INTEGRATION THROUGH INCENTIVES

WITHIN DIFFERENTIATED ORGANIZATIONS

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Abstract

The specialization of activity within organizations can make it worthwhile to motivate collaboration efforts, but also makes such efforts less effective through coordination challenges. Drawing on the concepts of organizational differentiation and integration, we present a formal analysis of the manner in which these two consequences of specialization shape the effectiveness of collaborative incentives in complex organizations. We show that ignoring the coordination challenges created by differentiation does not merely impede the achievement of gains from integration, but can lower organizational performance below the levels achieved when such gains are simply ignored. Thus, treating inter-unit collaboration purely as a problem of motivating cooperation can be counter-productive.
“Every organized human activity – from making pots to placing a man on the moon – gives rise to two fundamental and opposing requirements: the division of labour into various tasks, and the coordination of these tasks to accomplish the activity.


In this paper, we develop a theoretical framework to study the use of collaborative incentives to manage interdependence within organizations. Collaborative incentives motivate efforts towards interdependence management across organizational units by tying at least some portion of employee compensation within one unit to the performance of other units, instead of rewarding unit performance only. Compared to other inter-unit linking mechanisms such as standards, plans, teams and integrators (Lawrence & Lorsch, 1967; March & Simon, 1958; Mintzberg, 1980; Nadler & Tushman, 1997; Thompson, 1967) collaborative incentives have received limited attention in the literature on organization design. Apart from the general intuition that collaborative incentives can be useful when there are gains from managing interdependence, we know little about what the optimal structure of such incentives should be (i.e. the relative emphasis to be placed on individual unit and group performance), or indeed about the boundary conditions under which collaborative incentives are useful for managing interdependence at all. While there is a substantial literature on group incentives in both the economics and social psychology traditions, this literature has abstracted away from a central feature of interest to organization theorists – the existence of specialized organizational sub-units within complex organizations (Mintzberg, 1980; Perrow, 1987; Simon, 1962).

The core argument we develop in this paper is that specialization influences the usefulness and structure of collaborative incentives. While the productivity gains from specialization are well-known, our focus is on two additional consequences of specialization – gains from managing interdependence and differentiation. Specialization inevitably leads to interdependence in the sense that the specialized parts must eventually work together. Unless interdependence can be completely managed through standards and interfaces (Sanchez &
Mahoney, 1996) there will be potential gains from managing it collaboratively. In their pioneering work, March and Simon (1958) argued that regardless of the basis for partitioning organizations into specialized units, interdependence across units and potential gains from inter-unit collaboration are ubiquitous (see also Thompson, 1967; Nadler and Tushman, 1997; Heath and Staudenmayer, 2000). However, as Lawrence and Lorsch (1967) showed, as specialized organizational units adapt to their local circumstances, they become “differentiated” from each other in terms of their internal structures, behaviours, and the attitudes of constituent members (see also Dougherty, 1992). The coordination challenges created by this heterogeneity can impede the effectiveness of inter-unit collaboration or “integration”, even when employees are motivated to undertake collaborative efforts. The specialization of activity within organizations therefore gives rise to opposing forces, as it makes inter-unit collaboration valuable while also making it difficult. Building on prior work on group incentives and the gains from managing interdependence (Siggelkow, 2002; Wageman & Baker, 1997) we formally analyse how these dual implications of specialization influence the usage of collaborative incentives in complex organizations.

Our central result is that even when there are significant potential gains from managing interdependence, collaborative incentives can lower organizational performance below what would be obtained from ignoring interdependence and setting narrow unit-based incentives. Whether collaborative incentives (and the collaborative interdependence management efforts they encourage) enhance the value of the organization beyond that of independent units depends on the balance between two effects. These are the “integration effect”, which refers to the realization of gains from managing interdependence and the “differentiation effect”, which arises because inter-unit collaborative efforts are in general less productive than within unit production activity due to differentiation and resulting coordination challenges (Lawrence and Lorsch, 1967). We show that the differentiation effect creates a threshold in the integration effect. Below the threshold, using collaborative incentives can lower organizational
performance below levels achieved when interdependence is ignored. We also analyse how this threshold is affected by the degree of differentiation, as well as asymmetry and uncertainty associated with the potential gains from managing interdependence.

We note that our results are distinct from those generated just by free riding or risk aversion, two well-known constraints on the usefulness of collaborative incentives that have been extensively studied by agency theorists and social psychologists (Kollock, 1998; Prendergast, 1999). Rather, the differentiation and integration effects we focus on in this study are uniquely organizational as they are a consequence of the specialization of activity within complex organizations. Several decades after their initial formulation, the concepts of organizational differentiation and integration and the tension between them continue to interest business scholars studying a wide variety of problems: inter-departmental collaboration in product development (Dougherty, 1992, 2001), organizational ambidexterity (Tushman, Smith, Wood, Westerman & O'Reilly, 2004; Tushman & O'Reilly, 1996), post-merger integration (Puranam, Singh & Zollo, 2006), spin-offs and new ventures (Siggelkow & Levinthal, 2003), the structuring of multinational corporations (Ghoshal & Nohria, 1989) and the organization of vertical relationships (Gulati, Lawrence & Puranam, 2005). Our contribution to this literature is to focus on a specific integration mechanism (collaborative incentives) and specify the boundary conditions for its use in terms of two important consequences of specialization – potential gains from managing interdependence and differentiation.

**COLLABORATIVE INCENTIVES IN COMPLEX ORGANIZATIONS**

**Relevant prior literature**

The limited literature on collaborative incentives within complex organizations suggests that they help to motivate efforts towards managing inter-unit interdependence, but does not provide much guidance on the boundary conditions for their use, or their optimal structure. For instance, Gupta and Govindarajan argue that in multi-divisional firms, the extent of resource sharing between divisions and the incentive system are linked. Collaborative
incentives for division heads are associated with business unit effectiveness when resource sharing is important (Gupta & Govindarajan, 1986). In a sample of diversified manufacturing firms, John and Harrison find that potential manufacturing synergies between business units are more likely to be realized when incentives that encourage inter-unit collaboration exist (John & Harrison, 1999). Argyres argues that less divisionalized firms tend to have broader firm level incentives compared to more divisionalized firms that typically employ narrow division level incentives. He therefore predicts that the more divisionalized the firm, the less likely that it will pursue an R&D strategy that would require extensive collaboration across divisions (Argyres, 1995).

While typically anchored in the individual/group level rather than the organizational level of analysis, there is a substantial literature developed by agency theorists and social psychologists on the limits of group incentives. Group incentives represent a specific instance of collaborative incentives that are as broad as possible – they tie compensation to the performance of the group rather than to that of a particular individual. Free riding and risk aversion are two well-known constraints on the use of group incentives.

Free riding occurs when group level performance is used to reward individual effort, because purely self-interested employees have an incentive to avoid effort while fully sharing in the rewards of group activity as long as their withholding of efforts remains hard to detect or deter. The problem is exacerbated as group size increases, as the link between individual effort and group outcomes grows weaker, and individual effort becomes harder to observe (see Prendergast, 1999, pgs: 39-44 for a review of the empirical tests of free riding). An extensive literature in agency theory explores various solutions to this problem, such as the use of monitoring and sanctions (Alchian & Demsetz, 1972), target rate incentives (Holmstrom, 1982; Petersen, 1992) and expected future interactions (Baker, Gibbons& Murphy, 2002). Scholars investigating free riding in the social psychology tradition argue that communication enables individuals to better understand the impact of their actions on individual and group outcomes.
through a process of discussion and learning (Dawes, 1980), and that group identity induces individuals to take the group interest into account when making their own decisions (Bouas & Komorita, 1996). For a comprehensive review of solutions to the free-riding problem, see Kolklock (1998).

Risk aversion is a potentially important constraint on the use of performance-based incentives in general (Gibbons, 1998). Group level incentives may motivate employees to collaborate but also forces them to bear the risks associated with noise in not only their own, but other’s performance as well (Baker, 2002). However, the empirical evidence for the hypothesized trade-off between incentives and risk in general remains weak (Prendergast, 2002a, b).

In our view, while the extensive theoretical and empirical literature on free riding and risk aversion is clearly relevant to the analysis of collaborative incentives in complex organizations, it is still a starting point rather than the final destination. This is because this literature largely ignores the defining feature of complex organizations – the specialization of activity resulting in complicated patterns of interdependence between differentiated organizational units.

The implications of specialization for incentives in complex organizations

Specialization within organizations means that different units take on different subsets of the organization’s activities. This has notable consequences besides improved unit level productivity through economizing on bounded rationality (Ethiraj and Levinthal, 2005) and focused learning by doing (Jacobides & Winter, 2005). These are the need to ensure that the results of activities divided across units can be ultimately combined again (interdependence) and the emergence of significant differences in structural and behavioural attributes across units (differentiation). We discuss each in turn.

Specialization and gains from managing interdependence
In general, “as the specialization of tasks proceeds, the interdependency of the specialized parts increases” (Simon, 1991, p42). Thompson’s typology (1967) and later extensions (eg. Adler, 1995) provide useful characterizations of different types of interdependence between organizational units in terms of the direction and magnitude of information flows required to manage them. However, our focus is on the magnitude of gains from managing interdependence. We argue that these depend on the extent to which the nature of interactions between units is well understood, and the extent to which actions taken by one unit impose constraints on the other.

In an insightful analysis, Postrel shows that even when units are sequentially interdependent, such as design and manufacturing units, there may be little need for actively managing interdependence between them if the nature of interactions between units is well understood and decisions taken in one unit do not pose binding constraints for the decisions in the other. Indeed, specialization and the resulting gain in production competence may effectively decouple units in such contexts (“black-boxing”) by relaxing the constraints on what is feasible for each unit (Postrel, 2002). In contrast, if the actions of specialized units impose binding constraints on each other, or if the underlying nature of interactions between the units is unknown or ambiguous (Ethiraj & Levinthal, 2004a, b; Siggelkow, 2002) there can be significant gains from collaboration (Rivkin & Siggelkow, 2003). The literature on product development (Iansiti, 1998) and the design/manufacturing interface (Adler, 1995; Monteverde, 1995) is a rich source of instances where gains from inter-unit collaboration are significant because the underlying nature of interactions is not known but must be discovered, and because the choices in one unit may pose binding constraints on the choices in the other. Under these situations, interdependence cannot be managed effectively through standardized interfaces alone. Thus, specialization can give rise to varying magnitudes of gains from collaboratively managing interdependence, depending on how well interdependence is understood, and the extent of constraint across activities it poses.
Specialization, Differentiation and Impediments to Collaboration

Specialization typically brings improvements in productivity in primary production tasks through learning effects; but at the same time specialization makes collaboration efforts less productive because of coordination difficulties (Lawrence and Lorsch, 1967). When all units pursue identical tasks, there is no qualitative difference between engaging in “own” tasks (production) and “helping” others with their tasks (collaboration) – the two are substitutes. Free riding in un-specialized organizational contexts, such as a team of workers lifting a heavy load (Alchian and Demsetz, 1972) is fundamentally no different from an employee shirking at his individual job, as captured in principal-agent models (Eisenhardt, 1989). The incentive problem in specialized organizations is distinct from that in unspecialized contexts, because incentives must motivate two different kinds of efforts – collaboration and production – and achieve a balance between them.

Specialization not only creates a conceptual distinction between production and collaboration efforts, but also causes a divergence in the effectiveness of these two kinds of efforts, making them less substitutable for each other. As noted by Lawrence and Lorsch, specialization of activity is well known to enhance competence at production, but it also generates differentiation – “not just the simple fact of partition and specialized knowledge” but “fundamental differences in attitude and behaviour” (Lawrence and Lorsch, 1967, p.9). Differentiation is the “state of segmentation of the organizational system into subsystems, each of which tends to develop particular attributes in relation to the requirements posed by its relevant external environment” (Lawrence and Lorsch, 1967b: 4). It thus describes the emergence of differences across organizational units as a consequence of local adaptation to specialized tasks, and it results in organizational heterogeneity. This makes collaboration between units more difficult relative to within-unit production activity, through effects on both motives and cognition.
As individuals begin to prioritize unit goals over organizational goals ("sub-goal pursuit" in the language of March and Simon, 1958), there may be limited motivation to pursue the management of interdependence. While the motivation problem can be addressed through mechanisms like incentives or identification with the larger organization (Kogut & Zander, 1996; Simon, 1991) the resulting efforts at collaboration may still be ineffective because of coordination failures.

Coordination is distinct from cooperation (Camerer & Knez, 1996, 1997; Gulati et al., 2005; Heath & Staudenmayer, 2000). In essence, the problem of cooperation (aligning interests) is a problem of motivation, and can be alleviated if not resolved through incentives. In contrast, coordination problems (aligning actions) are fundamentally cognitive in origin, and require shared understanding and common ground to be solved. Coordination failures in experimental settings have been studied extensively by behavioural game theorists (Camerer, 2003; Weber, Camerer, Rottenstreich & Knez, 2001; Weber & Camerer, 2003). Heath and Staudenmayer (2000) present a number of examples of organizational failures due to poor coordination even when the motives of all involved were aligned towards success. Both experimental and field examples converge on the idea that in the absence of a sufficient stock of common knowledge, reciprocal predictability of action does not obtain and coordination fails.

Members of differentiated organizational units are likely to experience coordination difficulties because they belong to distinct “thought worlds”, with mutually incompatible representations, language, interpersonal and time orientations (Lawrence and Lorsch, 1967; Dougherty, 1992). Communication across differentiated units is likely to be less effective, because individuals may not even recognize the need for communication, and encounter translation problems when they do communicate (Heath and Staudenmeyer, 2000). Indeed, the use of language itself is a coordination problem, which may not be solved unless there exists some commonly shared knowledge about conventions of usage and meaning (Bechky, 2003;
Clark, 1996). Differentiation thus lowers the effectiveness of collaborative effort even when such efforts are undertaken, because of the coordination challenges generated due to the absence of common knowledge and language (Camerer and Knez, 1996; pgs 102-105).

Employees in any specialized unit within a complex organization thus not only face two different tasks (production within the unit and collaboration with other units) but also their productivity in the two tasks may be inversely related. The divergence between the productivity of production and collaboration efforts arises because specialization makes the two kinds of activities less similar, as they increasingly draw on distinct skills and knowledge bases. This is a natural consequence of each unit’s production activities developing their own distinctive skill and knowledge base. The shrinking pool of common knowledge however makes collaboration less effective due to insufficient common ground and the coordination challenges that creates.

Any attempts to manage interdependence via collaborative incentives must therefore take into account the fact that collaboration efforts are likely to be less productive than production efforts. This difference in the productivity of collaboration and production bears some resemblance to the problem of multi-tasking: faced with multiple tasks, employees may allocate their hard-to-observe efforts to tasks in a manner that is optimal for them, but not necessarily for the employer (Baker & Gibbons, 1994; Holmstrom & Milgrom, 1991). The consequence of the multi-tasking problem that has been well studied by agency theorists is that pay for performance may result in employers “getting what they pay for”. Since performance measures are often imperfect, employees may take actions that maximize the performance measure rather than actions that maximize performance. This literature however typically deals with the problem of a single agent choosing how to allocate effort to different non-interdependent tasks, and the problem of the principal who must design an incentive contract based on noisy measures of performance for the two tasks. We are concerned with group
incentives for agents whose tasks are interdependent, but whose efforts at collaboration and production are not equally productive.

A MODEL OF COLLABORATIVE INCENTIVES
IN COMPLEX ORGANIZATIONS

In this section, we develop a formal model to analyze the design of collaborative incentives in complex organizations. Our model accounts for the differences in the effectiveness of production and collaboration efforts induced by differentiation, as well as potential gains from integration. We consider an organization with two organizational units $i = 1, 2$. While such an organization may appear more “simple” than complex, our focus is on understanding aspects of complexity in organizations unrelated to the number of units – specifically, the extent of differentiation of units and the complicated patterns of interdependence between them.

Each organizational unit is administered by a unit manager who puts in a total of $\eta_i = x_i + y_i$ units of effort, where $x_i$ represents effort spent on production within the home unit, and $y_i$ represents effort spent in collaborating with the other unit, $j$. Note that the total amount of effort, $\eta_i$, is endogenously determined by the incentive structure imposed on the manager in our model. We think about the unit manager as a decision maker who must decide how to allocate the aggregated efforts of all her unit’s employees in a manner that takes into account the cost of efforts of her employees. In this organization, production effort refers to the sum of all efforts undertaken by employees within a unit that pertain to the primary tasks of the organizational unit ($x_i + x_j$) whereas collaboration refers to the sum of all efforts that cover the units’ boundary spanning activities ($y_i + y_j$) to manage interdependence between them.

Insert Figure 1 about here
Our model specification rests on three assumptions. The variable compensation, determined by an organization designer, for unit manager $i$ is defined as

$$\alpha \pi_i + \beta \pi_j$$  \hspace{1cm} (A1)

where $\alpha + \beta = k$ are parameters governing the incentive structure for the unit manager, and unit outputs are $\pi_i, \pi_j$. Manager $i$ gets paid purely on own unit’s performance if $\beta = 0$, and on overall organizational performance if $\alpha = \beta = k/2$. In our model, the structure of collaborative incentives is described by the value of $\beta$ (the “breadth” of incentives) vis-à-vis $k$. The variable $k$ denotes incentive intensity or “depth”, as larger $k$ implies greater variable (i.e. performance based) compensation. We restrict $k \leq 1$, so that the managers cannot be paid more than total output. $\beta$ thus lies between 0 and $k/2$, and $\alpha = k - \beta$. Put differently, $k$ describes how much of the organization’s total output the unit managers obtain, while $\alpha, \beta$ describe how much of this amount comes from the manager’s own and other units. This formulation allows us to focus on the trade-off between motivating production and collaboration that arises at any given level of incentive depth; increases in $\beta$ must come at the expense of $\alpha$ for any value of $k$.

A1 represents a linear compensation policy, which we chose for three reasons. First, linear compensation contracts have the appealing property that they motivate effort at all levels of performance. Target rate schemes that pay all or nothing based on the agents hitting a pre-defined target performance level (eg. see Holmstrom, 1982) could be a powerful alternative, but these schemes discourage efforts if agents are below the target or even marginally above it. Further, such schemes are open to the dangers of the principal being able to secretly nudge down reported outputs in order to avoid reaching the target and therefore having to pay bonuses to the agents. Second, the linear compensation policy we define in A1 is flexible enough to accommodate several related kinds of policies – for instance, other compensation policies that place some weight on unit level and some on organization wide performance.
(Wageman and Baker, 1997) or which reward managers for the difference in output across units can be expressed as linear transformations of A1. Third, the linear policy is simple, both in terms of the processing capacity required by agents and designer, as well as in terms of tractability.

We use the following specification of unit output $\pi_i$:

$$\pi_i = \alpha_i + (1 - \tau)\gamma y_j + \tau\gamma y_j + \epsilon_i$$

(A2)

The total output function is simply $\Pi = \pi_i + \pi_j$. This specification captures the two consequences of specialization we wish to study – gains from integration ($\gamma$) and differentiation ($\tau$) – as explained below. To fix ideas, consider two divisions – “Soaps” and “Detergents” – within a consumer goods company. These correspond to units $i$ and $j$ in our model. Each unit has measurable output ($\pi_i$). For instance, output may be measured in terms of sales volume, product innovation, or profit contribution etc. The production ($x_j$) and collaboration ($y_j$) efforts represent a decomposition of activities in each unit into portions that only affect the output of that unit (e.g. only help to sell soaps or detergents) and that contribute towards managing interdependence between the two units, which we describe further below. Our focus is on understanding how the potential value of collaboration between the units as well as the ability to collaborate are affected by the consequences of specialization – interdependence and differentiation – that we focus on in this paper.

The potential value of collaboration: Specialization can create potential gains from integration, and therefore greater potential value to collaboration. For instance, while the Soaps and Detergents divisions specialize in different product lines, they are ultimately part of the same corporation. This means that in the interests of enhancing corporate performance, the units may need to manage interdependence between their activities through collaboration. Gains from integration may arise from a) effective utilization of shared infrastructure (i.e. cost
synergies from spreading fixed costs over multiple units) b) ensuring inter-operability (eg. design for manufacturing) c) scheduling activities (eg. in new product development) d) sharing best practices between units. These can cover both “cost synergies” as well as “revenue synergies”.

A2 specifies that the output of unit $i$, $\pi_i$, depends on $x_i$ and $y_j$ - i.e. on the effort spent in production by its employee as well as the effort spent by unit $j$’s employee in collaborating with unit $i$’s employee – what we refer to as incoming collaboration (see Figure 1). For gains from integration to exist, we require $\partial^2 \pi_i / \partial x_i \partial y_j = \gamma \geq 0$ in A2. The nonnegative parameter $\gamma$ (constrained to be $< 2$ for model tractability) thus captures the magnitude of the potential gains from collaboration between units. This formulation of gains from managing interdependence between activities has a tradition in prior research (Cremer, 1990; Siggelkow, 2002) and is a specific instance of the notion of positive complementarities (Milgrom & Roberts, 1990).

The ability to collaborate: Increasing specialization enhances the productivity of primary production activity $x$, but simultaneously reduces the productivity of incoming collaborative effort $y$. This divergence between the productivity of production and collaboration efforts arises because specialization makes the two kinds of activities less similar. In unspecialised settings, the acts of producing and helping somebody else produce both draw on the same knowledge and skill base. Put differently, production efforts and incoming collaboration efforts are close substitutes. However, with increasing specialization, commonality of skills and knowledge declines, which is the essence of the process of differentiation (Lawrence and Lorsch, 1967). This makes collaboration less effective due to insufficient common ground and the coordination challenges this creates. Thus, as the work of the Soaps and Detergents units becomes more specialized, the activities of the individuals in these two units look increasingly different and they begin to inhabit distinct “thought worlds”,

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the challenge of inter-unit coordination becomes more severe and the ability to collaborate declines.

We capture the twin effects of specialization on the productivity of production and collaboration efforts in A2 by making $1/2 \leq \tau \leq 1$. In the spirit of Lawrence and Lorsch (1967), this specification of specialization makes explicit the trade-off created by specialization – between improved productivity at production vs. greater differentiation leading to lowered productivity in collaboration – by keeping the average level of productivity constant.\textsuperscript{iv} We note that we are not modelling the process of coordination failure by which differentiation lowers the productivity of collaboration efforts, or the process by which it raises the productivity of production effort (through gains from specialization). We take as given that differentiation generates these outcomes, and then explore how these outcomes influence the structure of collaborative incentives.

In sum, increases in $\gamma$ represent enhanced potential value from collaboration, whereas increases in $\tau$ represent a lower ability to collaborate effectively as well as a greater ability at production. We do not specify an explicit link between $\gamma$ and $\tau$ as this allows us to study the effect of differentiation for any given level of interdependence gains, and vice versa.

Finally, we assume that employees face a convex cost of total effort, which we model in the standard quadratic form.

$$\mu_i = x_i^2 + y_i^2 \quad (A3)$$

The assumption of quadratic cost of effort is common in the literature on teams, and agency theory in general (Baker, 2002; Cremer, 1990; Gibbons, 1998; Prendergast, 1999; Siggelkow, 2002) and simply captures the notion of increasing marginal disutility of an additional unit of effort, or increasing marginal cost of an additional unit of resources in general. This formulation where the two kinds of efforts are unlinked implies that they come from different sources- different individuals in the unit may perform these activities, or they may be resourced
from different budgets. This avoids building in an additional trade-off between the amount of collaboration and production efforts in addition to the one we focus on in our study – the motivation of collaboration at the expense of production (A1). We explore a variant of our model with a linked cost structure in our discussion section. The manager of unit \( i \) chooses \( x_i \) and \( y_i \) to maximize her share of total output subject to that being larger than her reservation utility \( U_i \).

We also note what is implicitly excluded in our model. First, the managers are risk neutral so that the trade-off between incentives and insurance plays no explicit role in our model. We note that the inclusion of the error term \( \varepsilon \) in A2 serves only to justify the use of a linear compensation contract in A1 – in the presence of noise (even without risk aversion), linear compensation contracts have advantages over alternatives such as target rate schemes. It has no other role in the analysis, and all payoffs we calculate can be thought of as expected payoffs. The effects of noise and risk aversion on incentives have already been studied exhaustively in prior literature, though the empirical evidence for the existence of these effects is weak (Gibbons, 1998; Prendergast, 2002a). Second, we assume that it is not possible (or too expensive) for the organization designer to monitor and enforce effort levels by unit managers, or to create a context for infinitely repeated interactions. Thus, sanctions, target rate schemes and shadow-of-the-future effects are ruled out, so that we can focus purely on the structure of collaborative incentives. Third, we also ignore social cohesion, group identity, and learning effects. In our discussion, we revisit the impact of these assumptions on our results. These assumptions serve as boundary conditions for our analysis- we explore the robustness of our results to them in the discussion.

Model mechanics

We assume self-interested and rationally optimising behaviour by both managers and the designer. Specifically, we assume that the incentive structure is decided by an organization
designer who maximizes his payoff, which is equal to the total output generated in the two units minus the compensation paid to the managers. The managers maximize their payoff, which is their share of total output minus their costs of efforts. The designer first determines the incentive structure, and the managers respond by choosing effort levels. We assume that the equations A1-A3 and the parameters therein are common knowledge, and solve the model through backward induction. Thus, we first calculate the best response functions for the managers, i.e. the equilibrium levels of production and collaboration efforts that maximize their payoffs given the incentive structure. These effort levels represent a Nash equilibrium in a game being played between the two managers.

The first-order conditions for production and collaboration efforts for agent $i$ are

\begin{align}
(k - \beta)(\tau + \gamma y_j) - 2x_i &= 0 \\
\beta((1 - \tau) + \gamma x_j) - 2y_i &= 0
\end{align}

As can be seen, ceteris paribus, collaborative efforts increase in $\beta$, whereas production efforts decrease in $\beta$. Further, solving these first-order conditions for effort levels will yield maxima, as the second derivatives of these expressions are negative. Solving the system of equations implied by the first-order conditions, we obtain the following equilibrium effort levels ($i = 1, 2$):

\begin{align}
x_i^* &= \frac{(k - \beta)(2\tau + \beta \gamma(1 - \tau))}{4 - k\beta \gamma^2 + \beta^2 \gamma^2} \\
y_i^* &= \frac{\beta(\gamma(k - \beta)\tau + 2(1 - \tau))}{4 - k\beta \gamma^2 + \beta^2 \gamma^2}
\end{align}

As expected, both production and collaborative efforts increase in $k$. We then calculate the total output generated by the two managers by substituting $x_i^*$ and $y_i^*$ into $\pi_i$. Denote these by $\pi_i^*$ (for full expressions please see technical appendix) and total output in equilibrium as $\Pi^*$. The organization designer chooses an incentive structure to maximize his payoff, which is:
\[ \Pi^* - k\Pi^* = (1-k)\Pi^* \]  

subject to the constraint that

\[ (k - \beta)\pi_i^* + \beta\pi_j^* \geq U_i \]

The designer’s choice of the incentive structure, i.e. parameters \( k \) and \( \beta \) (\( k = \alpha + \beta \)) combined with the resulting effort levels represents a Nash equilibrium in a game played between the designer and the two managers, with the designer acting as first mover. Without loss of generality, we normalize \( U_i = \mu_i \) (cost of effort), which implicitly sets the value of the outside option to zero. This ensures that the managers’ participation constraints are met, and that the designer can optimize (5) without constraints.

Our focus is on the value of \( \beta \) relative to \( k \), or the breadth of incentives for any given depth of incentives. The choice of \( k \) by the designer represents a trade-off between the interests of the designer and that of the managers, in the sense that higher \( k \) allocates more of the total output to the managers and less to the designer. However, the choice of optimal \( \beta \) by the designer does not imply such a trade-off; what creates higher payoffs for the designer also does so for the managers. That is, the choice of \( \beta \) that maximizes \( (1-k)\Pi^* \) will also maximize \( k\Pi^* \) for any given \( k \). As a benchmark for the effectiveness of collaborative incentives we use the case where incentives are purely at the unit level (\( \beta = 0 \)). In this case, interdependence is ignored and both units operate autonomously. Collaborative incentives (\( \beta > 0 \)) are valuable to the designer and the managers only if total output with such incentives exceeds the output under the autonomous incentive regime.

Increasing the breadth of collaborative incentives – i.e. changing managers’ incentive structures such that each manager’s payoff depends increasingly on total output rather than on unit level output – has two significant effects on total outputs in this model:
The Integration effect: Increasing incentive breadth motivates collaborative action to manage interdependence. By making unit $i$ manager’s compensation partly contingent on unit $j$’s performance, she is encouraged to invest effort in collaborating with unit $j$. This can generate value when there are gains from integration (A2). Figure 2 shows that holding the extent of differentiation at zero, for any level of gains from integration, the total output increases with collaborative incentives relative to the autonomous incentive regime. This effect is strengthened by the magnitude of gains from managing interdependence – a larger $\gamma$ equates to a larger integration effect.

The Differentiation effect: When incentives are broadened, the incentives towards collaboration tasks rise but the incentives towards production tasks fall. This is a direct consequence of A1, as for any given incentive depth, placing more emphasis on the other unit’s performance comes at the expense of de-emphasizing own unit performance. Therefore, broadening incentives encourages both unit managers to expend effort in inter-unit collaboration (greater “$y$” effort), but diminishes incentives towards own production tasks (lower “$x$” effort). Since differentiation lowers the productivity of collaboration efforts due to coordination challenges, broadening incentives effectively encourages less productive kinds of efforts (collaboration) at the expense of more productive efforts (production) – this is the differentiation effect. Figure 3 shows that holding gains from integration at zero, for any level of differentiation, total output declines with collaborative incentives relative to the autonomous incentive regime. This effect is strengthened by the degree of differentiation – larger values of $\tau$ equate to larger differentiation effects.

Insert Figures 2 and 3 about here

Our analysis consists of identifying the conditions under which the integration effect dominates the differentiation effect, and the structure of collaborative incentives (i.e. $\beta$ relative to $k$) that the designer must choose to optimize total output.
By way of comparison, the first best (efficient) outcome would be one where the designer and agents jointly maximize total profits, i.e. total output less the total cost of effort:

$$\max_{x_i, y_i} \left( \Pi - \sum_{i} \mu_i \right)$$

(7)

Note that the incentive parameters $\beta$ and $k$ play no role in this problem; they simply govern the distribution of outputs between managers and designer, which is irrelevant to the cooperative (first best) outcome. The first-order conditions for production and collaboration efforts in the first-best case are:

$$\tau + \gamma y_j - 2x_i = 0$$

(8)

$$\left(1 - \tau\right) + \mu y_i - 2y_i = 0$$

(9)

Comparing the first-order conditions for the first best outcome with those in the Nash equilibria defined in equations 1 and 2, we find (not surprisingly) that effort levels are higher in the first best case. Solving the system of equations implied by 8 and 9, we find that the equilibrium effort levels are:

$$x^{FB} = \frac{2\tau + (1 - \tau)\gamma}{4 - \gamma^2}$$

(10)

$$y^{FB} = \frac{2(1 - \tau) + \tau \gamma}{4 - \gamma^2}$$

(11)

It is worth noting that the difference in effort levels between the first best case and in the Nash equilibrium level is constant in $\beta$ for a given $k$ if there are neither interdependence gains ($\gamma = 0$) nor differentiation ($\tau = 1/2$). This also shows how our model uniquely captures consequences of specialization (the differentiation and integration effects) that are absent in standard free-riding models. The free riding effect is typically measured relative to the first best cooperative outcome rather than the autonomous incentive regime, when incentives are linked purely to unit level performance. As the comparison of equilibrium effort levels in the first best case and the Nash equilibrium shows, in the absence of specialization and its...
consequences –interdependence and differentiation – the degree of breadth of incentives has no effect on free riding. This is depicted in Figure 4, in which the extent of free riding is measured as the difference between the effort levels in the cooperative outcome and in the Nash equilibrium. We see that with increasing incentive breadth, production effort decreases and collaboration effort increases. However, total effort remains constant, because in unspecialised organizations, there is no difference between production and collaboration efforts, and there are no gains to managing interdependence. This also helps explain why the breadth of incentives is not an interesting variable in traditional free-riding models – absent specialization, incentives of any degree of breadth are equivalent.

**Insert Figure 4 about here**

**OPTIMAL INCENTIVE BREADTH IN COMPLEX ORGANIZATIONS**

*Integration, Differentiation and Optimal incentive breadth*

Our first proposition establishes the relationship between breadth of incentives ($\beta$) and gains from integration ($\gamma$) in complex organizations – i.e. organizations consisting of specialized (and therefore differentiated) units ($\tau > 1/2$):

**Proposition 1:** In complex organizations, there is a threshold level for the integration effect. For an integration effect below this threshold, collaborative incentives can lower performance levels below that achievable through completely narrow, unit-level incentives.

We explain the intuition for this result in terms of the differentiation and integration effects of incentive breadth. (Formal proofs of all propositions are in the appendix). If organizational units were not differentiated, then the integration effect would imply that broader incentives would always enhance outputs relative to the autonomous (unit-level) incentive regime, leading to an optimal incentive structure that was as broad as possible (i.e. organization-wide incentives). However, the differentiation effect reduces total outputs relative to the autonomous incentive regime. Increasing incentive breadth therefore enhances total
outputs over the autonomous incentive regime only when the integration effect dominates the
differentiation effect. This creates the threshold noted in P1. Analytically, the threshold in the
integration effect (i.e. the threshold level of $\gamma$) as a function of incentive depth and
differentiation can be expressed as follows:

$$
\gamma = \left( \frac{1}{k} \right) \left( \frac{3}{2} - \frac{3}{2r} + \frac{\sqrt{1 - 2r + 9r^2}}{2r} \right)
$$

(12)

For all values $\gamma < \gamma$, it does not increase output to set collaborative incentives. Figure 5
plots the integration threshold in terms of the extent of differentiation and incentive depth. This
figures captures the essence of how problems of coordination and motivation interact in
shaping incentive structure. The threshold level is unattainable for combinations of low
incentive depth and high differentiation, and can be lowered either by increasing incentive
depth, or by lowering differentiation.

**Insert Figure 5 about here**

The extent of differentiation may vary considerably across units. We formalize the
impact of the extent of differentiation on the structure of collaborative incentives as follows:

**Proposition 2**: a) The threshold level of the integration effect *increases* in the extent of
differentiation of organizational units, and b) the optimal incentive breadth *decreases* in the
extent of differentiation of organizational units.

The intuition for these results is similar to that for P1. The threshold arises because
differentiation makes investing efforts in collaborating with other units less productive than
focusing on production tasks within the unit. Lower degrees of differentiation decrease the
magnitude of the differentiation effect, and thus lower the threshold, while greater
differentiation raises the threshold (P2a). The optimal incentive breadth is one that balances the
differentiation and integration effects to maximize total outputs. Greater differentiation
increases the rate at which the differentiation effect increases with incentive breadth, so that a stronger differentiation effect also implies a lower optimal incentive breadth (P2b).

Another way to express the intuition for P2b is as follows: Increasing incentive breadth has two effects. The marginal benefits to the employee of one unit of y increase while they decrease for x. The optimal incentive breadth equates the benefit from encouraging collaborative effort with the cost from discouraging production effort. \( \tau \) affects the relative productivity of production effort versus collaborative effort, so that higher values of \( \tau \) generate a higher "cost" of discouraging production effort, which implies a lower optimal incentive breadth. Conversely, higher values of \( \gamma \) increase the marginal benefit of y more (since x is higher than y in equilibrium and therefore \( \gamma x > \gamma y \)), so that optimal incentive breadth increases.

Insert Figure 6 about here

Figure 6 summarizes Propositions 1 and 2 by plotting optimal incentive breadth as a function of the magnitude of the integration effect (\( \gamma \)), for different levels of differentiation (\( \tau \)) and for \( k=1 \) (the figure is qualitatively the same for any value of \( k>0 \)). The optimal incentive breadth (solid line) is zero for small integration effects and then increases gradually up to a value below \( \beta = \frac{1}{2} \) (which would imply equal weight on home and other unit performance, i.e. an organization wide incentive scheme). As can be seen, the threshold level increases and optimal incentive breadth decreases as units become more differentiated. This is counter to the intuition that collaborative incentives enhance outputs in the presence of any gains from managing interdependence – such an intuition is valid only in simple organizations consisting of undifferentiated units (\( \tau = 1/2 \), represented by the dashed line in Figure 5) but not in the complex organizations we encounter in reality.

We describe some implications of our results in two empirical settings: post-merger integration and inter-divisional/departmental relationships. In these settings, the integration effect is often referred to as “synergy”. Synergies refer to potential gains (either through
revenue enhancement or cost reduction) from acknowledging and managing certain kinds of interdependencies, such as the sharing of best practices, knowledge and technology or through the consolidation, customisation or combination of activities (Gupta & Govindarajan, 1986; Markides & Williamson, 1996). We will assume that the level of synergies is exogenous and fixed, though the effects of differentiation may be partly manageable.

Our results suggest that higher degrees of differentiation make collaborative incentives less likely to be effective for any given magnitude of the integration effect. For instance, as a consequence of operating in different regions, subsidiaries within multi-national corporations may become highly differentiated from each other; at the same time, they may continue to share significant upstream portions of their value chains (Ghoshal and Nohria, 1989). Subsidiaries in the same region with substantial overlaps in their value chains are more likely to be linked effectively by collaborative incentives than subsidiaries with comparable degrees of overlap in value chains but located in different regions. Similar reasoning suggests that for comparable synergies, collaborative incentives are more likely to be effective at achieving integration when the acquirer and target firm have similar organizational practices and cultures (Haspeslagh & Jemison, 1991).

All other things being equal, units related horizontally across value chains (eg. R&D departments for product lines 1 and 2) are likely to be less differentiated from each other than units related vertically within the same value chain (eg. the R&D and manufacturing units for the same product line). This is because the tasks undertaken in horizontally related units are more similar than those in vertically related units. Therefore, for comparable magnitude of integration gains, collaborative incentives are more likely to be effective across horizontally related units than vertically related units. Of course, the actual magnitude of integration gains in these two cases may not be similar – vertical relationships may generate larger gains- and the coordination challenges of differentiation may be allayed to the extent that the two units
invest in improving their ability to collaborate, or have a longer history of having learnt to work with each other.

If we assume that some combination of selection pressures and profit seeking weed out at least some sub-optimal incentive structures, then we can also predict how observed structures of collaborative incentives are likely to vary (P2b). In general, the greater the organizational differences between collaborating units, the narrower the incentive structure. Another implication of our results (as shown in Figure 5) is that for individual units within differentiated organizations, optimal incentive breadth will rarely be completely broad. For instance, we would expect that even after acquisition, acquired firms that are operated as subsidiaries have an incentive structure that gives primacy to their own performance, though it might include the performance of other parts (or the whole) of the combined firm.

In situations where the integration and the differentiation effects are both of low magnitude or both of high magnitude (so that it is likely that the integration effect is close to but does not exceed the threshold), setting collaborative incentives may not be sufficient to create value alone. Instead, some combination of differentiation reducing measures and collaborative incentives are more likely to be effective. Prior literature suggests a number of mechanisms that explicitly aim to build common knowledge and shared understanding across units (Lawrence and Lorsch, 1967; Dougherty, 1992) like the rotation of employees between units (Edstrom & Galbraith, 1977), multi-skilling (Shaw, Gupta & Delery, 2001), standardization of language (Kogut and Zander, 1996) and procedures (Mintzberg, 1980) as well as process structures that force interaction across unit boundaries, for example, membership in cross-unit teams (Nadler and Tushman, 1997), or in strategic planning processes (Ketokivi & Castaner, 2004). While our model does not feature any of these mechanisms, our results do suggest that such measures in combination with collaborative incentives are necessary when the differentiation and integration effects are of comparable
magnitudes. Table 1 maps out combinations of $\tau$ and $\gamma$ and implications for collaborative incentive structure from our results.

Insert Table 1 about here

_Uncertainty and Asymmetry in the Integration effect_

So far, we have assumed that the magnitude of the integration effect ($\gamma$) is common knowledge among the managers and the designer. We now consider the case where the organization designer does not know the magnitude of gains from integration with certainty. While such gains are probably never known with great precision, it may sometimes be necessary to set incentive breadth without even knowing if they are above or below threshold levels. This is especially relevant for questions of merger integration, as firms are often acquired with a general notion that some synergies exist, but the exact degree and strength of these synergies is unknown at the time of post-merger integration and the design of incentive breadth (Haspeslagh & Jemison, 1991).

**Proposition 3:** In complex organizations **a)** the threshold level of the integration effect _decreases_ and **b)** the optimal incentive breadth _increases_ with uncertainty about the magnitude of the integration effect.

Production and collaboration effort levels each increase the marginal value of the other because of the gains from integration (A2). As a consequence, total output increases at an increasing rate in the magnitude of interdependence gains – i.e. total output is convex in the gains from integration. Therefore, there is a lot to gain from setting broad incentives when the designer correctly guesses that synergies lie above the threshold, while the loss from setting broad incentives when the designer is mistaken in thinking that the synergies are above the threshold is smaller. In other words, the opportunity costs from an unrealized integration effect are larger than the costs arising from the differentiation effect when broad incentives are used erroneously. Further, the upside potential of the integration effect increases with uncertainty, as
the distribution expands to include higher values of $\gamma$. Therefore, when there is uncertainty about the magnitude of the integration effect, it is preferable to err on the side of optimism (P3a), and use collaborative incentives for lower expected magnitude of the integration effect (P3b).

We note some implications of these results. First, when the magnitude of the integration effect is unknown – for instance in post-merger integration – it is better to begin with broad incentives and revise them downwards if necessary rather than the other way around (P3b). Second, we expect to observe the use of broad incentives even when the expected value of the integration effect is below the threshold that would be applicable in the case of certainty (P3a). As long as there is significant uncertainty about the magnitude of the integration effect, the potential upside from using broad incentives will dominate the potential downside. Thus, even “low synergy” target firms (in terms of their expected value) may face group incentives after acquisition, as long as there is “upside” uncertainty about the true strength of synergies. Finally, we note that uncertainty is a force that counteracts differentiation as it lowers the threshold level of the integration effect. Therefore, the differentiation effect may not discourage the use of collaborative incentives as much in contexts with significant uncertainty about the gains from integration.

Lastly, we allow for asymmetric gains to integration across units, i.e. the gains unit $i$ receives from managing the interdependence with unit $j$ may differ from the gains to unit $j$ when it manages the interdependence with unit $i$. For a given magnitude of the integration effect, the pattern of specialization can also affect whether these gains accrue symmetrically or asymmetrically to collaborating units. For instance, consider the interdependence between the design department and the sales unit for a product. The two units may be interdependent in that the design unit can help coach the sales team on the technical aspects of a product in order to convince potential customers about its value. The gains from managing this form of
interdependence are likely to accrue largely to the sales team in terms of enhanced sales and commissions. However, it is also possible that customer feedback, aggregated and conveyed to the design department by the sales force, can help the design unit develop product extensions or new products (von Hippel, 1994). The benefits from managing this form of interdependence are likely to accrue largely to the design department (particularly if the feedback results in new products rather than product extensions). Situations of asymmetric interdependence may occur not only in vertically adjacent parts of the value chain, as in the example above, but also horizontally, as in multi-business firms when smaller or poorer performing subsidiaries may gain more from collaborating with larger or better performing subsidiaries than the other way around.

While gains from integration may be asymmetric, incentive structure is often kept uniform within organizations to minimize wasteful social comparisons and influence activity (Bradach & Eccles, 1989; Milgrom & Roberts, 1988; Zenger & Hesterly, 1997). We revisit the assumption of symmetric incentives in the discussion section. Here, we investigate the impact of asymmetry in the integration effect on incentive breadth in a uniform incentive scheme. Proposition 4 illustrates how asymmetries influence the basic relationships set out in Propositions 1 and 2.

**Proposition 4:** In complex organizations a) the threshold level of the integration effect decreases and b) the optimal incentive breadth increases with asymmetry in the gains from integration.

For a given average level of the magnitude of the integration effect, asymmetry means that the gains from integration in one unit are below-average, and the other above-average. Since total output is convex in the gains from integration, the positive effect of a high-gain unit dominates the negative effect of a low-gain one. Figure 7 shows how a combination of a high-
gain and a low-gain unit (dotted line) will generate outputs that are higher than the output from an amalgamation of intermediate gain units (solid line).

**Insert Figure 7 about here**

Asymmetry in interdependence gains therefore strengthens the effective integration effect for any level of incentive breadth and average magnitude of gains from integration. This leads directly to \textbf{P4a}: if a given level of (symmetric) integration gains were just at the threshold level, so that optimal collaborative incentives create as much value as completely narrow incentives, asymmetric gains with a \textit{lower} average level of gains from integration could attain the same level of output. A similar intuition holds for \textbf{P4b}: for comparable average levels of gains from integration, the greater the asymmetry, the larger the effective integration effect. In the limit, an organization comprising a single “star” (i.e. high-gain) unit that benefits enormously from “incoming” collaboration and several units that enjoy limited gains from “incoming” collaboration may still optimally have a broad incentive regime.

**DISCUSSION, LIMITATIONS AND CONCLUSION**

Our analysis points to a distinctive constraint on the use of collaborative incentives within complex organizations – the coordination challenges imposed by differentiation. The differentiation effect we model captures the simple organizational reality that inter-unit collaboration efforts are typically less productive than within unit production efforts (Dougherty, 1992; Camerer and Knez, 1996). Differentiation therefore creates a threshold that the integration effect must surpass for collaborative incentives to improve performance above levels achieved by simply ignoring interdependence, and setting unit-level incentives. Uncertainty and asymmetry in the gains from managing interdependence enhance the magnitude of the integration effect for any given average level of such gains, and so makes the threshold easier to achieve. Our results rest on features unique to complex organizations
(interdependence and differentiation) and are distinct from those generated by standard models of the impact of free-riding and risk aversion on incentive structure.

While our analysis focuses on collaborative incentives, we believe there is a general insight here: treating inter-unit collaboration within complex organizations purely as a problem of motivating cooperation (thus ignoring coordination) is dangerous. Collaborative incentives are one specific mechanism that motivates efforts towards collaboration at the expense of production; but given constraints on cognitive and material resources, other mechanisms such as cross-unit teams, standardization, employee rotation, or even creating a “culture of collaboration” may have similar effects. In an insightful piece written for practitioners, Goold and Campbell warn managers in multidivisional firms against “desperately seeking synergy”. They argue that many synergy-seeking initiatives fail because managers do not adequately size up the opportunity by comparing the potential gains from collaborating to achieve synergy against the costs of “not focusing management’s time and efforts elsewhere” (Goold & Campbell, 1998).

**Extensions & Boundary Conditions**

In the interests of clarity and tractability, we have made a number of simplifying assumptions in our model. In this section we extend the features of our basic model and explore the robustness of our core result about the utility of collaborative incentives as an integration mechanism – the existence of a threshold effect in gains from integration that arises from differentiation. We note only the conclusions from this analysis here; complete technical details are available from the authors on request.

**Intrinsic motivation.** In our analysis, we assume away intrinsic motivation and focus only on extrinsic motivation as delivered through the incentive structure. Intrinsic motivation may arise from enjoying the work itself, or from a feeling of satisfaction at having contributed to a collective enterprise (Osterloh & Frey, 2000; Williamson, 1985) or having collaborated with somebody with whom a history of prior relationship is shared. While not all aspects of
intrinsic motivation can be accommodated by our modelling framework, a plausible representation in terms of our model is that the cost of an additional unit of effort is lower in the presence of intrinsic motivation. We model this by the following modified cost of effort function:

$$
\mu_i = \delta x_i^2 + \phi y_i^2
$$

(A3b)

Uniform intrinsic motivation for both kinds of effort would be reflected in \( \phi = \delta < 1 \).

With this modification to our model, we find that uniform intrinsic motivation towards both production and collaboration effort lowers the threshold, but the threshold still exists. The threshold also exists with asymmetric intrinsic motivation (where either production or collaboration is preferred).

An intrinsic preference for production (or dislike of collaborative effort) would imply \( \delta < \phi \), so that production effort is less costly than collaborative effort. On the other hand, if production effort is less enjoyable than collaborative effort, then \( \delta > \phi \). There is an interesting asymmetry between the two cases in terms of their implications. As the intrinsic motivation towards collaborative tasks increases, the threshold always decreases; but as the intrinsic motivation towards production effort increases, the threshold first rises and then decreases, which reflects two counteracting effects. An inherent preference for production effort implies higher production effort in equilibrium, implying a higher opportunity cost of incenting collaboration effort through broad incentives. Conversely, higher production effort also implies that small levels of collaborative effort carry a significant performance increase (through the multiplicative collaboration term). The opportunity cost dominates the potential gains if the difference in intrinsic motivation for production vs. collaboration is not too high, but in the case of strong preference for production effort it is worth encouraging collaboration effort even at lower levels of gains from integration. In all cases, however, the threshold still exists, with intrinsic motivation serving to change the level of the threshold.
Collaboration spillovers. Our model specification decomposes total collaborative activity within the organization into contributions by each of the units \((y_i + y_j)\). Further, we assumed that each unit does not benefit directly from its own collaboration activity (i.e. \(y_i\) does not contribute to the output \(\pi_j\)) to maintain a clear distinction between activities that improve home unit performance – production – and activities that improve the performance of other units – collaborative effort. To allow for increases in home unit output through that unit’s own collaborative effort, we modified A2 as follows:

\[
\pi_i = \alpha x_i + (1 - \tau)y_j + \theta y_i + \gamma y_i y_j + \varepsilon_i
\] (A2a)

The parameter \(\theta\) indicates the extent to which own-unit output increases with that unit’s collaborative effort. We find that with this modified version of our model, a threshold effect still exists. The threshold value is higher however because some of the benefits from collaboration will be generated even if incentives are narrow – the autonomous incentive benchmark is higher and harder to beat through collaborative incentives despite the differentiation effect. Thus, allowing for some spillovers from collaboration to accrue directly to the unit providing collaborative effort raises the threshold in integration gains, but the threshold still exists.

Linked costs of effort The efforts in our model have been assumed to be separable and to “come out of different buckets” – they are unlinked in the sense that the level of one effort has no implications for the marginal costs of the other. This corresponds to an assumption that these activities are resourced from different budgets. As an alternative, we modified A3 to

\[
\mu_i = x_i^2 + y_i^2 + (2 - \rho)x_i y_i
\] (A3a)

This specification covers the case where \(\rho = 0\) so that both types of effort come out of the same “bucket” (e.g. the time of a single individual). Letting the parameter \(\rho\) vary allows for
varying the extent to which the two sorts of effort can be treated as coming from the same source. Our basic model corresponds to a special case of this formulation with $\rho = 2$.

We find that the threshold value of $\gamma$ decreases with $\rho$. Thus, our basic result of a threshold value for $\gamma$ still exists as long as $0 < \rho < 2$. Finally, we find that for $\rho = 0$ (i.e. fully linked efforts), no values of $\gamma, \tau$ can outperform the autonomous level of firm outputs, which arises from our boundary condition that $\gamma < 2$. Thus, allowing for production and collaboration efforts to come from the same source raises the threshold, but a threshold still exists.

Maximizing net payoffs. In our basic setup, we assumed that the designer and the managers maximized their respective payoffs. However, an alternative would be to let the designer care about total profits – the total output less the costs of effort borne by the employees. We therefore set up and solve the model under the assumption that the designer’s problem now is: $\max_{k,\rho} \left( \Pi - \sum H_i \right)$. Note that this is not equivalent to solving for the first best cooperative outcome, because the managers still maximize their own payoffs. It only means that $k = 1$ as the designer is assumed to care only about total profits and not how they are distributed between the managers and the designer, and as the managers are risk neutral the designer plays no role in bearing risk. Even with this model structure, we find a threshold level of $\gamma$ below which collaborative incentives do not improve output. However, the threshold occurs only for high levels of differentiation. In contrast, in the model in which the designer cares about his own profits, a threshold exists for all values of differentiation. This suggests that the threshold effect arises partly from the incentive conflict between the managers and partly from the conflict between the managers and the designer, given the low productivity of their collaborative efforts; by eliminating one source of incentive conflict (i.e. by making the designer care only about total profit) the threshold effect is weakened. Thus, allowing the designer to maximize total profits weakens the threshold effect- but a threshold level of gains from integration still exists for high values of differentiation.
Asymmetric Incentives. For P4, we assumed that the incentive structure was symmetric even when the gains from integration were not, as this captures pressures within organizations for uniformity. (Note that asymmetry in incentives only matters when the gains from integration are asymmetric). In the scenario with asymmetric gains from integration, we explore the existence of a threshold effect when it is possible to set different incentives for the different units. Suppose that \( \gamma_i < \gamma_j \), and each unit has a distinctive threshold \( \gamma_i, \gamma_j \). Then, as long as \( \gamma_i < \gamma_j \) then unit j will have a threshold; i.e. if even one of the units fails to clear its own threshold, the other unit will have a threshold. Thus, a threshold effect will still exist for both units, as long as it binds for one. (If both fail to clear their thresholds, thresholds must exist by definition). However, if it is not binding for either, the existence or behaviour of the threshold is indeterminate in our model; in any case a threshold appears to be of little practical interest in such cases as it does not constrain the use of collaborative incentives in either unit.

Repeated interactions. Another aspect of motivation that we have assumed away is the possibility of repeated interactions generating the “shadow of the future effect”. The cooperative outcome is one in which the managers would act as if they were maximizing total output minus total costs of efforts for a given \( k \), with no role for \( \beta \). Such an outcome could arise with repeated interactions for an infinite (or uncertain) horizon with a sufficiently low discount rate, and is known as the shadow of the future effect (Axelrod, 1984).

The cooperative outcome generated by the shadow of the future would mean that the differentiation effect would vanish, as it arises from \( \beta \) emphasizing collaboration at the expense of production. The organization’s output would then depend only on the magnitude of the integration effect. Put differently, our original model describes situations where the shadow of the future does not operate because of finite time horizons, high discount rates or both. This is therefore a crucial boundary condition for our model.

Limitations
Despite several alternate formulations and the essential robustness of our core results, we realize several limitations to our study. As with all models in the social sciences, we face a trade-off between realism and rigor. Formal mathematical models merely highlight this trade-off more sharply. They accentuate the benefits of clearly stating assumptions, and the value to using solution concepts (like the Nash equilibrium) that can generate non-intuitive insights. Their assumptions also appear more stark and unrealistic. We follow other students of organization who believe that the simplifying assumptions of mathematical models are justified as long as they provide a rigorous basis for improving our understanding of a complex phenomenon, and generate interesting and testable predictions (Lave & March, 1993).

Another limitation of this research is that the analysis is essentially static, in the sense that we do not study how the relationships in the model could evolve over time. However, even though our model only features a single interaction, there are some simple dynamic extensions that can be considered. A history of working together, for instance, could be interpreted in terms of a weakening of the differentiation effect, as coordination between units becomes more effective as they learn to work together (Mayer and Argyres, 2004). Another aspect of learning might be a progressive reduction in uncertainty surrounding the real value of collaboration – in which case our results for uncertainty (see P3) can be extrapolated over time. This would indicate that thresholds rise and optimal incentive breadth narrows over time. Lastly, repeated interactions may also result in an increase in gains from integration – we could think of $\gamma$ increasing over time as collaborators spot new sources of value creation from collaboration.

Yet, there is no doubt that an explicit dynamic formulation would incorporate feedback loops and changes in how the model components interact over time, which our current formulation does not allow. Simulation models of adaptation on rugged landscapes do not suffer these shortcomings, and scholars using such models have begun to investigate the link between incentives and interdependence (Dosi, Levinthal & Marengo, 2003; Rivkin &
Siggelkow, 2003). However, such studies do not focus on the consequences of difficult inter-unit coordination per se but rather on the value of broad incentives in generating feedback on the global performance consequences of local actions. Coordination across units in such models is essentially tacit, as it simply involves taking cognisance of the effects of actions in one unit on the performance of the other. We believe that our analysis provides related but complementary insights about the challenges of managing interdependence when the magnitude of gains from doing so are known, but explicit coordination is difficult to achieve because of differentiation. Dynamic models that focus on the challenges of inter-unit coordination would undoubtedly enhance our insight.

Despite these limitations, we believe that our formalization helps represent the classic organizational tension between differentiation and integration in a rigorous manner to generate novel insights. A key contribution of our paper is to present a simple yet flexible model that can yield a very rich variety of insights (as we have begun to explore in our extensions). Additional areas for research such as modularisation as an alternative to inter-unit collaboration, or the relative advantages of differentiation reducing vs. incentive aligning collaboration strategies also appear feasible with this model platform.

CONCLUSION

As Simon notes, the “means of coordination in organizations, taken in combination with the motivational mechanisms....creates possibilities for enhancing productivity and efficiency through the division of labour and specialization” (Simon, 1991; pg 42). This study reiterates that while the lure of specialization is enhanced competence at performing specialized tasks, specialization also creates both cooperation and coordination problems, and the goal of organization design is to provide solutions to them (March & Simon, 1958). The challenge is to move beyond the simple proposition that both matter, to understanding how coordination considerations shape incentives and vice versa. This paper is a step in this direction. We hope to take many more.
<table>
<thead>
<tr>
<th>Low Gains from Integration (low $\gamma$)</th>
<th>Use collaborative incentives only in combination with other mechanisms to improve coordination</th>
<th>Do not use collaborative incentives</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Gains from Integration (high $\gamma$)</td>
<td>Use collaborative incentives</td>
<td>Use collaborative incentives only in combination with other mechanisms to improve coordination</td>
</tr>
</tbody>
</table>

Table 1: Magnitude of Integration and Differentiation Effects & Implications for Collaborative Incentive Structure.

Figure 1: Production and Collaboration for Unit $i$
Figure 2: The Integration Effect
Figure 3: The Differentiation Effect

Figure 4: Free-riding without gains from integration or differentiation
Figure 5: Integration thresholds, incentive depth and differentiation

Figure 6: Collaborative Incentives and Integration thresholds in Complex Organizations (k=1)
Figure 7: Convexity of Total Outputs in Integration gains
References


Appendix: Proofs for Propositions 1-4.

We first state several model properties that we use in the proofs of proposition 1-4:

§1: The equilibrium production and collaborative efforts by the managers are

\[ x_i^* = \frac{(k - \beta)(22 + \beta \gamma (1 - \tau))}{4 - k \beta \gamma^2 + \beta^2 \gamma^2}, \quad y_i^* = \frac{\beta(\gamma (k - \beta)\gamma + 2(1 - \tau))}{4 - k \beta \gamma^2 + \beta^2 \gamma^2}. \]

§2: For \( \beta = 0 \), the autonomous incentive level of outputs is \( \Pi^A = k \tau^2 \)

§3: For \( \beta = 0 \), \( \frac{\partial x_i}{\partial \beta} < 0, \quad \frac{\partial y_i}{\partial \beta} > 0 \). Refer to FOC for production and collaboration efforts respectively:

\[ (k - \beta)(r + \gamma y_j) - 2x_i = 0 \quad \text{and} \quad \beta((1 - \tau) + \gamma x_j) - 2y_i = 0 \]

§4: At \( \beta^* \), \( \partial \Pi/\partial x_i = \partial \Pi/\partial y_i \) (the equal compensation principle, Milgrom and Roberts, 1992, p. 228). Consider the case if this were not true. In this case, encouraging the activity with the higher marginal contribution by changing \( \beta \) would increase output (§3), so that the original value of \( \beta \) could not have been optimal. The optimal incentive breadth will therefore be the value of \( \beta \) at which no change can improve output, i.e. \( \partial \Pi/\partial x_i = \partial \Pi/\partial y_i \).

§5: \( \partial \beta^* / \partial \gamma > 0 \), i.e. higher gains from integration imply higher optimal incentive breadth. To see why, recall that at \( \beta^* \), \( \partial \Pi/\partial x_i = \partial \Pi/\partial y_i \) (§4). Substituting equilibrium effort levels (§1) into output, we get:

\[
\frac{\partial \Pi}{\partial x_i} = \tau + \gamma \left( \frac{\beta (k - \beta) \gamma + 2(1 - \tau)}{4 - k \beta \gamma^2 + \beta^2 \gamma^2} \right)
\]

\[
\frac{\partial \Pi}{\partial y_i} = (1 - \tau) + \gamma \left( \frac{(k - \beta)(22 + \beta \gamma (1 - \tau))}{4 - k \beta \gamma^2 + \beta^2 \gamma^2} \right).
\]

Both \( \partial \Pi/\partial x_i \partial \gamma > 0 \) and \( \partial \Pi/\partial y_i \partial \gamma > 0 \), but for any \( \tau > 1/2 \), \( \partial \Pi/\partial x_i \partial \gamma > \partial \Pi/\partial y_i \partial \gamma \). To maintain equilibrium, an increase in \( \gamma \) must be countered by an increase in \( \beta^* \) (§3).

§6: Total output is convex in gains from integration (\( \partial^2 \Pi/\partial^2 \gamma > 0 \)) for any given level of differentiation. Twice differentiating equilibrium production and collaboration effort levels from §1

\[
\frac{\partial x_i^*}{\partial^2 \gamma} = \frac{2\beta(k - \beta)^2(\beta \gamma (\gamma (\beta - k)(\beta \gamma (\tau - 1) + 6) - 12(\tau - 1))) + 8r}{(4 + \beta \gamma^2 (\beta - k))^3} > 0
\]

\[
\frac{\partial y_i^*}{\partial^2 \gamma} = \frac{-(2\beta\gamma (\beta - k)(8 - 8\tau + \gamma (\beta - k)(-12 \tau + \beta \gamma (-6 + (6 + \beta \gamma - \gamma k) r)))}{(4 + \beta \gamma^2 (\beta - k))^3} > 0
\]

for all permissible values of \( k, \tau, \beta, \gamma \) (recall that we limit \( \gamma \in [0,2], \beta \in [0,1/2], \tau \in [1/2,1] \) and \( k \in [0,1] \)).

\[
\therefore \frac{\partial (\gamma x_i^* y_j^*)}{\partial^2 \gamma} > 0 \quad \text{(by product rule)}
\]

Since unit outputs are a summation of production and collaboration effort as well as the multiplicative term above \( (\pi_i = \pi x_i + (1 - \tau) y_j + \gamma x_i y_j + \varepsilon_i) \) outputs are convex in gains from integration \( (\partial^2 \Pi/\partial^2 \gamma > 0) \).
Proof of Proposition 1:
Rather than calculate $k^*, \beta^*$ directly (which are not tractable expressions), we instead prove P1 by showing that whereas a designer will always set $k^* > 0$ (because there are no fixed costs of effort, and setting positive $k$ will always elicit effort and generate positive output), he will set $\beta^* > 0$ only if the magnitude of interdependence gains is above a certain threshold.

We proceed in three steps. a) First we show that $\frac{\partial \Pi}{\partial \beta} \bigg|_{\beta \to 0} > 0$ iff $\gamma \gamma$ (threshold effect). b) Next we verify that if $\frac{\partial \Pi}{\partial \beta} \bigg|_{\beta \to 0} < 0$, $\frac{\partial \Pi}{\partial \beta} < 0$ for all $\beta$ (no value of collaborative incentives are useful if $\gamma < \gamma$). c) Finally we show that $\beta^* < k / 2$ (internal solution).

a) Substitute the equilibrium values of $x^*_i$ and $y^*_j$ (§1) into output functions, we get
\[
\Pi = \frac{2(8k \tau^2 + 8\beta + 12k\beta \tau \gamma + 2k\beta^3 \gamma^3 + 12\beta^2 \tau^2 \gamma + \beta^4 \tau^2 \gamma^3 + k^2 \beta^2 \tau^2 \gamma^3)}{\left(4 + \beta^2 \gamma^2 - k\beta \gamma^2\right)^2}
- \frac{2(16\beta \tau + 12\beta^2 \tau \gamma + \beta^4 \tau \gamma^3 + k^2 \beta^2 \tau \gamma^3 + 2k\beta^3 \tau \gamma^3 + 12k\beta \tau \gamma)}{\left(4 + \beta^2 \gamma^2 - k\beta \gamma^2\right)^2}
\]
\[
\frac{\partial \Pi}{\partial \beta} = \left(\frac{8}{\left(4 + \beta^2 \gamma^2 - k\beta \gamma^2\right)^2}\right)\left(8 - 16\tau + 2k\beta \gamma^2 + 2\beta^3 \tau \gamma^3 - 3k\beta^2 \tau \gamma^3 + k^2 \beta^2 \tau \gamma^3 + 12\beta \tau \gamma^2 - 4k \tau \beta \gamma^2 - 2\beta^2 \tau \gamma^3 + 3k\beta^2 \tau \gamma^3 - k^2 \beta^2 \tau \gamma^3 - 2\beta - 12k\tau \gamma^2 + 24\beta \tau \gamma^2 - 8k \tau ^2 \beta \gamma^2 + 4k^2 \gamma^2 \tau^2 + 12k \gamma \tau^2 - 24k \gamma \tau - 6 \beta^2 \gamma^2\right)
\]
\[
\left(1.1\right)
\]

The first term is positive, so to determine whether the expression is positive as $\beta \to 0$ (i.e. whether output increases with broadening incentives), we need to determine the sign of the second term as $\beta \to 0$. The limit is:
\[
\frac{\partial \Pi}{\partial \beta} \bigg|_{\beta \to 0} = \left(\frac{1}{8}\right)\left(8 - 16\tau + 4k^2 \gamma^2 \tau^2 + 12k \gamma \tau^2 - 12k \gamma \tau^2\right)
\]
\[
\left(1.2\right)
\]

We can see that for low values of $\gamma$, the constant negative term $\left(8 - 16\tau\right)$ dominates. For higher $\gamma$, the expression becomes positive. The threshold value of $\gamma$ is
\[
\gamma = \frac{1}{\lambda} \left(\frac{3}{2} - \frac{3}{2\tau} + \sqrt{\frac{1 - 2\tau + 9\tau^2}{2\tau}}\right).
\]

Therefore, in complex organizations ($\tau > \frac{1}{2}$), there is always a threshold effect in the gains from integration ($\gamma > \gamma$), for any positive incentive depth ($k > 0$).

b) $\frac{\partial \Pi}{\partial \beta} \bigg|_{\beta \to 0} < 0$ implies that at $\beta = 0$ encouraging collaborative effort decreases output, and therefore
\[
\frac{\partial \Pi}{\partial x_i} \bigg|_{\beta \to 0} > \frac{\partial \Pi}{\partial y_j} \bigg|_{\beta \to 0} \left(3,4\right). \text{ Note that } \frac{\partial \Pi}{\partial x_i} \frac{\partial x_i}{\partial \beta} > 0 \text{ because } \frac{\partial \Pi}{\partial x_i} \frac{\partial x_i}{\partial \gamma} > 0 \left(A2\right) \text{ and } \frac{\partial x_i}{\partial \beta} > 0 \left(3\right), \text{ and } \frac{\partial \Pi}{\partial y_j} \frac{\partial y_j}{\partial \beta} < 0 \text{ because } \frac{\partial \Pi}{\partial y_j} \frac{\partial y_j}{\partial \gamma} > 0 \left(A2\right) \text{ and } \frac{\partial x_i}{\partial \beta} < 0 \left(3\right). \text{ Therefore if } \frac{\partial \Pi}{\partial x_i} > \frac{\partial \Pi}{\partial y_j} \text{ at } \beta = 0, \text{ this will apply for all values of } \beta. \text{ This also implies that if there is an optimal value of } \beta^* > 0, \text{ there will only}
be a single one as these effects are monotonic in $\beta$, i.e. there will only be one point at which $\frac{\partial \Pi}{\partial x_i} = \frac{\partial \Pi}{\partial y_j}$.

c) We evaluate the output function’s derivative with respect to $\beta$ \(1.2\) at $\beta = k / 2$. This is, after some simplification:

$$\frac{\partial \Pi}{\partial \beta} \bigg|_{\beta \to k/2} = \left(1 - \frac{\gamma^2k^2}{4 - 4\left(\frac{1}{2} - k^2\gamma^2\right)}\right)
(1.4)$$

Thus, in complex organizations, optimal incentive breadth is always less than completely broad. ■

**Proof of Proposition 2a:** From the Proof of Proposition 1 we know that the minimum level of interdependence gains for broad incentives to increase firm outputs is

$$\gamma = \left(1 - \frac{3}{k} \left(\frac{1}{2} - \frac{\sqrt{1-2\tau + 9\tau^2}}{2\tau} + \frac{\gamma}{2}\right)\right).$$

The derivative $\frac{\partial \gamma}{\partial \tau} = \frac{3\sqrt{1-2\tau + 9\tau^2} - (1-\tau)}{2\tau \sqrt{1-2\tau + 9\tau^2}} > 0$, so that the threshold level of interdependence gains ($\gamma$) increases in the extent of differentiation ($\tau$). ■

**Proof of Proposition 2b:** The marginal contribution to firm output by $x_i$ and $y_i$ can be written as $\partial \Pi/\partial x_i = \tau + \gamma y_j$, and $\partial \Pi/\partial y_i = (1 - \tau) + \gamma x_j$. Substituting equilibrium values $x_i^*$ and $y_i^*$ (§1) for $y_j$ and $x_j$ respectively:

$$\frac{\partial \Pi}{\partial x_i} = \tau + \gamma \left(\frac{\beta (\gamma (k - \beta) \tau + 2(1 - \tau))}{4 - k\beta \gamma^2 + \beta^2 \gamma^2}\right)$$

$$\frac{\partial \Pi}{\partial y_i} = (1 - \tau) + \gamma \left(\frac{(k - \beta)(2\tau + \beta \gamma (1 - \tau))}{4 - k\beta \gamma^2 + \beta^2 \gamma^2}\right)$$

The derivatives with respect to $\tau$ are:

$$\frac{\partial \Pi}{\partial x_i, \partial \tau} = 1 - \beta (\gamma \left(\frac{2 - (k - \beta)\gamma}{4 - k\beta \gamma^2 + \beta^2 \gamma^2}\right)) > 0$$

$$\frac{\partial \Pi}{\partial y_i, \partial \tau} = \left(1 - (k - \beta)\gamma \left(\frac{2 - \beta \gamma}{4 - k\beta \gamma^2 + \beta^2 \gamma^2}\right)\right) < 0$$

From the proof of P1 we know that $\frac{\partial \Pi}{\partial x_i, \partial \beta} > 0$ because $\frac{\partial \Pi}{\partial x_i, \partial y_j} > 0$ (A2) and $\frac{\partial y_j}{\partial \beta} > 0$ (§3), and $\frac{\partial \Pi}{\partial y_i, \partial \beta} < 0$ because $\frac{\partial \Pi}{\partial y_i, \partial y_j} > 0$ (A2) and $\frac{\partial x_j}{\partial \beta} < 0$ (§3). To balance the marginal contributions to output of production and collaboration efforts, the value of $\beta^*$ at which the effects are equal must be lower for higher values of $\tau$, i.e. higher differentiation. Thus, the optimal incentive breadth ($\beta^*$) decreases in the extent of differentiation ($\tau$). ■

**Proof of P3a:** We know from model property §6 that total output is convex in gains from integration. Now suppose $\gamma$ is distributed uniformly with an upper and lower bound, i.e. $\gamma \in [\gamma^-, \gamma^+]$, with the
expected value being $\tilde{\gamma} = \frac{\gamma^- + \gamma^+}{2}$. Invoking §6, a bigger (mean-preserving) spread will increase output as the expected gain from high-$\gamma$ cases dominates the expected loss from low-$\gamma$ cases. Therefore, for higher spread ($\gamma^+ - \gamma^-$), which corresponds to higher uncertainty about $\gamma$, the threshold in synergies $\tilde{\gamma}$ decreases.

**Proof of P3b:** Define an “implicit $\gamma$” (denoted $\gamma^\pm$) such that we obtain:

$$\Pi^*(\gamma^\pm) = E(\Pi^*(\gamma)), \gamma \in [\gamma^-, \gamma^+]$$

That is, the output generated by this value of $\gamma$ in a certain world exactly equals the expected output in an uncertain world when expected synergy is $\tilde{\gamma}$. Since uncertainty increases expected total output (P3a), $\gamma^+ > \tilde{\gamma}$. Since $\partial \beta^*/\partial \gamma > 0$ (§5) and $\gamma^\pm > \tilde{\gamma}$, it thus follows that $\beta^*(\gamma^\pm) > \beta^*(\tilde{\gamma})$. Thus, if collaborative incentives are used, optimal incentive breadth increases in the extent of uncertainty about gains from integration.

**Proof of P4a:** Recall that total output is convex in $\gamma$ (§6). Therefore, adding $\delta/2 > 0$ to one unit’s gains while subtracting $\delta/2$ from the other’s increases overall output. Suppose now that a symmetric firm ($\delta = 0$) has $\Pi_N^* = \Pi_A$, i.e. outputs in the broad and narrow incentives regimes are identical. Increasing $\delta$ will increase output so that $\Pi_N^*(\beta^*, \gamma, \delta > 0) > \Pi_A$. By continuity, the value of $\gamma$ fulfilling $\Pi_N^*(\beta^*, \tilde{\gamma}, \delta > 0) = \Pi_A$ is $\tilde{\gamma} < \gamma$. Therefore, the average threshold level of the integration effect for which it is effective to use collaborative incentives decreases in the extent of asymmetry in gains from integration across units.

**Proof of P4b:** Suppose that $\beta^* > 0$. We construct an “implicit $\gamma^\pm$, $\gamma^\delta$, which is the equivalent of the level of symmetric $\gamma$ that generates the same total firm value as the two asymmetric units:

$$\Pi_N^*(\beta^*, \tilde{\gamma}, \delta > 0) = \Pi_N^*(\beta^*, \gamma^\delta, \delta = 0)$$

From P4a we know that firm value increases in $\delta$, which implies that $\gamma^\delta > \tilde{\gamma}$, i.e. the implicit level of interdependence gains is higher than the average value of asymmetric gains from integration. Since $\partial \beta^*/\partial \gamma > 0$ (§5) and $\gamma^\delta > \tilde{\gamma}$, $\beta^*(\gamma^\delta) > \beta^*(\tilde{\gamma})$. Thus, if collaborative incentives are used, optimal incentive breadth increases in the extent of asymmetry of integration gains.

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i This is also known as the “1/n” effect in the literature, where n is the group size, and the relationship between individual effort and group outcome varies as a function of 1/n.

ii We will write $j \neq i$ to denote actions and payoffs of the “other” unit.

iii This simplifying assumption is in line with prior literature that has treated firms in inter-organizational relationships such as alliances and networks as unitary actors.

iv This is not essential to our results; see the proof for P1 in the technical appendix.

v In a separate analysis (available upon request) we show that including noise and risk aversion in our model would simply affect the reservation utilities of the managers and therefore affect $k$, but not our qualitative conclusions about the value of $\beta$ relative to $\alpha$.

vi Alternatively, one could interpret these conclusions as being purely normative.

vii Note that a weakly positive relationship between uncertainty and upside potential remains even if output is not always convex in the magnitude of the integration effect, as long as it is increasing in the magnitude of the integration effect.