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Interfaces with Other Disciplines

Do you want to know a secret? Strategic alliances and competition in product markets

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ABSTRACT

Strategic alliances make firms' boundaries permeable to information leakages that may benefit the competitive position of partnering firms. In this paper, we examine the implications of information leakage on the incentives to join a strategic alliance and the nature of competition in the product market. We show that information leakage can trigger opportunistic behaviours in which firms engage in unprofitable alliances simply because the possibility of learning sensitive information about their competitors increases the expected private rents that firms earn when competing in the product market. Thus, our findings uncover a purely informational mechanism through which information leakage affects the incentives to join a strategic alliance that does not rely on the firm's ability to absorb spillovers from other firms. We also show that the incentives to devise alliances to gain access to the partner's sensitive private information may remain even if the negatively affected firm can pursue compensation for the damage that this deceptive business practice may cause.

1. Introduction

Strategic alliances — interfirm collaborative models that allow firms to create value through collaboration in competitive environments (Das & Kumar, 2011), are fraught with the risk of opportunism that arises from information and knowledge that firms can acquire from their partners. Indeed, once a firm (intentionally or unintentionally) shares valuable sensitive information with its partners, its ability to control or limit what these partners do with this information can be severely compromised.

The dispute between Corbis and Infoflows is a good example of the risks inherent to these interfirm collaborations. Corbis, a company founded by Bill Gates in 1989, was in the business of digital image licencing. Infoflows, a start-up company founded by Steve Stone after he left Microsoft in 2004, was developing a service for identifying, tracking, and managing control of digital objects on the Internet (an Object Management Service, OMS). In September 2005, Corbis' attorney David Weiskopf contacted Stone about a possible collaboration for developing a license management system intended to operate on InfoFlows' technology. Weiskopf and Stone had lunch, during which Stone (he would later testify) explained to Weiskopf his idea for a digital image license management system based on Infoflows' OMS. Stone claimed that he even drew his concepts on a placemat to aid Weiskopf in understanding what he was trying to explain. Two weeks later, Weiskopf emailed Corbis' general counsel Jim Mitchell, claiming he had 'developed a very realistic solution' to digital rights management after 'conversations and proposals with vendors' (Corbis Corp. v. Stone, 2012). The email included PowerPoint slides with diagrams that Stone testified were almost identical to those he drew for Weiskopf during that lunch (Corbis Corp. v. Stone, 2012). Corbis and Infoflows entered into a collaborative agreement in November 2005. Nonetheless, Corbis terminated this agreement in October 2006 under arguments about InfoFlows 'failing to deliver a working 'alpha' demonstration of the system' (Corbis Corp. v. Stone, 2012). InfoFlows sued Corbis and obtained a favourable jury verdict for misappropriation of trade secrets,

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[2] Yang, Zheng, and Zaheer (2015) describe another example in which Cisco and XpertUniverse entered an agreement that was terminated after three years of partnership when Cisco dropped out of the agreement and launched a product almost identical to that of XpertUniverse. According to Yang et al. (2015, p. 358), this was a *'covert attempt to learn from the partner by Cisco'*. In the context of supply chains, Kong, Rajagopalan, and Zhang (2017) discuss the case of Newbury Comics, a Northeast retail chain that stopped sharing its information after it realised it was losing its competitive advantage because middlemen used the valuable information it was sharing to make inventory planning and replenishment decisions at retailers.

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fraud and breach of contract with more than 20 million of awarded damages (Buley, 2010; Lohr, 2010).[2]

Corbis–Infoflows example raises several questions. To what extent the possibility of unintended access to sensitive private information affects the incentives to form collaborative partnerships? How do unintended leakages of information affect the development of these partnerships? How do these collaborative agreements (and the associated risk of information leakage) affect market competition? Prior research on strategic alliances and information sharing has predominantly focused on the implications of knowledge leakages — the extent to which the focal firm's private knowledge is intentionally appropriated by or unintentionally transferred to partners (Jiang, Li, Gao, Bao, & Jiang, 2013, p.984) rather than information leakage — the unauthorised sharing of a firm's information with another organisation, on strategic alliances (e.g., Jiang, Bao, Xie, & Gao, 2016; Oxley & Sampson, 2004; Raza-Ullah, 2021). This is unfortunate because a firm without the appropriate ability to absorb, assimilate, and apply knowledge to commercial ends may fail to leverage any new knowledge about its partners outside the alliance. However, it may benefit from new information about its partners by adjusting its behaviour to this new information. Even if firms possess such ability, it still is possible that the leakage of sensitive private information changes the nature of competition in the product market.

In this paper, we aim to fill this research gap by theoretically examining the implications of information leakage on the firms' incentives to pursue strategic alliances and the nature (and intensity) of market competition between the partners and, thus, to shed some light on questions such as those arising from the Corbis–Infoflows example. To this end, we develop a game-theoretic framework in which two firms competing in quantities in a homogeneous product market must collaborate to successfully exploit a business opportunity based on some innovation owned by firm 1. Firms are asymmetrically informed about their competitors' production costs and the value of the profits they expect to generate through collaborative activity. Engaging in this collaborative activity involves the possibility of (unintended) leakage of confidential information regarding firms' production processes, allowing firms to update their beliefs about their competitors' production costs and the value of profits from the collaborative activity.[3] Following the literature on strategic alliances (Das & Teng, 2000a, 2000b; Grant & Baden-Fuller, 2004), we model this partnership as an informal 'relational contract' in which firms first engage in some *preliminary conversations* and then sign a more formal contractual agreement regarding the production (and commercialisation) of the new product. Implementation of the partnership (i.e., whether to carry out the actual productive tasks related to the business opportunity) occurs only if firms ratify their participation after preliminary conversations.

We show that information leakage can trigger opportunistic behaviours in which firms engage in alliances that are expected to yield negative profits simply because the possibility of learning sensitive information about their competitors increases the private rents that firms expect to earn when competing in the product market. Thus, our results suggest the existence of a spillover effect (Ried, Eckerd, Kaufmann, & Carter, 2021) associated with information leakage that may lead some firms to devise economically unprofitable alliances with the hope of accessing the internal barriers of their competitors and, thus, to learn sensitive private information. We also use our theoretical framework to examine the consequences of this *Trojan-horse behaviour* in environments where the negatively affected firm can pursue compensation for the (alleged) damage that this deceptive business practice may have caused.[4] We show that the incentives to devise alliances to gain access to the partner's sensitive private information remain true for compensation values that are not too high. However, the fact that we model this compensation in expected terms –i.e., as the product of the amount of money that a firm receives conditional on winning in court times the probability of winning in court, suggests that compensations may not work effectively against the emergence of this type of deceptive behaviour in environments in which proving that information leakages have occurred is difficult.

1.1. Related literature

Sharing information in oligopoly is a topic that has received considerable attention in the economics and management literature (Gal-Or, 1985; Palfrey, 1985; Vives, 1984). Li (1985) distinguishes between private information about the demand and firm-specific parameters and shows that firms will not reveal information unless there is uncertainty about firm-specific parameters. Ganuza and Jansen (2013) examine the welfare effects of sharing acquired cost information in Cournot oligopoly. They find that information sharing among competing firms may increase the consumer surplus as the precision of the firms' information increases. Okuno-Fujiwara, Postlewaite, and Suzumura (1990) and Van Zandt and Vives (2007) consider the problem of information sharing in oligopolies where firms receive their private information before taking action. These authors provide conditions under which (verifiable) information unravels due to firms' willingness to be perceived as low-cost. Currarini and Feri (2015) study bilateral exchange of information and show that correlation of signals in a Cournot oligopoly favours the transmission of information but may also prevent all information from being transmitted. Kopel and Putz (2021) examine the incentives for firms to voluntarily share the details of their managerial contracts in a Cournot-Bertrand duopoly. They find that firms share contract information only if products are sufficiently differentiated.[5]

In the context of strategic alliances, sharing information about a common activity may cause unintentional revelation of confidential information to their partners due to the incomplete nature of formal procedures — such as legal contracts, to control which knowledge and information are shared and which are protected (Gast, Gundolf, Harms, & Collado, 2019; Kumar, 2010), unintended disclosure of small details about firms' private valuable information (Walter et al., 2015), informal mechanisms of communication (Naesens, Pintelon, & Taillieu, 2007), or loose collaborative environments (Jiang et al., 2013). As a result, these leakages of information may trigger opportunistic behaviours in which one of the parties in the alliance uses this information about their partners in a manner that was not agreed beforehand (Luo, 2007; Walter et al., 2015; Yang et al., 2015).

[3] Firms in our model do not spend effort trying to observe their partner's private information; instead, they know that there is a chance to observe this information while interacting in the alliance due to inevitable leakages of little details that give away valuable private information to the other party (Walter, Walter, & Müller, 2015).

[4] The Trojan-Horse behaviour allegory that we use to refer to the opportunistic behaviour of the partnering firms has been introduced previously in the literature. Hennart, Roehl, and Zietlow (1999) use it to depict the behaviour of Japanese firms entering into joint ventures with non-Japanese firms to learn about their partner just enough to acquire the firms later or dissolve them.

[5] In the supply chain management literature, scholars have discussed optimal information sharing strategies of the informed party under information leakage (Anand & Goyal, 2009; Fang & Ren, 2019; Wang, Zhen, & Yan, 2021), the evaluation and mitigation of the risk of information leakage (Kong, Rajagopalan, & Zhang, 2013; Zhang, Cao, Wang, & Zeng, 2012), or how information leakage affects supply chain relationships from a network perspective (Ried et al., 2021). In the context of R&D alliances, the literature has focused on informational spillover from R&D investments, which is the driving force behind the competitive interactions of the partnering firms (e.g., Conti & Marini, 2019; d'Aspremont & Jacquemin, 1988; Perez-Castrillo & Sandonis, 1997).

Instead of strategic alliances, firms could use mergers and acquisitions (M&A) to bridge the gap in resources and knowledge for a particular business plan or strategy (Bauer & Matzler, 2014; De Man & Duysters, 2005). M&A differentiate from strategic alliances in that they require a complete structural change for the involved parties. In contrast, alliances involve collaborative work while maintaining separate organisations (Hagedoorn & Duysters, 2002; Vanhaverbeke, Duysters, & Noorderhaven, 2002).[6] Sawler (2005) shows that alliances are preferred to mergers because the involved parties reap the benefits of combining operations while avoiding the adverse effects of the merger paradox — non-merging firms expand as they get a larger market share. Teng (2007) argues that acquisitions are not always an option due to antitrust regulations and the price that has to be paid for the resources to acquire, which becomes exacerbated when considering the information asymmetry between the acquirer and the acquiree. In this context, alliances are more flexible alternatives that allow firms to share costs and risks. Yin and Shanley (2008) argue that industry conditions related to commitments, flexibility, and other structural conditions shape decision-making on whether firms engage in alliances or M&A.

Cooperating in uncertain environments has gathered academic attention over the years, particularly in situations where the distribution of benefits is central for cooperating agents (Özcan, Gök, & Weber, 2023; Weber, Gök, & Kropat, 2011). This issue is relevant in problems like ours, in which the parties must decide on partnerships without knowing the profits associated with the collaboration.[7] Cooperative interval games provide a framework to address situations where the potential rewards and costs are not known for certain (Alparslan-Gök, Miquel, & Tijs, 2009).[8] Another set of valuable tools to address uncertainty in cooperative environments comes from stochastic optimal control theory. Baltas and Yannacopoulos (2019) apply these tools to model uncertainty in environments where agents observe information signals about the future evolution of volatile asset subject to observational noise. Similarly, Baltas, Xepapadeas, and Yannacopoulos (2019) use robust stochastic optimal control theory to examine cases where a decision maker might not believe a given model is the proper way to incorporate the world's future states.[9] Savku (2023) approaches differential games through constrained stochastic control problems and offers an example of collaboration between a bank and an insurance company that can coordinate to share their client database and jointly create new products. The idea of rumour provides another practical conceptual framework to analyse uncertainty about some informational-related issues. A rumour can be understood as unverified and unconfirmed information that can be confirmed as true or false (Belen, Kropat, & Weber, 2011). Rumour propagation models provide a framework to understand information dissemination processes (Gürbüz, Mawengkang, Husein, & Weber, 2022), or information diffusion in networks and populations (Belen, Kaya, & Pearce, 2005; Gürbüz et al., 2022).[10]

The remainder of the paper is organised as follows. We outline the model in Section 2. Section 3 presents the paper's theoretical analysis and main results. Section 4 provides some discussion. Section 5 concludes with some final remarks. Technical proofs not included in the main text are presented in Supplementary Material.

2. The baseline model

Consider a market for a homogeneous good (henceforth, the core market) characterised by an (inverse) continuous decreasing demand function with a choke price strictly higher than c_H and populated by two risk-neutral firms, firm 1 and firm 2 that compete in this market by choosing their quantities. Firm 1 is a long-standing firm (an incumbent) that chooses its quantity first. Firm 2 is a new entrant that behaves as a follower choosing its quantity only after firm 1 has chosen its.

Firm 1 has developed an innovation that can lead to a new product, different from the one commercialised in the core market. However, this firm lacks certain technical skills to transform this innovation into a new, marketable product. Firm 2, however, possesses these capabilities, which it acquired while developing the technology needed to enter the core market. Thus, firms must actively collaborate to exploit the profits of the innovation, and strategic alliances provide an excellent outlet to share risks and to pool critical resources that cannot be obtained via market exchanges or mergers (Eisenhardt & Schoonhoven, 1996; Hora, Gast, Kailer, Rey-Marti, & Mas-Tur, 2018). Firm 1 is unaware of the specifics of firm 2's technology; hence, it does not know for certain firm 2's cost. However, firm 1 knows that (i) firm 2's cost is either low (c_L) or high (c_H), with $c_L < c_1 < c_H$; (ii) the common knowledge prior probability that firm 2's cost is high is $\mu_0 \in (0,1)$. It is common knowledge that firm 2 has the capabilities to turn firm 1's innovation into a new product.[11]

Let $t \in [\underline{t}, \bar{t}]$ subsume all relevant characteristics associated with firm 1's innovation (we may think of this as the quality of firm 1's innovation), and $\theta(t)$ denote the (reduced-form) net profit associated to the production and commercialisation of the product that obtains from exploiting firm 1's innovation. We assume that $\theta(\cdot)$ is common knowledge and a strictly increasing function of t. Initially, firm 2 is unaware of the exact value of t (it is firm 1's private information), and it only knows that it follows a cumulative distribution function (cdf) $F(\cdot)$, with positive density $f(\cdot)$, and full support. Moreover, $\mathbb{E}[\theta(t)] = 0$. Occasionally, we refer to the parameter t and the cost c_τ, $\tau = L, H$, as firm 1's and firm 2's types, respectively.

Firm 1 can invite firm 2 to form a collaborative partnership (a strategic alliance) to produce and commercialise the new product obtained from firm 1's innovation. Prior to production (and commercialisation) of the new product, firms engage in *preliminary conversations*, after which they evaluate whether to sign a more formal contractual agreement. We do not delve into the different contractual agreements that firms are capable of reaching; instead, we assume that some uninterested third party (a mediator) who does not know the types of the firms and does not possess any private information itself offers a 50–50 sharing rule over the gains of the partnership that firms must (simultaneously) ratify after preliminary conversations are over if they are to continue in the partnership.[12]

[6] We can also think of alliances as precursors of M&A. For instance, Hagedoorn and Sadowski (1999) show that for the technology sector, only a tiny portion of alliances lead to M&A of the companies. Alternatively, Vanhaverbeke et al. (2002) show that a sequence of strategic alliances between two partners increases the likelihood of acquiring one of the parties.

[7] Notice, however, that this paper focuses on the implications of information leakage on strategic alliances and not on the different contractual agreements that firms can reach through bargaining or some other alternative mechanism.

[8] Cooperative interval games – also referred to as 'grey games' in the Operational Research literature (Palancı, Alparslan Gök, Ergün, & Weber, 2015) – can be applied to inventory problems (Olgun, Gök, & Özdemir, 2016), sequential production (Alparslan Gök, 2014) and other situations in which collective payoffs can be influenced by interval uncertainty (Branzei, Branzei, Alparslan Gök, & Tijs, 2010). Stochastic extensions of these games have shown to have stable cooperative solutions (Parilina & Tampieri, 2018), and some fuzzy extensions have been used to address related topics (Khalilpourazari, Mirzazadeh, Weber, & Pasandideh, 2020; Özcan, Gök, & Weber, 2023; Özcan, Sledzinski, Gök, Butlewski, & Weber, 2023; Roy, Midya, & Weber, 2019; Tirkolaee, Goli, & Weber, 2019).

[9] Other ways to model uncertainty in decision problems are parallelepiped uncertainty (Kara, Özmen, & Weber, 2019), polyhedral uncertainty sets (Özmen, Kropat, & Weber, 2017; Özmen, Weber, Batmaz, & Kropat, 2011), and ellipsoidal uncertainty (Kropat, Weber, Alparslan-Gök, & Özmen, 2014).

[10] We are concerned with situations in which information that leaks can be verified at no cost. As such, information in our context may not qualify as a rumour, which is information that (presumably) requires costly effort to verify whether it is true or not.

[11] Our results continue to hold if we assume more general convex cost functions that can be ordered such that $c_L(q) < c_1(q) < c_H(q)$, $q \geq 0$.

[12] Following Gerchak and Khmelnitsky (2019), offering a 50–50 sharing rule must solve the mediator's problem as disagreement renders firm 1's innovation useless (which appears to be a reasonable assumption in the current case).

During preliminary conversations, firms can experience *involuntary* leakages of sensitive private information, which occurs independently of any protective measure that firms may adopt. Formally, during these preliminary conversations, firms observe the realisation of a pair (s_1, s_2) of independent random signals such that (i) $s_1 = c_\tau$ with probability $q \in (0,1)$, where c_τ is firm 2's true cost, and with complementary probability $(1-q)$ the signal s_1 is independently drawn from a probability distribution that assigns probability μ_0 to $s_1 = c_H$ and probability $1-\mu_0$ to $s_1 = c_L$, and (ii) $s_2 = t$ with probability $p \in [0,1]$, and with probability $(1-p)$ signal s_2 is i.i.d noise coming from the distribution $F(\cdot)$. Firms can distinguish which kind of signals they observe; they know whether any specific signal contains the truth.[13] Signals are publicly observed; hence, learning (or not) each other's type becomes common knowledge in all subsequent stages of the game.[14]

The timing of the game is as follows. After firms learn their private information, firm 1 chooses whether or not to invite firm 2 to form an alliance. If firm 2 rejects this invitation, then firms move to the final stage of the game. If firm 2 accepts firm 1's invitation, both firms begin preliminary conversations during which involuntary leakages of firms' private information may occur. Right after these information leakages happen, an uninterested third party without knowledge of firms' types (or about any private information) publicly announces a 50–50 sharing rule over the partnership's gains, which firms must simultaneously ratify for the alliance to continue. The alliance terminates if either firm chooses not to ratify this sharing rule, in which case no action regarding the production of the new product is taken, and no profit associated with exploiting firm 1's innovation is realised. Firms' ratification decisions become common knowledge in every subsequent stage. At the final stage, firms compete in the core market according to the Stackelberg model of quantity competition, with firm 1 as the leader and firm 2 as the follower. The game's final stage is reached regardless of whether the alliance continues after the preliminary conversations. We adopt Perfect Bayesian equilibrium (equilibrium henceforth) as the equilibrium concept.[15]

3. Analysis

Consistent with sequential rationality, we analyse the game stage in which firms compete according to the Stackelberg model of competition (with firm 1 as the leader). To focus on well-behaved games, we assume that the demand function is such that $\frac{\partial P(Q)q_i}{\partial q_i}$ is decreasing with respect to q_j, $j \neq i$.[16] Because firms reach this stage regardless of whether or not they cooperate in exploiting firm 1's innovation, let $\mu \in [0,1]$ denote some arbitrary belief about firm 2 having a high cost. Firms' (reduced-form) profits are:

$$\pi_1^*(\mu) := \max_{q_1 \geq 0} \left\{ \mathbb{E}[P(q_1 + q_\tau(q_1))] - c_1 \right\} q_1, \tag{1}$$

$$\pi_\tau^*(q_1) := \max_{q_2 \geq 0} \left[P(q_1 + q_2) - c_\tau \right] q_2, \tag{2}$$

where $q_\tau(\cdot)$ is firm 2's reaction function (the solution to firm 2's maximisation problem) when this firm's type is τ, $\tau = L, H$, and $q_1^*(\mu)$ is firm 1's optimal quantity when this firm's belief about type H of firm 2 is given by $\mu \in (0,1)$. The following result will prove useful in the remainder of the analysis.

Proposition 1. *Let $\mu \in [0,1]$ be firm 1's belief about firm two having cost c_H. Firms' profits functions (1) and (2) satisfy: (i) firm 1's profit is a strictly increasing and convex function of μ; (ii) firm 2's profit is a strictly decreasing function of μ; (iii) $[\pi_L^*(\cdot) - \pi_H^*(\cdot)]$ is a strictly decreasing function of μ.*

3.1. Information leakages and strategic alliances

Firms ratify their participation in the alliance after observing the outcome of the preliminary conversations, which may include knowledge about their competitors' private information. Because ratification is a costless action, firm 1 has strong incentives to offer *any* alliance (say, a very unprofitable one) with the hope of learning firm 2's private information and then walking away from the agreement at no cost. To avoid this, we assume that firm 1 incurs in some cost $K > 0$ (due to litigation or a loss in reputation) whenever firm 1 invites firm 2 to hold preliminary conversations and does not ratify its participation in the alliance.

Consider any continuation game following a history in which both firms learn each other types. In any such continuation game, competition occurs under complete knowledge of firms' costs; hence, firms' decisions to ratify (or quit) the alliance do not affect the information structure under which they compete in the product market. Hence, quitting whenever $\theta(t) < 0$ and ratifying whenever $\theta(t) \geq 0$ must be firm 2's optimal decision regardless of firm 1's. Given this behaviour, ratifying will be optimal for firm 1 whenever the following holds:

$$\pi_1^*(\mu_\tau) + \max\left\{ \frac{\theta(t)}{2}; 0 \right\} > \pi_1^*(\mu_\tau) - K,$$

where $\mu_H = 1$ and $\mu_L = 0$. It is fairly clear that firm 1's optimal decision is to ratify regardless of the value of K whenever it expects firm 2 to ratify alliances with $\theta(t) \geq 0$ and to quit alliances with $\theta(t) < 0$.

Next, consider any continuation game that follows a history in which only firm 1 learns its competitor's type (i.e., firm 2 does not learn firm 1's type). In this case, firm 2's optimal decision depends on what this firm believes about firm 1's type after observing an invitation. Suppose that firm 2 believes that only types of firm 1 above a certain threshold t_1 are willing to extend an invitation. With some abuse of notation, let $G(\theta|t_1)$ denote the distribution of $\theta(t)$ truncated on the left at $\theta(t_1)$. Momentarily suppose that firm 2 expects firm 1 to ratify any alliance it offers. Then, firm 2's expected payoff from continuing in the alliance conditional on firm 1's type being at least t_1 is equal to the probability that it does not learn firm 1's type, $(1-p)$, times:

$$(1 - F(\theta^{-1}(t_1))) \left(\frac{\int_{\theta_1}^{\bar{\theta}} \frac{\theta}{2} dG(\theta|t_1)}{1 - F(\theta^{-1}(t_1))} \right) = \int_{\theta_1}^{\bar{\theta}} \frac{\theta}{2} dG(\theta|t_1), \tag{3}$$

where $\theta_1 := \theta(t_1)$ and $\bar{\theta} = \theta(\bar{t})$. This integral is nonnegative regardless of the value of θ_1 (because the expectation of $\theta(\cdot)$ is zero). Hence, firm 2's optimal action must be to ratify its participation in the alliance after any history in which it does not learn firm 1's type.[17] Consequently,

[13] Our focus is not on the refinement of signals; we are primarily concerned about how the learning affects the firms' incentives to form alliances.

[14] This simplifies the analysis by preventing any issue regarding higher-order beliefs about the firms' types.

[15] An equilibrium is a collection of sequentially rational strategies that specify firm 1's decision to offer a collaborative partnership to firm 2, the ratification decision, and the quantity to produce in the core market, and firm 2's decision to accept or reject firm 1's invitation, its ratification decision, and the quantity to produce in the core market, together with a system of beliefs about firms' types derived according to Bayes' rule when possible.

[16] Given constant marginal costs and $P'(\cdot) < 0$, this condition – known as the decreasing marginal revenue condition – is sufficient for firm 1's profit to be strictly concave in q_i, and for firm's best responses to be strictly downward sloping functions (Vives, 1999).

[17] The integral is positive whenever $\theta_1 \geq 0$. Hence, let $\theta_1 < 0$. Then:

$$\begin{aligned}\int_{\theta_1}^{\bar{\theta}} \theta dG(\theta|t_1) &= \frac{1}{1-F(\theta_1)} \left[\int_{\theta_1}^{\bar{\theta}} \theta dF(\theta) + \int_{\underline{\theta}}^{\theta_1} \theta dF(\theta) - \int_{\underline{\theta}}^{\theta_1} \theta dF(\theta) \right] \\ &= \frac{1}{1-F(\theta_1)} \left[\int_{\underline{\theta}}^{\bar{\theta}} \theta dF(\theta) - \int_{\underline{\theta}}^{\theta_1} \theta dF(\theta) \right] \\ &= \frac{1}{1-F(\theta_1)} \left[- \int_{\underline{\theta}}^{\theta_1} \theta dF(\theta) \right],\end{aligned}$$

which is nonnegative because the values between $\underline{\theta}$ and θ_1 are negative and $f(\cdot) > 0$.

firm 1 is better off ratifying the alliance if:

$$\pi_1^*(\mu_\tau) + \frac{\theta(t)}{2} \geq \pi_1^*(\mu_\tau) - K,$$

which holds true whenever $\theta(t) \geq 0$ regardless of the value of K. If $\theta(t) < 0$, then firm 1 will be better off ratifying if $\frac{\theta(t)}{2} \leq K$, and quitting otherwise.

Lemma 1. *Any continuation game that follows a history in which both firms learn each other's types must have an equilibrium in which firm 1 and both types of firm 2 ratify their participation if $\theta(t) \geq 0$ and do not do so if $\theta(t) < 0$. Likewise, any continuation game in which only firm 1 learns its competitor's type must have an equilibrium in which firm 1 ratifies if $\frac{\theta(t)}{2} \geq -K$ and it does not ratify otherwise, and both types of firm 2 ratify their participation decisions.*

Next, consider any continuation game in which firm 1 does not learn firm 2's type. Because firm 2's decision is type-dependent, this firm's choice has the potential to signal its private information. First, consider continuation games in which firm 2 learns the value of t. Let $\theta(t_2)$ be a threshold value such that, on path, both types of firm 2 are expected to ratify if $\theta(t) \geq \theta(t_2)$ and not to ratify if $\theta(t) < \theta(t_2)$. Take type τ of firm 2, $\tau \in \{L, H\}$. On path, this type expects a payoff equal to:

$$\pi_\tau^*(\mu_0) + \frac{\theta(t)}{2},$$

because firm 1 remains unaware of firm 2's type when competing in the product market. Alternatively, this type's expected payoff depends on firm 1's belief about firm 2's type upon observing firm 2's (off-path) decision not to ratify. Let $\tilde{\mu}$ denote the probability that firm 1 assigns to firm 2 having cost c_H upon observing not ratification. Then, the expected payoff of type τ of firm 2 becomes $\pi_\tau^*(\tilde{\mu})$. Suppose further that $\tilde{\mu} > \mu_0$. From part (ii) of Proposition 1 we have $\pi_\tau^*(\tilde{\mu}) < \pi_\tau^*(\mu_0)$, whereas part (iii) implies:

$$\pi_L^*(\tilde{\mu}) - \pi_L^*(\mu_0) < \pi_H^*(\tilde{\mu}) - \pi_H^*(\mu_0) < 0.$$

Let $\theta(t_H) = 2[\pi_H^*(\tilde{\mu}) - \pi_H^*(\mu_0)]$, and $\theta(t_L) = 2[\pi_L^*(\tilde{\mu}) - \pi_L^*(\mu_0)]$. It is fairly clear that $\theta(t_L) < \theta(t_H) < 0$, and hence, both types of firm 2 must be willing to ratify if $\theta(t) > \theta(t_H)$ because not doing so becomes equilibrium dominated, whereas not ratifying must be optimal if $\theta(t) < \theta(t_L)$. However, if $\theta(t) \in (\theta(t_L), \theta(t_H))$ then:

$$\pi_L^*(\mu_0) + \frac{\theta(t)}{2} > \pi_L^*(\tilde{\mu})$$

and,

$$\pi_H^*(\mu_0) + \frac{\theta(t)}{2} < \pi_H^*(\tilde{\mu}),$$

and different types are willing to take different actions, which is inconsistent with an equilibrium in which firm 2's ratification decision is characterised by a single threshold $\theta(t_2)$ such that both types of firm 2 ratify if $\theta(t) \geq \theta(t_2)$, and do not do so if $\theta(t) < \theta(t_2)$. We can apply a similar argument to rule out equilibria characterised by a single cutoff if firm 1's off-path belief is such that $\tilde{\mu} < \mu_0$. Consequently, $\tilde{\mu} = \mu_0$ must be the unique off-path belief consistent with an equilibrium in which firm 2's behaviour can be characterised by a single threshold $\theta(t_2)$ –which in this case is equal to zero, such that both types ratify if $\theta(t) \geq \theta(t_2) = 0$ and quit otherwise. This implies a payoff equal to:

$$\pi_1^*(\mu_0) + \max\left\{\frac{\theta(t)}{2}; 0\right\},$$

for firm 1 if this firm also ratifies, and a payoff equal to $\pi_1^*(\mu_0) - K$ if this firm does not. Hence, firm 1 finds optimal to ratify regardless of the value of K in response to both types of firm 2 ratifying when $\theta(t) \geq 0$ and not to ratify when $\theta(t) < 0$. The following lemma is immediate.[18]

Lemma 2. *Let firm 1's belief about firm 2's type be equal to μ_0 regardless of firm 2's decision about ratification. The continuation game that follows a history in which firm 1 does not learn firm 2's type and firm 2 learns firm 1's has an equilibrium in which firm 1 and both types of firm 2 ratify their participation if $\theta(t) \geq 0$, and they do not do so if $\theta(t) < 0$.*

The following corollary follows directly from Lemmas 1 and 2, and it characterises the equilibrium in continuation games in which neither seller learns its competitor's type.

Corollary 1. *Any continuation game that follows a history in which neither firm learns its competitor's type has an equilibrium in which both types of firm 2 ratify their participation in the alliance, and firm 1 ratifies it when $\theta(t) \geq -2K$, and does not ratify when $\theta(t) < -2K$. This equilibrium can be sustained using passive off-path beliefs such that firm 1 assigns probability μ_0 to firm 2 with cost c_H whenever it observes no ratification.*

The characterisation of the optimal behaviour of firms after preliminary conversations allows us to focus on the reduced-form game in which firm 1 decides whether to invite firm 2 to participate in the alliance, and firm 2 chooses whether to accept or reject any such invitation. In what follows, we construct a (putative) equilibrium in which both types of firm 2 are expected to accept on path any invitation that firm 1 extends. As mentioned, inviting firm 2 to hold preliminary conversations may signal some relevant information about firm 1's type. Let t_1 be the lowest type of firm 1 willing to extend an invitation to firm 2. On path, firm 2 updates its belief about the profitability of the alliance according to Bayes' rule such that $G(\theta|t_1)$ describes firm 2's belief about firm 1's type, with $\theta_j := \theta(t_j)$, $j = 1, 2$, $\underline{\theta} := \theta(\underline{t})$, and $\overline{\theta} := \theta(\overline{t})$.[19] The payoff a firm τ expects to earn if it accepts firm 1's invitation is:

$$\begin{aligned}&\Pi_\tau^*(q|t_1) = \\ &q\pi_\tau^*(\mu_\tau) + (1-q)\pi_\tau^*(\mu_0) + \\ &\underbrace{p\left[q\int_0^{\overline{\theta}} \frac{\theta}{2} dG(\theta|t_1) + (1-q)\int_{\max\{\theta(t_1);0\}}^{\overline{\theta}} \frac{\theta}{2} dG(\theta|t_1)\right] + (1-p)\int_{\max\{\theta(t_1);-2K\}}^{\overline{\theta}} \frac{\theta}{2} dG(\theta|t_1)}_{\mathbb{E}_G(\theta|t_1)},\end{aligned} \tag{4}$$

where $\mu_L = 0$ and $\mu_H = 1$. The first line captures firm 2's expected payoff in the product market as a result of information leakages, whereas the second line captures the expected payoff from the implementation of the alliance (which we label as $\mathbb{E}_G(\theta|t_1)$ for future reference) taking into account the ratification decisions of the firms characterised in Lemmas 1, 2 and Corollary 1, and the fact that firm 2 believes that $\theta(t)$ must be at least equal to $\theta(t_1)$.

In the putative equilibrium we are constructing, rejecting firm 1's invitation is an off-path action. Therefore, the payoff that type τ of firm 2 expects to earn depends on firm 1's off-path belief about firm 2's type after observing rejection. Intuition suggests that this off-path belief may depend on the value of q because it is possible that firm 1 learns about firm 2's private information, which alters the information structure in the product market. However, some algebra and part (iii) of Proposition 1 shows that:

$$\pi_H^*(1) - \Pi_H^*(q|t_1) > \pi_L^*(1) - \Pi_L^*(q|t_1),$$

and therefore, rejecting firm 1's invitation is more attractive for a firm 2 with cost c_H than a firm with cost c_L whenever firm 1 believes that rejection comes from the firm with cost c_H. Moreover, (i) $\pi_H^*(1) - \Pi_H^*(0|t_1) > \pi_L^*(1) - \Pi_L^*(0|t_1)$; and (ii) the gain from deviating towards rejecting firm 1's invitation increases (decreases) for the high (low)

[18] There are cases in which firm 2's ratification decision may signal this firm's private information. However, this behaviour only occurs for certain combinations of parameters and off-path belief specifications. See the Supplementary Material for a formal analysis of this point.

[19] Of course, firm 2 also updates its belief whenever it is not invited to participate in the alliance. However, this updated belief is unimportant because no alliance is ever formed.

type of firm 2 the higher the value of q. Consequently, rejecting when firm 1 expects acceptance of its invitation must be more attractive for firm 2 with the cost c_H regardless of the value of q, and this putative (pooling) equilibrium must survive (Cho & Sobel, 1990)'s intuitive criterion, regardless of the value of q, $q \in (0,1)$. Moreover, because $\Pi_H^*(q|t_1) \geq \pi_H^*(1)$ implies $\Pi_L^*(q|t_1) \geq \pi_L^*(1)$, it suffices that firm 2 with the cost c_H accepts firm 1's invitation for the firm 2 with cost c_L to be willing to do so as well.

A firm 1 with type t that extends an invitation to form an alliance expects a payoff equal to:

$$\Pi_1(q|t) = q[\mu_0\pi_1^*(1) + (1-\mu_0)\pi_1^*(0)] + (1-q)\pi_1^*(\mu_0) + p\max\left\{0; \frac{\theta(t)}{2}\right\} + (1-p)\max\left\{-K; \frac{\theta(t)}{2}\right\},$$

because regardless of its type, firm 2 does not ratify any unprofitable alliance with probability p (which is the probability with which it learns firm 1's type), and firm 1 quits any alliance whose profit is less than the penalty K. Momentarily assume that $-K < \frac{\theta(t)}{2}$ such that firm 1 always prefers to ratify. Define $\Gamma(q|\mu_0,t)$ by:

$$\Gamma(q|\mu_0,t) = \Pi_1(q|t) - \pi_1^*(\mu_0),$$

and such that type t of firm 1 offers an alliance whenever $\Gamma(q|\mu_0,t) \geq 0$, and it refrains from doing so otherwise. Because $\pi_1^*(\mu)$ is a convex function of μ (part (i) of Proposition 1), $\Gamma(q|\mu_0,t) > 0$ if $\theta(t) \geq 0$. This together with continuity of $\Gamma(q|\mu_0,t)$ implies the existence of some threshold value $\theta(t_1) < 0$ implicitly defined by:

$$\Gamma(q|\mu_0,t) + \frac{\theta(t_1)}{2} = 0,$$

such that $\Gamma(q|\mu_0,t) \geq 0$ if $\theta(t) \geq \theta(t_1)$, and $\Gamma(q|\mu_0,t) < 0$ if $\theta(t) < \theta(t_1)$. This threshold characterises the highest amount of money firm 1 is willing to lose to face the chance of learning firm 2's private information.

From part (ii) of Proposition 1, $\pi_H^*(\mu_0) > \pi_H^*(1)$. Moreover, $\mathbb{E}_G(\theta|t_1) \geq 0$ (with t_1 implicitly defined by $\theta(t_1)$ above) and hence:

$$\Pi_2^*(q|\theta_1) - \pi_H^*(1) = (1-q)[\pi_H^*(\mu_0) - \pi_H^*(1)] + \mathbb{E}_G(\theta|t_1) > 0.$$

Therefore, on path both types of firm 2 are indeed willing to accept any invitation that firm 1 extends.

Proposition 2. *For all $q > 0$, and $p \neq 1$, there exists an equilibrium in which:*

1. *Firm 1 invites firm 2 to form an alliance whenever $t \geq t_1$, where t_1 is implicitly defined by:*

   $$q[\mu_0\pi_1^*(1) + (1-\mu_0)\pi_1^*(0) - \pi_1^*(\mu_0)] + (1-p)\frac{\theta(t_1)}{2} = 0,$$

   types of firm 1 for which $\theta(t) < \theta(t_1) < 0$ refrain from extending any invitation to firm 2.
2. *Firm 1 assigns probability μ_0 to type H of firm 2 upon observing acceptance of its invitation to form an alliance and probability one to this type upon observing rejection of it. Thus, by accepting firm 1's invitation firm 2 does not signal any of its private information.*
3. *On path, alliances with strictly negative profits are implemented with probability one whenever firm 1 is the only firm that learns the competitor's type, and $\frac{\theta(t)}{2} \geq -K$. In all other cases, only alliances that yield strictly positive profits are implemented.*

Proposition 2 is interesting because it shows a strictly positive probability that firm 1 uses alliances as a *Trojan-horse* to learn sensitive information about their competitors. Intuitively, this occurs because the gains that firm 1 expects as a result of a more favourable competitive position in the core market outweigh, in expected terms, the costs of losing money due to the possibility of implementing an unprofitable alliance. How much money firm 1 is willing to lose increases not only with the probability of learning firm 2's private information — which suggests that $\theta(t_1)$ can be considered as an estimate of how much firm 1 *values* firm 2's private information, but also with the probability that firm 2 learns firm 1's. As expected, firm 1's cost of learning firm 2's private information falls with the value of p because the higher the probability that firm 2 becomes aware that it is immersed in an unprofitable deal, the more likely it is that this firm quits the agreement.

Firm 2, on the other hand, is willing to accept firm 1's invitation mainly because of the inferences that firm 1 makes about its cost when firm 2 *rejects* firm 1's invitation. In fact, after observing a rejection firm 1 believes that it is facing a firm 2 with cost c_H because this type is the one that has the most to gain by not participating in the alliance (profits of firm 2 with cost c_H are weakly higher when firm 1 remains unaware of its true cost). As a result, type H of firm 2 anticipates a worse payoff when it rejects than when it accepts firm 1's invitation because accepting involves a strictly positive probability of firm 1 remaining unaware of firm 2's type and firm 2 learning the true profitability of firm 1's innovation. This, in turn, implies a strictly positive probability that type H of firm 2 walks away from the alliance without having its cost revealed. In contrast, firm 2, with cost c_L, is better off with information leakage because it can credibly communicate its cost to firm 1. Because type L is the most efficient type in the market, letting firm 1 know this information softens competition and increases firm 2's profits in the core market when its cost is c_L.

3.2. Deceptive behaviour and compensation for damages

According to Proposition 2, there are alliances whose purpose appears to be the access and appropriation of competitors' private information rather than the exploitation of a genuine business opportunity. In most cases, these *deceptive alliances* cause a deterioration of firm 2's competitive position in the product market, manifesting as reduced profits. In this section, we examine environments in which this kind of misconduct triggers legal disputes in which firm 2 goes to court in search of some compensation that mitigates the (alleged) damages.

Definition 1. An alliance is said to be *deceptive* if the following two conditions simultaneously hold: (i) $\theta(t) < 0$; and (ii) firm 2's profits in the core market fall as a result of its participation in the alliance relative to the profits that this firm would have earned in the absence of any alliance.

Several comments are in order here. First, genuinely profitable business opportunities are not considered deceptive even if they cause a fall in firm 2's profits in the core market. The idea here is that cases against firm 1 would not hold in court because firm 1 can argue that the invitation was made in good faith (after all, the alliance is a profitable business opportunity) and under complete ignorance about firm 2's type. Second, because damages to firm 2's competitive position can only be evaluated after competition in the core market, a deceptive alliance must be defined in ex-post rather than ex-ante terms. Third, an alliance can only be considered deceptive if firm 1 learns firm 2's private information after preliminary conversations because firm 2's profits in the core market are unaffected by its participation in the alliance if firm 1 is unaware of firm 2's cost. Fourth, the definition of deceptive alliances estimates the harm to firm 2's competitive position using the profits that this firm would have earned without any alliance. This is an adequate benchmark because the profits that firm 2 would have obtained if it had rejected firm 1's invitation depends on firm 1's (off-path) belief about firm 2's type, which is an equilibrium object.

To account for the consequences associated with the legal disputes that deceptive alliances are likely to trigger, we adopt a reduced-form approach in which firm 2's participation in a deceptive alliance triggers a legal process in which the court finds out the actual value of t (and

		Firm 2: Continuing	Firm 2: Quitting
Firm 1	Continuing	$\pi^*_\tau(\mu_\tau) + \frac{\theta(t)}{2} + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_2$	$\pi^*_\tau(\mu_\tau) + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_2$
	Quitting	$\pi^*_\tau(\mu_\tau) + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_1$	$\pi^*_\tau(\mu_\tau) + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_1$

Fig. 1. Type τ' payoffs.

hence, of $\theta(t)$) with probability $\alpha_1 \in (0,1)$ if firm 1 walks away before the alliance is ratified, and with probability $\alpha_2 \in (0,1)$ if the firm remains in the alliance until the end of its term, where $\alpha_1 \geq \alpha_2$. Thus, different from the analysis performed in the previous section, we now assume that firm 1's decision not to ratify an alliance involves paying some positive amount of money only if firm 1's invitation to form an alliance proves deceptive. Furthermore, the assumption about α_1 being greater than α_2 is motivated by the previous idea that a guilty firm 1 (i.e., a firm 1 that offers a deceptive alliance) has stronger incentives not to ratify when this is a costless decision. As a result, not ratifying should be interpreted as *suggestive* of firm 1's deceptive behaviour and hence, subject to legal investigation.[20] In what follows, we let $P_1 = \alpha_1\kappa$ denote the expected compensation that firm 1 pays to firm 2 whenever it invites firm 2 to participate in a deceptive alliance from which firm 1 walks away after preliminary conversations are over, and $P_2 = \alpha_2\kappa$ the expected compensation that this firm pays if it continues (ratifies its participation) until the end. Define $\theta(t_L)$ by:

$$\theta(t_L) = 2[\pi^*_L(\mu_0) - \pi^*_L(0)], \tag{5}$$

with $\theta_H = 0$. Then, $\theta(t_L) < 0$ because $\pi^*_L(0) > \pi^*_L(\mu_0)$ from part (ii) of Proposition 1 and thus, for an alliance to be catalogued as deceptive from type L's perspective, it must be true that the profits associated to the alliance are sufficiently negative.

Consider a continuation game that follows a history in which both firms learn each other types. For type τ of firm 2, ratifying the participation in the alliance yields a payoff equal to:

$$\pi^*_\tau(\mu_\tau) + \frac{\theta(t)}{2} + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_2,$$

whenever firm 1 also ratifies its participation, and a payoff equal to $\pi^*_\tau(\mu_\tau) + \mathbb{I}_{[\theta(t)<\theta_\tau]}P_1$ if firm 1 does not ratify its participation, where $\mu_H = 1$, $\mu_L = 0$, and $\mathbb{I}_{[\cdot]}$ is an indicator function. In contrast, not ratifying the alliance yields type τ of firm 2 a payoff equal to $\pi^*_\tau(\mu_\tau)$ plus P_1 if firm 1 decides not to ratify its participation in an alliance that turns out to be deceptive, or P_2 if firm 1 ratifies its participation (and the alliance is deceptive). Fig. 1 summarises type τ's payoffs, where we have used the notation μ_τ for $\mu_H = 1$ and $\mu_L = 0$. As it is fairly clear from the figure, type τ of firm 2 is weakly better off not ratifying the alliance when $\theta(t) < 0$ (ratifying involves a chance to lose half the value of $\theta(t)$ in case of a deceptive alliance), and ratifying when $\theta(t) \geq 0$. Given this, firm 1 expects a payoff equal to $\pi^*_1(\tau)$ minus $\mathbb{I}_{[\theta(t)<\theta_\tau]}P_2$ if it ratifies, or $\mathbb{I}_{[\theta(t)<\theta_\tau]}P_1$ if it does not ratify. Because $P_1 \geq P_2$ firm 1's optimal action in response to firm 2 not ratifying must be to ratify regardless of the value of $\theta(t)$ (see Fig. 1).

Next, consider a continuation game that follows a history in which firm 1 learns firm 2's type and firm 2 remains unaware of firm 1's. Suppose that type τ of firm 2 expects firm 1 to ratify whenever $\theta(t)$ exceeds some $\theta_1 := \theta(t_1)$. Let $G(\cdot|\theta_1)$ denote the distribution of θ conditional on being greater than θ_1. Then, ratifying yields this type of firm 2 an expected payoff equal to:

$$\pi^*_\tau(\mu_\tau) + \int_{\theta_1}^{\bar\theta} \frac{\theta}{2} dG(\theta|t_1) + G(\theta_\tau|t_1)P_2,$$

because firm 2 receives compensation P_2 only in the event that $\theta(t) < \theta_\tau$, $\tau = L, H$. Alternatively, not ratifying yields an expected payoff of:

$$\pi^*_\tau(\mu_\tau) + G(\theta_\tau|t_1)P_2.$$

Because the integral in the previous expression is nonnegative, firm 2 must find optimal to ratify the alliance whenever it expects firm 1 to ratify if $\theta(t) \geq \theta_1$. As of firm 1, ratifying the alliance when it expects both types of firm 2 to ratify yields a payoff equal to:

$$\pi^*_1(\tau) + \frac{\theta(t)}{2} - \mathbb{I}_{[\theta(t)<\theta_\tau]}P_2,$$

whereas not ratifying yields a payoff equal to:

$$\pi^*_1(\tau) - \mathbb{I}_{[\theta(t)<\theta_\tau]}P_1.$$

It is fairly clear that ratifying if $\theta(t) \geq 0$ is firm 1's optimal response in this case. For cases in which $\theta(t) < 0$, firm 1 is better off ratifying if:

$$\theta(t) \geq \theta_\alpha := -2\kappa[\alpha_1 - \alpha_2]. \tag{6}$$

The expression (6) formalises the intuition about firm 1 ratifying its participation in deceptive alliances in cases in which losses are less than the payment that firm 1 is expected to make if it walks away. Interestingly, the higher the probability that a court of law rules in favour of firm 2 after observing the early termination of the agreement, the more likely it is to observe the implementation of economically unprofitable ventures.

Lemma 3. *Any continuation game in which both firms learn each other's type must have an equilibrium in which firm 1 ratifies for any value of $\theta(t)$ and both types of firm 2 ratify if $\theta(t) \geq 0$ and do not do so if $\theta(t) < 0$. Likewise, any continuation game in which firm 1 learns firm 2's type and firm 2 remains unaware of firm 1's must have an equilibrium in which firm 2 ratifies, and firm 1 ratifies if $\theta(t) \geq \theta_\alpha$, and does not do so if $\theta(t) < \theta_\alpha$, where θ_α is defined in expression (6).*

Equilibria of continuation games that originate after histories in which either firm 2 is the only firm that learns the competitor's type or no firm learns its competitor's private information can be characterised along the lines of Lemma 2 because alliances in which firm 1 remains unaware of firm 2's are not considered to be deceptive. In particular, continuation games in which only firm 2 learns firm 1's type have an equilibrium in which firm 1 ratifies its participation in the alliance and both types of firm 2 ratify theirs if $\theta(t) \geq 0$, and quit the alliance if $\theta(t) < 0$. Likewise, continuation games in which no firm learns its competitor's type have an equilibrium in which both types of firm 2 ratify their participation in the alliance, and firm 1 ratifies its if $\theta(t) \geq 0$, and quits if $\theta(t) < 0$ (because $K = 0$ in the current setup).

Similar to the analysis in the previous section, consider a putative equilibrium in which both types of firm 2 accept firm 1's invitation with probability one. The payoff that type τ of firm 2 expects to receive when it accepts firm 1's invitation can be written as follows:

$$\begin{aligned}\Pi^*_\tau(q|\tilde t_1) &= q\pi^*_\tau(\mu_\tau) + (1-q)\pi^*_\tau(\mu_0) + \\ &q\left[p\int_0^{\bar\theta}\frac{\theta}{2}dG(\theta|\tilde t_1) + (1-p)\int_{\max\{\theta_1,\theta_\alpha\}}^{\bar\theta}\frac{\theta}{2}dG(\theta|\tilde t_1)\right] \\ &+ (1-q)\int_{\max\{\theta_1;0\}}^{\bar\theta}\frac{\theta}{2}dG(\theta|\tilde t_1) + \\ &q\left[pG(\theta_\tau|\tilde t_1)P_2 + (1-p)\left(G(\theta_\tau|\tilde t_1)G(\theta_\alpha|\tilde t_1)P_1 + G(\theta_\tau|\tilde t_1)\right.\right.\end{aligned}$$

[20] Moreover, observe that in the current setup, there is no other motive than accessing its competitor's technological know-how that can explain firm 1's decision to form an alliance from which it pulls off before reaching its term.

$$\times \ (1 - G(\theta_\alpha|\tilde{t}_1))P_2)\big],$$

where $\tilde{t}_1$ is the lowest type of firm 1 willing to invite firm 2 to participate in preliminary conversations, $\theta_1 := \theta(t_1)$, θ_L is given by expression (5), $\theta_H = 0$, and θ_α is given by (6). The two novelties of this expected payoff concerning that in expression (4) are the inclusion of θ_α in the computation of the expected profit in those cases in which firm 1 is the only firm learning the competitor's type, and the inclusion of the expected compensations that firm 2 receives every time firm 1 offers a deceptive alliance. Note that the amount of this (expected) compensation depends on whether firm 1 does not ratify the alliance (which occurs when $\theta(t)$ is lower than θ_α) or it ratifies it (which occurs if $\theta(t)$ is greater than θ_α). Firm 2 expects no compensation in any continuation game in which firm 1 does not learn firm 2's type.

As before, rejecting firm 1's offer is an off-path action. Applying a similar argument as that employed in the previous section, we let firm 1 assign probability one to the type H of firm 2 whenever it observes rejection such that $\Pi_H^*(q|t_1) \geq \pi_H^*(1)$ suffices to guarantee that both types of firm 2 are willing to accept firm 1's invitation.

Next, consider the optimal decision of firm 1. By extending an invitation firm 1 expects a payoff equal to:

$$\begin{aligned}\Pi_1(q|t) = \\ q[\mu_0\pi_1^*(1) + (1-\mu_0)\pi_1^*(0)] + (1-q)\pi_1^*(\mu_0) + p\max\left\{0; \frac{\theta(t)}{2}\right\} \\ + (1-p)\mathbb{I}_{[\theta(t)\geq\theta_\alpha]}\frac{\theta(t)}{2} \\ - q\left[\mu_0\mathbb{I}_{[\theta(t)<0]} + (1-\mu_0)\mathbb{I}_{[\theta(t)<\theta_L]}\right]P_2 - q(1-p)\mathbb{I}_{[\theta(t)<\theta_\alpha]}P_1.\end{aligned} \tag{7}$$

Notice that only profitable alliances are implemented conditional on firm 2 learning firm 1's type. In contrast, unprofitable alliances can be implemented if $\theta(t)$ is not too low to deter firm 1 from not ratifying.

Let $\alpha_1 > \alpha_2$ (such that $\theta_\alpha < 0$) and momentarily suppose that firm 1 offers an alliance with slightly negative $\theta(t)$ such that $\max\{\theta_\alpha, \theta_L\} < \theta(t) < 0$. Firm 1's expected payoff becomes:

$$\Pi_1(q|t) = q[\mu_0\pi_1^*(1) + (1-\mu_0)\pi_1^*(0)] + (1-q)\pi_1^*(\mu_0) + (1-p)\frac{\theta(t)}{2} - q\mu_0 P_2.$$

By not offering any alliance, firm 1 expects a payoff equal to $\pi_1^*(\mu_0)$. Hence, firm 1 will find it profitable to offer this alliance when $\Pi_1(q|t) \geq \pi_1^*(\mu_0)$, which is equivalent to:

$$(1-p)\frac{\theta(t)}{2} + q\left[\mu_0\pi_1^*(1) + (1-\mu_0)\pi_1^*(0) - \pi_1^*(\mu_0) - \mu_0 P_2\right] \geq 0. \tag{8}$$

Because $\pi_1^*(\cdot)$ is convex with respect to μ, the term within square brackets must be nonnegative at least for values of κ not too high. Therefore, it still is possible for firm 1 to find it attractive to offer a deceptive alliance provided that either it is unlikely that firm 1 loses in court or, conditional on losing, the amount that firm 1 has to pay as compensation for this misleading business practice is low (or both).

Let κ_1 be given by:

$$\kappa_1 = \frac{1}{\alpha_2}\left[\pi_1^*(1) - \pi_1^*(0) - \frac{\pi_1^*(\mu_0) - \pi_1^*(0)}{\mu_0}\right]. \tag{9}$$

The following proposition summarises our discussion so far.

Proposition 3. *If $\kappa < \kappa_1$, then there exists an equilibrium in which firm 1 invites firm 2 to form an alliance whenever $\theta(t) \geq \theta(\tilde{t}_1)$, where $\theta(\tilde{t}_1) < 0$ is given by:*

$$\theta(\tilde{t}_1) = -\frac{2q}{1-p}\left[\pi_1^*(0) - \pi_1^*(\mu_0) - \mu_0\left[\pi_1^*(0) - \pi_1^*(1) + \alpha_2\kappa\right]\right],$$

whereas types for which $\theta(t) < \theta(\tilde{t}_1)$ refrain from extending any invitation. Beliefs on and off path are similar to those described in Proposition 2.

Similar to Proposition 2, the previous result provides a characterisation of conditions under which firm 1 offers deceptive alliances even though it faces the possibility of paying compensation to its competitor for incurring this misleading business practice. This result suggests that these types of legal measures (payments in case of damages) might not effectively inhibit these types of deceptive behaviours, especially if the probability of being caught in such misleading practice is low.

4. Discussion

In this section, we explore the extent to which the paper's main findings depend on key assumptions about the asymmetry in firms' private information, the number of competitors, and the form of competition in the product market.

4.1. Symmetric private information

Asymmetry in the private information about sellers' costs has been justified on the basis that firm 1's cost is already revealed by earlier conduct in the industry. We now consider the case in which there is no such asymmetry (perhaps because the technological advances make it difficult for firms to infer from conduct the actual technology that competitors use). In this version of the model, firm j, $j = 1, 2$, knows that (i) the competitor's cost is either low (c_L) or high (c_H), with $c_L < c_H$; (ii) the probability that firm j's cost is equal to c_H is $\mu_0 \in (0, 1)$. To avoid signalling at the stage in which firms must choose quantities, we model competition in the core market as Cournot competition.[21]

Because firm 1's cost is this firm's private information, firm 1's 'type' becomes a tuple (t, c_τ) where t denotes the quality of firm 1's innovation and c_τ firm 1's cost. This raises two issues. First, firm 1's decision to invite firm 2 to participate in preliminary conversations may signal not only the quality of this firm's innovation but also its cost. Second, it may be possible that information leakages allow firm 2 to learn t but not c_τ, or c_τ but not t. We address the first issue by restricting to equilibria in which both types of firm 1 take the same decision about inviting firm 2 to participate in the alliance for any given value of t. Regarding the second issue, we accommodate this possibility by letting firm 2 learn the value of t with probability $p_1 \in (0, 1)$, and the value of c_τ with probability $p_2 \in (0, 1)$. For simplicity, we assume that signals related to t and firm 1's costs are i.i.d. random variables.

Proposition 4. *There exists a threshold value $\tilde{t}$ such that $\theta(\tilde{t}) < 0$ and both types of firm 1 invites firm 2 to form an alliance whenever $\theta(t) \geq \theta(\tilde{t})$, and these types do not invite firm 2 when $\theta(t) < \theta(\tilde{t})$. This equilibrium can be sustained using passive beliefs, that is, beliefs according to which firm j does not infer anything new about its competitor's type whenever it observes an off-path action.*

The intuition behind propositions 2 and 4 are similar. This occurs because the properties that sustain the equilibrium we previously constructed remain valid in the current setup, particularly the convexity of firm 1's profits with respect to beliefs about firm 2's cost. As a result, firm 1 still finds it attractive to pay money for the chance to learn firm 2's private information in the form of an invitation to an alliance with negative economic value (which may be implemented with strictly positive probability). Nonetheless, these incentives are weaker (stronger) when firm 1's cost is c_L (c_H) relative to the case in which firm 1's cost is assumed common knowledge. To see this, assume that $c_1 = c_L$. In the baseline model, conditional on information leakage (which occurs with probability q), firm 1's expected payoff is:

$$\mu_0\pi_1(c_L, c_H) + (1-\mu_0)\pi_1(c_L, c_L),$$

where we have used the notation $\pi_1(c_L, c_2)$ to highlight the payoff that firm 1 with cost c_L expects when firm 2's cost is $c_2 \in \{c_L, c_H\}$.

[21] Assuming that firms compete a la Cournot yields similar results as those obtained under Stackelberg's. The reason is that the assumptions on $P(\cdot)$ guarantee equilibrium existence under Cournot's and that firms' profits satisfy all three properties outlined in Proposition 1.

In contrast, in the case in which firm 1's is private information, this conditional payoff becomes:

$$\mu_0[p_2\pi_1(c_L,c_H)+(1-p_2)\pi_1(\bar{c}_1,c_H)]+(1-\mu_0)[p_2\pi_1(c_L,c_L)+(1-p_2)\pi_1(\bar{c}_1,c_L)].$$

Because $c_L < \bar{c}_1$, $\pi_1(c_L,c_2) > \pi_1(\bar{c}_1,c_2)$ and hence, as long as $p_2 > 0$ firm 1 with cost c_L expects a lower payoff conditional on information leakage in the environment in which its cost is private information (a similar analysis shows that firm 1's payoff conditional on not learning firm 2's cost is lower in the latter case). Intuitively, this occurs because the possibility that firm 2 *does not* learn firm 1's type harms firm 1 competitive position as this type benefits from market competition when firm 2 knows that it is facing a firm with the most efficient cost (the opposite holds for a firm 1 with cost c_H).

4.2. Competition with many firms

Another assumption underlying the previous analysis is the restriction to two firms in the market (those that eventually form a strategic alliance). In this section, we study an extension of the baseline model in which there are more than two competitors, keeping the structure in which firm 1 behaves as the market leader, firm 2 as a new entrant with a cost structure unknown to other firms (including firm 1), and the rest of the firms as followers. Firms other than firm 1 choose quantities simultaneously after observing firm 1's choice.[22]

We make two additional simplifying assumptions. First, let costs of firms other than firm 2 be common knowledge and equal to $c_f \in (0,1)$ (the argument being that firm 1 and firms other than firm 2 have been in the market long enough for their costs to be revealed by their earlier conduct in the industry). Second, we assume a linear market demand given by the (inverse) function $P(Q) = 1 - Q$. We also assume that all conditions needed for an interior equilibrium are satisfied.

The existence of more competitors in the market (followers) introduces an issue that was absent in the baseline model. Because firm 1 may learn firm 2's cost through information leakage, this firm's choice of quantity can signal this information to the remaining firms (that behave as followers) in the market. Given the symmetry of followers, we analyse this issue assuming that $n = 3$ (that is, there is one leader (firm 1) and two followers, namely, firm 2 (the new entrant) and firm 3), and then generalise our findings to the more general case in which n is arbitrary.

Suppose firm 1 learns that firm 2's cost is c_L (through information leakage). Moreover, suppose that in equilibrium firm 1 chooses a quantity q_1^L that perfectly signals this information to the other firms.[23] Standard results allow us to compute firm 1's profits as follows:

$$\pi_1^L(c_1,c_L) = \frac{(1+c_f-3c_1+c_L)^2}{12}.$$

Alternatively, suppose that firm 1 chooses some quantity $\tilde{q}_1$ such that no information is transmitted to other firms. After observing $\tilde{q}_1$ firm 3's belief about firm 2's cost remains at μ_0, and hence, the highest profit that firm 1 can obtain by choosing any such quantity is:

$$\pi_1^{nL}(c_1,c_L) = \frac{(2+2c_f-6c_1+2c_L-\mu_0(c_H-c_L))^2}{48}.$$

It is fairly straightforward that $\pi_1^L(c_1,c_L) > \pi_1^{nL}(c_1,c_L)$, which suggests that there cannot be some quantity $\tilde{q}_1$ that does not signal the information firm 1 has learned about firm 2's cost. Thus, profits remain the same as in the baseline model up to the correction of the number of additional followers. Hence, the analysis carried out in Section 3 remains valid, as do all propositions. Nonetheless, incentives to offer an alliance (and to accept such invitations) change as the number of firms increases. Some standard calculations yield firm 1's payoff when it faces n followers:

$$\pi_1(c_1,c_f,c_2|n) = \frac{[1+(n-1)c_f-(n+1)c_1+c_2]^2}{4(n+1)},$$

where $c_2 = c_\tau$, $\tau = L,H$, whenever firm 1 learns firm 2's cost, and $c_2 = \bar{c} = \mu_0 c_H + (1-\mu_0)c_L$ whenever it does not learn firm 2's cost. Recall that firm 1 is willing to offer unprofitable alliances because the core market expected payoff from learning firm 2's cost with probability q is strictly greater than the core market payoff that firm 1 expects if it does not invite firm 2 to form an alliance. Substituting the profits when there are n firms in the market yields:

$$q[\mu_0\pi_1(c_1,c_f,c_H|n)+(1-\mu_0)\pi_1(c_1,c_f,c_L|n)]+(1-q)\pi_1(c_1,c_f,\bar{c}_2|n), \quad (10)$$

as the expected core market payoff when firm 1 invites firm 2 to form an alliance, and $\pi_1(c_1,c_f,\bar{c}_2|n)$ if firm 1 does not invite it. Write firm 1's problem when firm 2's cost becomes known after information leakage (which we obtain after solving for the equilibrium of the Cournot game played between firm 2 and the $(n-2)$ remaining followers):

$$\max_{q_1\geq 0}\left[1-c_1-\frac{(1-c_\tau)}{n}-\frac{(n-2)(1-c_f)}{n}-\frac{q_1}{n}\right]q_1.$$

If $c_1 = c_f$ this problem reduces to:

$$\frac{1}{n}\max_{q_1\geq 0}\left[2(1-c\tau)-(1-c_\tau)-q_1\right]q_1,$$

and therefore, firm 1's optimal quantity is independent of the number of followers. This 'Stackelberg independence' (Hinnosaar, 2021) implies that as the number of followers increases, the total quantity in the market approaches the perfectly competitive one and thus, price tends to marginal cost. The case in which $c_1 \neq c_f$ is slightly more involved (because we cannot isolate the leader's problem from the number of followers). However, it can be readily shown that the rate at which expression (10) grows as n increases is the same as that of $\pi_1(c_1,c_f,\bar{c}_2|n)$ and hence, the difference between the two terms approaches zero. Consequently, firm 1's incentives to offer unprofitable alliances disappear as the number of followers increases or, equivalently, as market competition intensifies.

Proposition 5. *Let n be the number of followers competing in the core market in which firm 1 is the leader. Then:*

$$\lim_{n\to\infty}\left\{\mu_0\pi_1(c_1,c_f,c_H|n)+(1-\mu_0)\pi_1(c_1,c_f,c_L|n)-\pi_1(c_1,c_f,\bar{c}_2|n)\right\}=0,$$

and thus, there exists some N such that for all $n > N$, firm 1 invites firm 2 to participate in alliances only if $\theta(t) \geq 0$.

4.3. Alternative forms of competition

Throughout the paper, we have maintained the assumption about quantity as the relevant strategic variable with which firms compete in the core market. Thus, our model can be considered as the reduced form of some capacity game followed by price competition when the cost of capacity is high.[24] In this section, however, we examine the consequences of firms competing in prices rather than quantities. We do so using an extension of the baseline model (two firms, with firm 1's cost being common knowledge and firm 2's being this firm's private information) in which firms choose the prices of their differentiated goods simultaneously.

Let $q_j = D_j(\mathbf{p})$ denote the demand of firm j's product, where $\mathbf{p}$ is the price vector. We assume that $D_j^{-1}(0) > c_H$, demands are downward

[22] We thank an anonymous reviewer for suggesting this analysis.

[23] Even though firm 2 knows its own information, it is essential that firm 2 knows that firm 3 has learned this information to avoid issues related to higher-order beliefs.

[24] See Chapter 5 in Tirole (1988) for a discussion about reduced-form profits like the ones we employ resulting from short-run price competition with given capacities.

sloping (i.e., $\frac{\partial D_j(\mathbf{p})}{\partial p_j} < 0$ for all j), goods are gross substitutes ($\frac{\partial D_j}{\partial p_k} \geq 0$, $k \neq j$), and demands posses the increasing difference property ($\frac{\partial^2 D_j}{\partial p_j \partial p_k} \geq 0$).[25]

At the competition stage, firms choose prices simultaneously regardless of whether or not they undertake the cooperative activity. Let $\mu_i \in [0,1]$ denote the probability that firm 1 assigns to firm 2's cost equal to c_H. Firm 1's expected profit when it choose price $p_1 \in [0,\infty)$ and firm 2 uses a pricing strategy $p_2 : \{c_L, c_H\} \to [0,\infty)$ is:

$$\pi_1(p_1, \bar{p}_2) = (p_1 - c_1) \underbrace{\left[\mu D(p_1, p_2(c_H)) + (1-\mu) D(p_1, p_2(c_L))\right]}_{\mathbb{E}_i[D_1(p_1, p_2(c_2))]},$$

where the expectation is taken with respect to firm 1's belief μ_i. Likewise, profits of firm 2 with cost c_τ are:

$$\pi_\tau(p_1, p_2) = (p_2 - c_\tau) D_2(p_1, p_2).$$

Finally, denote by $p_1^i \in \operatorname{argmax}_{p_1 \geq 0} \pi_1(p_1, p_2^i)$, and $p_\tau^i \in \operatorname{argmax}_{p_\tau \geq 0} \pi_\tau(p_1^i, p_\tau)$ such that $p_2^i(c_\tau) := p_\tau^i$, where the superscript refers to firm 1's belief μ_i. Assumptions on $D_j(\cdot)$ guarantee the existence (and uniqueness) of these prices.

Proposition 6. *Suppose that $D_j(\mathbf{p})$ satisfies $\frac{\partial D_j(\mathbf{p})}{\partial p_j} < 0$, $\frac{\partial D_j}{\partial p_k} \geq 0$ and $\frac{\partial^2 D_j}{\partial p_j \partial p_k} \geq 0$, $k \neq j$, $j = 1, 2$. Then, the profit function of firm 1 is increasing and convex on this firm's belief about firm 2's type, and firm 2's profit is decreasing with respect to this belief.*

An immediate corollary of this proposition is that the analysis we carry out in Section 3 applies almost verbatim to the current version of the baseline model. Intuitively, this occurs because firms' decisions about ratification are not affected by the specific form of core market profits. As a result, continuation equilibria previously constructed remain valid, and so do the resulting expected profits associated with firm 1's invitation to form an alliance. Moreover, the fact that firm 1's expected profit is convex in this firm's beliefs implies that firm 1 strictly prefers the chance to learn firm 2's private information even if it knows that the development of its innovation is unprofitable.

5. Conclusions and final remarks

In this paper, we investigate the implications of information leakage on the firms' incentives to join strategic alliances and the nature and intensity of competition in the product market in which firms compete. We derive conditions under which it is optimal for the focal firm to devise unprofitable alliances to learn its competitor's sensitive private information. Our findings do not depend on the existence of a cost-reducing parameter, as has been customary in the literature. Thus our findings support the idea that firms without the adequate capacity to absorb knowledge from their partners can still benefit from observing confidential information about their competitors. Our findings continue to hold even if the negatively affected firm can pursue compensation for the (alleged) damage that its partner's deceptive behaviour may have caused. Therefore, imposing fines (or compensations) to deter this deceptive practice may not be effective in environments where proving that information leakage has occurred is difficult to prove.

Our theoretical analysis helps uncover an interesting mechanism through which information leakage affects firms' incentives to participate in a strategic alliance. In our model, learning sensitive information about a competitor alters the information structure under which partners compete, affecting the private rents that firms expect to earn when collaborating. Thus, neither the firms' capacity to create value from cooperation nor their ability to appropriate the collaborative profits determine firms' incentives to join a strategic alliance. Instead, it is information leakage what determines the interplay between collaboration and competition and hence, the decision to pursue a strategic alliance.

[25] These assumptions together with constant production costs, are sufficient to guarantee that firm j's marginal profits are increasing in the competitor's price and hence, best response functions are strictly upward increasing. See Vives (1999) for a detailed discussion on this topic.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ejor.2023.10.004.

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