Designing Managerial Incentives in Competitive Markets*

Juan Sebastián Ivars†

Abstract

This paper investigates how market competition shapes the design and provision of incentive contracts for managers. We study a moral hazard setting where two principals each employ a risk neutral agent (manager). Each agent makes a decision on effort leading stochastically to an outcome. These outcomes are observable for each principal and used to design incentives based on their joint realizations. We isolate the effect of market competition in two channels: *market information* and *market structure*. First, market information captures the correlation between the outcomes generated by the agents. Second, market structure indicates the profits that each principal obtains from a given realization of agents' outcomes. As a result, the incentive schemes that are optimal from an informational perspective need not be used in equilibrium when competition reduces the returns to effort. This framework provides a unified explanation for variation in incentive design across competitive environments and clarifies how competition affects managerial discipline through the profitability of incentive provision rather than through the design of performance measures.

Keywords: Moral Hazard, Principal-Agent, Competition, Managerial Incentives.
JEL Classification: D21, D43, D86, M12, L13, J33.

*I am fully indebted to Jeanne Hagenbach and Pierre Fleckinger for their guidance and support. I am particularly grateful to Malin Arve, Joaquín Coleff, Walter Cont, David Martimort and Franz Ostrizek for their invaluable comments. Additionally, this work has benefitted from the exchanges with Daniel Barreto, Catherine Bobtcheff, Henrique Castro-Pires, Guillermo Caruana, Michele Fioretti, Cassandre Lebot, Gerard Llobet, Markus Reisinger, Fausto Spiga, Nikhil Vellodi and Nikiforos Zampetakis. The main result of this paper was previously in a working paper called *Optimal Incentives for Competing Organizations*. All remaining errors are my own. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n°850996 – MOREV).

†Department of Applied Economics, University of Balearic Islands. Email: juan-sebastian.ivars@uib.cat

I Introduction

How does market competition shape the design and provision of optimal incentive contracts for managers? This paper addresses this question by studying a setting in which firms reward their managers based not only on individual performance but also on how their performance compares to that of competitors. The empirical relevance of such cross-firm comparisons is well established: performance pay is widespread, and a significant share of it is explicitly linked to relative or market-based performance metrics (Bloom and Van Reenen, 2007; Vrettos, 2013; Feichter et al., 2022; Bao et al., 2023; Bloomfield et al., 2023b,a; Bloomfield, 2024). Yet the theoretical literature has produced ambiguous predictions about how market competition influences managers' incentives.

This paper contributes to this question by separating two effects often conflated in the literature: *market information* across firms and *market structures.* Contrary to the well-established literature on managerial compensation under market competition, we show that the qualitative form of compensation schemes depends only on market information. Market structure affects whether the optimal compensation schemes that minimize the costs of effort implementation are profitably implementable.

We study a moral hazard model with two risk-neutral principals who each hire a risk neutral agent (manager).[1] Each agent makes a binary effort choice, either shirk or work, that is stochastically related to a binary individual outcome, success or failure. Once realized, each agent's outcome of effort becomes public information for both principals. We assume that agents incur a private cost of effort, are protected by limited liability, and that their efforts are neither observable nor contractible. Crucially, the two effort outcomes may be correlated, reflecting exogenous informational spillovers of the market - what we call *market correlation.* Principals offer incentive contracts contingent on the joint outcomes of the two agents, but without observing the contract offered by the other firm.

We study three generic market structures that can be linked to standard competition models: *winners-take-all*, *strategic substitutes*, and *strategic complements.* A winners-take-all market can be represented by a contest in which only the firm whose agent outperforms the other earns profits. A strategic substitutes market is one where asymmetric outcomes generate higher joint profits than symmetric ones.[2] By contrast, a strategic complements market is less competitive, with higher profits in symmetric outcomes (both success or both failure) than in asymmetric ones.[3]

Our contribution is twofold. First, we characterize the optimal incentive scheme as a function of the sign of the market correlation, following Fleckinger et al. (2024). This result offers a simple mapping from information structure to contract form, echoing Holmström's (1979) *sufficient statistics principle* in a multi-principal context. *Lemma 2* shows this trichotomy: (i) a positive

[1]We use 'agent' as the formal term in the model and proofs and 'manager' when we refer to the real-world or empirical interpretations; the two terms denote the same economic actor.

[2]This class of market structure includes standard competition models such as Cournot, Bertrand, and Hotelling. Strategic substitutes in this setting refers to agents' outcomes rather than firms' reaction functions, making our results comparable to Antón et al. (2023). Further examples appear in the appendix.

[3]These markets capture settings with complementary goods or capacity constraints.

market correlation leads to Relative Performance Evaluation (RPE), rewarding agents for outperforming their rivals; (ii) a negative market correlation leads to Joint Performance Evaluation (JPE), rewarding agents when both firms' agents succeed; and (iii) a zero market correlation leads to Independent Performance Evaluation (IPE), where agents are rewarded solely on their own performance. Second, *Proposition 1* shows when the principal benefits by inducing the agent to exert an effort. The cost of the incentive schemes depend on both market correlation and the productivity of the agent hired by the rival principal so then we analyze these interacts with the underlying market structure.[4]

To study the impact of competition on optimal incentive schemes, *Proposition 2* derives sharp comparative statics on principals' costs and profits (within a given market structure) of effort implementation. First, a higher absolute value of informational correlation increases the informativeness of success and therefore decreases the cost of inducing effort. This makes optimal schemes cheaper to implement, independently of market structure. Second, higher rival agent's productivity facilitates RPE — since it increases the informativeness of outperformance — but makes JPE harder to implement because joint success becomes less informative and less profitable.

We also examine the comparative statics of principals' profits and find strong interdependence between rival agent's productivity and market structure. In this sense, our paper is closely related to Vives (2008). In winners-take-all or strategic substitutes markets, higher rival productivity reduces the revenues available to a principal. Under these conditions, RPE schemes are the easiest to implement. By contrast, in strategic complements markets, higher rival productivity improves the sustainability of JPE schemes by increasing the profitability of joint success. This provides an alternative way of softening competition by conditioning effort incentives on joint success, as in Aggarwal and Samwick (2002). These comparative statics clarify when high-powered relative schemes are viable and when firms instead adopt flatter, joint-based incentives. Our analysis also identifies two sufficient statistics linking competition and incentive design, with potential empirical counterparts.

Our analysis sheds light on why incentive design varies across industries. It explains why RPE schemes dominate in highly competitive or adversarial environments, while JPE emerges in settings with strategic complementarities. In doing so, it bridges contract theory and industrial organization, offering a unified framework to interpret conflicting empirical findings on competition and performance pay.

Related Literature

Our paper contributes to the well-established literature on managerial incentives under market competition. While this well-established literature provides ambiguous results, our paper unifies its main contributions. The main theoretical literature (Hart, 1983; Scharfstein, 1988; Hermalin, 1992; Salas Fumas, 1992; Martin, 1993; Hermalin, 1994) has considered principal–agent organizations in which agents exert costly effort to improve the profitability of firms that were competing

[4] Our framework recovers classic results on competition and incentives , without assuming zero correlation or observability of rival contracts.

under given market structures—either *Cournot* or *Bertrand*. By contrast, Aggarwal and Samwick (2002) study pricing or output as stochastically inferred actions. In that way, it shows that market structure is relevant for managerial incentives and, in particular, that the optimal incentive schemes yield JPE under *Bertrand* competition and RPE under *Cournot* competition. In our framework, effort is a prior action that shapes these quantity or price decisions. We show that, in this case, what matters is not whether these actions—prices or quantities—are strategic substitutes or complements, but whether the market equilibria are strategic substitutes or complements with respect to the outcomes of effort.[5]

More recently, Schmidt (1997) revisits this problem but accounts for different market structures in reduced form, as we do in this paper. Likewise, Raith (2003) who studies a similar problem in a Salop framework. Both papers, like the previous ones, do not separate the effects of *market information* and *market structure*.[6] Our paper differs from Schmidt (1997) by not requiring any form of liquidation to study the pass-through from market structure to optimal incentives. In fact, the threat of liquidation serves as an incentive device for the manager in this paper. Contrary to Schmidt's paper, in our model the optimal incentive is independent of market structure and fully characterized by the correlation between agents' efforts; the market structure only determines its sustainability. This crucial difference leads to sharp departures from the previous results. By doing so, we separate the effect of market competition into two components: (i) the effect of information on the cost of incentives, and (ii) the effect of effort provision on profit generation within a given market structure. Our results can be easily illustrated with standard models such as *Cournot*, *Bertrand*, and *Hotelling*, as well as some particular variants.

Our paper is closely related to Vives (2008), which studies how market structure affects firms' innovation and strategy choices.[7] Using a different approach, that paper studies the effect of market structure on two strategic actions taken by firms. Our setting differs in two ways: (i) we focus on effort provision within an agency relationship rather than on two conflicting actions taken by firms; and (ii) we model market structure in reduced form and consider complementarities or substitutabilities in agents' outcomes rather than in principals' strategic choices.

Our framework also provides a sharp perspective on the classic *quiet life* intuition. In our model, the form of incentive provision—whether based on relative or joint performance—is entirely determined by the informational environment and is independent of market conditions. However, market structure governs the returns to inducing effort, and therefore whether firms choose to implement these incentive schemes. As a result, competition affects managerial discipline not by changing how incentives are designed, but by affecting whether it is profitable to induce effort at all. This distinction clarifies that the "quiet life" mechanism operates through the

[5]More recently Güth et al. (2015) have studied worker compensation and competition intensity. In their case, they restrict the analysis to both fixed industry and incentive schemes. They find that more competition induces better compensation schemes and more effort provision. Differently, our model generalizes the market structure and the information generated by it so we can study the optimal incentive schemes under different conditions.

[6]Having an explicit model of market competition has the advantage of providing sharp comparative statics of how market-structure parameters affect optimal incentives. However, this explicit characterization comes at the expense of mixing the informational effect on incentive costs with the strategic effect of effort within a given market structure.

[7]Also related to our paper is Spulber (2013) which shows that competition induces innovation when there is a market for inventions and these inventions are appropriable in a market with downward sloping reaction functions.

profitability margin rather than through the informational content of performance measures.[8]

Finally, we build on rank-based and relative incentive schemes (Green and Stokey, 1983; Nalebuff and Stiglitz, 1983; Lazear and Rosen, 1981; Celentani and Loveira, 2006), as well as on extensions to multi-agent contexts using sufficient-statistics methods (Holmstrom, 1982; Mookherjee, 1984; Innes, 1990; Itoh, 1991; Che and Yoo, 2001; Fleckinger, 2012).[9] See Fleckinger et al. (2024) for a survey. Unlike them, we adapt the tools used to analyze single-principal, multi-agent settings to an environment with multiple principals and agents. Our analysis offers an alternative explanation for the empirical puzzle in RPE use (Aggarwal and Samwick, 1999; Bloomfield, 2024). RPE may be underused because it is too costly to implement, or because alternative schemes (JPE, IPE) help soften competition and increase profits in some markets.

II Model

In this section, we present the model. First, we outline the environment. Second, we describe the information structure linking agents' efforts to outcomes and highlight the role of market correlation, which we refer to as the *market information*. Next, we specify the timing, agents' preferences, and the incentive schemes. Finally, we present principals' preferences, their contracting problem, and we define the different *market structures* to be studied.

Environment

We consider a situation where each risk neutral-principal, indexed by $i \in \{1, 2\}$, hires an agent (a manager). Each agent working for principal i is protected by limited liability. After an agent makes an effort decision, he obtains an outcome in his project, denoted by $R_i \in \{S, F\}$, where S represents "Success" and F "Failure". Each agent, working for principal i, privately chooses to either exert effort ($e_i = 1$) or to shirk ($e_i = 0$) and incurs a cost $c(e_i) = ce_i$, where $c > 0$. Effort is not observable, but the outcomes are observable and verifiable by the principal.

Market Information: links between agent's efforts and outcomes

We now describe the relationship between agents' efforts and outcomes. Efforts and outcomes are stochastically related by a conditional probability distribution $P(R_i|e_i, e_{-i})$. First, we assume that the outcome of agent i depends only on the effort of agent i, indicating technological independence between agents' effort working for different principals.[10]

Assumption 1 (A1). *Technological independence:* $P(R_i|e_i, e_{-i}) = P(R_i|e_i) \in (0, 1)$.

We denote the likelihood that agent i succeeds when making effort decision e_i as $p_{e_i} = P(R_i = S|e_i)$. Then, $p_1 = P(R_i = S|e_i = 1)$ and $p_0 = P(R_i = S|e_i = 0)$. The difference between the likelihood of a successful outcome when an agent exerts effort and shirks is denoted $\Delta p := p_1 - p_0$.

[8]'The best of all monopoly profits is a quiet life', (Hicks, 1935).

[9]In a different setting, Admati and Pfleiderer (1997) studies the use of benchmarking and rank-based tools in optimal portfolio choice.

[10]This means there are no productive externalities from one agent's effort to another one, such as help, synergies, sabotage, etc.

Second, we assume that an agent's success is more likely when the agent exerts effort rather than shirks.

Assumption 2 (A2). $p_1 > p_0$.

Third, we assume that agents' outcomes are informationally correlated, and we denote this correlation by γ.[11] This means that each principal can make inferences about agent i's effort by observing agent $-i$'s outcome. We assume that γ is effort-independent and has an absolute value small enough to ensure that no probability exceeds one.[12] We adapt Fleckinger (2012), also used in Fleckinger et al. (2024), to allow for this type of correlation in the stochastic structure. Denote by $R := (R_i, R_{-i})$ the pair of outcomes for agents i and $-i$, and by $\mathbf{e} := (e_i, e_{-i})$ the pair of efforts.

Assumption 3 (A3). *Market correlation. There exists a γ independent from e_i, e_{-i} such that:*

$$P(R|\mathbf{e}) = \begin{cases} P(R_i|e_i)P(R_{-i}|e_{-i}) + \gamma & \text{if } R_i = R_{-i} \\ P(R_i|e_i)P(R_{-i}|e_{-i}) - \gamma & \text{if } R_i \neq R_{-i} \end{cases} \tag{1}$$

(A3) restricts the joint distribution of outcomes by introducing correlation across agents' signals while preserving the marginal distributions specified in *(A1)*. A positive γ implies a higher likelihood for a principal to observe two identical agents' outcomes—either $(R_i, R_{-i}) = (S, S)$ or (F, F). Conversely, a negative γ implies a higher likelihood of observing (S, F) or (F, S). A γ of zero implies that the outcomes of both agents are independent and exhibit no informational externalities. Market correlation represents non-productive information linking agents' outcomes. This can be understood as any shock transmitted through the market—such as macroeconomic conditions or exogenous technological changes.

The choice of a γ market correlation independent is a simplifying assumption, that renounces to generality. Fleckinger (2012) shows that effort-dependent informational correlation provides a richer setting with more nuanced results.[13] However, for tractability and clarity of exposition, we consider this more restrictive scenario, which is sufficient to characterize the main effects of market competition on incentives.

Timing, Agents' Preferences and Incentive Schemes

We introduce the timing, the incentive scheme used by the principal, and agents' preferences. The timing is as follows. At date 0, each principal offers an incentive scheme to his agent; at date 1, agents simultaneously choose their effort levels; and at date 2, outcomes are realized.

Each agent's ex-post utility depends on the actual wage and the effort exerted:

$$u_i(w, e_i) = w - c(e_i) \tag{2}$$

[11] In the literature informational correlation can also be found as statistical correlation. These correlations are used to shape incentives in several economic applications, e.g. tournaments, benchmarking in regulation, etc.

[12] To be more precise this means that $|\gamma| < \min\{P(R_i|e_i)P(R_{-i}|e_{-i})\}, \forall (R_i, R_{-i})$ and (e_i, e_{-i}).

[13] In particular, there is less frequent use of monotone incentive schemes like Joint Performance Evaluation or Relative Performance Evaluation and more pronounced use of Mixed Incentive Schemes that mix increasing and decreasing rewards on the rival agent outcome.

where w is the wage obtained for a given joint realization of the agents' outcomes. The ex-ante utility of the agent is the expected ex-post utility conditioned on agents' efforts:

$$U_i(w|\mathbf{e}) = \mathbb{E}_{\mathbf{R}}(w_{\mathbf{R}}|\mathbf{e}) - c(e_i) \tag{3}$$

We consider contingent contracts on the set of information available to the principal. The information set is $\mathbf{R}$, which contains every realization R, and the incentive scheme is the collection $\mathcal{W} := \{w_{SS}, w_{FS}, w_{SF}, w_{FF}\}$. We use the standard definition from Che and Yoo (2001) to characterize the incentive scheme.

Definition 1. ***(Che and Yoo, 2001)*** *An incentive scheme,* $\mathbf{w}$*, for the agent working for principal* i *exhibits:*

- ***Relative Performance Evaluation (RPE)*** *when:* $(w_{SF}, w_{FF}) > (w_{SS}, w_{FS})$
- ***Joint Performance Evaluation (JPE)*** *when:* $(w_{SS}, w_{FS}) > (w_{SF}, w_{FF})$
- ***Independent Performance Evaluation (IPE)****:* $(w_{SS}, w_{FS}) = (w_{SF}, w_{FF})$

In an RPE incentive scheme, the principal offers to an agent i a decreasing incentive scheme on agent's $-i$ outcome regardless of the performance of agent i, as shown by $w_{SF} > w_{SS}$ and $w_{FF} > w_{FS}$. The opposite holds in a JPE scheme which implies that the principal offers to agent i an increasing incentive scheme on agent's $-i$ outcome, regardless the performance of agent i, as seen $w_{SS} > w_{SF}$ and $w_{FS} > w_{FF}$. Thus, an RPE scheme creates competition among agents, while a JPE scheme creates cooperation. The main difference from Che and Yoo (2001) is that, in this paper, each agent works for a different principal. Thus, the comparison pertains to the other firm's performance (i.e., the rival agent's outcome).

Principals' Contracting Problem and Market Structures

Each principal aims to maximize profits by incentivizing agents' efforts at minimum cost. Following Grossman and Hart (1983), we split the principals' problem into two parts. First, each principal looks for the optimal incentives that implements effort, assuming that agents' effort is desirable for the principal. Second, each principal checks whether it is cost-effective to induce effort implementation under the optimal incentives.

Denote by $\mathbf{1} := (1, 1)$ the pair of efforts equal to one. In the first step, the optimal contract offered by principal i that implements effort is:

$$\min_{w_R \in \mathcal{W}} \ \mathbb{E}_{\mathbf{R}}[w_{\mathbf{R}}|\mathbf{1}] \tag{4}$$

$$(LL): \quad w_R \geq 0, \forall R \in \mathbf{R} \tag{5}$$

$$(IC): \quad U_i(w|\mathbf{1}) \geq U_i(w|0, 1). \tag{6}$$

where limited liability rules out the possibility of negative transfers, and incentive compatibility requires that agent i prefers to exert effort, given agent $-i$'s effort. We use a discrete version of the *sufficient statistic theorem* by Holmström (1979) that pins down the main result for the contracting problem:

Definition 2. ***(Fleckinger, 2012)*** *For any realization of the informational set* $\mathbf{R}$*, its* ***effort informativeness*** *is:*

$$H(R) \equiv \frac{Prob(R|\mathbf{1})}{Prob(R|0,1)}, \tag{7}$$

and the ***incentive efficiency*** *of* w_R *is:*

$$I(R) \equiv 1 - \frac{1}{H(R)} = \frac{Prob(R|\mathbf{1}) - Prob(R|0,1)}{Prob(R|\mathbf{1})} \tag{8}$$

Incentive efficiency represents the ratio between marginal incentive gains and marginal incentive costs, and it is useful for characterizing the optimal incentive scheme.[14]

In the second step, the principal needs to decide whether to induce effort encouragement or not. Since the effort decision is binary, the *first-best* and *second-best* efforts are identical when implemented, $e^{FB} = e^{SB} = 1$. Given that implementing the *second-best* effort is more costly than the *first-best* one, the principal may decide not to induce effort exertion under some circumstances. A principal decides to induce an agent to exert effort if and only if doing so is preferable for the principal to not inducing it. This condition is stated in the following way:

$$\Delta V_i = V_i(\mathbf{R}|1, e_{-i}) - V_i(\mathbf{R}|0, e_{-i}) \geq 0 \tag{9}$$

where V_i denotes the profit function of principal i.

$$V_i(\mathbf{R}|\mathbf{e}) = \sum_{R \in \mathbf{R}} Prob(R|\mathbf{e})\Pi_i(R) - \mathbb{1}\mathbb{E}_{\mathbf{R}}(w^*_{\mathbf{R}}|\mathbf{e}) \tag{10}$$

where $\mathbb{E}_{\mathbf{R}}(w^*_{\mathbf{R}}|\mathbf{e})$ is the expected wage of the optimal contract, characterized by equations (4), (5) and (6), that implements effort; and $\mathbb{1}$ is an indicator function that takes the value 1 if the agent has been offered a positive contract, and 0 otherwise. A principal does not pay a positive wage for an agent whose effort is not required. We denote $\Pi(R)$ as the total equilibrium profit in the market for a given $R \in \mathbf{R}$. Additionally, we denote $\Pi_i(R)$ as the profits received by firm i for each realization $R \in \mathbf{R}$.[15] We define the following types of market structures:

Assumption 4 (A4). *We consider three market structures:*

- ***Winners-take-all:*** $\Pi_i(S, F) > 0$ $\Pi_i(\mathbf{R}') = 0$*, where* $\mathbf{R}' := \{R \ |R \neq (S, F)\}$*,*
- ***Strategic Substitutes:*** $\Pi_i(S, F) > \Pi_i(S, S) > \Pi_i(F, F) > \Pi_i(F, S)$*, and* $\Pi_i(S, F) + \Pi_i(F, S) > \Pi_i(S, S) + \Pi_i(F, F)$

[14] We restrict attention to deterministic contracts. This is without loss of generality because, given linearity (and concavity in risk-averse extension) of the agent's utility and linearity of transfers in the principal's objective, any randomized payment scheme is irrelevant (or can be replaced by its certainty equivalent) to relax the incentive (and/or individual rationality) constraint.

[15] In our framework, competition takes place in reduced form. Once efforts are realized and outcomes obtained, the market structure determines a profit $\Pi(R)$ for every state R.

- ***Strategic Complements:*** $\Pi_i(S,F) > \Pi_i(S,S) > \Pi_i(F,F) > \Pi_i(F,S)$, *and* $\Pi_i(S,F) + \Pi_i(F,S) < \Pi_i(S,S) + \Pi_i(F,F)$.

We assume that an agent's successful effort reduces the marginal cost of the firm, while failure results in no change. A *winners-take-all* market structure represents a contest environment, where high payoffs accrue only to the top performer. A *strategic substitutes* market structure rewards the better-performing firm more, but both can still earn positive profits when performance is symmetric. In a *strategic complements* market structure, each firm earns more when agents' performances are symmetric, since mutual failure softens market competition.[16]

III Results

This section outlines our results. First, we derive the optimal contract that implements effort. Second, we analyze principals' decisions to induce agents' effort. Finally, we study the effect of competition on optimal incentives by conducting a comparative statics analysis. All omitted proofs are provided in the *appendix*.

Optimal Contract Form in Competitive Markets

Every contract in an incentive scheme is ranked by its incentive efficiency. The optimal contract that implements effort at minimum cost is the one with the highest incentive efficiency.

Lemma 1. *The only positive contract is the one with the highest incentive efficiency.*

With positive contract we refer to the only strictly positive non-trivial wage. The identical trivial wage, is the one equal to zero. Using the previous lemma, we compare the incentive efficiency across outcomes and obtain the optimal incentive scheme in the following lemma.

Lemma 2. *Let (A1)-(A3) be satisfied. Any optimal incentive scheme that induce* $e_i = 1$ *offered by principal i pays a strictly positive wage in exactly one outcome and exactly zero in all the others. The positive wage is fully characterized by the market correlation,* γ*, as follows:*

$$w_R^* = \begin{cases} w_{SS} = \frac{c}{\Delta p \; p_{e_{-i}}}, & \text{if } \gamma < 0, \\ w_{SF} = \frac{c}{\Delta p \; (1-p_{e_{-i}})}, & \text{if } \gamma > 0, \\ w_{SS} = w_{SF} = \frac{c}{\Delta p}, & \text{if } \gamma = 0. \end{cases}$$

In the proof, we show that $\gamma < 0$ implies that $P(R \mid \mathbf{e})$ is log-supermodular in the pair (R_{-i}, e_i), meaning that efforts are strategic complements and the optimal incentives are JPE. The opposite holds when $\gamma > 0$: efforts are strategic substitutes, $P(R \mid \mathbf{e})$ is log-submodular, and the optimal incentive scheme is RPE. Finally, when $\gamma = 0$ the optimal incentive scheme is IPE.

[16] In the appendix, we show standard examples that are related to the market structures defined above. Specific examples (Cournot, Bertrand, Hotelling) are not our focus. In fact, they illustrate that our reduced-form characterization of market structure captures the essential strategic properties across a wide range of canonical models.

Thus, the sign of the market correlation determines strategic complementarity or substitutability, and this interaction pins down the optimal contract regardless of the market structure.[17]

Effort Inducement under Different Market Structures

A principal decides to induce an agent to exert effort if and only if doing so is preferred to leave him shirking, as stated in equation (9). Denote the revenues of principal i obtained by inducing effort implementation by $G := \Delta p \left[p_{e_{-i}}(\Pi_i(SS) - \Pi_i(FS)) + (1 - p_{e_{-i}})(\Pi_i(SF) - \Pi_i(FF))\right]$. The next proposition highlights this result.

Proposition 1. *Let assumptions (A1)-(A3) be satisfied. The optimal incentive scheme is bounded as follows:*

$$\frac{c}{P(R|\mathbf{1}) - P(R|0,1)} \leq w_R^* \leq \frac{G}{P(R|\mathbf{1})}. \tag{11}$$

Where, $w_R^* > 0$ *and* $\forall w \in \mathcal{W} \setminus w_R^* :\ w = 0.$

Proposition 1 highlights the bounds within which an optimal incentive scheme can be implemented. The lower bound represents the minimum compensation the agent is entitled to receive, as computed in *Lemma 2*. The upper bound captures the maximum profits a principal can obtain in a given market structure by inducing effort implementation.

The concentration of pay on a single outcome state reflects the standard combination of risk neutrality and limited liability. However, the characterization of the optimal contract as a function of the market correlation does not rely on this bang-bang solution. When agents are risk-averse, payments are optimally distributed across states, but correlation continues to affect the relative weights placed on different outcomes. In other words, optimal payments are ranked according to their incentive efficiency. The third subsection in section IV shows this explicitly.

Comparative Statics

In this section, we study how changes in market competition affect agents' incentives (e.g.: managerial incentives) under different market structures. We define market competition through two elements that shape the informational linkage between agents' effort choices: (i) the correlation between agents' outcomes, denoted by γ, and (ii) the productivity of the agent, $p_{e_{-i}}$.

To capture the effect of intensified competition, we focus on changes in the rival agent's productivity $p_{e_{-i}}$. In our reduced-form market representation, a higher $p_{e_{-i}}$ corresponds to a more capable rival agent, which increases competitive pressure. Formally, this parameter affects both the *market informativeness* and the market interaction (through revenues G). Thus, comparative statics in $p_{e_{-i}}$ offer a tractable way to study how stronger competition modifies incentive costs and sustainability.

Denote by $\epsilon := \frac{\frac{\partial G}{\partial p_{e_{-i}}}}{\frac{c}{I(R')}}$ the ratio of marginal revenue changes to the cost of inducing effort that we refer to as the revenue effect of inducing effort, and by $\nu := \frac{d \ln I(R')}{dp_{e_{-i}}}$ the elasticity of

[17] To be more precise, we should state that $P(\mathbf{R}|\mathbf{e})$ is log-super(sub)modular in the pair (R_{-i}, e_i), for every R_i and $e_{-i} = 1$.

information to effort, where $R' := \max_R I(R)$. The revenue effect of inducing effort, ϵ, is the key parameter that shows the interaction between market structure and agents' effort. The elasticity of information to effort, ν, captures the percentage change in cost of effort provision for an optimal incentive scheme, regardless the market structure. Note that ϵ is non-positive in *winners-take-all* or *strategic substitutes* markets, and non-negative in *strategic complements* markets. Additionally, ν is non-negative for (S, F) and non-positive for (S, S). The next proposition states the effect of market competition on agents' incentives for a principal inducing effort.

Proposition 2. *Let (A1)-(A4) be fulfilled.*

1. ***Market informativeness:*** $\frac{\partial \Delta V}{\partial |\gamma|} > 0$.

2. ***Market Interaction:*** *fix the optimal incentive scheme and consider an increase in* $p_{e_{-i}}$.

   - *Under JPE,* $\frac{\partial \Delta V}{\partial p_{e_{-i}}} < 0$ *in all markets except strategic complements when* $\epsilon > -\nu$.
   - *Under RPE,* $\frac{\partial \Delta V}{\partial p_{e_{-i}}} > 0$ *in strategic complements markets, and in strategic substitutes and winner-take-all markets if and only if* $\epsilon > -\nu$.

The first point is intuitive: higher absolute value of the correlation increases the informativeness of the performance outcome of the rival agent, decreasing the cost of incentivizing effort. Since effort provision becomes less costly, higher absolute value of the market correlation increases effort inducement by the principal. Note that this effect is purely informational, since it does not affect either the stochastic relationship between effort and outcome for both principals nor the benefits that a principal can extract from the market by inducing effort.

The second point lies at the heart of this paper, as it captures how informational interdependencies (via $p_{e_{-i}}$) interact with market structure. Recall that JPE and RPE correspond to the incentive schemes $\{w^*_{SS}, 0, 0, 0\}$ and $\{0, w^*_{SF}, 0, 0\}$, respectively, where w^*_{SS} and w^*_{SF} are positive.

In *winners-take-all* and *strategic substitutes* markets, increasing the rival agent's productivity reduces the sustainability of w^*_{SS} for two reasons. First, it reduces expected revenue, since principal i benefits more when the rival agent fails. Second, it lowers the efficiency of incentives under w^*_{SS} by decreasing the informativeness of outcomes. Note that an increase in $p_{e_{-i}}$ implies a relative reduction of γ in the joint probability of success, this reduction implies that the rival's outcome becomes less informative about agent i's performance. Conversely, the use of w^*_{SF} becomes more attractive if and only if the revenue loss (measured by ϵ) is smaller than the gain in incentive efficiency (measured by $-\nu$). While an increase in $p_{e_{-i}}$ improves the incentive efficiency of w^*_{SF} and increases its sustainability, its ultimate optimality depends on the sign of γ.

In *strategic complements* markets, an increase in rival productivity improves the sustainability of w^*_{SF} and may decrease that of w^*_{SS}, depending on the elasticities. The former effect happens because both the revenue and incentive efficiency under w^*_{SF} improve. Revenue improves as the likelihood of observing $\Pi_i(SF) - \Pi_i(FF)$ declines and the chance of $\Pi_i(SS) - \Pi_i(FS)$ rises, which in turn implies $\Pi_i(S, F) + \Pi_i(F, S) < \Pi_i(S, S) + \Pi_i(F, F)$. The incentive efficiency channel mirrors the one described above. Meanwhile, w^*_{SS} is implemented if and only if the revenue gains offset the higher cost of effort implementation.

Finally, in the special case where $\gamma = 0$, the optimal contract becomes insensitive to changes in $p_{e_{-i}}$, since there is no signal correlation. However, firm revenues still depend on $p_{e_{-i}}$: in strategic complements, higher rival productivity increases profits, while in strategic substitutes or winners-take-all markets, it decreases them. Hence, strategic complements markets allow for potentially higher-powered incentives even when incentive schemes are informationally unaffected.

Empirical interpretation. The previous results highlight a key distinction between the determinants of optimal incentive design and its empirical implementation. While the correlation parameter γ characterizes the optimal contract structure (relative versus joint performance evaluation), its empirical relevance depends on whether such contracts can be sustained in equilibrium. In contrast, the sufficient statistics ϵ and ν directly govern the implementability of incentive schemes. The term ϵ captures how rival productivity affects firm profitability, while ν measures how it affects the informativeness of performance signals. Together, they determine whether an increase in competition strengthens or weakens the sustainability of a given incentive scheme. This distinction has important empirical implications. Observed compensation structures need not reflect the contract that would be optimal based on informational considerations alone, but rather the subset of contracts that remain profitably implementable given the competitive environment. In this sense, the sign of $\epsilon + \nu$ summarizes the direction in which competition shifts the set of implementable incentive schemes. In practice, ϵ may be proxied by the industry-level sensitivity of firm profits to competitors' performance, while ν can be related to changes in the informativeness of relative outcomes for incentive provision. We leave such empirical exploration to future work.

IV Discussion

Extensions to Market competition

Note that the measures of market competition in this paper are simplified. The main characteristics of competition are captured by the functions $\Pi(\cdot)$ and the productivity parameter $p_{e_{-i}}$. Although this simplification might be seen as a limitation, this model can account for several features that affect market competition without significant changes. Examples include barriers to entry, product differentiation, or fixed costs, which could be easily incorporated into a less reduced-form characterization of $\Pi_i(\cdot)$. Finally, the number of firms can be accounted for by assuming that each principal compares his own agent with the most efficient rival agent working for another principal, together with an appropriate adaptation of $\Pi_i(\cdot)$. This implies that $p_{e_{-i}} = \max p_{e_j}$ for all $j \neq i$, where $i = 1, 2, \ldots, n$. In other words, an increase in the number of firms intensifies market competition and has effects equivalent to an increase in the productivity of a rival agent, along with a decrease in $\Pi_i(\cdot)$ for every firm.

Internal Organization and Multi-agent Firms

Other important extension involves the analysis of multi-agent organizations. Recent empirical papers, such as Gong et al. (2011); Vrettos (2013); Feichter et al. (2022); Antón et al. (2023) and Giebel and Rösner (2026), study how market competition affects internal comparisons of agents' outcomes within an organization. Although this is an important aspect to consider, the extension is beyond the scope of this paper. However, some insights on this topic are analyzed in a paper by Ivars (2024).

Risk Aversion and Incentive Design

A relevant extension arises when considering risk-averse agents. In this case, the principal's trade-off shifts toward balancing risk insurance and effort provision. The purpose of this extension is to examine how agents' risk attitudes affect the results previously derived. To that end, we modify equation (2) to $u_i(w, e) = v(w) - ce_i$, with $v' > 0$ and $v'' < 0$. Similarly, equation (3) becomes $U_i(w|\mathbf{e}) = \mathbb{E}_R[v(w_R)|\mathbf{e}] - ce_i$, and the limited-liability constraint in (5) is replaced by an individual-rationality constraint:

$$(IR): \quad \mathbb{E}_R(v(w_R)|\mathbf{e}) - ce_i \geq 0. \tag{12}$$

The solution to the maximization program in (4), subject to (12) and (6) is summarized in the following proposition.

Proposition 3*. Let (A1)-(A4) be fulfilled and consider the maximization program defined by* (4)*, subject to* (12) *and* (6)*. The optimal incentive schemes has the following properties:*

1. *Each joint realization of the outcomes receives a positive payment:* $w_R^* = v'^{-1}\left(\frac{c}{1+\mu\ IE(R)}\right)$,
2. *The ordering of the payments is ranked according to their incentive efficiency,*
3. *The sign of* γ *fully characterizes the optimal use of JPE, RPE and IPE,*
4. *The optimal incentive scheme,* $\mathbb{E}(w_R^*)$*, is bounded upwards by* G*.*

Note that under risk aversion, leaves *Lemma 1* qualitatively unchanged. In other words, point 2 of the previous proposition implies that contracts are ranked according to their incentive efficiency, the main difference is that every outcome receives a positive non-trivial wage. This modification in the contracts alters *Lemma 2* and *Proposition 1*, by increasing the cost of incentivizing effort, but does not affect the optimal qualitative choice of JPE, RPE and IPE in the optimal incentive schemes, as pointed out in point 3 of the previous proposition. Furthermore, the last point of the previous proposition gives the same upper bound as in *Proposition 1*. Thus, *Lemma 2* is not driven by the bang-bang nature of the contract.

This modeling choice is useful to assess how restrictive the effects of risk aversion are across different market structures. The drawback is that it comes at the expense of losing a simple closed-form solution, although the other comparative statics—on rival productivity and informational correlation—remain qualitatively unchanged. As is straightforward to infer, an increase in risk aversion (i.e., in the curvature of agents' preferences) raises the cost of providing incentives, but does not affect either the revenues earned by the principals or the information they can extract. The effect is purely to increase the cost of implementing effort.

Empirical Relevance of the Results

Our paper helps organize the findings of several empirical studies. To do so, we use the two sufficient statistics derived from *Proposition 2* and the predictions from *Lemma 2.* Recall that ϵ captures how rival productivity affects firm profitability, while ν captures how it affects the informativeness of performance signals. Finally, γ characterizes the optimal contract structure, conditional on implementability. Our framework suggests that observed compensation schemes reflect not only informational considerations (γ), but also the subset of contracts that remain profitably implementable given the competitive environment (ϵ and ν).

Aggarwal and Samwick (2002); Gong et al. (2011); Vrettos (2013); Feichter et al. (2022) analyze the use of RPE. Aggarwal and Samwick (2002) show that JPE is more commonly used in Bertrand competition, whereas their theory predicts that such environments should encourage RPE; however, they do not find empirical support for this prediction. Gong et al. (2011) finds that the use of RPE is relatively small, with only about 25% of firms in their sample including it in their incentive plans. Vrettos (2013) finds that RPE across peers is less frequently used in strategic substitutes and more frequently used in strategic complements.[18] More specifically, they find that compensation tied to relative firm performance increases with the intensity of industry competition, which is consistent with the comparative statics of *Proposition 2.* Finally, Feichter et al. (2022) document a strong relationship between RPE and more competitive behavior in the product market, which is also consistent with *Proposition 2.* These findings are consistent with environments in which the revenue effect dominates the information effect ($\epsilon > -\nu$), making high-powered incentive schemes profitably implementable. In such cases, the choice between RPE and JPE depends primarily on informational considerations captured by γ.

One element that has been largely absent in the theoretical literature on managerial compensation and competition is the role of cartels. When cartels arise, competition decreases without necessarily changing its nature. In our model, this can be captured through the reduced-form representation of market structure. In other words, this can be interpreted as a case where ν remains relatively unchanged, while ϵ increases. An increase in effort now translates into higher market stakes. Bloomfield et al. (2023a) show that RPE schemes are generally underused and that their use is positively correlated with cartelized industries and with firms participating in cartels. They argue that this correlation is driven by costly sabotage.[19] This result is somewhat surprising, as prior theory suggests that RPE intensifies competition, implying that cartels should discourage its use. Consistent with this view, Antón et al. (2023) show that common ownership reduces pay–performance sensitivity in managerial compensation as a way of softening competition.

In contrast, Karpoff (2023) argue that, although the empirical correlation between RPE and cartels is robust, costly sabotage is unlikely to be the main explanation. They raise two main concerns. First, costly sabotage may harm the firm more than its rivals in this setting, making it an unattractive strategy. Second, if cartels are relatively stable over time, RPE contracts should

[18]Bloomfield et al. (2023a) cast doubt on the empirical identification strategies in these papers; we abstract from this discussion.

[19]In their framework, costly sabotage refers to aggressive strategies (e.g., underpricing) that harm the firm's own profits but may harm rivals even more, creating incentives for such behavior. Cartels can act as a mechanism to limit these strategies. However, when cartels are not profitably implementable or are detected, firms may avoid offering such incentive schemes.

undermine cartel stability. These findings are therefore puzzling. Moreover, Ha et al. (2024) document the opposite pattern, showing that JPE contracts are more prevalent in collusive markets. They argue that compensation schemes can be used to facilitate collusion. This mechanism can be captured in our model, in which compensation schemes are chosen prior to product market competition and can therefore act as a commitment device.[20,21]

V Conclusion

How does market competition shape the design and provision of manager incentives? This paper offers a unified answer to that question.

First, the sign of market correlation—non-productive information that links agents' outcomes—determines which incentive scheme minimizes the cost of inducing effort. Second, market structure—the way firms compete and the profits they can earn—determines which of these optimal schemes are actually profitably implementable. In doing so, the paper reconciles the ambiguous predictions of a well-established theoretical literature. It also provides guidance for empirical work by disentangling two distinct channels through which competition affects incentives: an informational one and a structural one.

References

Admati, A. R. and Pfleiderer, P. (1997). Does it all add up? benchmarks and the compensation of active portfolio managers. *The Journal of Business*, 70(3):323–350.

Aggarwal, R. K. and Samwick, A. A. (1999). The other side of the trade-off: The impact of risk on executive compensation. *Journal of political economy*, 107(1):65–105.

Aggarwal, R. K. and Samwick, A. A. (2002). Executive compensation, strategic competition, and relative performance evaluation: Theory and evidence. *The Journal of Finance*, 54(6):1999–2043.

Antón, M., Ederer, F., Giné, M., and Schmalz, M. (2023). Common ownership, competition, and top management incentives. *Journal of Political Economy*, 131(5):1294–1355.

Bao, R., De Loecker, J., and Eeckhout, J. (2023). Manager pay inequality and market power. Technical report, NBER.

Bloom, N. and Van Reenen, J. (2007). Measuring and explaining management practices across firms and countries. *The Quarterly Journal of Economics*, 122(4):1351–1408.

Bloomfield, M. J. (2024). Performance pay plans, power and product prices. *Power and Product Prices (March 25, 2024).*

[20]They study a policy change by the U.S. Department of Justice that reduced monitoring capacity in some regions, increasing the likelihood of collusion.

[21]In a related contribution, Giebel and Rösner (2026) show that long-term, profit-based compensation is associated with collusion, suggesting that JPE schemes may soften competition.

Bloomfield, M. J., Heinle, M. S., and Timmermans, O. (2023a). Relative performance evaluation and strategic peer-harming disclosures. *Available at SSRN 3936860.*

Bloomfield, M. J., Marvao, C., and Spagnolo, G. (2023b). Relative performance evaluation, sabotage and collusion. *Journal of Accounting and Economics*, page 101608.

Celentani, M. and Loveira, R. (2006). A simple explanation of the relative performance evaluation puzzle. *Review of Economic Dynamics*, 9(3):525–540.

Che, Y.-K. and Yoo, S.-W. (2001). Optimal incentives for teams. *American Economic Review*, 91(3):525–541.

Feichter, C., Moers, F., and Timmermans, O. (2022). Relative performance evaluation and competitive aggressiveness. *Journal of Accounting Research*, 60(5):1859–1913.

Fleckinger, P. (2012). Correlation and relative performance evaluation. *Journal of Economic Theory*, 147(1):93–117.

Fleckinger, P., Martimort, D., and Roux, N. (2024). Should they compete or should they cooperate? the view of agency theory. *Journal of Economic Literature*, 62(4):1589–1646.

Giebel, M. and Rösner, A. (2026). Do managerial incentives facilitate anti-competitive behavior? evidence from collusion. *SSRN.*

Gong, G., Li, L. Y., and Shin, J. Y. (2011). Relative Performance Evaluation and Related Peer Groups in Executive Compensation Contracts. *The Accounting Review*, 86(3):1007–1043.

Green, J. R. and Stokey, N. L. (1983). A comparison of tournaments and contracts. *Journal of Political Economy*, 91(3):349–364.

Grossman, S. J. and Hart, O. D. (1983). Implicit contracts under asymmetric information. *The Quarterly Journal of Economics*, pages 123–156.

Güth, W., Pull, K., and Stadler, M. (2015). Delegation, worker compensation, and strategic competition. *Journal of Business Economics*, 85(1):1–13.

Ha, S., Ma, F., and Žaldokas, A. (2024). Motivating collusion. *Journal of Financial Economics*, 154:103798.

Hart, O. D. (1983). The market mechanism as an incentive scheme. *The Bell Journal of Economics*, pages 366–382.

Hermalin, B. E. (1992). The effects of competition on executive behavior. *The RAND Journal of Economics*, pages 350–365.

Hermalin, B. E. (1994). Heterogeneity in organizational form: Why otherwise identical firms choose different incentives for their managers. *The RAND Journal of Economics*, pages 518–537.

Hicks, J. R. (1935). Annual survey of economic theory: the theory of monopoly. *Econometrica: Journal of the Econometric Society*, pages 1–20.

Holmström, B. (1979). Moral hazard and observability. *The Bell Journal of Economics*, pages 74–91.

Holmstrom, B. (1982). Moral hazard in teams. *The Bell journal of economics*, pages 324–340.

Innes, R. D. (1990). Limited liability and incentive contracting with ex-ante action choices. *Journal of economic theory*, 52(1):45–67.

Itoh, H. (1991). Incentives to help in multi-agent situations. *Econometrica*, 59(3):611–636.

Ivars, J. S. (2024). Optimal incentives in competing organizations. Technical report.

Karpoff, J. M. (2023). Unlikely sabotage: Comment on bloomfield, marvão, and spagnolo. *Journal of Accounting and Economics*, 76(2-3):101606.

Laffont, J.-J. and Martimort, D. (2002). *The theory of incentives: the principal-agent model.* Princeton university press.

Lazear, E. P. and Rosen, S. (1981). Rank-order tournaments as optimum labor contracts. *Journal of Political Economy*, 89(5):841–864.

Martin, S. (1993). Endogenous firm efficiency in a cournot principal-agent model. *Journal of Economic Theory*, 59(2):445–450.

Mookherjee, D. (1984). Optimal incentive schemes with many agents. *The Review of Economic Studies*, 51(3):433–446.

Nalebuff, B. J. and Stiglitz, J. E. (1983). Prizes and incentives: towards a general theory of compensation and competition. *The Bell Journal of Economics*, pages 21–43.

Raith, M. (2003). Competition, risk, and managerial incentives. *American Economic Review*, 93(4):1425–1436.

Salas Fumas, V. (1992). Relative performance evaluation of management: The effects on industrial competition and risk sharing. *International Journal of Industrial Organization*, 10(3):473–489.

Scharfstein, D. (1988). Product-market competition and managerial slack. *The RAND Journal of Economics*, pages 147–155.

Schmidt, K. M. (1997). Managerial incentives and product market competition. *The Review of Economic Studies*, 64(2):191–213.

Spulber, D. F. (2013). How do competitive pressures affect incentives to innovate when there is a market for inventions? *Journal of Political Economy*, 121(6):1007–1054.

Vives, X. (2008). Innovation and competitive pressure. *The Journal of Industrial Economics*, 56(3):419–469.

Vrettos, D. (2013). Are Relative Performance Measures in CEO Incentive Contracts Used for Risk Reduction and/or for Strategic Interaction? *The Accounting Review*, 88(6):2179–2212.

Appendix

Proof of Lemma 1

We follow the proof in Fleckinger et al. (2024). Each first-order condition (FOC) for the program summarized by equations (4), (5), and (6) is:

$$1 = \frac{1}{Prob(R|\mathbf{1})}\big[\lambda_R + \mu\big(Prob(R|\mathbf{1}) - Prob(R|0,1)\big)\big] \tag{13}$$

In equation (13), each λ_R is the Lagrange multiplier for the limited-liability constraint, and μ is the Lagrange multiplier for the incentive-compatibility constraint. Note that the FOC implies that contracts increase with their incentive efficiency. If $w_R > 0$, then $\lambda_R = 0$ and $I(R) = \frac{1}{\mu}$. Conversely, if a contract is zero, $w_{R'} = 0$, then $\lambda_{R'} > 0$ and $I(R') = \frac{1}{\mu}\left(1 - \frac{\lambda_{R'}}{Prob(R'|\mathbf{1})}\right) < \frac{1}{\mu} = I(R)$. Therefore, the only positive contract is the one with the highest incentive efficiency. Multiplicity arises only when more than one contract has the same incentive efficiency. □

Proof of Lemma 2

Comparing the incentive efficiency (or, more directly, the effort informativeness) across joint outcome realizations, we obtain the optimal incentive scheme. Because the principal faces a limited-liability constraint, she cannot penalize agents for shirking. Instead, she sets wages to zero whenever a 'Failure' outcome occurs; hence $w_{FS} = w_{FF} = 0$. Thus, the decision depends on comparing $H(S,S)$ and $H(S,F)$, given that $H(S,S) > H(S,F)$ if and only if $-\gamma(p_1 - p_0) > 0$. The optimal contracts are obtained directly from the incentive-compatibility constraint, noting that the limited-liability constraint binds for every contract other than the one with the highest incentive efficiency. This completes the proof of *Lemma 2*.

Proof of Proposition 1

The result follows directly from equation (9) and *Lemma 2*.

Proof of Proposition 2

Consider equation (9), G it is not affected by γ. Then we can take the optimal contracts, w^*_{SS} and w^*_{SF}. We know that the former one is implemented in equilibrium only when $\gamma < 0$ and the latter one when $\gamma > 0$. Let's consider the partial derivatives of these two optimal compensation schemes with respect to γ.

$$\frac{\partial w^*_{SS}}{\partial \gamma} = \frac{c}{\Delta p \ p_{e_{-i}}} > 0, \tag{14}$$

$$\frac{\partial w^*_{SF}}{\partial \gamma} = -\frac{c}{\Delta p \ (1-p_{e_{-i}})} < 0. \tag{15}$$

Note that (14) shows that the incentive scheme increases with an increase of γ, but in equilibrium w^*_{SS} is only chosen when $\gamma < 0$. This means, that increasing γ in this context implies decreasing $|\gamma|$. Thus, $\frac{\partial w^*_{SS}}{\partial|\gamma|} < 0$. The opposite happens for (15) which decreases with an increase in γ and in equilibrium is only chosen for $\gamma > 0$. This means that $\frac{\partial w^*_{SF}}{\partial|\gamma|} < 0$. Finally, this means that $\frac{\partial V}{\partial|\gamma|} = -\frac{\partial w^*_R}{\partial|\gamma|} > 0$.

For points 2 and 3 in the proposition, we can rewrite equation (9) it as follows:

$$\Delta V_i = G - \frac{c}{I(R')}, \text{ where } R' \text{ is such that } I(R') := \max_R\{I(R)\} \tag{16}$$

Note that:

$$\frac{\partial I(S,S)}{\partial p_{e_{-i}}} = \frac{\Delta p \ \gamma}{\left(p_1 p_{e_{-i}}+\gamma\right)^2} < 0, \tag{17}$$

$$\frac{\partial I(S,F)}{\partial p_{e_{-i}}} = \frac{\Delta p \ \gamma}{\left(p_1(1-p_{e_{-i}})-\gamma\right)^2} > 0. \tag{18}$$

Recall that optimally w^*_{SS} is implemented under $\gamma < 0$ and w^*_{SF} under $\gamma > 0$. Additionally, note that:

$$\begin{aligned} \frac{\partial G}{\partial p_{e_{-i}}} &= -\Delta p \Pi_i(S,F) < 0, \text{in a \textit{winners-take-all} market} \\ \frac{\partial G}{\partial p_{e_{-i}}} &= \Delta p\big(\Pi_i(S,S) + \Pi_i(F,F) - \Pi_i(F,S) - \Pi_i(S,F)\big) < 0, \text{in a \textit{strategic substitutes} market,} \\ \frac{\partial G}{\partial p_{e_{-i}}} &= \Delta p\big(\Pi_i(S,S) + \Pi_i(F,F) - \Pi_i(F,S) - \Pi_i(S,F)\big) > 0, \text{in a \textit{strategic complements} market} \end{aligned} \tag{19}$$

Using these results, we take the derivative of (16) with respect to $p_{e_{-i}}$:

$$\frac{\partial \Delta V_i}{\partial p_{e_{-i}}} = \frac{\partial G}{\partial p_{e_{-i}}} + c\frac{1}{I(R')^2}\frac{\partial I(R')}{\partial p_{e_{-i}}}. \tag{20}$$

This is equivalent to:

$$\frac{\partial \Delta V_i}{\partial p_{e_{-i}}} = \frac{\partial G}{\partial p_{e_{-i}}} + c\frac{1}{I(R')}\nu. \tag{21}$$

Therefore, an increase in market competition raises the sustainability of effort through a particular optimal incentive scheme if and only if:

$$\frac{\partial \Delta V_i}{\partial p_{e_{-i}}} > 0 \Longleftrightarrow \frac{\partial G}{\partial p_{e_{-i}}} + c\frac{1}{I(R')}\nu > 0 \Longleftrightarrow \epsilon > -\nu. \tag{22}$$

Recall that $\epsilon = \frac{\frac{\partial G}{\partial p_{e_{-i}}}}{\frac{c}{I(R')}}$ and $\nu = \frac{\frac{\partial I(R')}{\partial p_{e_{-i}}}}{I(R')}$. In *winners-take-all* and *strategic substitutes* markets, w_{SS^*} always reduces the region of implementation as $p_{e_{-i}}$ increases, since $\epsilon < 0$ and $-\nu > 0$. However, w^*_{SF} becomes more profitably implementable whenever $-\epsilon < \nu$, meaning that the ratio of revenue losses to the actual cost of effort implementation is lower than the percentage decrease in that cost. In other words, this reflects the elasticity of information with respect to an increase in the rival agent's productivity.

In *strategic-complements* markets, w^*_{SF} always expands the region of implementation as $p_{e_{-i}}$ increases, since $\epsilon > 0$ and $-\nu < 0$. However, w^*_{SS} becomes more profitably implementable whenever $\epsilon > -\nu$, meaning that the ratio of revenue gains to the actual cost of effort implementation is lower than the percentage increase in that cost. In other words, this corresponds to the negative of the elasticity of information with respect to an increase in the rival agent's productivity. □

Proof of Proposition 3

In this subsection, we restate the results for optimal incentives under risk aversion to show that the main qualitative insights remain unchanged. To ensure the concavity of the program, we apply a standard change of variables following Laffont and Martimort (2002), defining $v_R = v(w_R)$ for all R, with $w_R = h(v_R)$ and $h(\cdot) = v^{-1}(\cdot)$ convex and increasing. We then consider the maximization with respect to v_R.

$$\frac{\partial \mathcal{L}}{\partial v_{SS}} = -\,(p_1^2+\gamma)h'(v_{SS}) + \lambda(p_1^2+\gamma) + \mu p_1 \Delta p = 0, \tag{23}$$

$$\iff \quad \frac{1}{v'(w_{SS})} = \lambda + \mu I(S,S). \tag{24}$$

$$\frac{\partial \mathcal{L}}{\partial v_{SF}} = -\,(p_1(1-p_1)-\gamma)h'(v_{SF}) + \lambda(p_1(1-p_1)-\gamma) + \mu(1-p_1)\Delta p = 0, \tag{25}$$

$$\iff \quad \frac{1}{v'(w_{SF})} = \lambda + \mu I(S,F). \tag{26}$$

$$\frac{\partial \mathcal{L}}{\partial v_{SS}} = -\,((1-p_1)p_1-\gamma)h'(v_{FS}) + \lambda((1-p_1)p_1-\gamma) - \mu p_1 \Delta p = 0, \tag{27}$$

$$\iff \quad \frac{1}{v'(w_{FS})} = \lambda + \mu I(F,S). \tag{28}$$

$$\frac{\partial \mathcal{L}}{\partial v_{FF}} = -\,((1-p_1)^2+\gamma)h'(v_{FF}) + \lambda((1-p_1)^2+\gamma) - \mu(1-p_1)\Delta p = 0, \tag{29}$$

$$\iff \quad \frac{1}{v'(w_{FF})} = \lambda + \mu I(F,F). \tag{30}$$

Since $v'' < 0$, w_R is increasing in the incentive efficiency term that multiplies μ, as stated in *Lemma 1*, which leads to the optimal incentive scheme in *Lemma 2.* To complete the proof, we show that $\lambda > 0$ and $\mu > 0$. For $\lambda > 0$, let's add equations, (23), (25), (27) (29), from there we obtain:

$$\lambda = \sum_{R \in \mathbf{R}} \frac{P(R|1,1)}{v'(w_R)}. \tag{31}$$

Since $v'(\cdot) > 0$ then $\lambda > 0$. Now for μ, let's premultiply (24) and (28) by p_1, and (26) and (30) by $(1 - p_1)$ and substract (28) and (30) from (24) and (26). Thus, we obtain:

$$\mu = \left(\frac{p_1}{v'(w_{SS})} + \frac{1-p_1}{v'(w_{SF})} - \frac{p_1}{v'(w_{FS})} - \frac{1-p_1}{v'(w_{FF})} \right) \frac{\prod_{R \in \mathbf{R}} P(R|1,1)}{\Delta p (p_1^3 + (1-p_1)^3)}. \tag{32}$$

Since by the incentive compatibility constraint $p_1 v(w_{SS}) + (1-p_1)v(w_{SF}) - p_1 v(w_{FS}) - (1 - p_1)v(w_{FF}) = \frac{c}{\Delta p} > 0$, it follows that $p_1 w_{SS} + (1-p_1)w_{SF} > p_1 w_{FS} + (1-p_1)w_{FF}$ which implies that $\left(\frac{p_1}{v'(w_{SS})} + \frac{1-p_1}{v'(w_{SF})} - \frac{p_1}{v'(w_{FS})} - \frac{1-p_1}{v'(w_{FF})} \right) > 0$. Therefore, $\mu > 0$.

From equations (24), (26), (28) and (30) it is simple to see that:

$$w_R = (v')^{-1} \left(\frac{1}{\lambda + \mu \, IE(R)} \right) \tag{33}$$

Which proves property 1 and 2 in the proposition. Unlike the risk-neutral case, every contract is positive and there is no closed-form expression for *Proposition 1.*

Note that $\gamma > 0$ implies that $IE(S,F) > IE(S,S)$ but also that $IE(F,F) > IE(F,S)$. This means that $(w_{SF}, w_{FF}) > (w_{SS}, w_{FS})$ which is the definition of RPE. When $\gamma < 0$ then $IE(S,S) > IE(S,F)$ but also that $IE(F,S) > IE(F,F)$ which implies that JPE is the optimal compensation scheme. Finally, if $\gamma = 0$, then IPE is the optimal incentive scheme. Hence, risk aversion raises the cost of effort provision from a productive standpoint but does not alter the informational role of market signals, which proves point three in the proposition.

Finally, greater curvature of $v(\cdot)$ further increases these costs, making effort inducement less profitably implementable for the principal. Re-writing equation (9) it leads to:

$$\mathbb{E}\ (w_R^*|1,1) \leq G.$$

This completes the proof. □

Examples

In these applications, each principal faces a marginal production cost κ. The outcome of each agent—either success or failure—reduces the cost to κ' or leaves it at κ, respectively. After outcomes are realized, the marginal costs become public, and firms subsequently choose quantities or prices depending on the application. We present several examples in which either strategic-substitute or strategic-complement interactions arise. Note that the most commonly studied forms of competition, such as standard Cournot, Bertrand, and Hotelling models, typically involve strategic substitutes. By contrast, less competitive environments—such as markets with complementary goods or capacity constraints—tend to feature strategic complements.

Cournot Competition with Homogeneous Goods

Consider the case in which each principal sets quantities in a standard Cournot market with homogeneous goods. Demand is linear, $P(Q) = \alpha - Q$, where $Q = q_1 + q_2$ and $\alpha > 0$. We then compute the profit function Π for the four possible joint realizations of agents' outcomes. The best response function for principal i given an outcome of her agent is: $q_i := \max\{\frac{\alpha-\kappa_{R_i}}{2} - \frac{q_{-i}}{2}, 0\}$ where q_{-i} is the quantity set by the rival firm and κ_{R_i} is the marginal cost of producing after realization R_i. In this context, the optimal quantity is determined by $q_i^* = \frac{\alpha+\kappa_{R_{-i}}-2\kappa_{R_i}}{3}$ and we compute the optimal profits in the following table:

Table 1: $\Pi_i(\cdot)$ Function

$R_1 \backslash R_2$	S	F
S	$(\frac{\alpha-\kappa'}{3})^2$	$(\frac{\alpha+\kappa-2\kappa'}{3})^2$
F	$(\frac{\alpha+\kappa'-2\kappa}{3})^2$	$(\frac{\alpha-\kappa}{3})^2$

It is straightforward to verify that $\Pi_i(S,F)+\Pi_i(F,S) > \Pi_i(S,S)+\Pi_i(F,F)$, since $(\alpha+\kappa-2\kappa')^2 + (\alpha+\kappa'-2\kappa)^2 \geq (\alpha-\kappa)^2 + (\alpha-\kappa')^2$, which follows from $\kappa^2+\kappa'^2 \geq 2\kappa\kappa'$. This result supports Assumption (A4), which states that under strategic substitutes this inequality holds.

Bertrand Competition with Heterogeneous Goods

Consider now the case in which each principal sets prices for two heterogeneous goods. Consider the following linear demand functions: $q_i(p_i, p_{-i}) = \alpha - p_i + \delta p_{-i}$, with $\alpha > 0$ and $0 < \delta < 1$. After maximizing profits setting prices, principal's i best response function is $p_i = \max\{\frac{1}{2}(\alpha + \delta p_{-i} + \kappa_{R_i}), 0\}$, solving the system of linear equations we obtain that the optimal price is $p_i^* = \frac{\alpha(2+\delta)+\delta\kappa_{R_{-i}}+2\kappa_{R_i}}{4-\delta^2}$ and we compute the optimal profits are given below:

$$\begin{aligned}
\Pi_i(S,S) &= \frac{\big((2+\delta)(\alpha+\kappa')-\kappa'(4-\delta^2)\big)\big((4-\delta^2)\alpha-(1-\delta)(2+\delta)(\alpha+\kappa')\big)}{(4-\delta^2)^2}, \\
\Pi_i(S,F) &= \frac{\big(\alpha(2+\delta)+\delta\kappa+2\kappa'-\kappa'(4-\delta^2)\big)\big((4-\delta^2)\alpha-(\alpha(2+\delta)+\delta\kappa+2\kappa')+\delta(\alpha(2+\delta)+\delta\kappa'+2\kappa)\big)}{(4-\delta^2)^2}, \\
\Pi_i(F,S) &= \frac{\big(\alpha(2+\delta)+\delta\kappa'+2\kappa-\kappa(4-\delta^2)\big)\big((4-\delta^2)\alpha-(\alpha(2+\delta)+\delta\kappa'+2\kappa)+\delta(\alpha(2+\delta)+\delta\kappa+2\kappa')\big)}{(4-\delta^2)^2}, \\
\Pi_i(F,F) &= \frac{\big((2+\delta)(\alpha+\kappa)-\kappa(4-\delta^2)\big)\big((4-\delta^2)\alpha-(1-\delta)(2+\delta)(\alpha+\kappa)\big)}{(4-\delta^2)^2}.
\end{aligned} \tag{34}$$

It is straighforward to verify that $\Pi_i(S,F)+\Pi_i(F,S) > \Pi_i(S,S)+\Pi_i(F,F)$ since $\frac{2\delta(2-\delta^2)}{(4-\delta^2)^2}(\kappa-\kappa')^2 \geq 0$. This example shows that what matters is the effect of effort outcomes on payoffs, independent of the strategic interaction between firms. Note that Bertrand competition implies an upward-sloping best-response function, yet there are still strategic substitutes in terms of agents' effort outcomes.

Hotelling Competition

Consider two principals located at opposite ends of a unit interval $[0,1]$. Consumers are uniformly distributed along this interval, one per unit length. Principals set prices taking into account that consumers face linear transportation costs.

$$\begin{aligned} &\text{If buying from firm 1 (at 0)}: \quad p_1 + tx \\ &\text{If buying from firm 2 (at 1)}: \quad p_2 + t(1-x) \end{aligned}$$

Where $t > 0$. The consumer who is indifferent between the two firms satisfies:

$$p_1 + tx = p_2 + t(1-x) \tag{35}$$

Solving for x, the indifferent consumer is located at x^* and determines the demand for principal i: $x^* = \frac{1}{2} + \frac{p_{-i} - p_i}{2t} = q_i^*$. Given this demand function each principal maximizes profits by selecting prices. The best response function for principal i is $p_i = \max\{\frac{\kappa_{R_i} + t + p_{-i}}{2}, 0\}$ then the optimal $p_i^* = \frac{2\kappa_{R_i} + \kappa_{R_{-i}} + 3t}{3}$. The equilibrium profit functions for the four possible realizations of agents' outcomes are shown in the following table:

Table 2: $\Pi_i(\cdot)$ Function

$R_1 \backslash R_2$	S	F
S	$\frac{t}{2}$	$\frac{(3t+\kappa-\kappa')^2}{18t}$
F	$\frac{(3t+\kappa'-\kappa)^2}{18t}$	$\frac{t}{2}$

It is straightforward to verify that the sum of asymmetric equilibria exceeds that of symmetric ones.

Bertrand competition with complementary goods

Using the same model as in *Bertrand competition with heterogeneous goods*, but assuming $-\sqrt{2} < \delta < 0$, the goods become complements. In this case, $\Pi_i(S,F) + \Pi_i(F,S) < \Pi_i(S,S) + \Pi_i(F,F)$ since $\frac{2\delta(2-\delta^2)}{(4-\delta^2)^2}(\kappa - \kappa')^2 < 0$.

Cournot competition with capacity constraints

Using the same model as in *Cournot competition with homogeneous goods*, now assume capacity constraints $q_i \le K$ for all $i \in 1, 2$. In particular, suppose the capacity constraint satisfies $\frac{\alpha - \kappa'}{3} < K < \frac{\alpha + \kappa - 2\kappa'}{3}$, which generates a discrete jump and a non-convexity in the cost function:

$$c_i(q_i) = \begin{cases} \kappa_{R_i} q_i & \text{if } q_i \le K \\ \kappa_{R_i} q_i + \phi & \text{if } q_i > K \end{cases} \tag{36}$$

Considering this case of soft capacity constraints, a firm i prefers to exceed its soft capacity constraint ϕ after seeing a realization of outcomes (S,F) when $\Pi_i^u(S,F) - \phi > \Pi_i^K(S,F) = \frac{K(\alpha+\kappa-2\kappa'-K)}{2}$ and $\Pi_i^u(S,F)$ is the entry in table 1. Thus, for any $\phi < \phi_{\min} := \Pi_i^u(S,F) - \Pi_i^K(S,F)$, principal i always prefers to exceed its soft capacity constraint. Finally, by comparing $\Pi_i^u(S,F) - \phi + \Pi_i^u(F,S) < \Pi_i^u(S,S) + \Pi_i^u(F,F)$ for any $\phi > \frac{9}{4}(\kappa - \kappa')^2$ and $\alpha - \kappa > 5(\kappa - \kappa')$. The first condition requires ϕ to be of intermediate size—neither negligible nor excessive—while the second ensures that the market is sufficiently large, consistent with less competitive environments.