowledge of the difficulty associated with the execution of the initiative. We allow the PM to fully understand the difficulty of the initiative (expressed by the relationship between resources allocated and the likelihood of success); in contrast, the VP only knows that the initiative may be one with *difficult task execution* or one with *simpler task execution*. In order to capture tensions between stakeholders that is driven by the organization itself, we choose not to focus on the personal (private) effort of the project manager (PM) as the source of any misalignment between the objectives of the VP (principal) and the PM (agent). Instead, we posit that any disutility for the PM results from the risk of failing, and the ex-post penalties that he might incur. Thus, we consider a straightforward setting where the PM would rather be rewarded than penalized, and he chooses actions according to the utility he receives from each occurrence (success or failure). Given this interpretation of the managerial context, the firm's organizational culture (Kreps 1990, Hermalin 2008, Schein 2010) becomes an important element of our model. The culture determines the organizational norms which dictate the treatment a PM can expect following a failed outcome (i.e. the organizational penalty they incur[1]).

Our findings show that, contingent on the information asymmetry between the stakeholders and the difficulty of the initiative, a top-down process may prove more beneficial than a bottom-up one, and vice versa. Thus, we offer normative support regarding the need for *both* bottom up and top-down processes to co-exist within organizations, as advocated early on by Burgelman's (1983) seminal work. We analytically characterize when each respective process is more beneficial: initiatives with high expected difficulty, benefit from a bottom-up process; however, when the expected

[1] Such penalties may be as subtle as the manager receiving all the "unwanted" projects, or as explicit as being fired. Such penalties reflect the organization's set of rules and routines, that define "how things get done" and represent a key dimension of the organizational culture: the "tolerance for failure" (Manso 2009)

difficulty is low, a top-down process dominates. We then show that there does exist a resource allocation process that employs budgets and incentives tailored to the execution difficulty of the initiative, which dominates both, i.e. the top-down, and bottom-up approaches. Yet, the implementation of such a process for all types of initiatives is potentially involved (if not prohibitive) for most organizations[2]. Fortunately, there is a silver-lining: solely implementing budgets tailored to the difficulty of the initiative, also known as *strategic buckets*, can still offer benefits over both the top-down and bottom-up processes. In other words, strategic buckets enable the firm to expand the set of initiatives it can profitably fund. Our findings add an operational perspective to two important discussions: first, we offer insights on how managerial structure provided by the RAP impacts what initiatives the firm funds (Bower and Gilbert 2005), second, we offer an alternative explanation for the use of strategic buckets in organizations as a means of effective resource allocation (Chao and Kavadias 2008).

The rest of the paper is structured as follows. We review the relevant literature in §2 and introduce our model setup in §3. Following our model setup we provide the analysis of our model in §4. In our model analysis, we first characterize the first-best solution in §4.1, then follow this with a characterization of the top-down and bottom-up resource allocation processes in sections 4.2 and 4.3, respectively. We then provide an exposition of a resource allocation that captures elements of both the bottom-up and top-down processes in §4.4. Lastly, we close with a discussion and conclusions in §5.

2. Related Literature

A substantial body of research across various management disciplines, has addressed various challenges surrounding resource allocation decisions. Of these studies, the literature that is most relevant to our work comes from research in Operations Management (OM), Strategic Management and Corporate Finance.

Several 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. Roberts and Weitzman, 1981, Teisberg 1993,1994, 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 and the executor of the project tasks are one and the same. We relate to the overarching objective of these papers, as we look at the decision process associated with resource allocation and the choice to fund a project. However, we take a different perspective

[2] Mihm 2010 offers a rich discussion regarding why such tailored incentive contracts such as this are hard to implement.

as we account for the realities of the NPD process: hierarchical decision making, and the distributed nature of knowledge which gives rise to agency and incentive challenges. Recently, scholars in NPD have begun to account for the hierarchical nature of decision making (Siemsen 2008, Terwiesch and Xu 2008, Chao et al. 2009, Mihm et al. 2010, Mihm 2010, Erat and Krishnan 2010). Two of these studies, lie closer to our work: Chao et al. (2009) and Siemsen (2008). Specifically, Chao et al. (2009), being the closest, study a hierarchical setting where a senior manager (principal) chooses between "empowering" a business unit manager (agent) to adapt his innovation budget to the division sales, or to "control" the agent through issuing him a fixed innovation 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 each of these settings. We extend the setting of Chao et al. (2009) to characterize the optimal funding decision across different resource allocation processes. Although Chao et al. (2009) assume that the exact resource allocation is not observable by the principal, we posit that in our setting, resource budgets are in fact observable by senior management and that there is a more suitable source of asymmetry between the stakeholders that arises from knowledge specialization as opposed to accounting "noise". Siemsen (2008) explores another aspect of the hierarchical nature of the firm: the effect of career concerns on the task difficulty choice of the employee (agent). Siemsen focuses solely on the effects of career concerns, independent of any other incentive mechanism[3], and given that the agent's utility is reputation related. We build on his observation that specialists have superior knowledge of the difficulty associated with project tasks, and we incorporate this insight to solve for senior management's (the principal's) optimal choice regarding the resource allocation process and actual resource allocation in order to maximizes firm profits.

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 a common conceptualization of the resource allocation problem. We agree with the assumptions made in this stream of literature: decisions are decentralized and hierarchical; there exists asymmetry of information between the stakeholders; and that the compensation and incentive schemes rely on incomplete contracts. However, the context of NPD initiatives presents distinct challenges that are not of primary concern to this stream of literature: (i) the assumed returns on investment

[3] In a related follow up Katok and Siemsen (2009) elaborate on the principal's use of the value of the promotion in order to influence the agent's choice.

exhibit strong non-linearities (Loch and Kavadias 2002), different from the additive or linear profit functions predominantly used in capital budgeting; (ii) these non-linearities 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 specialization know-how held by the project team is not imitable by the senior management of the firm and therefore substitution of effort across stakeholders may not be possible; finally (iv) the disutility of the agent may be a result of organizational norms (i.e. penalties resulting from a failed initiative) and not solely a result of effort put towards a project. Our model formulation specifically accounts for these distinctions and operationalizes the resource allocation process in an NPD setting.

Finally, we owe special credit to the seminal work of Bower (1970) and Burgelman (1983) in the Strategic Management discipline, as 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 validates and explains their findings. In that vein, our work operationalizes the choice of resource allocation processes within a hierarchical organization and lends support to the observations that NPD processes require a hierarchical planning perspective (Anderson and Joglekar 2005).

3. Model Setup

In this section, we introduce the formal structure of our model. Consider a typical organizational hierarchy: senior management (the VP, i.e. principal) oversees a project manager (i.e. agent), who is responsible for the detailed execution of NPD initiatives. The project manager represents all of the interests and task specific knowledge of the entire project team; the VP acts as a proxy for the firm's interests, and she is responsible for the implementation of a dimension of corporate strategy, through an innovative initiative. The VP, assigns the initiative based on a simple rule: does the initiative add value, Π[4] to the firm, i.e. is $\Pi \geq \hat{\Pi}$? Where $\hat{\Pi}$ is the minimum value the firm must gain from an initiative in order for it to be considered worthwhile. Prior research (Bower 1970, Burgelman 1983, Coen and Maritan 2010) has identified a critical factor that influences

[4] Value can be thought of as monetary cash flow, monetary equivalents, e.g. other outcomes such as knowledge, etc.

the decision to fund an initiative or not: the *structural context* (i.e. the "organizational design, and compensation plans that top executives can manipulate to influence indirectly what type of strategic initiatives are defined and selected (Bower 1970)") in which the initiative is carried out. Then, given the specific initiative and its structural context, researchers have advocated that success and profitability depends on elements of the resource allocation process, i.e. who decides what (Bower and Gilbert 2005). In the following three sub-sections we detail these three constructs: the properties of the initiative, the structural context, and the structure of the resource allocation process, respectively. Our objective is to employ these constructs and characterize the value maximizing process choice given an initiative, for a particular firm. Our model setup offers some novel conceptual contributions to the general organizational design literature, which we highlight in §3.5.

3.1. The NPD initiative.

The initiative is defined by the value it yields, should it realize a successful outcome, and its likelihood of success. Without any loss of generality, we assume that the potential value V is fixed, and known by all of the stakeholders, i.e. the VP and the PM. However, the probability of success depends on two key factors: the *difficulty* of the tasks required to execute the initiative, and the *resources* allocated to the initiative.

The difficulty of the strategic initiative, depends on how arduous the respective tasks are for the project team. In order to fully understand the task details, specialized knowledge is required, which resides with the project team (i.e. project manager). Such knowledge is neither easily communicated (i.e. transferred), nor readily understood, by stakeholders who are *not* intimately involved with the execution of the specific tasks. Thus, the VP cannot understand the intricate details of the initiative. Let $\theta \in [0,1]$ be the difficulty of the specific tasks required by the initiative, where $\theta = 0$ represents an impossible task, and $\theta = 1$ represents tasks that have the highest chance of success for a given resource level allocated to them. θ is private knowledge held by the project manager. A-priori the difficulty is unknown to both stakeholders. The initiative may realize a difficult set of tasks for the project team ($\theta = \theta_d$), or an easier – more standard – set of tasks $\theta = \theta_e$, which we normalize to be $\theta_e = 1$. We refer to this type of initiative as one that is *standard* for the organization. The likelihood that the firm realizes the value V, is defined as follows: if R represents the resources allocated to the initiative, then let $P[R] \in [0,1]$ be the likelihood of success for a standard set of tasks, i.e. $\theta_e = 1$. However, for difficulty levels other than the standard, the likelihood of a successful outcome is the multiplicative function $\theta P[R]$. Then, the overall likelihood of success is $p[\theta, R] = \theta P[R]$, which we assume to be quasi-concave and super-modular in θ and R. More specifically: $\partial p/\partial R > 0$, $\partial p/\theta > 0$, $\partial^2 p/\partial R^2 < 0$, $\partial^2 p/\partial \theta^2 \leq 0$, and $\partial^2 p/(\partial R \partial \theta) > 0$. Our structural assumptions regarding $p[\theta, R]$ represent a set of intuitive properties: the likelihood of success is increasing in both the resources allocated to the initiative, and the ease with which tasks can be accomplished for each given resource level; there may be diminishing returns to the likelihood of success resulting from the resources allocated to the initiative; finally the resources allocated, and the ease by which the tasks are executed, are complementary inputs to the likelihood of success. Indeed, for the same level of resources (i.e. testing equipment, market research groups, etc.), an easier project has a higher likelihood of success than a more difficult one. Since the likelihood is endogenously determined by the allocated resources, the structural context, within which resource decisions are made, is essential to understand.

3.2. Structural context.

There are two key elements that comprise the structural context in our model: first, the degree of information asymmetry that exists between the VP and the project manager (the stakeholders); and second, the organizational norms that govern the implicit rules and expectations regarding "how things are done", namely the organizational penalties imposed upon managers who fail to achieve the strategic objectives[5].

We begin with a closer look at the information asymmetry. The project manager holds private knowledge regarding the actual difficulty of the required project tasks. As such, he knows θ, yet the VP only knows that θ may be difficult (θ_d) with probability q and easy (θ_e) with probability $(1-q)$. This intentional misalignment regarding the knowledge of task execution effectively captures an important reality of the NPD context. Specialists hold competencies that are hard to imitate, let alone replicate. This observation has been argued to lead to hierarchies in the first place (Zingales and Rajan 2001).

Organizational rules implicitly govern how things get done, i.e. dimensions of the firm's corporate culture (Schein 2010). In our context we focus on a particularly important"rule", namely what happens to the project manager if an initiative fails? There is ample evidence that organizations differ, in the consequences they impose, regarding such outcomes (e.g. a diminished intra-organizational status, reflected in the career paths or development programs the manager is considered for). Such (usually non-codified) rules comprise an organization's "corporate culture" (Kreps 1990, Hermalin 2008, Chao et al. 2009). The particular dimension of the corporate culture that we consider has recently drawn attention as an important determinant of task execution (Manso 2009), i.e. a firm's

[5] Note that the compensation and incentives might be considered part of the structural context, yet they could be adjusted within the context of a resource allocation process. Thus, we chose to discuss them together with the decisions regarding the resource allocation process in §3.3. In contrast, we posit that the organizational norms are rarely changeable within the scope of a single initiative.

"tolerance for failure", where a high tolerance is indicative of a low penalty[6]. Drawing upon several interviews with senior NPD managers, we have found that, such consequences are strongly associated with the resources allocated to the initiative (R). Even in a harsh corporate environment, an initiative that fails, yet consumes negligible resources, would not warrant detrimental consequences for the PM's career. However, for an initiative that consumes copious amounts of organizational resources, and fails, we would expect the consequences to proportionally be much greater. We capture the resource dependence of this organizational effect through a linear parametrization of the penalty: k_pR. Thus, k_p is exogenously fixed for a particular organization, since, as a dimension of the corporate culture, it reflects implicit policies, or accepted routines that are hard to change, at least within the context of a single initiative. In §3.4, we discuss how this organizational penalty factors into the overall utility of the project manager.

3.3. The resource allocation process (RAP)

Given the definition of the initiative itself (3.1), and the structural context (3.2), the VP considers the appropriate resource allocation process to use in order to maximize the organization's profits. Such a choice takes into account the previous constructs in order to define one crucial choice: Who decides on the resource levels, and how can the VP influence these decisions (Bower and Gilbert 2005)?

The VP assigns the strategic initiative when she expects the firm to receive value at least equal to $\hat{\Pi}$. The expected value to the VP is $\mathbb{E}[\Pi] = pV - R - W$, or the expected revenue of the project (pV), net of expenses associated with the allocation of resources (R), and wages (W), required to execute it. Yet, as we have described in 3.1, p is not an exogenously specified quantity, but a function of the resources allocated and the difficulty of the execution tasks. In addition, the VP does not know the latter with certainty. Under such circumstances, the VP can choose to enlist the detailed knowledge (project difficulty) of the PM, and delegate the resource allocation decisions to him, which we define as a *bottom-up* resource allocation process, or she can dictate the exact resource budget, which we define as a *top-down* resource allocation process. Changes in how resources are allocated might also warrant changes to the compensation structure, W, as well. Let $W[w, k_s] = w + k_s(V - R)$, represent a generic form of compensation offered to the PM; it is a combination of a fixed wage w portion and an output contingent profit-share mechanism, $k_s(V-R)$. Our analysis determines which parts of such generic compensation are rendered inactive, i.e. $w = 0$ or $k_s = 0$, under different choice of RAP. Regardless of whether the VP chooses a top-down or

[6] Failure does not necessarily imply an unsuccessful launch, it may surface as an abrupt stop in a subsequent "gate review", or "quarterly operations" meeting.

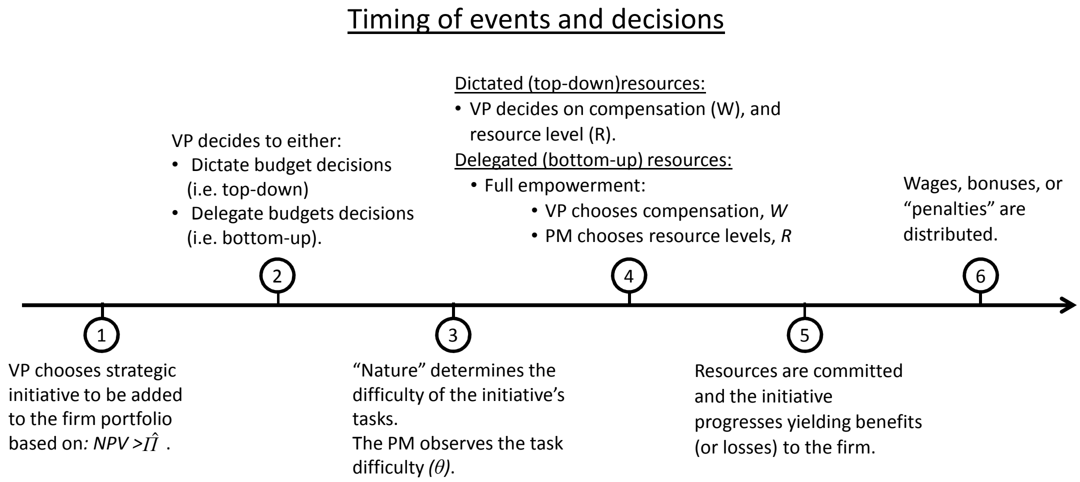

Figure 1 **The sequence of events and related decisions.**

a bottom-up resource allocation process, she must set compensation so that the project manager does not ex-ante expect to suffer a loss from undertaking the initiative. In other words, the PM expects to at least earn a level of utility equal to his opportunity cost ($\underline{U}$); which, without loss of generality, we normalize to zero (Baiman and Rajan 1995)[7].

The following two important observations drawn from field studies are supported by our assumptions regarding the resource allocation process: i) the PM is always given formal authority (Aghion and Tirole 1997) to recommend the initiative not be funded (i.e. alternatively, they are allowed to "opt-out") – the expectation is that they do so when their outside option ($\underline{U}$) is not met on expectation (Baiman and Rajan 1995)[8]; ii) the VP can not determine (or verify) the true underlying task difficulty (i.e. θ is not directly contractible) regardless of the outcome (success or failure), i.e. the contract is incomplete.

At this point one could rightfully ask the question: is there a way the VP could balance the trade-offs associated with the top-down and bottom-up processes through the use of some type of hybrid process? There is the option of designing an incentive feasible Bayesian mechanism, i.e. a menu of contracts with project type dependent non-linear compensation: the firm tailors

[7] The opportunity cost of the PM is common knowledge. The interpretation is intuitive: embedded in the opportunity cost is the benefit the PM can receive, net of switching costs, if they were to choose alternate employment. This simply captures the intuitive realization that, if you put a PM on a project where their exposure to failure is simply too high (and the resulting penalties too harsh), they would rather seek out alternative opportunities than risk, having their career prospects severely impacted.

[8] Note, that we claim the VP expects them to "opt-out" if their outside option is not met. To see this imagine that the VP only wanted to pursue simpler initiatives. Since she can not a-priori know what the difficulty is, nor can she ex-post confirm it, the only way for her to achieve this is to design compensation such that the PM opts-out of initiatives when they realize a difficult set of execution tasks. If the PM were *not* allowed (assumed) to opt-out, then the VP could not achieve this.

both the resource level and PM's compensation to the difficulty of the initiative. However, such an option may be prohibitive to many firms as a result of the complexity associated with its implementation. Obviously, such an added dimension of flexibility (an additional decision variable for the firm), allows the firm to earn a greater surplus. Yet, as advocated by recent studies in the NPD literature (Mihm 2010) and the Economics literature (Baker et al. 1988, Fehr et al. 2007) , the implementation of such complex incentive mechanisms may entail an additional direct or indirect cost $c[\cdot]$, which may render them infeasible or undesirable. Another option is where the VP defines distinct difficulty specific resource levels (R_θ), i.e. she uses "strategic buckets" to empower the PM, while offering a common compensation scheme (see Chao and Kavadias 2008, Terwiesch and Ulrich 2009). In such a scenario, the PM is empowered to choose the appropriate bucket, and the VP designates the resource levels so the PM chooses the resource bucket that fits his private knowledge of the difficulty.

We present the sequence of decisions, and the timing of information, relating to the resource allocation process for the innovative initiative in Figure 1. Our sequence reflects our own anecdotal evidence, but also rests upon the extensive volume of field studies conducted by Strategy researchers pertaining to the resource allocation process (Bower and Gilbert, 2005).

3.4. The feasible set of initiatives and stakeholder utilities

Now that we have discussed the main conceptual elements of our model, we formally define the expected profit of the VP, the expected utility of the PM and each stakeholder's respective maximization objective.

DEFINITION 1. THE EXPECTED PROFIT OF THE VP AND UTILITY OF THE PROJECT MANAGER.

<u>When resources are dictated:</u>
The VP maximizes her expected profit:

$$\max_{R,W} \quad \mathbb{E}[\Pi] = \mathbb{E}_\theta[\theta P[R]V - R - W]$$
$$\text{s.t.} \quad E[U] = \mathbb{E}_\theta[W - k_p(1-\theta P[R])R] \geq \underline{U} = 0$$

<u>When the PM is fully empowered:</u>
The VP maximizes her expected profit:

$$\max_{W} \quad \mathbb{E}[\Pi] = \mathbb{E}_\theta[\theta P[R_\theta]V - R_\theta - W[R_\theta]]$$
$$\text{s.t.} \quad \mathbb{E}[U] = \mathbb{E}_\theta[W[R_\theta] - k_p(1-\theta P[R_\theta])R_\theta] \geq \underline{U} = 0$$

and the PM chooses R_θ, where

$$R_\theta = \arg\max_{R_\theta} \quad W[R_\theta] - k_p(1-\theta P[R_\theta])R_\theta$$

Having stated each stakeholder's utility and objective function, we explain how the structural context and the resource allocation process impact the initiatives that the firm decides to fund, i.e. those strategic initiatives where $\mathbb{E}[\Pi] \geq \hat{\Pi}$. We define such initiatives as the *feasible set of initiatives*, i.e. those for which $\mathbb{E}[\Pi] \geq \hat{\Pi}$ for a given resource allocation process, and structural context; thus, the feasible set contains those initiatives that the VP is willing to fund. Ceteris paribus, a smaller feasible set of initiatives can be interpreted as a smaller opportunity set, within which the firm can seek profit. This conceptualization of a feasible set of initiatives, given the structural context, is an analog to Markowitz's (1952, p. 85) "attainable set" of investments for a specific individual investor. Markowitz explains that there is no single attainable set of investments for all investors, but that it depends on the individual's risk preferences. Our analysis investigates how a firm's structural context and resource allocation process impacts the feasible set of initiatives for an organization.

3.5. Summary of conceptual contributions

Prior to commencing our analysis, we provide a brief discussion of the conceptual contributions and some key distinctions of our model. In summary, our model formulation captures the following salient features of the NPD context:

- Knowledge necessary to make critical funding decisions is dispersed among various stakeholders resulting in distinct information asymmetries within the organizational hierarchy. In that respect, it is impossible to ex-post decouple what was the "cause" of the success or failure of an initiative (insufficient resource allocation or a random outcome).
- The utility functions of the stakeholders are risk neutral. Our assumption aims to avoid any *a priori* risk bias. We do this to isolate organizational effects, as opposed to individual behavioral traits, a usual reason provided to justify an organization's avoidance of risky initiatives (Hauser 1998).
- Whereas most traditional agency models assume managerial risk aversion and a disutility from task effort to justify the organization's tendency to forego difficult initiatives, and rely on output contingent compensation, we show that nonlinear returns and the presence of organizational penalties represent an alternative rationale.
- The only private component for the project manager is his knowledge of task difficulty θ. In that regard, we avoid any a-priori misalignment between the payoffs to the stakeholders, another highly cited reason for many organizations' failure to pursue risky initiatives (Siemsen 2008, Manso 2009, Mihm 2010). In our model, the "alignment"[9] between the VP and the managers lies within the VP's discretion.
- Additionally, we account for the interaction between project type (i.e. task difficulty) and the resources allocated. Such complementarities stem from the fact that NPD initiatives exhibit complex interactions such that additional difficulty along any single dimension could imply a disproportionate increase in the resources required to achieve the same likelihood of success.

[9] The alignment we refer to is strictly in terms of the objectives of each stakeholder (in line with prior literature, see Van Den Steen 2007). The stakeholders are aligned when their optimal solutions yield the same values.

4. Analytic results

In this section we present the results of our model analysis. Recall that, we aim to answer the following question: When is it better to have a process that delegates the resource allocation decision? In that regard, we start with the first-best outcome, i.e. when all stakeholders know the true difficulty of the initiative. Despite the restrictive nature of any first-best outcome, it allows us to establish a baseline result and develop some key metrics, as well as our intuition. Then, we move to the more realistic setting, where information asymmetries exist, regarding the initiative difficulty. Within such a setting we first present a top-down resource allocation process, and then we contrast it with the bottom-up process of delegation via a fully empowered PM. Following our comparison, we seek to identify whether a particular RAP could mitigate the challenges associated with the top-down and bottom-up processes. We find that if we relax the assumption that requires the organization to apply a universal (i.e. difficulty independent) compensation scheme (i.e. fix w and/or k_s), and instead allow the firm to offer the PM resource levels and compensation tailored to the difficulty of the tasks, (an incentive feasible menu of contracts) then we can achieve a RAP that dominates both the top-down and bottom-up processes for all levels of expected difficulty. We discuss the limitations of such a process in practice, as identified by the prior literature, and we point out that a simplified version of such a RAP can (weakly) supersede the traditional top-down and bottom-up processes. Eventually, we point out that this simplified version resembles and justifies the widely used practice of implementing "strategic-buckets".

4.1. Baseline: First-best solution

We begin our model analysis with a look at the first-best setting, where no information asymmetries are present. The difficulty of the initiative is known to all stakeholders. In this setting, for an initiative of known type θ, the optimal choice for the VP is to determine resource levels and ensure implementation through the use of a fixed wage compensation plan. We formally state these results below and defer the proofs to the appendix, for clarity of exposition.

PROPOSITION 1. FIRST BEST RESOURCE ALLOCATION AND THE FEASIBLE SET.

(a) The optimal resource level R^{fb} solves: $\partial P[\cdot]/\partial R = (1+k_p(1-\theta P[R]))/(V+k_pR)$ and it is increasing in the ease of the project tasks θ, i.e. $\partial R^{fb}[\cdot]/\partial\theta > 0$

(b) The feasible set of initiatives is defined by: $\mathcal{F}^{fb} = \left\{\theta \geq \hat{\theta}, \hat{\theta} = \theta : P[R] = \frac{(\hat{\Pi}+1+k_p)R}{\theta(V+k_pR)}\right\}$ and $\mathcal{F}^{fb}$ increases as θ increases.

The first-best resource level has an economic interpretation. For each additional unit of resources the VP allocates, the probability of success p increases, $(V-R)$ decreases, and the managers face a larger penalty k_pR should the project fail. The optimal resource allocation equates marginal expected value from each additional unit of resource, to the marginal cost of compensation the VP must bear to cover the PM's the potential organizational penalty. Beyond this resource level, any marginal value gained from an additional resource $(V\partial P[\cdot]/\partial R - 1)$ is outweighed by the marginal wages $(k_p(1-P[\cdot]-R\partial P[\cdot]/\partial R))$ required to offset the potential penalty faced by the managers.

As θ decreases (i.e. a more difficult set of tasks), the optimal level of resources decreases. The result stems from the assumed complementarity between the task difficulty and the resources allocated. Finally, we obtain the baseline feasible set of initiatives.

4.2. Top-down resource allocation

In a top-down resource allocation process, the VP dictates the level of resources, and the compensation plan. In such a setting, the VP needs to ensure that the compensation offered to the project manager provides him with an expected utility at least equal to his reservation utility, regardless of the realization of the initiative's difficulty. The following proposition outlines the implications of implementing a top-down resource allocation process.

PROPOSITION 2. A TOP-DOWN RESOURCE ALLOCATION PROCESS AND ITS FEASIBLE SET. *The following statements hold when the VP chooses a top-down resource allocation process:*

(a) *The VP offers compensation in the form of a fixed wage.*
$k_s^* = 0$ *and* $w^* = k_pR^*(1-\theta_d P[R^*])$, *where* R^* *is the optimal level of resources.*

(b) *The optimal level of resources* R^* *solves:*
$1 + k_p(1-\theta_d P[R]) - \frac{\partial P[R]}{\partial R}(k_p dR - V\mathbb{E}[\theta]) = 0$, *is increasing in* θ_d, *i.e.* $\frac{\partial R^*}{\partial \theta_d} > 0$
and it is strictly less than the first-best, i.e. $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$

(c) $\mathcal{F}^{td} = \left\{\mathbb{E}[\theta] : \mathbb{E}_\theta[\Pi] \geq \hat{\Pi}^{td}\right\}$, $\mathcal{F}^{td} < \mathcal{F}^{fb}$ *for all non-standard initiatives,* $\mathbb{E}[\theta] < 1$, *and* $\mathcal{F}^{td}$ *gets smaller as* k_p *increases.*

When the resource levels are dictated to the project manager, it is suboptimal to use compensation schemes that are contingent on the outcome. If the VP were to use output contingent compensation with a fixed incentive parameter k_s, then in the event the PM realizes θ_e, i.e. a standard project, the PM is disproportionately (over) compensated, thus increasing the firm's loss. This loss is a result of the assumed complementarity between θ and R. It follows that it is better for the firm, if the VP avoids such a loss by offering a fixed wage.

Next, we compare the resource allocation dictated by the VP under asymmetric information, with the resource level dictated by the VP for an initiative with the same mean difficulty, but no information asymmetry. So long as *some* level of asymmetry exists, the resources assigned are always less than the first-best level. This is a result of the uncertainty regarding task difficulty and the fact that the VP needs to offset a more costly expected penalty, i.e. $k_pR(1-\theta_dP[R]) > k_pR(1-\mathbb{E}[\theta]P[R])$ in order to ensure that the initiative is executed. The difference between the optimal resource allocation under a top-down RAP and that of the first-best setting, is moderated by both the organizational penalty k_p and the expected difficulty $\mathbb{E}[\theta]$. This is again, a direct result of the VP's inability to know the PM's expected penalty for a given resource level, and her need to tailor the resource allocation to the worst case scenario, θ_d. It follows that in a harsher organization, the VP must account for a higher k_p which results in a greater loss due to the firm leaving additional surplus for the PM who realizes θ_e. Overall, for initiatives that encompass more difficulty than is usually undertaken (not well understood task domains), the VP ends up significantly under-investing resources when employing a top-down RAP.

A critical implication of the information asymmetry is whether the VP deems it worthy to fund the initiative. Our analysis highlights the fact that projects live and die by how well understood they are by the stakeholders of the firm (Bower 1970). Whereas in the first-best θ was known and we defined $\mathcal{F}^{fb}$ in terms of θ, for the top-down RAP we define the feasible set of initiatives $\mathcal{F}^{td}$ in terms of $\mathbb{E}[\theta]$, and compare it to $\mathcal{F}^{fb}$. The feasible set of initiatives becomes smaller when the stakeholders are more asymmetrically informed for a given set of task difficulties. Although our result is intuitive, it is valuable to understand both how and why it occurs. What drives fewer initiatives to be funded? As we have discussed, the VP under invests ($R^* < R^{fb}$) in order to ensure that even when the PM realizes θ_d, he still is sufficiently compensated (i.e. his reservation utility is met). The necessity to compensate the project manager for a θ_d realization impacts the VP in two ways: not only does a lower θ_d exaggerate the under-investment, but it also drives the VP to compensate the PM beyond what he might require, to undertake a θ_e set of tasks. The former implies that the overall profits generated will on expectation be less, while the latter allows the PM to appropriate a greater portion of the profits that are generated. Ultimately, initiatives that were deemed worthy of funding under a first-best scenario, no longer are. This effect gets exacerbated in the context of an organization with a low tolerance for failure (high k_p). Organizations that impose harsh penalties for failed initiatives, significantly reduce their feasible set of initiatives. Less projects meet the $\hat{\Pi}$ criteria required for the firm to fund them. When thought of in terms of a firm's overall ability to innovate, any factor that limits the size of the feasible set can have a significant impact on the firm. To see this, think of the feasible set as an opportunity set. Limiting the set of feasible initiatives amounts to limiting the opportunities for the organization; a result most firms would rather avoid.

4.3. Bottom-up resource allocation through full-empowerment

We now examine the situation where the VP gives up the decision rights (Aghion and Tirole 1997) regarding the resource levels and delegates such a decision to the project manager (i.e. a bottom-up resource allocation process). Recall that, the extant Strategic Management literature advocates the value of such delegation (Bower and Gilbert 2005). In such a setting, the only decision made by the VP is to set the compensation such that the project manager executes the initiative (i.e. does not exercise his authority to opt-out of particular initiatives) regardless of θ.

Proposition 3. The full-empowerment resource allocation process. *The following statements hold when the VP chooses a full-empowerment resource allocation process:*

(a) The VP offers compensation that is contingent on outcome:
$w^* = 0$[10] *and* $k_s^* = \frac{k_p R^*[\theta_d](1-\theta_d P[R^*[\theta_d]])}{(V-R^*[\theta_d])\theta_d P[R^*[\theta_d]]}$

(b) The PM allocates resource levels
$R^*[\theta_d]$ *that solves* $\frac{\partial P[R^*[\theta_d]]}{\partial R} = \frac{VP\left[R^*[\theta_d]\right]\left(1-P\left[R^*[\theta_d]\right]\theta_d\right)}{(V-R^*[\theta_d])R^*[\theta_d]}$
$R^*[\theta_e]$ *that solves* $\frac{\partial P[R^*[\theta_e]]}{\partial R} = \frac{P\left[R^*[\theta_e]\right]\left(VP\left[R^*[\theta_d]\right]\theta_d - R^*[\theta_d]\right) - P\left[R^*[\theta_d]\right]\theta_d\left(V-R^*[\theta_d]\right)}{R^*[\theta_d](V(1-P[R^*[\theta_d]]\theta_d)-R^*[\theta_e])+VP[R^*[\theta_d]]\theta_d R^*[\theta_e]}$

(c) When $\theta_d = \frac{(1+k_p)R^{fb}[\theta_d]}{(k_p R^{fb}[\theta_d]+V)P[R^{fb}[\theta_d]]}$, *the resource level chosen by the project manager is equal to the first-best resource level.*

(d) The set of feasible initiatives is: $\mathcal{F}^{fe} = \left\{\mathbb{E}[\theta] : \mathbb{E}_\theta[\Pi] \geq \hat{\Pi}\right\}$. $\mathcal{F}^{fe} < \mathcal{F}^{fb}$, *and gets smaller as* k_p *increases.*

In contrast to the top-down resource allocation process, under full-empowerment, the VP is strictly better off by implementing an output-contingent compensation scheme[11]. Since, the only cost faced by the PM is the potential organizational penalty $k_p R$, the VP must offer output-contingent compensation to induce the project manager to allocate any resources at all. If a fixed wage were offered to the project manager, then regardless of θ, he would be better off allocating the minimum level of resources ($\epsilon \to 0$). In other words, a fixed wage yields the PM w with certainty when the minimum level of resources are allocated, whereas if the PM allocates significant levels of resources ($R > \epsilon$), at best he can earn w, but he faces $w - k_p R$ with some positive probability. Thus, if the PM is given full-empowerment after receiving a fixed wage, he has minimal incentive to allocate resources. Given an output-contingent compensation, the project manager faces the following trade-off: he increases the resources allocated in order to increase likelihood of success $P[R]$, and decrease the likelihood of a penalty; yet, he needs to limit the resources allocated in order

[10] Recall, the PM's reservation utility is set to zero.

[11] The VP designs compensation to ensure that the reservation utility is met for all initiatives she funds.

to preserve the profit, $V - R$ and limit the penalty $k_p R$ should the initiative fail. To accomplish the optimal balance, the project manager accounts for his private information and decides on the resources allocated accordingly. The VP sets the compensation such that the PM executes the initiative (with a non-zero resource allocation), regardless of the difficulty. This translates into an incentive parameter designed for θ_d.

Once the compensation is set, the project manager's decision is solely affected by the relationship between the share of profits (k_s) and the harshness of the penalty (k_p). Note that, neither the PM's resource level choice, nor the VP's incentive choice is affected by the likelihood of the different difficulty realizations (i.e. q); only the expected profits are affected. The manager is unaffected by q, as he makes his decision under full knowledge of the difficulty. The VP need not account for q in her choice of incentive since she knows that the project manager is unaffected by it, and the fact that she designs the incentives solely with the most difficult realization in mind, θ_d, not the likelihood that such a difficulty realizes.

Interestingly, it is possible to achieve the first-best level resource allocation when the VP delegates the resource allocation decision via full-empowerment. Furthermore, the firm can attain a resource allocation of $R^{fb}[\theta]$ under full-empowerment for both θ_d and θ_e, when the firm's expected difficulty meets the condition outlined in Proposition 3 (c). Why does this happen for both difficulty realizations? Recall that, under full-empowerment the PM sets the resource levels with full knowledge of the task difficulty θ for a given incentive k_s. The incentive parameter is set based on θ_d, and is independent of the resources allocated under a θ_e realization. Said differently, regardless of the realization of θ, the PM receives the same share of profits should the initiative succeed. Similarly, the magnitude of k_p is constant, i.e. independent of the difficulty realization. Knowing that the PM's resource allocation decision is driven by k_s and k_p, and that both are independent of θ, we see that when the relationship between k_s and k_p is such that the objectives of the firm and those of the PM are aligned, R^{fb} can be achieved regardless of θ, by empowering the PM. Below, we outline the implications for the choice of RAP resulting from this ability to achieve such alignment between the VP and the PM.

Theorem 1. When full-empowerment dominates a top-down process. *For an organization with $k_p < \bar{k}_p$:*

(a) For initiatives with low expected difficulty (i.e. as $E[\theta] \to 1$) a top-down resource allocation process yields a higher profit.

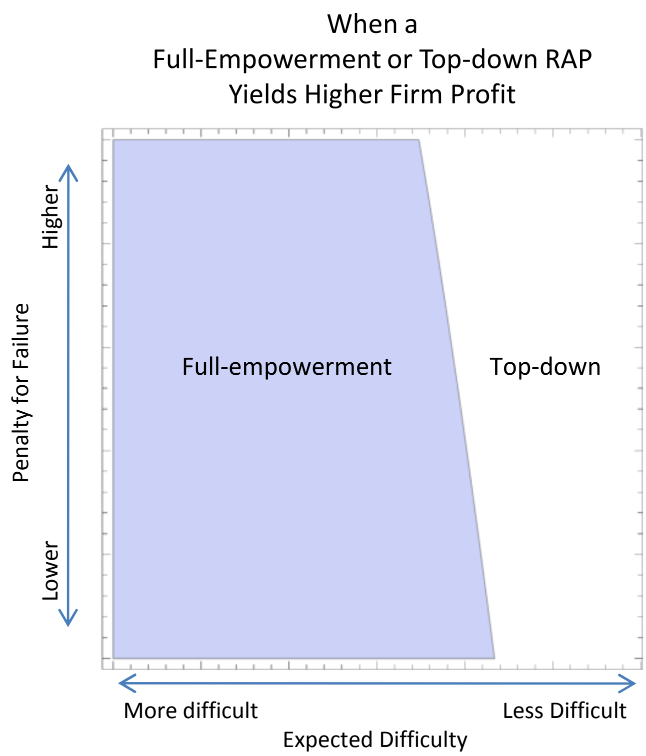

Figure 2 **Resource allocation under full-empowerment and top-down resource allocation processes.**

(b) For initiatives in the interval $[\theta_\ell, \bar{\theta}]$*, a full-empowerment resource allocation process yields higher profit than a top-down resource allocation process* [12]*, where* $\theta_\ell < \frac{(1+k_p)R^{fb}[\theta_d]}{(k_p R^{fb}[\theta_d]+V)P[R^{fb}[\theta_d]]} < \bar{\theta}$ *and* $q > \hat{q}$

(c) For sufficiently high $\hat{\Pi}$*, a top-down process always dominates a full-empowerment resource process (and the feasible set is always smaller with a full-empowerment resource process).*

Theorem 1 elaborates on the inherent trade-offs between the type of resource allocation process used, and the profitability objectives of the firm. Neither resource allocation process strictly dominates in all possible situations. The finding lends normative support to Burgelman's (1983) claim that organizations need to employ multiple processes for innovation, an observation also presented recently by Chao and Kavadias (2009). Thus, it is important to understand when each resource allocation process is most appropriate. Clearly, when the initiative is fairly standard (i.e. $E[\theta] \to \theta_e$), the firm expects to earn greater profits by dictating the resource level. This is a clear situation

[12] Let the superscripts td and fe denote top-down and full-empowerment respectively. Then for the crossing points between the profit functions $\Pi^{td}[\theta]$ and $\Pi^{fb}[\theta]$ as shown in the proof of Theorem 1 if $\hat{\theta} : \Pi^{fe}[\hat{\theta}] = 0$, the lower threshold on the interval of Theorem 1 (b) is $\theta_\ell = \max\{\hat{\theta}, \underline{\theta}\}$.

where the VP benefits from efficiency and control. In such cases, the VP knows the difficulty of the undertaking with relative accuracy, and thus the value of the private knowledge of the project manager is diminished. However, as $\mathbb{E}[\theta]$ decreases (either because the asymmetry between the stakeholders increases, or the initiative has a lower θ_d), the value of the project manager's private knowledge increases. In Proposition 3 we show that the incentives offered to the project manager can induce him to make the first-best resource allocation. Given this observation, the only loss to the VP results from the need to use an outcome contingent incentive k_s, which yields less profit as compared to the use of a fixed-wage. Such a loss, increases in the magnitude of k_p (Proposition 2) such that for low enough k_p the compensation loss is dominated by the gain in expected overall profit due to the first-best resource allocation. In the end, the loss from the outcome contingent compensation is mitigated when k_p is relatively low (i.e for organizations that are not severely harsh) and the context is one of high asymmetry and difficulty, where the gains are larger from obtaining the first best resource allocation. In other words, under such settings the organization can successfully fund and execute high difficulty initiatives (such as developing a radically new technology or entering an entirely new market).

Finally, we turn to the VP's criteria for funding initiatives. As the VP's threshold ($\hat{\Pi}$) becomes higher (e.g. resulting from high value alternatives considered for the firm's portfolio), the VP does two things: restrict the overall feasible set of initiatives (as shown in Proposition 1), and renders a full-empowerment process inferior to a top-down process for all feasible initiatives.

4.4. A resource allocation process utilizing buckets

Thus far we have presented two resource allocation processes that highlight the trade-off between, the *control and efficiency* gained by centrally deciding on the resource budgets at the VP level, and the *effective use of knowledge*, that comes from empowering the project manager to tailor resource levels to the difficulty of the initiative. Yet, our observations open up a question of whether it is possible for the VP to maintain *some* control, and the associated efficiency benefits, while empowering the PM to have *some* influence on what the resource levels should be, and thus reap benefits from the PM's expertise.

In this section we analyze whether the firm can accomplish such a balance between control and empowerment. We seek to identify whether a RAP exists that offers an optimal mechanism, i.e. the firm does better than under either the top-down or full-empowerment approaches. We show that such a process must depart from the assumption that the compensation scheme must be universally applied in a "fair" manner, regardless of the difficulty of the initiative (Baker et al. 1988, Fehr et al. 2007). In other words, compensating the PM through a profit-sharing bonus is not sufficient to get the "best" allocation (i.e. most effective use of his knowledge); the bonus would need to be tailored to the initiative. We present such a resource allocation process that tailors both resources and compensation to the potential difficulty realizations (an incentive feasible Bayesian mechanism). However, a disclaimer is in order: portraying such a process at parity with the prior processes ignores the additional complexities and the (potentially prohibitive) costs associated with implementing such an involved scheme (see Mihm 2010 for a discussion of the complications associated with implementing incentive feasible, Bayesian mechanisms in practice). Given these concerns, we simplify the optimal process and present a close "next-best" resource allocation process where we avoid the complications associated with compensation schemes tailored to the difficulty realizations of a PM, and instead we only vary the resource level that can be allocated. Note that such a process represents a well defined managerial practice referred to as "strategic buckets" (Cooper et al. 2001, Chao and Kavadias 2008, Terwiesch and Ulrich 2009).

Recently more firms have adopted a hierarchical resource allocation process, where resources are "earmarked" for a particular *type* of initiative[13]. In such a setting, the VP may associate the different difficulty initiatives into specific strategic buckets (e.g. buckets aimed at funding initiatives that strengthen current product lines, or those that stretch the organization into entirely new market segments, see Loch and Kavadias 2010). These practices have been advocated as a means to "protect" resources for a "long enough" period of time so as the firm can undertake radical (difficult) initiatives and see them come to fruition (Chao and Kavadias 2008). Our analysis points to an alternative justification for employing strategic buckets that stems from the need to offer implicit incentives to project managers in order to promote them to make the most effective use of their expertise. Below we formally present the optimal resource allocation process.

Proposition 4. The optimal resource allocation process. *The following statements hold when the resource allocation process entails the VP tailoring both resource allocations* and *compensation:*

(a) The output contingent portion of the compensation is always set to zero ($k_s^* = 0$).

(b) The VP defines two options with the following properties:

$(w^*_{\theta_d}, R^*_{\theta_d})$, *and* $(w^*_{\theta_e}, R^*_{\theta_e})$ *that satisfy:*

(i) $w^*_{\theta_d} = k_p R^*_{\theta_d}(1 - \theta_d P[R^*_{\theta_d}])$

(ii) $w^*_{\theta_e} = k_p \left(P\left[R^*_{\theta_d}\right] R^*_{\theta_d}(\theta_e - \theta_d) + R^*_{\theta_e}\left(1 - P\left[R^*_{\theta_e}\right]\theta_e\right)\right)$

(iii) $R^*_{\theta_d}$ *solves* $P\left[R_{\theta_d}\right] = \frac{q\left(1 - V\theta_d P'\left[R_{\theta_d}\right]\right) + k_p\left(q - R_{\theta_d}(\theta_d - (1-q)\theta_e)P'\left[R_{\theta_d}\right]\right)}{k_p(\theta_d - (1-q)\theta_e)}$, *where* $R_{\theta_d} < R^{fb}[\theta_d]$

[13] First hand conversations with executives at Fortune 500 companies have outlined processes whereby they earmark specific funds for specific types of projects.

(iv) $R^*_{\theta_e} = R^{fb}_{\theta_e}$

THEOREM 2. RESOURCE ALLOCATION PROCESSES WITH TAILORED COMPENSATION AND IMPLEMENTATION COST.

(i) *When there is no implementation cost associated with implementing tailored compensation schemes* and *resource allocations, such a process dominates top-down or bottom-up for any* $E[\theta]$.

(ii) *There exists a cost threshold* $\bar{c} \in \mathbb{R}^+$ *such that for all* $c \geq \bar{c}$ *tailored compensation and resource allocations is less profitable than either top-down or full-empowerment.*

When employing such a RAP, a fixed wage dominates any output-contingent compensation. The logic is similar to that discussed in Proposition 2. The VP's goal when implementing such a resource allocation process is to categorize the initiatives, in order to set the appropriate resource levels, and therefore, extract maximum surplus through the use of tailored compensation. To accomplish her objectives, the VP designs the buckets to strictly adhere to the conditions outlined in (b) of Proposition 4. These conditions accomplish the aforementioned objectives in the following manner: for the most difficult initiatives (θ_d),the resource levels and wages offered, are such that the project manager only expects to meet his reservation utility, whereas a PM who realizes θ_e difficulty, earns a surplus (on expectation). If the VP tried to extract the full surplus from standard initiatives (i.e. drive the PM to his reservation utility on θ_e initiatives), then when the the PM realized a θ_e initiative, he would choose the bucket designed for the difficult one (and earn a surplus)[14]. As such the VP leaves some surplus for the PM. As already discussed, the optimal process may be hard to implement. As such, we explore the possibility that strategic-buckets could offer a good "next-best" process.

PROPOSITION 5. A RESOURCE ALLOCATION PROCESS THAT USES STRATEGIC BUCKETS. *The following statements hold when the VP chooses to use strategic buckets as the resource allocation process:*

(a) *The output contingent portion of the compensation is always set to zero* ($k^*_s = 0$).

(b) *The VP offers strategic buckets with the following properties (where* $\theta' < \theta'' < 1$*):*

$(w^*,\ R^*_{\theta_d})$, *and* $(w^*, R^*_{\theta_e})$ *satisfy:*

[14] There is another option that would force the PM to execute the standard initiative (θ_e) and be forced to his reservation utility. In such an option the PM *only* undertakes standard initiatives (i.e. the VP purposefully designs the RAP to induce the PM to opt-out of difficult initiatives). We choose not to focus on those cases as they are counter to our focus on understanding resource allocation processes that allow organizations to undertake initiatives with expected difficulty $\mathbb{E}[\theta]$ regardless of the actual realization of the difficulty.

(i) *For* $\theta_d \leq \theta'$

(a) $w^* = k_p R^*_{\theta_d}(1 - \theta_d P[R^*_{\theta_d}])$

(b) $R^*_{\theta_e}(1 - \theta_e P[R^*_{\theta_e}]) = R^*_{\theta_d}(1 - \theta_e P[R^*_{\theta_d}])$

(ii) *For* $\theta' < \theta_d \leq \theta''$

(a) $w^* = k_p R^*_{\theta_d}(1 - \theta_d P[R^*_{\theta_d}])$

(b) $R^*_{\theta_e} = P^{-1}[\frac{1}{V}]$

(iii) *For* $\theta_d > \theta''$, $R^*_{\theta_d} = R^*_{\theta_e}$

A strategic buckets allocation process works in concert with the organizational norms (i.e. the penalty for failure) as follows: first, it provides a greater level of resources to θ_e initiatives (i.e. $R^*_{\theta_e} > R^*_{\theta_d}$), such that when coupled with the organizational penalty k_p, accepting an $R^*_{\theta_e}$ allocation when θ_d is realized yields less than the reservation utility for the PM. In other words, the ability to offer distinct resource options creates an implicit "compensation" effect through the organizational norms themselves (and in addition, provides a rationale for such penalties). This allows the VP to adequately tailor the strategic buckets and ensure that the project manager selects the correct one. This is a powerful insight regarding the ability of the firm to define distinct buckets without necessitating distinct and explicit compensation (i.e. wages) to appropriate the benefits. We characterize the benefits below by contrasting the strategic buckets with the top down process.

Theorem 3. The choice between a top-down and strategic buckets process.

(i) *There exists a threshold* $\hat{\theta}$ *such that for all* $E[\theta] < \hat{\theta}$*, the profits from implementing a strategic buckets process dominate those under a top-down resource process.*

(ii) *For sufficiently low* $\hat{\Pi}$*, the feasible set of initiatives under a strategic buckets process is larger than under a top-down process.*

(iii) *A strategic buckets process weakly dominates a full-empowerment process for all* $E[\theta]$[15]*.*

As we did in Theorem 1, in Theorem 3 we characterize the difference between delegating resource allocation via a strategic buckets process, and dictating resources via a top-down process, and we contrast the strategic buckets RAP with the full-empowerment one. Again, we find that for initiatives with a higher potential difficulty, the use of delegation (i.e. the choice of between available buckets) to capitalize on the knowledge of the PM becomes more beneficial. However, strategic buckets make use of a very powerful aspect of delegation: they "earmark" the resources for initiatives that may otherwise seem too far-fetched to receive *any* funding. Thus, although it may be

[15] When the set of potential difficulty levels for the initiative contains more than two elements, then a strategic buckets RAP may not be dominant for all expected difficulty levels. In the Appendix we offer such an example for three potential difficulty levels.

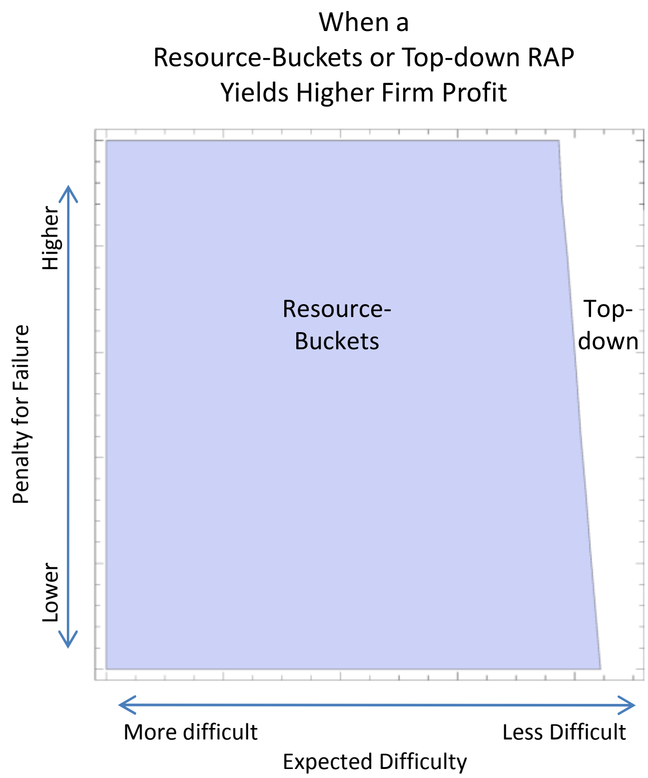

Figure 3 **Resource allocation under full-empowerment and top-down resource allocation processes.**

hard to dictate these initiatives, a strategic buckets RAP ensures enough funding for such long-shot projects. Therefore, the firm can profitably go after initiatives that may be more difficult (i.e. more "radical"), in the sense that they are not well grounded in the firm's competencies and may represent more difficulty to the firm.

Theorem 3 (iii) eludes to the power of using a strategic buckets RAP. Such a process dominates a full-empowerment one for the following reason: both the full-empowerment and the strategic buckets processes utilize a common compensation scheme, albeit full-empowerment employs profit sharing, while a strategic buckets process uses a fixed wage. The inefficiency of the full-empowerment process arises because the common compensation is the only lever the VP has, i.e. the PM controls the resource allocation, resulting in over-investment for initiatives with lower expected difficulty. Yet, when the VP categorizes the resource allocation, and an appropriately set wage, she can replicate any solution obtained through full-empowerment given the control she has over the resource levels of the strategic buckets. However, it is worthwhile to point out that, this result does not always hold when the project types are defined with more granularity. In such cases, the lack of a clear cut dominance stems from the fact that the VP needs to offer a premium to induce the proper sorting of the initiatives into their respective buckets, and this premium may be too great to allow the VP to sort the initiatives into all of the different buckets, i.e. even though there are n type of difficulty for the initiative, the VP may only be able to segment the initiatives into $n' < n$ buckets. In the end, the loss from the premium and the added need to sort the initiatives may result in a greater loss under the strategic buckets RAP than the loss incurred through delegation. Thus, it may happen that it is less costly to allow the PM to fully define the resources for the initiative on his own, as opposed to inducing him to adopt a pre-defined funding option up front, i.e. strategic buckets.

5. Discussion and Conclusions

In this paper we set out to explore a fundamental question regarding resource allocation: what resource allocation process should a firm use when undertaking a NPD initiative? Since Bower's (1970) early work regarding the resource allocation processes in organizations, scholars have observed in numerous field studies the presence of different approaches. Surprisingly enough, few studies have looked at when and how such different processes should (and could) be implemented. Our study aims to address this gap. We consider a problem setting where the senior management of a firm aims to implement a key strategic NPD initiative. As articulated in the prior literature, certain organizations allocate resources in a *top-down* fashion, i.e. resource decisions are made at senior levels within the organization; while others follow a *bottom-up* resource allocation process, where initiatives are outlined at senior levels but the resource decisions are made by middle-management (project managers). At the time funding decisions are made, rarely does senior management understand the tasks required to execute the initiative as well as the project manager himself. This difference between the stakeholders' knowledge of the initiative (information asymmetry), prompts a distinct agency setting that results from the fact that the stakeholders face different consequences should the initiative fail (i.e. the firm incurs the full cost of resources, and the PM suffers career setbacks). To address the inefficiencies associated with this agency setting, the VP faces a choice between empowerment and control. Control is maintained by dictating a fixed resource budget to the PM, with the objective to efficiently allocate resources. Unfortunately such efficiency comes at a cost; the VP rarely knows the exact difficulty of the initiative and she needs to decide on budgets given this uncertainty. In contrast, empowerment delegates the resource allocation decision to the PM, and represents the VP's effort to capitalize on the effective use of the PM's specialized knowledge about executing the initiative. Yet, delegation comes with its own cost as well, it requires substantial incentive compensation in an effort to align the objectives of both stakeholders.

Our model analysis provides an operational perspective in support of Burgelman's (1983) early observation that no single project definition process (i.e. top-down or bottom-up) is appropriate for all firms and all initiatives. We are able to identify under what conditions each process applies. That is, firms should apply resource allocation processes that maintain control, when their objective is to fund relatively well known domains (initiatives with low expected difficulty), while delegating the resource allocation decision is more beneficial when the domain is less known (initiatives with high expected difficulty). Yet, our most intriguing insight stems from the pursuit of an optimal resource allocation process. In order to define such a process we need to depart from the use of a single, common rule for compensation, i.e. a common fixed wage or a common profit-sharing incentive. Admittedly, this adds complexity in the implementation of such a process (Mihm 2010) and raises potential issues of fairness (Fehr at el. 2007). Nonetheless, we characterize such a process as it lends insight for feasible firm practices that could further improve resource allocation when the associated implementation costs are not severe. More importantly though, it gives rise to a related "next-best" process that has found much use in practice: resource allocation via strategic buckets. Our results elaborate on the implications of the resource allocation process on the firm's ability to adapt its portfolio, and how such an ability is strongly dependent on the resource allocation process and the structural context (incentives, decision rights and culture) of the firm.

Each firm's choice of a RAP depends on the strategic objectives, the organizational norms that define the PM's consequences for failed initiatives, and how well senior management understands the detailed tasks required to execute the initiative. We find that for those firms wishing to fund relatively well known domains (standard tasks), the benefits they incur by tailoring resource allocation levels to the task difficulty are outweighed by the efficiency gained when senior management dictates the resource allocation. However, when the information asymmetry is high, this may no longer be the case. In such instances, of high asymmetry, the VP benefits from offering incentives that align the PM's interests with the overall firm objectives. When this is the case, the gains realized from aligning the stakeholder objectives outweigh the cost of incentives and the firm reaps benefits from effectively tailoring resource allocations. There is a caveat, a firm with low tolerance for failure (i.e. a harsh penalty for failure) may preclude the firm from achieving alignment on such high difficulty initiatives. In a harsh environment, it may never be beneficial to delegate; the need to offset the failure consequences makes it too costly to provide incentives that align the utility of the PM with the objectives of the firm (utility of the VP).

Additionally, our research offers an alternative justification for the use of strategic buckets, which is often observed in practice. Strategic buckets are widely cited as a means to ensure that funds

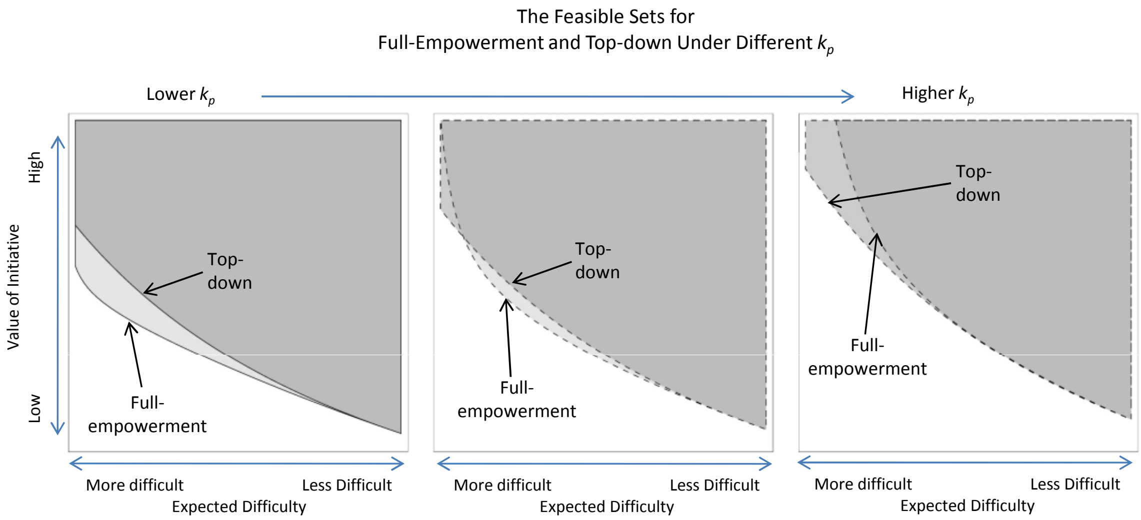

Figure 4 **Resource allocation under full-empowerment and top-down resource allocation processes. The left panel represents a lower penalty for failure and each panel to the right represents the feasible sets with increasing penalties, where eventually as shown in the right panel, the top-down feasible set is dominant as compared with the full-empowerment one.**

are earmarked for difficult (i.e. radical) initiatives. Generally, they are advocated based on forward looking statements (Chao and Kavadias 2008), or statements based on fear of mismanagement (Terwiesch and Ulrich 2008). The logic is as follows: firms know they need to conduct radical (difficult) projects; yet if they do not protect funds for radical projects for long enough periods of time, or if those funds are not explicitly labeled for such difficult initiatives, then the funds will get used elsewhere, i.e. on more incremental and short-term initiatives. Armed with such a capability the firm can address the issue of what portion of projects should be more radical or incremental. Our explanation for strategic buckets is somewhat different: senior managers of NPD organizations are unsure of the exact difficulty of the strategic initiative they aim to implement. In an effort to ensure that resources are properly tailored to execute the appropriate difficulty initiative, such that the firm does not only pursue incremental initiatives under the premise of more difficult ones, senior management can use strategic buckets to segment the projects, and thus more effectively fund them. In addition, this result highlights a positive side effect of having at least *some* penalty for failure. Such organizational norms allow implicit means by which the firm can manage the PM's utility, and influence his decisions, without implementing complex compensation, i.e. incentive feasible Bayesian mechanisms, with non-linear, project type dependent compensation.

Finally, an important implication of the choice of the "right" resource allocation process, i.e. a RAP contingent on the context within which initiatives are executed, is the firm's ability to adapt its portfolio to a given strategy. Our results on the feasible set of initiatives show that the choice of resource allocation process given the organizational norms, dictates whether an initiative, and as such, part of the firm's strategy, can be executed. The feasible set of initiatives represents bounds on the initiatives the firm can execute, and it is an analog to Markowitz's (1952) notion of an attainable set of investments that an individual investor can include in their portfolio given a particular set of risk preferences. Thus, given a particular resource allocation process, there is a feasible set of initiatives that the firm can fund (i.e the maximum expected difficulty the firm can undertake for a given potential value). Although the organizational norms impact the feasible set in a unidirectional manner (i.e. regardless of the process, a higher penalty implies a smaller feasible set), the impact is more severe when the resource allocation process is one of empowerment. A graphical representation of this is shown in Figure 4.

In conclusion, our work places emphasis on the need for senior management to consider operational details of NPD initiatives when determining the firm's resource allocation process. As a first step towards this direction, we bear limitations that open potential avenues for future research. Future work needs to shed additional light on the delegation of strategy definition (which initiatives to pursue) and account for effects of competition. Furthermore, future work should also establish how certain organizational norms, i.e. the penalty for failure, come to fruition, thus adding detail to such a temporal process (Chassang 2010). Finally the effects of the collaborative and cross-functional nature of innovation should come under scrutiny.

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References

Aghion, P., J. Tirole. (1997) Formal and real authority in organizations. *The Journal of Political Economy.* 105 (1), pp. 1-29

Anderson, E. and N. Joglekar. (2005) A Hierarchical Product Development Planning Framework. *Production and Operations Management.* 14 (3), pp. 344-361

Antle, R. and G.D. Eppen. (1985) Capital Rationing and Organizational Slack in Capital Budgeting. *Management Science.* 31 (2), pp. 163-174

Baiman, S. and M.V. Rajan. (1995) Centralization, delegation, and shared responsibility in the assignment of capital investment decision rights. *Journal of Accounting Research.* 33, pp. 135-164

Baker, G.P., M.C. Jenses, and K.J. Murphy. (1988) Compensation and Incentives: Practice vs. Theory. *The Journal of Finance*. 43 (3), pp. 593-616

Bower, J. (1970) *Managing the Resource Allocation Process: A Study of Corporate Planning and Investment.* Harvard Business School Press. Boston, MA.

Bower, J.L. and Y.L. Doz. (1979) Strategic Management: A New View of Business Policy and Planning. In D.E. Schendel and C.W. Hofer. *Strategic Management: A New View of Business Policy and Planning.* Little, Brown and Company, Inc., Boston.

Bower, J.L. and C.G. Gilbert. (2005) *From Resource Allocation to Strategy.* Oxford University Press, New York.

Burgelman, R. (1983) A Model of the Interaction of the Strategic Behavior, Corporate Context, and the Concept of Strategy. *The Academy of Management Review* 8 (1), pp. 61-70

Chao, R.O. and S. Kavadias (2008). A Theoretical Framework for Managing the NPD Portfolio: When and How to Use Strategic Buckets.*Management Science*. 54 (5), pp. 907-921

Chao, R.O., S. Kavadias and C. Gaimon (2009). Revenue Driven Resource Allocation: Funding Authority, Incentives and NPD Portfolio Management. *Management Science*. 55 (9), pp. 1556-1569

Chao, R.O. and S. Kavadias (2009) Organization Structure, Incentives, and the Innovation Portfolio. Presentation, INFORMS Annual Conference. San Diego, CA.

Coen, C.A. and C.A. Maritan. (2010) Investing in Capabilities: The Dynamics of Resource Allocation. *Forthcoming in Organization Science.*

Chassang, S. (2010) Building Routines: Learning, Cooperation, and the Dynamics of Incomplete Relational Contracts. *The American Economic Review.* 100(1), pp. 448-465

Cooper, R.G., S. J. Edgett and E.J. Kleinschmidt. (2001) *Portfolio Management for New Products 2nd Edition.* Perseus Books, Mass.

Erat, S. and V. Krishnan. (2010) Managing Delegated Search Over Design Spaces. UCSD Working Paper. SSRN: Abstract id: 1567599

Fehr, E., A. Klein, and K.N. Schmidt. (2007) Fairness and Contract Design. *Econometrica.* 75 (1), pp. 121-154

Harris, M., C.H. Kriebel, and A. Raviv. (1982) Asymmetric Information, Incentives and Intrafirm Resource Allocation. *Management Science*. 28 (6), pp. 604-620

Hauser, J. (1998) Research, Development and Engineering Metrics. *Management Science* 44 (12), pp. 1670-1689

Hermalin, B. (2008) Leadership and Corporate Culture. Forthcoming in R. Gibbons and J. Roberts (eds.), *The Handbook of Organizational Economics*. Princeton, NJ: Princeton University Press.

Katok, E. and E. Siemsen (2009) The Influence of Career Concerns on Task Choice: Experimental Evidence. Working Paper.

Kavadias, S. and J. Kovach (2010) Cooper Lighting: Innovation 2.0. Georgia Institute of Technology Case Study.

Kreps, David M. (1990). Corporate Culture and Economic Theory. in J. E. Alt and K. A. Shepsle., *Perspectives on Positive Political Economy.* Cambridge University Press, Cambridge, England.

Laffont, J.L. and D. Martimort. (2001) *The Theory of Incentives: The Principal-Agent Model.* Princeton University Press. Princeton, N.J.

Loch, C.H. and S. Kavadias. (2002) Dynamic Portfolio Selection of NPD Programs Using Marginal Returns. *Management Science.* 48 (10), pp. 1227-1241

Loch, C.H. and S. Kavadias (2009) Implementing Strategy Through Project Portfolios. in Morris P., Pinto J. and Soderlund J. (eds.) *Oxford Handbook in the Management of Projects.*

Huchzermeier, A. and C.H. Loch. (2001) Project management under risk: Using the real options approach to evaluate flexibility in R&D. *Management Science.* 47 (1), pp. 85-101

Manso, G. (2008). Motivating Innovation. MIT Sloan School of Management Working Paper

Maritan, C.A. (2001) Capital Investment as Investing in Organizational Capabilities: An Empirically Grounded Process Model. *Academy of Management Journal.* 44 (3), pp. 513-531

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance.*7 (1), pp. 77-91

Mihm, J. (2010) Incentives in New Product Development Projects and the Role of Target Costing. *Management Science.* 56 (8), pp. 1324-1344

Mihm, J., C.H. Loch, D. Wilkinson, and B.A. Huberman. (2010) Hierarchical Structure and Search in Complex Organizations. *Management Science.* 56 (5), pp. 831-848

Schein, E. H. (2010) *Organizational Culture and Leadership. 4th Edition* Jossey-Bass Publishers, San Francisco, CA.

Siemsen, E. (2008). The Hidden Perils of Career Concerns in R&D Organizations. *Management Science.* 54 (5), pp. 863-877

Sting, F. and C.H. Loch (2009) How Top-Down and Bottom-Up Strategy Processes are Combined in Manufacturing Organizations. INSEAD Working paper.

Terwiesch, C. and K.T. Ulrich. (2009) *Innovation Tournaments.* Harvard Business Press. Boston, MA.

Terwiesch, C. and K.T. Ulrich. (2008) Managing the Opportunity Portfolio. *Research Technology Management.*, pp 27-38

Terwiesch, C. and Y. Xu. (2008) Innovation Contests, Open Innovation, and Multiagent Problem Solving. *Management Science.* 54 (9), pp. 1529-1543

Van den Steen, E. (2010) On the Origin of Shared Beliefs (and Corporate Culture). *Forthcoming in RAND Journal of Economics.*

Wheelwright, S.C. and K.B. Clark. (1992) *Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality.* The Free Press. New York, NY.

Zingales, L. and R.G. Rajan. (2001) The Firm as a Dedicated Hierarchy: A Theory of the Origins and Growth of Firms with. *Quarterly Journal Economics*, pp. 805-851

6. Appendix

A.1. Proof of Proposition 1

From Definition 1 the expected profit for the VP is: $\Pi = \theta P[R]V - R - W$ The VP maximizes $\max_{R,w} \theta P[R]V - R - w$ such that: $w - k_p R(1-\theta P[R]) \geq 0$ ($\underline{U}=0$). For the problem to be well behaved (concave utility for the VP) the second order derivative must be negative: $\left(\frac{\partial P[\cdot]}{\partial R}\right) \Big/ \left(\frac{\partial^2 P[\cdot]}{\partial R^2}\right) < -(V + k_p R)/(2k_p)$. Next, from the first order conditions we arrive at the implicit solution for the optimal resources: R^{fb} solves $\frac{\partial P[\cdot]}{\partial R}(V + k_p R) - k_p(1 - P[\theta, R]) - 1 = 0$ or equivalently, R^{fb} solves: $\frac{\partial P[R]}{\partial R}\theta(V + k_p R) - (1 + k_p(1 - \theta P[R])$. With the participation constraint binding the VP's profit becomes: $\theta P[R]V - R - k_p R(1-\theta P[R])$ and solve for $P[\theta, R]$: $P[\theta, R] = \left((\hat{\Pi} + 1 + k_p)R\right) \Big/ (V + k_p R)$. □

Corollaries to the first-best solution should be clear: the size of the feasible set is reduced when either k_p or $\hat{\Pi}$ increases. Note $\partial R^{fb}/\partial\theta > 0$. The Proof is as follows: Implicitly differentiating with respect to θ $\frac{\partial P[R^{fb}[\theta]]}{\partial R}\theta(V + k_p R^{fb}[\theta]) - (1 + k_p(1 - \theta P[R^{fb}[\theta]]) = 0$ yields (suppressing notation and letting $R = R^{fb}$) $\frac{\partial R}{\partial \theta} = \frac{1+k_p}{\theta^2\left(2k_p \frac{\partial P[R]}{\partial R} + (k_p R + V)\frac{\partial^2 P[R]}{\partial R^2}\right)} \Rightarrow \frac{\partial R}{\partial \theta} > 0 \Leftrightarrow 2k_p \frac{\partial P[R]}{\partial R} + (k_p R + V)\frac{\partial^2 P[R]}{\partial R^2} < 0$, where the R.H.S. condition represents the condition for concavity. □

A.2. Proof of Proposition 2

The VP has two options (or any combination of the two): w and k_s. The VP must meet the participation constraint of the PM. The worst case is: θ_d. When w is offered she offers $w = k_p R(1 - \theta_d P[R])$ (i.e highest expected penalty). If the VP chooses to use k_s, k_s must be set where $k_s\theta_d P[R](V - R) - k_p R(1 - \theta_d P[R]) = 0$, or $k_s = (k_p R(1 - \theta_d P[R]))/(\theta_d P[R](V - R))$. Clearly, when $\theta = \theta_d$ both forms of compensation are equivalent (i.e. for any wage there is an equivalent k_s that offers both manager and VP the same expected utility). For $\theta \neq \theta_d$, this does not hold. Specifically, for $\theta_e > \theta_d$ w and k_s remain the same ($w = k_p R(1 - \theta_d P[R]$ and $k_s = (k_p R(1 - \theta_d P[R]))/(\theta_d P[R](V - R))$ then $\Pi[\theta_e]$ becomes:

(under fixed wage) $\theta_e P[R]V - R - k_p R(1 - \theta_d P[R])$, and

(profit-sharing) $(1 - \frac{k_p R(1-\theta_d P[R])}{\theta_d P[R](V-R)})\theta_e P[R](V - R) - R(1 - \theta_e P[R])$. Subtracting the latter from the former we get: $\frac{Rk_p(1-\theta_d P[R])(\theta_e P[R] - \theta_d P[R])}{\theta_d P[R]}$, which is both positive and increasing as the θ becomes greater than θ_d. Thus, it is always better to implement a fixed wage.

Recall that we normalize $\theta_e = 1$ $\Pi = (q\theta_d + (1-q))\, P[R]V - R - k_p\theta_d R(1 - \theta_d P[R])$. The concavity conditions for the objective are $\left(\frac{\partial^2 P[R]}{\partial R^2}\right) \Big/ \left(\frac{\partial P[R]}{\partial R}\right) < -\frac{2k_p\theta_d}{\mathbb{E}[\theta]V + Rk_p\theta_d}$, which is satisfied by the conditions imposed on the first-best scenario. We solve for R^* using the first order conditions: R^* solves $1 + k_p\,(1 - \theta_d P[R]) - \frac{\partial P[R]}{\partial R}\,(\mathbb{E}[\theta]V + Rk_p\theta_d) = 0$ $R^{fb} > R^*$ implies $\frac{\partial}{\partial R}\Pi^{fb}[R^*] > 0$ $\frac{\partial}{\partial R}\Pi^{fb}[R] = -1 - k_p(1 - \mathbb{E}[\theta]P[R]) + \frac{\partial P[R]}{\partial R}\mathbb{E}[\theta]\,(V + Rk_p)$ for $\theta = \mathbb{E}[\theta]$, and R^* is defined by $P[R^*] = \frac{1+k_p - \frac{\partial P[R^*]}{\partial R}\left(\mathbb{E}[\theta]V - R^* k_p\right)}{k_p\theta_d}$ such that if $R^{fb} > R^*$ then $-1 - k_p(1 - \mathbb{E}[\theta]P[R^*]) + \frac{\partial P[R^*]}{\partial R}\mathbb{E}[\theta]\left(V + R^* k_p\right) > 0$ substituting $P[R^*] = \frac{1+k_p - \frac{\partial P[R^*]}{\partial R}\left(\mathbb{E}[\theta]V - R^* k_p\right)}{k_p\theta_d}$ and rearranging yields $\frac{-(\mathbb{E}[\theta]-\theta_d)\left(1+k_p - \mathbb{E}[\theta]VP'[R]\right)}{\theta_d} < 0$, which is true since $\mathbb{E}[\theta] - \theta_d > 0$, $\theta_d > 0$ and since $P[R] > 0 \Rightarrow P[R^*] = \frac{1+k_p - \frac{\partial P[R^*]}{\partial R}\left(\mathbb{E}[\theta]V - R^* k_p\right)}{k_p\theta_d} > 0$ which implies that $1 + k_p - \frac{\partial P[R^*]}{\partial R}\left(\mathbb{E}[\theta]V - R^* k_p\right) > 0$. $\mathcal{F}^{td} < \mathcal{F}^{fb}$ follows directly from the fact that $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$, since for any $\mathbb{E}[\theta] : \Pi^{fb} = 0 \Rightarrow \Pi^{td} < 0$ since $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$ and trivially $\Pi[R] < \Pi[R^{fb}] \forall R < R^{fb}$ □

A.3. Proof of Proposition 3

The PM knows θ, the VP does not, and has no way to verify θ ex-post. A fixed wage implies the PM's objective is: $\max_R w - k_p R(1-\theta P[R])$. Which has a maximum at $R=0$ since $w - k_p R(1-\theta P[R]) < w \forall R > 0$ (only when $\lim_{R\to\infty} w - k_p R(1-\theta P[R]) \to w$). In order to induce non-zero R, the VP uses profit-sharing with parameter k_s, with reservation utility at 0, and the PM's expected utility is $u = k_s \theta P[R](V-R) - k_p R(1-\theta P[R])$ we arrive at $k_s^* = \frac{k_p R_d (1-\theta_d P[R_d])}{(V-R_d)\theta_d P[R_d]}$. Concavity conditions on the PM's utility require: $\frac{\partial^2 P[R]}{\partial R^2} < \frac{2(R-V\theta P[R])\frac{\partial P[R]}{\partial R}}{R(V-R)}$ Then note that the PM's resource allocation choice is influenced by the ratio of k_s/k_p as follows. The first order conditions are: $\theta k_s \left((V-R)\frac{\partial P[R]}{\partial R} - P[R]\right) = k_p \left(1 - \theta P[R] - R\theta \frac{\partial P[R]}{\partial R}\right)$, which implies that the PM's choice is based upon $\frac{k_s}{k_p} == \frac{R\theta\frac{\partial P[R]}{\partial R} - (1-\theta P[R])}{\theta\left(P[R]+(V-R)\frac{\partial P[R]}{\partial R}\right)}$ Substituting k_s^* into the first order conditions for a PM realizing $\theta = \theta_d$ yields: $\frac{k_p\left(-VP[R_d]+VP[R_d]^2\theta_d+(V-R_d)R_d\frac{\partial P[R_d]}{\partial R}\right)}{P[R_d](V-R_d)}$ which yields the implicit solution for R_d^* that solves: $-VP[R_d] + VP[R_d]^2\theta_d + (V-R_d)R_d\frac{\partial P[R_d]}{\partial R} = 0$, or equivalently: $\frac{\partial P[R_d]}{\partial R} = \frac{VP[R_d](1-\theta_d P[R_d])}{(V-R_d)R_d}$. Likewise the utility for the PM realizing $\theta = \theta_e$ yields first order conditions (after substituting k_s^*): $\frac{k_p\left(P[R_e](VP[R_d]\theta_d - R_d)+R_d(V-R_e)P'[R_e]-P[R_d]\theta_d\left(V\left(1-R_e\frac{\partial P[R_e]}{\partial R}\right)-R_d\left(1-V\frac{\partial P[R_e]}{\partial R}\right)\right)\right)}{P[R_d](V-R_d)\theta_d}$, which yields the implicit solution for R_e^*: $P[R_e](VP[R_d]\theta_d - R_d) + R_d(V-R_e)P'[R_e] - P[R_d]\theta_d\left(V\left(1-R_e\frac{\partial P[R_e]}{\partial R}\right) - R_d\left(1-V\frac{\partial P[R_e]}{\partial R}\right)\right) = 0$, or equivalently: $\frac{\partial P[R_e]}{\partial R} = \frac{P[R_e](V\theta_d P[R_d]-R_d)-P[R_d](V-R_d)\theta_d}{VP[R_d]R_e\theta_d + R_d(V(1-P[R_d]\theta_d)-R_e)}$ The first best resource level satisfies $\frac{\partial P[R^{fb}]}{\partial R} = \frac{1+k_p(1-\theta P[R^{fb}])}{\theta\left(V+R^{fb}k_p\right)}$, equating this solution to that of the PM's we can clearly see that they are equal when $\theta_d = \frac{R(1+k_p)}{P[R](V+Rk_p)}$, where $R = R^{fb}[\theta_d] = R_d^*$. In fact this clearly follows from the objectives of the firm and the PM in that both objectives are aligned when $k_s = \frac{k_p}{1+k_p}$, thus when $\theta_d = \frac{R(1+k_p)}{P[R](V+Rk_p)}$ both $R_d = R^{fb}[\theta_d]$ and $R_e R^{fb}[\theta_e]$ $\square$

A.4. Proof of Theorem 1

For such a setting we claim that for any organization with a tolerance for failure $k_p < \bar{k}_p$ there exists a crossing point between the profitability under a top-down process and that under a full-empowerment one. The proof follows from the equivalence between both $R^*[\theta_d] = R^{fb}[\theta_d]$ and $R^*[\theta_e] = R^{fb}[\theta_d]$ when $\theta_d = \theta_d^{**} = \frac{R^{fb}[\theta_d](1+k_p)}{P[R^{fb}[\theta_d]]\left(V+R^{fb}[\theta_d]k_p\right)}$. Note, $\Pi^{fe} = q\Pi^{fe}[\theta_d] + (1-q)\Pi^{fe}[\theta_e]$ and that $\Pi^{fb}[\theta_d^{**}] = \Pi^{fe}[\theta_d^{**}]$ then the only loss occurs as a result of the need to offer incentives $k_s^* = \frac{k_p R[\theta_d](1-\theta_d P[R[\theta_d]])}{\theta_d P[R[\theta_d]](V-R[\theta_d])}$, where the firm would rather offer a fixed wage, or equivalent $k_s' = \frac{k_p R[\theta_d](1-P[R[\theta_d]]\theta_d)}{P[R[\theta_e]](V-R[\theta_e])}$, resulting in a loss of: $R[\theta_d]k_p(1-P[R[\theta_d]]\theta_d)\left(\frac{1}{P[R[\theta_d]](V-R[\theta_d])\theta_d} - \frac{1}{P[R[\theta_e]](V-R[\theta_e])}\right)(V-R[\theta_e])$. R_d^* that solves: $\frac{\partial P[R_d]}{\partial R} = \frac{VP[R_d](1-\theta_d P[R_d])}{(V-R_d)R_d}$. and R_e^*solves: $\frac{\partial P[R_e]}{\partial R} = \frac{P[R_e](V\theta_d P[R_d]-R_d)-P[R_d](V-R_d)\theta_d}{VP[R_d]R_e\theta_d+R_d(V(1-P[R_d]\theta_d)-R_e)}$, both of which are independent of k_p. Thus for $\theta_d = \theta_d^{**}$, $\Pi^{fe} = q\Pi^{fe}[\theta_d] + (1-q)\Pi^{fe}[\theta_e]$
$= q\Pi^{fb}[\theta_d] + (1-q)\left(\Pi^{fb}[\theta_e] - R[\theta_d]k_p(1-P[R[\theta_d]]\theta_d)\left(\frac{1}{P[R[\theta_d]](V-R[\theta_d])\theta_d} - \frac{1}{P[R[\theta_e]](V-R[\theta_e])}\right)(V-R[\theta_e])\right)$.
Clearly as $q \to 1 \Rightarrow \Pi^{fe} \to \Pi^{fb}$, then for a given k_p define $\hat{q} : \Pi^{fe} = \Pi^{fb}$, then clearly increasing k_p renders $\Pi^{fe} < \Pi^{fb}$, and likewise for $q < \hat{q}$. Thus define $\bar{k_p}, \hat{q} : \Pi^{fe} = \Pi^{fb}$ Furthermore we know that when $\theta_d \to \theta_e = 1 \Rightarrow \Pi^{td} \to \Pi^{fb}$ and $\Pi^{fe} < \Pi^{fb}$. Then from continuity in the profit functions, for $q > \hat{q}$ and $k_p < \bar{k_p}$, $\Pi^{fe}[\theta_d^{**}] > \Pi^{td}[\theta_d^{**}]$ such that there exists some θ_d', where $\theta_d' : \Pi^{fe}[\theta_d'] = \Pi^{td}[\theta_d']$ and $\theta_d^{**} < \theta_d' < 1$. We next look at the equivalence between the top-down and full-empowerment: $R^{fe}[\theta_d] = R^{td}[\mathbb{E}[\theta]] \Rightarrow \frac{\partial P[R^{fe}[\theta_d]]}{\partial R} = \frac{\partial P[R^{td}[\mathbb{E}[\theta]]]}{\partial R} \Rightarrow \frac{VP[R_d[\theta_d]](1-P[R_d[\theta_d]]\theta_d)}{(V-R_d[\theta_d])R_d[\theta_d]} = \frac{1+k_p-P[R_d[\theta_d]]k_p\theta_d}{V-qV+qV\theta_d+k_p\theta_d R_d[\theta_d]}$, solving for θ_d and abbreviating $R[\theta_d]$ as R_d we

get: $\theta_d = \theta_d^{***\pm} = \frac{1}{2VP[R_d](qV+k_pR_d)}\left(qV^2-(1-q)V^2P\left[R_d\right]+k_p\left(2V-R_d\right)R_d \pm \sqrt{Q}\right)$, where $Q = V^4\left(q+(1-q)P\left[R_d\right]\right)^2 - 4qV^3R_d + 2V^2\left(2q-\left(2-q-(1-q)P\left[R_d\right]\right)k_p\right)R_d^2 + 4Vk_pR_d^3 + k_p^2R_d^4$. Note that $\theta_d^{***-} < \theta_d^{**} < \theta_d^{***+}$ And clearly for either θ_d^{***-} or θ_d^{***+}, $\Pi^{td}[\theta_d^{***\pm}] > \Pi^{fe}[\theta_d^{***\pm}]$ and furthermore for all $\theta_d < \theta_d^{***-} \Rightarrow \Pi^{td}[\theta_d] > \Pi^{fe}[\theta_d]$ □

A.5. Proof of Proposition 4

The compensation decision is the same exact logic as for top-down resource allocation. The firm profit satisfies the Spence-Mirrlees condition: $\Pi_\theta = \theta P[R]V - R - w$. $\frac{\partial}{\partial\theta}\left(\frac{\partial\Pi_\theta}{\partial R}\right)/\left(\frac{\partial\Pi_\theta}{\partial w}\right) \lesseqgtr 0$ Which equates to $\frac{\partial}{\partial\theta}\left(1-\theta V\frac{\partial P[R]}{\partial R}\right) = -V\frac{\partial P[R]}{\partial R} < 0$, which clearly satisfies the condition. Only local incentive compatibility needs to be checked. Due to the monotonicity of the $\frac{\partial R^*}{\partial\theta}$, i.e. $\frac{\partial R^*}{\partial\theta} > 0$. Similarly, $\frac{\partial w^*}{\partial\theta} > 0$. In order to create an incentive feasible separating contract (Laffont and Martimort, 2001, p. 90.) the following constraints must hold (by the Revelation Principle): $(i)/, w_{\theta_d}^* = k_pR_{\theta_d}^*(1-\theta_dP[R_{\theta_d}^*])$ and $(ii)/, w_{\theta_e}^* - k_pR_{\theta_e}^*(1-\theta_eP[R_{\theta_e}^*]) = w_{\theta_d}^* - k_pR_{\theta_d}^*(1-\theta_eP[R_{\theta_d}^*])$. We can then represent w_{θ_d} as $w_{\theta_d} = k_pR_{\theta_d}\left(1-P\left[R_{\theta_d}\right]\theta_d\right)$ and w_{θ_e} as $w_{\theta_e} = k_p\left(P\left[R_{\theta_d}\right]R_{\theta_d}\left(\theta_e-\theta_d\right)+R_{\theta_e}\left(1-P\left[R_{\theta_e}\right]\theta_e\right)\right)$. Then the VP's objective becomes (substituting w_{θ_d} and w_{θ_e}:

$$\max_{R_{\theta_d},R_{\theta_e}} q\left(\theta_dP\left[R_{\theta_d}\right]V - R_{\theta_d} - k_pR_{\theta_d}\left(1-\theta_dP\left[R_{\theta_d}\right]\right)\right) + (1-q)\left(\theta_eP\left[R_{\theta_e}\right]V - R_{\theta_e} - k_p\left(P\left[R_{\theta_d}\right]R_{\theta_d}\left(\theta_e-\theta_d\right)+R_{\theta_e}\left(1-P\left[R_{\theta_e}\right]\theta_e\right)\right)\right)$$

Solving the FOC for R_{θ_e} yields the implicit solution for $R_{\theta_e}^*$ that solves1 + $k_p\left(1-P\left[R_{\theta_e}\right]\theta_e\right) - \left(V+k_pR_{\theta_e}\right)\theta_eP'\left[R_{\theta_e}\right] = 0$ or equivalently: $P\left[R_{\theta_e}\right] = \frac{1+k_p-\left(V+k_pR_{\theta_e}\right)\theta_eP'\left[R_{\theta_e}\right]}{k_p\theta_e}$ which is the same solution as the first best. Similarly, the FOC for R_{θ_d} yields: $R_{\theta_d}^*$ that solves $q\left(1-V\theta_dP'\left[R_{\theta_d}\right]\right) + k_p\left(q+\left((1-q)\theta_e-\theta_d\right)\left(P\left[R_{\theta_d}\right]+R_{\theta_d}P'\left[R_{\theta_d}\right]\right)\right) = 0$, or equivalently $R_{\theta_d}^*$ solves $P\left[R_{\theta_d}\right] = \frac{q\left(1-V\theta_dP'\left[R_{\theta_d}\right]\right)+k_p\left(q-R_{\theta_d}\left(\theta_d-(1-q)\theta_e\right)P'\left[R_{\theta_d}\right]\right)}{k_p\left(\theta_d-(1-q)\theta_e\right)}$, where $R_{\theta_d} < R^{fb}\left[\theta_d\right]$ The corollary follows since without any implementation cost, adding an additional lever (the ability to adapt the specific fixed wage allows any of the other contracts to be replicated with that presented above thus by optimality the optimal contract must be at least as good as any of the prior contracts presented. □

A.5a. Proof of Theorem 2

It is straightforward to see that when the firm can adjust w_{θ_d} and w_{θ_e} as well as the resource levels, any solution to a top-down or bottom-up process can be replicated. It should be clear that if we construct the solution to the tailored incentive and compensation such that the firm earns $\Pi^{tc}[\mathbb{E}[\theta]]$, we can set $\bar{c} = \max\left\{\max_{q,\theta}\Pi^{tc}[\mathbb{E}[\theta]] - \Pi^{td}[\mathbb{E}[\theta]], \max_{q,\theta}\Pi^{tc}[\mathbb{E}[\theta]] - \Pi^{td}[\mathbb{E}[\theta]]\right\}$, which would render it suboptimal for all initiatives. □

A.6. Proof of Proposition 5

Again, the compensation decision is the same exact logic as for top-down resource allocation. The following constraints must hold: (i) $w - k_pR_{\theta_d}(1-\theta_dP[R_{\theta_d}]) \geq 0$ (ii) $w - k_pR_{\theta_e}(1-\theta_eP[R_{\theta_e}]) \geq 0$ (iii) $w - k_pR_{\theta_e}(1-\theta_eP[R_{\theta_e}]) \geq w - k_pR_{\theta_d}(1-\theta_eP[R_{\theta_d}])$ (iv)$w - k_pR_{\theta_d}(1-\theta_dP[R_{\theta_d}]) \geq w - k_pR_{\theta_e}(1-\theta_dP[R_{\theta_e}])$ Which reduce to: (i) $w \geq k_pR_{\theta_d}(1-\theta_dP[R_{\theta_d}])$ (ii) $w \geq k_pR_{\theta_e}(1-\theta_eP[R_{\theta_e}])$ (iii)$R_{\theta_e}(1-\theta_eP[R_{\theta_e}]) \leq R_{\theta_d}(1-\theta_eP[R_{\theta_d}])$ (iv) $R_{\theta_d}(1-\theta_dP[R_{\theta_d}]) \leq R_{\theta_e}(1-\theta_dP[R_{\theta_e}])$ Note that if both (iii) and (iv) are binding then the only solution is that $R_{\theta_e} = R_{\theta_d}$. Note the following properties. $R(1-\theta P[R])$ obtains a unique maximum ($\hat{R}$) on $\mathbb{R}^+$ and is monotonically decreasing for $R > \hat{R}$: $\frac{\partial}{\partial R} R(1-\theta P[R]) = 1 - P[R] - R\frac{\partial P[R]}{\partial R}$ such that $\hat{R}$ solves $\frac{\partial P[R]}{\partial R} = \frac{1-P[R]}{R} \Rightarrow \forall R > \hat{R}$ $R(1-\theta P[R])$ is decreasing. Now note there are three potential cases: (a) (i) and (iii) are binding and all other constraints are slack, (b) (i) is binding and all other constraints are binding, or (c) all constraints bind in which case $R_{\theta_d} = R_{\theta_d}$ and the allocations reduce to the single top-down resource allocation. (iii) binds when: $R_{\theta_d}(1 - P[R_{\theta_d}]) = R_{\theta_e}(1 - P[R_{\theta_e}])$. We can represent $R_{\theta_d} = \alpha[\theta] R_{\theta_e}$, where $\alpha[\theta]$ is decreasing in θ. Then (iii) binds when $\alpha[\theta] < \hat{\alpha}$, where $\hat{\alpha}$ solves $\alpha R_{\theta_e}(1 - P[\alpha R_{\theta_e}]) = R_{\theta_e}(1 - P[R_{\theta_e}])$, and is slack for $\alpha[\theta] > \hat{\alpha}$. Thus for low θ (iii) is binding and for higher θ it is not. Next note that (iv) binds if $R_{\theta_d}(1 - \theta_d P[R_{\theta_d}]) = R_{\theta_e}(1 - \theta_d P[R_{\theta_e}])$ which occurs for $\theta_d \geq \hat{\theta}_d = \frac{R_{\theta_e} - R_{\theta_d}}{P\left[R_{\theta_e}\right] R_{\theta_e} - P\left[R_{\theta_d}\right] R_{\theta_d}}$. Note that R such that (iii) binds is less than R such that (iv) binds (the condition amounts to: $(1-P[R])R < (1-\theta P[R])R$, which holds). Next we show that $\hat{\theta}_d < 1$ which implies that (iv) is binding for $\theta < 1$ and then remains binding for $\theta \in [\hat{\theta}, 1]$, which then implies that $R_{\theta_d} = R_{\theta_e}$ over this same interval, which implies that resource buckets reduce to the top-down process for this interval and this also gives us an ordering: low θ implies constrained (by (iii)) moderate θ allows for unconstrained solutions, and higher θ reduces to top-down. $\square$

A.7. Proof of Theorem 3

Follows directly from the proof above since $\hat{\theta} < \theta_e = 1$.

Alternatively the replication between the full-empowerment and strategic buckets can be seen as follows: Trivially any top-down process can be replicated with a strategic buckets process. Similarly, for two types any full-empowerment process can be represented by an appropriately constructed strategic buckets process. Denoting the respective resource bucket and full-empowerment allocations by $R_{b,\theta}$ and $R_{f,\theta}$, as we have seen before the contributions from the difficult task realization are the same when $R_{b,\theta_d} = R_{f,\theta_d}$ since $\Pi_{b,\theta_d} = \theta_d P[R_{b,\theta_d}]V - R_{b,\theta_d} - k_p R_{b,\theta_d}(1 - P[R_{b,\theta_d}]) = \Pi_{f,\theta_d} = (1 - \frac{R_{b,\theta_d}(1-\theta_d P[R_{b,\theta_d}])}{(V-R_{b,\theta_d})\theta_d P[R_{b,\theta_d}]})\theta_d P[R_{b,\theta_d}](V - R_{b,\theta_d}) - R_{b,\theta_d}(1 - P[R_{b,\theta_d}])$ when $R_{b,\theta_d} = R_{f,\theta_d}$. Then we need to find R_{b,θ_e} such that $\Pi_{f,\theta_e} = (1 - \frac{R_{b,\theta_d}(1-\theta_d P[R_{b,\theta_d}])}{(V-R_{b,\theta_d})\theta_d P[R_{b,\theta_d}]}) P[R_{f,\theta_e}](V - R_{f,\theta_e}) - R_{f,\theta_e}(1 - P[R_{f,\theta_e}]) = \Pi_{f,\theta_e} = P[R_{f,\theta_e}]V - R_{f,\theta_e} - k_p R_{b,\theta_d}(1 - P[R_{b,\theta_d}])$

$\Rightarrow P[R_{b,\theta_e}] = \frac{R_{b,\theta_e} - R_{f,\theta_e} + k_p R_{b,\theta_d}(1-\theta_d P[R_{b,\theta_d}]) + R_{f,\theta_e} P[R_{f,\theta_e}] + \frac{(V-R_{f,\theta_e})(\theta_d V P[R_{b,\theta_d}] - R_{b,\theta_d}) P[R_{f,\theta_e}]}{\theta_d (V - R_{b,\theta_d}) P[R_{b,\theta_d}]}}{V}$ $\square$

A.8. An example of strategic buckets with three types

If we solve for the top-down, full-empowerment and the strategic buckets solutions for the case of $k_p = 0.01$, $q = 1/2$, $\theta_d = .3$, $V = 8$, $P[R] = \frac{R^2}{1+R^2}$ we solve for:

$\Pi^{td} = 2.16022$, $R^{td} = 1.82971$

$\Pi^{fe} = 2.22092$, $R^{fe}[\theta_d] = 1.02992$, $R^{fe}[\theta_m] = 1.78162$, $R^{fe}[\theta_e] = 2.25543$

$\Pi^{sb} = 2.19765$, $R^{sb}_{\theta_d} = 1.65614$, $R^{sb}_{\theta_m} = 1.65614$, $R^{fe}_{\theta_e} = 2.23012$

For the example below $k_p = 0.01$, $q = 1/2$. Here for the case of moderate difficulty, the full-empowerment RAP dominates that of the strategic buckets RAP.

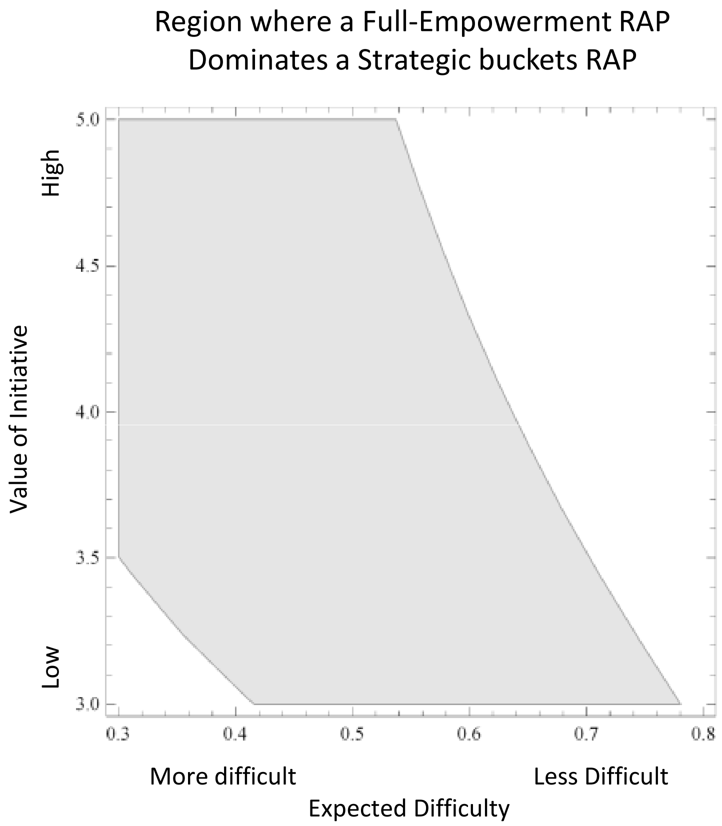

Figure 5 **An example to show that when strategic buckets are defined with finer granularity than two buckets, a full-empowerment RAP may still have regions of dominance.**