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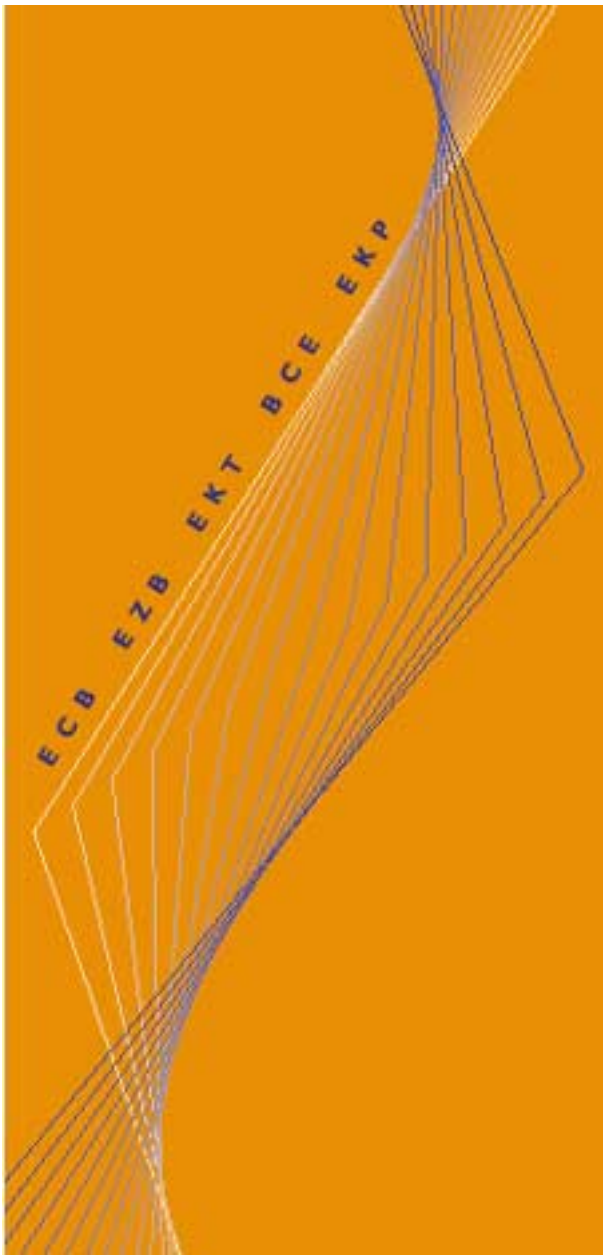

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BY

DIEGO RODRIGUEZ PALENZUELA

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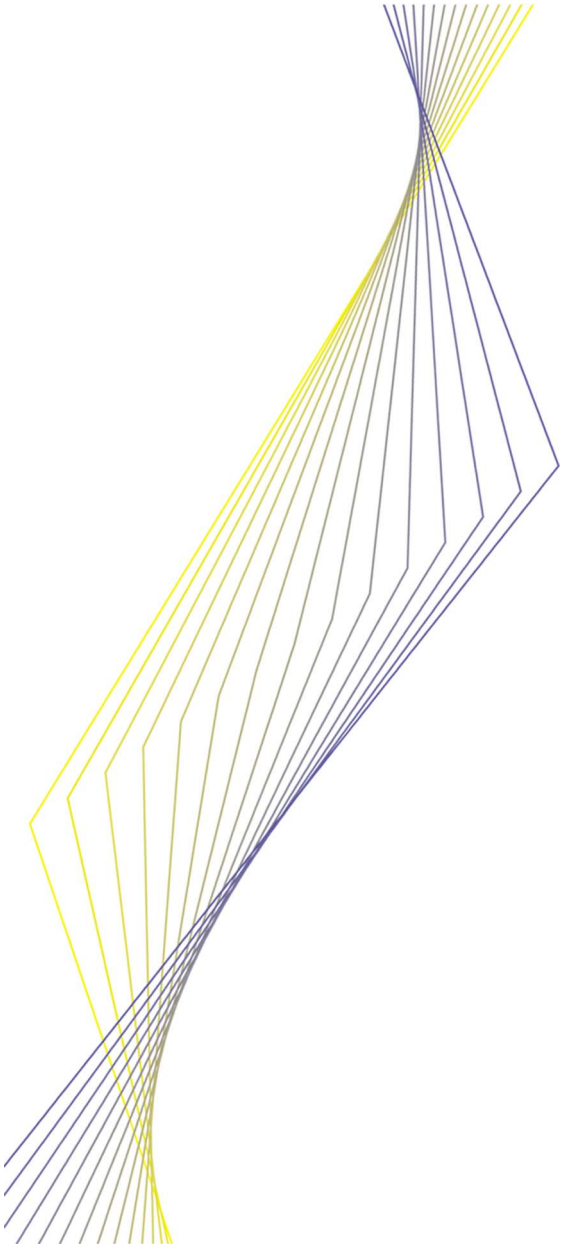

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DIEGO RODRIGUEZ PALENZUELA*

February 2001

* *A previous version of this paper circulated with the title: "Endogenous Spillovers, Increased Competition and Reorganizational Waves". The opinions expressed in it do not reflect views of the European Central Bank but those of the author.*

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ISSN 1561-0810

Contents

Abstract

We build on the imperfection of intellectual property rights as the central motivation for the organization of firms. There are several characteristics specific to a theory of the firm grounded on the absence of intellectual property rights: monetary incentive schemes arise naturally as a element of the organization and strategy of the firm, since profits are verifiable; firm's boundaries and the degree of centralization respond to the same economic principle; the sunk cost of physical assets plays a role of "anchoring" non-patentable knowledge inside the firm, improving the appropriability of intellectual capital. Moreover, the model implies that "small" changes in primitives (particularly small reductions in entry costs) may have drastic implications in organizations, inducing firms to shift from a strategy of building up physical capital, which improves appropriability, to a strategy of reliance on employee "empowerment" (under which employees combine equity holding with being fully informed). The former strategy is characterized instead by flat wages and by employees' restricted access to the intellectual capital of the firm. The model may shed light in the theoretical explanation of observed industrial restructuring.

Non-technical Summary

Recent empirical work increasingly points to imperfect intellectual property rights as an important determinant of firms' organization and integration strategy.

This paper argues that imperfect intellectual property rights, and the ensuing importance of reducing information leakages outside innovating firms, are at the core of recent trends towards increased decentralization of firms. We further argue that in this process of decentralization firms change the mechanisms they use in order to achieve protection of intellectual property. In particular, parallel to decentralization, firms move from the reliance on *secrecy within the firm* and the large-scale investment in inanimate assets (which discourage competition and therefore also information leakages), to a strategy of information sharing inside the firm and intensive use of employees' stock options and monetary incentive schemes (which facilitates the retention of information inside the firm). This implies that firm decentralization correlates with a transformation in the process of employees' skill acquisition within the firm, which is accelerated under decentralization.

Imperfect intellectual property rights are relevant for firm organization because they imply that entrepreneurs face a threat of information leakages, initiated typically by employees inside the firm, towards external agents. The interest of the entrepreneur is therefore to efficiently distort the scope of collusive communication between firm's members and non-members. If communication takes the form of direct collusive communication between employees and non-members, the entrepreneur has an interest in undertaking strategic actions and investments that erode the collusion stake.

We consider three types of entrepreneur's actions oriented to retaining intellectual property in the firm through the erosion of collusion stakes: employees' incentive schemes, the strategic investment in physical assets (capacity) and the extent of information releases to employees by the entrepreneur (which is our characterization of decentralization).

Our main result is that under a sensible specification of the strategic interaction, the strategies of capacity (sinking the cost of physical assets) and centralization (employees are partially informed by the entrepreneur) complement each other, whereas the strategy of incentive schemes is substitute of the other two. This implies that two distinct types of firms predominate: physical assets intensive firms that are centralized and give flat wages to diskilled employees (we label such firms *traditional*), and human capital intensive firms that are decentralized and give strong incentives to employees, which have skills similar to those of the entrepreneur. We label this second type the knowledge firm. An additional implication is that there is a discontinuity in the optimal organizational form as a function of the cost of entry and the level of technological development. Under high entry cost and low technological development the traditional firm is more profitable than the knowledge firm, but, beyond a given treshold, decreases in entry costs or increases in technological development make the organization of the knowledge firm superior to that of the traditional firm.

In terms of implications for public policy, two conclusions are drawn from the analysis. First, the model suggests that restrictions to use stock option schemes and, more generally, restrictions to wage flexibility inside the firm have welfare reducing effects. Second, we find that competition policy (in addition to the conventional effects on price setting by firms) facilitates the promotion of the "knowledge firm", since entry barriers are the leading obstacle for the success of the decentralization strategy.

1 Introduction

A number of structural transformations have been witnessed in the last years in the most developed economies, most notably in the US. Regarding macroeconomic aggregates, the growth of productivity has accelerated since 1995 in the US (see for instance Gordon (2000) for an assessment[1] of the "New Economy"). An increase in the skill premium of wages, which has led to increased wage inequality, has been documented for the US starting at least in the late eighties (Katz and Murphy (1992)). In addition, structural change has been observed in patterns of organization and factor allocation at the firm level. Although such organizational changes at the micro level are much more difficult to quantify than shifts in macroeconomic variables, a number of authors have documented the existence of a trend towards increased decentralization in the organization of firms, which can be traced back to Piore and Sabel (1984). A synthetic but informative account of organizational changes since the 1980s can be found in Rajan and Zingales (1998) and in Aghion et al. (2000). Rajan and Zingales (1998) describe[2] such changes as an increased recurrence by firms to outsourcing and the spinning-off of activities, an increased importance of human capital relative to physical assets and a wide-spread use of monetary incentive schemes inside the firm. Aghion et al (2000) characterize recent organizational change as a move toward flatter organizations, which means fewer hierarchical layers and increased decentralization of decision making in the firm. The decentralized firm replaces vertical (hierarchical) communication channels with horizontal (more informal) ones. An additional transformation is a trend towards increased segregation of employees skills across working places, which has been documented by Kremer and Maskin (1996) for some European countries and the US and by Dunne et al. (1999) for the US. Increased segregation means that the working place becomes an environment where there is lower skill heterogeneity since workers with a given skill level tend to be grouped more often with workers with similar skills.

Some of these major transformations in microeconomic organization and macroeconomic outcomes have received attention in the literature and a number of theories have been proposed to account for them. Productivity growth and the increase in the skill premium have been explained as a consequence of skill-biased technological change (see for instance Krusell et al. (2000)). Increased segregation may be a consequence of assortative matching, as shown by Kremer and Maskin (1996). However, the literature seems to have lagged behind in providing an explanation of the apparent shift in predominant organizational forms at the firm level (which maybe partly due to the obvious difficulties in establishing the relevant stylized facts for the case). Optimally, candidate theoretical explanations of the recent transformations in corporate organization should also contribute (together with other factors like exogenous skill-biased technological change) to explain aggregate growth and wage inequality, since technological progress and employees' income and skills are largely determined in the workplace.

[1] Other recent contributions on the links between productivity growth and technological change and firm organization are Jorgenson and Stiroh (1999) and Greenwood and Jovanovic (1999).

[2] Correspondingly, a characterization of the previously predominant traditional firm is in Chandler (1990).

A satisfactory explanation of recent trends in corporate reorganization that is moreover consistent with the broader picture of macroeconomic developments (higher productivity growth, movements in the skill premium) should combine at least three desirable properties. The first, which is a pre-condition for being able to discuss causes of corporate decentralization, is that the theory uses as a building block a model of firms' boundaries. Secondly, the theoretical framework should provide a well-defined concept of decentralization and moreover should account for increased use of incentive schemes at the lower end of the corporate hierarchy. Third, the theory should predict that firms recur more often to decentralization as a function of changes in exogenous variables that can be related to observables.

Regarding the first condition (use of a theory of the firm), there are good reasons to regard the Arrow-Debreu setting as not fully adequate for this purpose[3]. Some form of agency problem should therefore be a central element of the argument. A consistent framework to model the boundaries of the firm is provided by the property rights research agenda of Grossman, Hart and Moore[4]. Within this line of research, Grossman and Helpman (1999) derive a model where firm's boundaries are determined endogenously together with market equilibrium. But, arguably, the theory of firm's boundaries based on contract incompleteness has difficulties in accommodating the existence of explicit monetary incentive schemes inside the firm, since the theory builds on the assumption of unverifiable profit streams. In addition, as argued by Holmström and Roberts (1998), other foundations of the theory of the firm different to ex post renegotiation may be possible, which may complement the property rights view. In this paper we build on ideas related to the role of the firm in knowledge transfers in a context where ex post renegotiation is absent, in the spirit of Arrow (1975)[5]. Nonetheless, the precise failure of intellectual property rights that we invoke is different to the one in Arrow (1975), which is based on the difficulties in trading information in a setting of asymmetric information. We focus instead on what may be characterized as a failure of trade secret law or absence of copyrights. In our setting[6], even if information is complete, trade of knowledge is distorted by parties' inability to contractually prevent the posterior re-sale of the traded knowledge to third parties.

Regarding the second ingredient in a theory of increased decentralization (a model of delegated authority), the literature provides fewer elements than in the previous case, as stressed for instance by Hart (1995). Important contributions in this respect are Aghion and Tirole (1997) and (1995), which develop a theory of decentralization based on the amount of information that units in a firm are required to share with top management [7]. For the unit, having to report little information acts as a shield against posterior interventions (and expropriations) by the top. Our concept of decentralization (which should be seen as complementary to the previous one) is based precisely

[3] For discussions on the limits of the competitive model as a framework to formulate a theory of the firm see Tirole (1988), Hart (1988), Holmstrom and Tirole (1993) and Aghion et al. (2000).

[4] Hart(1995) has an overview of the property rights theory of the firm. For a discussion on the limitations and adventages of this strand of the literature see Tirole(1999), Maskin and Tirole (1999), and Hart and Moore (1999).

[5] The insight in Arrow (1975) has recently been extended in Anton and Yao (1994) and (1995).

[6] See Rodriguez-Palenzuela (1993) for a related but different treatment of this theme.

[7] See also Stein (2000) for a very related theory of decentralization based on the nature of information transfered in the decision-making process.

on the reverse principle, but is close in spirit. We define a firm as fully decentralized when top management provides all its knowledge to the employees and the firm is centralized when the top transfers only a fraction of its knowledge to employees. In a setting of imperfect intellectual property rights there is a clear tension between giving information to employees (and risking leakage of sensible information) and retaining information at the top (and reducing employees' skills).

This paper lays out a simple model aimed at contributing to explain trends in organizational form and that attempts to satisfy the conditions discussed above. By making the imperfection of intellectual property rights the center of the analysis we are able to develop an argument under which the boundaries of the firm are well defined and firm's profits are verifiable (so that incentive schemes associate to profits are well defined)[8].

The relevance of imperfect intellectual property rights seems to be increasingly enhanced by recent empirical work. Cohen et al. (2000) conclude from a survey to 1478 R&D research laboratories in the US that *secrecy and lead time are the most important mechanisms [in comparison to patents] to protect the profits from invention* [9], since weak intellectual property rights protection is pervasive. Regarding time trends, they find that *for the protection of product innovations, secrecy now seems to be much more heavily employed across most industries than previously.* [10] Additional evidence of the increasing relevance of intellectual property rights issues is Gans et al. (2000), who develop a survey to firms to gather information on the strategies in the Biotechnology sector motivating the small firms' decision to commercialize new products in-house or in collaboration with a large, established firm. They report evidence for imperfections in the "market for ideas" being a cause of in-house development. Interestingly, Gans et al. (2000) and Gans and Stern (2000) document the role that sunk costs of physical assets play in the firm for enhancing the appropriability of the firm's intellectual capital.

The imperfection of intellectual property rights implies that entrepreneurs face a threat of information leakages, initiated typically by employees inside the firm, towards external agents. This undesired flow of information damages the entrepreneur, particularly when the recipient of the information is a competitor. In this environment, an important aspect of management efforts is to fight against, and if possible preempt, undesired outflows of information. Indeed, once the importance of imperfect intellectual property rights has been recognized, the boundaries of the firm can be interpreted as an (imperfect) substitute of intellectual property rights, namely, as a contractual device to achieve separation among those that are given access to sensible information and those for which such information should remain secret.

Imperfect intellectual property rights imply that the interest of the entrepreneur is to efficiently distort the scope of collusive communication between firm's members and

[8] We model a moral hazard in teams under complete (non-renegotiated) contracts (as in Holmstrom (1978)). The moral hazard variable here is employees making offers to coalitions for the purpose of taking information out of the firm.

[9] Cited from the authors, Cohen et al. (2000), abstract and section 3.

[10] Ibidem.

non-members. If communication between employees and competitors takes the form of employees turnover towards competing firms, the entrepreneur engages in setting up barriers to workers' mobility[11]. If communication takes the form of direct collusive communication between employees and non-members, the entrepreneur has an interest in undertaking strategic actions and investments that erode the collusion stake. In this paper we take the view that both channels of communication are relevant in practice, but we focus the analysis on the second of the two channels[12].

The rest of the paper is organized as follows. Section 2 summarizes the model and the main results. Section 3 presents the model. In section 4 we first derive the firm's organization when secrecy can be achieved contractually. We then introduce the possibility of collusion. Section 5 concludes. All proofs are contained in an Appendix at the end of the paper.

2 Summary of Model and Results

We consider three types of entrepreneur's actions oriented to retaining intellectual property in the firm through the erosion of collusion stakes: employees' incentive schemes, the strategic investment in physical assets (capacity) and the extent of information releases to employees by the entrepreneur (which is our characterization of decentralization).

Regarding the first one, since leakage of sensible information deteriorates the strategic position of the firm *vis a vis* competitors, employees' incentive schemes improve their incentives to be secretive with respect to outsiders. The need to give incentive schemes to employees introduces an (endogenous) cost of increasing the number of employees: having more employees holding profit related incentives implies the dilution of stake in the firm[13]. The second deterring action is the investment in inanimate assets. There is an obvious parallel between the role of physical assets to achieve employees secrecy here and to deter entry by a potential entrant in the Industrial Organization literature, namely the fact that capacity investments by the incumbent entrepreneur reduces the returns to entry. The difference is that here the presence of a potential entrant is endogenous and is determined by the existence of collusion between employees and outsiders. As a result, the role of physical assets in our setting is to *anchor* sensible information to the firm, enhancing the protection of the entrepreneur's intellectual property. Finally, the entrepreneur has a margin of action to deter communication in the degree of secretism he exerts with respect to employees: the cost of having

[11] This is the route taken by Rajan and Zingales (2000). It should be stressed that theirs is a model of incomplete contracts: in addition of having employees being able to quit the firm -taking away sensible knowledge- they assume the unverifiability of firm´s accounts. Both features make Rajan and Zingales (2000) very different to our model in this paper.

[12] Although it is clear that such collusive communication is unlawful behavior, it may as well be hard to detect by the court, particularly if the return to communication for employees is delayed in time.

[13] This follows for instance under limitted liability constraints (which imply a cost of setting employees in an incentive scheme) or if the firm's budget constraint cannot be "broken" (i.e., it is not possible or there are no benefits to having ex post a wage bill greater than firm's revenues -here we follow this second route).

employees incompletely informed (diskilling) may be compensated by the employees' reduced ability to leak out information.

In this paper we lay out a tractable model where the entrepreneur can engage in these three strategies to enhance appropriability of intellectual property. Our main result is that under a sensible specification of the strategic interaction, the strategies of capacity (sinking the cost of physical assets) and centralization (employees are partially informed by the entrepreneur) complement each other, whereas the strategy of incentive schemes is substitute of the other two. This implies that two distinct types of firms predominate: physical assets intensive firms that are centralized and give flat wages to diskilled employees (we call such firms *traditional* firms), and human capital intensive firms that are decentralized and give strong incentives to employees, which have skills similar to those of the entrepreneur. We label this second type the *knowledge* firm. An additional implication is that there is a discontinuity in the optimal organizational form as a function of the cost of entry and the level of technological development. Under high entry costs and low technological development the traditional firm is more profitable than the knowledge firm, but, beyond a given treshold, decreases in entry costs or increases in technological development make the organization of the knowledge firm superior to that of the traditional firm.

Intuitively, the argument is the following. Take in the first place the case with high entry costs and consider the level of investment in physical assets that is high enough so that the scope of collusion becomes negligible. The entrepreneur can in this case hire as many employees as needed and pay them flat wages without fear of information leakages. Since endowing employees with information increases the chances of collusion, the abundance of workers makes it acceptable to keep them relatively uninformed and inefficient. At the other extreme, consider a setting where the sunk costs of physical assets are negligible. Physical assets then do not contribute to retaining information in the firm. Incentive schemes strategies are now the crucial element to achieve secrecy. Considerations of dilution of stake in the firm become important: the firm must therefore economize in the number of employees, that should be made as efficient (informed) as possible.

Linking the main argument of the model with the initial discussion on structural transformations in the US, is suggestive of the following interpretation. Increased competition arising from international trade together with technological developments that increased the importance of human capital relative to physical capital in the 1980s (like developments in information technology and in general the increased scope for radical innovations), eroded the strategic value of physical assets to anchor inside the firm knowledge not protected by intellectual property rights and therefore to develop innovations in large established firms. Predominant organizational forms shifted towards achieving intellectual property protection through employee "empowerment" (the combination of full release of information to employees with wide equity-holding by employees), with direct implications: an increase in the level of employees' skills and the posterior step increases in productivity growth and skill premia in the transformed firms.

3 The Model

The market for product Q meets in two time periods, $t = 1, 2$. Each period the inverse demand function of the good is $P_t(Q_t) = D_t - Q_t$. The good is supplied by $i = 1, .., M_t$ firms and $Q_t = \sum_{i=1}^{M_t} Q_t^i$.

Production costs depend on the number n_t^i and the skill level θ_t^i of the employees in firm i. Let $j = 1, .., n_t^i$ be the index of employees in firm i and let q_t^{ij} the quantity produced by each employee (so that $Q_t^i = \sum_{j=1}^{n_t^i} q_t^{ij}$). We assume for simplicity quadratic production costs for employee j in firm i: $c(\theta_t^i, q_t^{ij}) = \frac{1}{2\theta_t^i}(q_t^{ij})^2$. The role of skill θ is to reduce the employees marginal cost of production. Total costs in firm i is: $C^i = \sum_{j=1}^{n_t^i} c(\theta_t^i, q_t^{ij})$.

Supply conditions and the timing of production are not equal in periods 1 and 2. The important difference between periods is that in period 1 there is one incumbent firm only and in period 2 competition is endogenously determined.

First period $t = 1$

In the first period there is an entrepreneur with skill level $\bar{\theta}$. The entrepreneur sets up the incumbent firm $i = 1$: she hires n_1^1 employees and decides the level of information related to the skill that she wants to disclose to them: $\theta_1^1 \in [0, \bar{\theta}]$ (so that partial disclosure ($\theta_1^1 < \bar{\theta}$) is possible) and the allocation of production $\left(q_1^{11}, .., q_1^{1n_1^1}\right)$. Employees are given incentives schemes that specify payments contingent on firm's performance in each of the two periods, $w^j(\pi_1^1, \pi_2^1)$ where π_t^i are firms' profits. Finally, the sale of Q_1^1 by firm 1 as a monopolist takes place.

Second period $t = 2$

The incumbent firm has an advantage at production and decides the number of employees n_2^1 and the total quantity produced Q_2^1 before potential entrants.

After production of Q_2^1 each of the n_1^1 senior employees (those that were present in the firm at $t = 1$) has the ability to secretly make one take it or leave it offer to any set of agents (the collusive coalition) specifying side-payments among coalition members and the release of employee j's skill level in the previous period (which equals θ_1^1) to any subset of members of the collusive coalition. If all members of the collusive coalition accept j's offer, trade takes place.

If collusion takes place, informed outsiders become entrants by sinking an entry cost $F = F_o - \theta_1^1$, which is assumed to be linear for simplicity. Entrants decide the quantity $Q_2^i, i \neq 1$ taking the incumbents quantity as given. Finally, the market for product Q meets at the end of the second period.

The timing of the strategic interaction is summarized as follows.

$t = 1$

1. The incumbent sets up firm $i = 1$.
2. Final market for Q meets.

$t = 2$

1. The incumbent sets up firm $i = 1$.
2. Senior employees make collusive offers. Offers accepted or rejected.
3. Entry by informed outsiders takes place.
4. Final market for Q meets.

We assume that agents are not liquidity constrained, so that teams are organized in order to maximize members' joint surplus. Information is complete. In particular and regarding skill θ, we assume that agents can disentangle the knowledge that enhances skill levels from the knowledge that allows the valuation of the skill level. This implies that if agent j has skill level θ she can proof to agent k that j's skill level is θ without increasing the skills of agent k. Finally, collusive communication and side-transfers among employees and outsiders are not verifiable by a court.

4 Results

In this section we first derive the entrepreneur's organization when communication between her employees and outsiders can be avoided contractually. We then derive the optimal organization of the firm when collusion between members and non-members is possible.

4.1 First-Best allocation

The entrepreneur's program under no possibility of collusion with outsiders is:

$$\max_{\left\{n_t^1, \theta_t^1, q_t^{1j}\right\}} \sum_{t=1,2} \left\{ P_t\left(Q_t^1\right) Q_t^1 - \sum_{j=1}^{n_t^1} \frac{1}{2\theta_t^1} \left(q_t^{1j}\right)^2 \right\} \tag{1}$$

which has a straightforward solution:

Result 1: under verifiable communication, in equilibrium there is:

- Only one firm at $t = 1$ (the entrepreneur's firm $i = 1$)
- Full information sharing: $\theta_1^1 = \bar{\theta}$
- $q_t^{ij}(*)$ is arbitrarily small and n_t^1 is arbitrarily large. Total costs tend to:

$$c_q\left(\bar{\theta}, 0\right) Q_t^1(*) = 0,$$

- The optimal quantity $Q_t^1(*)$ is given by the monopolist solution under zero cost: $Q_t^1(*) = \frac{D_t}{2}$.

The first-best contract (for the coalition of the entrepreneur and her employees) is mute on the team members' incentives scheme $w^j(.,.)$. When the entrepreneur has the possibility to restrict communication between members and non-members, this restriction is used to avoid entry and competition in the final market.

4.2 Collusion with outsiders

Consider in the first place the entrepreneur's objective function. From the absence of liquidity constraints the entrepreneur maximizes her firm's surplus plus the employees rents derived from information sales. This is given by:

$$\max_{\left\{n_t^1,\theta_t^1,q_t^{1j}\right\}} \sum_{t=1,2} \left\{ P_t\left(Q_t\right) Q_t^1 + \sum_{j=1}^{n_t^1} \left(r_t^j - \frac{1}{2\theta_t^1}\left(q_t^{1j}\right)^2 \right) \right\} \tag{2}$$

where r_t^j are rents from collusive communication obtained by employee j in period t.

There are two differences between expression (2) and entrepreneur's objective function under verifiable communication in (1). The first one is that in (2) the amount supplied by the incumbent firm Q_2^1 and total market supply Q_2 in the second period are not necessarily the same. The second difference is that under no liquidity constraints the entrepreneur captures the possible gains from employees' collusion with outsiders, given by the term r_t^j in (2). These differences arise from the possibility of collusive communication between members of the entrepreneur's network and non-members. Communication ultimately determines entry. The entrepreneur affects entry conditions through the strategic organization of the firm.

In order to derive the solution to (2) we first characterize two properties of the solution in Lemmas 1 and 2, derive the optimal incentive scheme in period 2 and finally characterize comparative static properties of the equilibrium with respect to entry costs (F_o) and the level of expertise introduced by the entrepreneur ($\overline{\theta}$).

4.2.1 Production at t = 2

In the second period information leakages are not a concern for any firm (since there are no subsequent periods) and therefore there are no productive distortions. The following results is straightforward.

Lemma 1: *All firms in period $t = 2$ produce Q_2^i efficiently: for $i = 1, .., M_2$, $q_2^{ij} \to 0$, $\theta_2^i = \overline{\theta}$ and $n_2^i \to \infty$.*

Second period costs are therefore negligible in all firms. Firms that enter in the second period simultaneously react to the incumbents production at $t = 2$. If firm $i \neq 1$ expects the other firms to produce Q_2^{-i}, i produces $Q_2^i\left(Q_2^{-i}\right) = \frac{1}{2}\left(D_2 - Q_2^{-i}\right)$ units. Lemma 1 shows that the incumbent is better off deterring entrants' production at $t = 2$.

Lemma 2 : *In equilibrium, collusive communication is deterred.*

Proof: in the Appendix

Since there are entry costs and entrants are not more efficient than the incumbent, the only role of allowing entry by some firms is to introduce competition so as to discourage further entry by additional firms. Lemma 2 shows that the incumbent is better off playing this entry-deterring role himself.

4.2.2 Optimal incentive schemes

In order to identify the incumbent's optimal deterring strategy, consider the employees' incentive compatibility constraint for secrecy. From Lemma 1 the relevant condition for information leakages that we should consider is the one governing the decision to diffuse by one employee only. Clearly this condition is not affected by employees' retribution in the first period, which is a bygone at the collusion stage. Let $\pi_t^i(M_t-1, Q_t^1)$ be firm i's profits (gross of entry costs) when there are M_t-1 entrants and the incumbent has produced Q_t^1. The relevant secrecy condition is given by:

$$w_2^j(\pi_2^1(0, Q_2^1)) \geq w_2^j(\pi_2^1(1, Q_2^1)) + \pi^2(1, Q_2^1) - F(\theta_1^1) \tag{3}$$

The left hand side of (3) is the employee's stake in the incumbent firm when she refrains from selling information. The right hand side is that stake when she sells the skill to an outsider, plus the gains from entry, which are captured by the information seller.

Intuitively, the secrecy condition (3) reveals that there are three types of strategies available to the incumbent firm in order to deter communication between employees and outsiders. The first type can be labelled a physical assets strategy: By increasing the second period quantity Q_2^1 the incumbent firm hurts potential entrants more than what it hurts itself. The former effect is given by $\partial\pi^2/\partial Q_2^1$ which is typically more negative than the latter effect which is related to the effect of capacity on incremental profits: $\partial\left(\pi^1\left((0, Q_2^1)\right) - \pi^1(1, Q_2^1)\right)/\partial Q_2^1$. Physical assets play the role of improving appropriability conditions inside the firm.

The second type of deterring strategy is secrecy. By engaging in partial disclosure in her own firm at $t = 1$ (i.e., $\theta_1^1 < \overline{\theta}$) the entrepreneur increases the entry cost of an outsider that communicates with an employee, which reduces the collusion stake. Finally, the third type of strategy are incentive schemes. Secrecy constraint (3) is relaxed if $\Delta w_2^j \equiv \left(w_2^j(\pi_2^1(0, Q_2^1)) - w_2^j(\pi_2^1(1, Q_2^1))\right)$ is large. Lemma 3 shows that, in spite of employees unlimited liability, the threat of collusion among stake holders (which includes non-employees) prevents making Δw_2^j arbitrarily large. The secrecy constraint will be binding in equilibrium.

Lemma 3 : *Uninformed agents are given no stake in the incumbent's firm. Moreover, optimal incentives schemes are linear in incumbent's firm profits.*

Proof: in the Appendix

The first part of the claim in Lemma 3 (only employees are stake-holders) is that there are no gains of creating a sink of ex ante contributions, that is distributed ex post depending on performance. This result hinges on the assumption that money cannot be destroyed in any case ex post. The argument is that if a third-party who is not informed about θ is made residual claimant to the sink under information leakages,

this creates incentives for employees to make collusive offers (that are accepted) to a coalition that includes the claimant to the sink. Secrecy fails.

The second part of the claim (linearity is optimal) intuitively follows from the fact that built-in non-linearities in the incentive scheme originates arbitrage opportunities at the collusion game, violating secrecy. Absence of liquidity constraints together with linear incentive schemes are interpreted as employees purchasing firm's equity at the outset of the employment relationship. In particular, the result is that it is optimal to have equity evenly split among senior members of the firm ($w_t^j = \pi_t^j / n_1^1$ for all j and t).

Given linearity, the secrecy constraint can be rewritten as:

$$\frac{1}{n_1^1} = \frac{\max\{\pi_2^2(1, Q_2^1) - F(\theta_1^1), 0\}}{\pi_2^1(0, Q_2^1) - \pi_2^1(1, Q_2^1)} \equiv r(\theta_1^1, Q_2^1) \geq 0 \tag{4}$$

which is satisfied with equality in equilibrium since hiring one more employee without violating (4) always increases profits.

4.2.3 Optimal corporate organization.

From equality (4), the objective function of the incumbent firm is:

$$\max_{\{\theta_1^1, Q_1^1, Q_2^1\}} V(\theta_1^1, Q_1^1, Q_2^1) = \{\pi_1^1(0, Q_1^1) - \frac{1}{2\theta_1^1}(Q_1^1)^2 r(\theta_1^1, Q_2^1) + \pi_2^1(0, Q_2^1)\} \tag{5}$$

where $r(\theta_1^1, Q_2^1)$ is defined in (4).

Comparison of (1) and (5) reveals three trade-offs due to information spillovers. Firstly, regarding knowledge diffusion, there is a motivation to release information to reduce costs. But transparency inside the firm implies facilitating entry through employees collusion (since $F_\theta < 0$, r_θ in (5) is positive). Secondly, regarding firm size, there is a cost reduction motivation to hire more employees in the first period. But increasing first period employees (everything else given) increases dilution of members' stakes, facilitating collusion. Finally, regarding capacity Q_2^1, there are benefits of increasing capacity in the second period (collusion stake is reduced). But increasing capacity reduces the incumbent profits, as prices drop below optimal levels.

Solutions to (5) follow into two possible categories, depending on whether the term $r(\theta_1^1, Q_2^1)$ is positive or zero[14] at the solution. The following definition will be used:

Definition 1 *If in equilibrium $r(\theta_1^1, Q_2^1) = 0$, the incumbent firm is called a "traditional" firm . Otherwise it is called a "knowledge-firm".*

We first characterize each type of solution and then show that under large entry costs the incumbent firm is traditional and under low entry costs it is a knowledge firm.

[14] r is always non-negative

The traditional firm. The program of the traditional firm is

$$\max\{\pi_1^1(0,Q_1^1) + \pi_2^1(0,Q_2^1)\},\ \textit{subject to}:\ r(\theta_1^1,Q_2^1)=0$$

The important point is that the traditional firm does not distort first period production: by making collusion stake vanish in the second period, collusion is deterred even if employees have no stake in the firm. The collusion stake vanishes only if Q_2^1 is sufficiently high (overproduction) and θ_1^1 is sufficiently low (secrecy). This is formally shown in:

Lemma 4 : In the traditional firm there is under-provision of skills, $\theta_1^1 = \underline{\theta}$ and overproduction in the second period, $Q_2^1 > Q_2^1(*)$.

Proof: in the Appendix

The knowledge firm corresponds to interior solutions (with respect to Q_2^1) of (5). Although such an interior solution may not exist, if it exist it satisfies:

Lemma 5 : *The knowledge firm engages in overproduction:* $Q_2^1 > Q_2^1(*)$ *and has a small number of employees in the first period, compared to the first best:* $n_1^1 > n_1^1(*)$.

Proof: in the Appendix

The knowledge firm has greater pressure to disclose information since it is limiting the number of employees in the first period, which exacerbates first period production inefficiencies. In particular, we show that if entry costs are sufficiently low, the knowledge firm engages in full information disclosure to employees and moreover the knowledge firm overperforms the traditional firm. On the contrary, if entry costs are sufficiently high the traditional firm engages in secrecy (minimal information disclosure) and it overperforms the knowledge firm. This is summarized in Proposition 1. Let $\hat{F}_o\left(\overline{\theta}\right) \equiv \overline{\theta} + \left(\frac{D}{4}\right)^2$. $\hat{F}_o$ is the lowest level of the entry costs component compatible with secrecy under first best capacity and full information release inside the firm. Clearly, the non-trivial cases to consider correspond to $F_o < \hat{F}_o$.

Proposition 1: *There are two values* $(\overline{F}_o, \underline{F}_o)$ *with* $\underline{F}_o < \overline{F}_o < \hat{F}_o$*, such that, if* $F_o > \overline{F}_0$ *then the solution satisfies:* $\theta_1^1 = \underline{\theta}$*,* $r(\underline{\theta}, Q_2^1) = 0$ *(i.e., the firm is "traditional"). If* $F_o < \underline{F}_0$ *then at the solution:* $\theta_1^1 = \overline{\theta}$ *and* $r(\underline{\theta}, Q_2^1) > 0$ *(i.e., it is a "knowledge firm"). Moreover, for any non-trivial value of* F_o*, there is a value* $\overline{\theta}$ *sufficiently high such that the knowledge firm dominates the traditional firm and* $\theta_1^1 = \overline{\theta}$.

Proof in the Appendix.

The interpretation of Proposition 1 is that the traditional firm is more efficient at reducing first period costs, since it benefits from the increasing marginal costs technology by hiring "many" marginal employees. The traditional firm can accomplish this since it attains secrecy even under full stake dilution. On the other hand, the traditional firm is restricted in general to overproduce: to preempt communication while

giving employees zero stake, it commits to produce beyond the revenue maximizing level, reducing profits. The overall efficiency of the traditional firm depends on entry costs being high. High entry costs facilitate the preemption of communication.

The knowledge firm is less cost efficient since employees work at marginal costs bounded away from zero. The benefit of the knowledge firm is not necessarily that it produces output relatively closer to the monopolist revenue maximizing output. Rather, the benefit of the knowledge firm is that it is robust to the reduction of entry costs. In particular, the knowledge firm yields positive profits from first stage production when technological entry costs are zero (whereas the traditional firm yields zero profits from second stage production in this case). This is because the knowledge firm hinges on the principle of keeping "small" teams (although not necessarily small output -relative to the traditional firm) so as to facilitate secrecy in the original team.

In summary, high entry costs favor the "communication preemption strategy", whereas the profits from the "small team strategy" are robust to nil entry costs. Moreover, a greater level of expertise introduced by the entrepreneur in the first place ($\overline{\theta}$) favors the knowledge firm strategy.

Allowing the demand function change over time better illustrates the efficiency of the traditional firm to protect present rents relative to future rents and correspondingly the superiority of the knowledge firm to protect future rents at the sake of present rents. This is shown in:

Proposition 2: *Let $D_1 \neq D_2$: If the maturity of the industry $\mu \equiv \frac{D_1}{D_2}$ is high enough the traditional firm dominates the knowledge firm. If μ is low enough (the industry is immature enough) the knowledge firm dominates the traditional firm.*

Since the traditional firm distorts relatively more the second period profits, it is preferred when first stage production is relatively more important. We interpret this finding as a relative advantage of the traditional firm in mature sectors. Symmetrically, since the knowledge firm distorts relatively more the allocation of first stage production, it is preferred when second stage market is larger than the first (i.e., when the industrial sector is immature).

5 Conclusion

In this paper we take a different approach than the incomplete contracts literature to model firm's boundaries and internal organization. We build on the imperfection of intellectual property rights as the central motivation for the organization of firms. The importance of this topic has been recognized since Arrow (1975) and has received increased attention in the empirical and theoretical literatures in the last years. We argue that there are a number of appealing characteristics of a theory of the firm grounded on the absence of intellectual property rights and that such theory complements well the incomplete contracts approach (particularly when applied to innovation intensive environments).

The main characteristics of the model of imperfect intellectual property rights that we lay out are the following. First, monetary incentive schemes arise naturally as an element of the organization and strategy of the firm, since profits are verifiable. Second, firm's boundaries and the degree of centralization respond to the same economic principle of compromising between productive efficiency (releasing knowledge to employees) and the probability of undesired information spillovers. Third, the sunk cost of physical assets plays in the setting a specific role of "anchoring" non-patentable knowledge inside the firm, improving the appropriability of intellectual capital. Finally, the model implies that "small" changes in primitives (particularly small reductions in entry costs) may have drastic implications in organizations, inducing firms to shift from a strategy of building up physical capital, which improves appropriability, to a strategy of reliance on employee "empowerment" (under which employees combine equity holding with being fully informed). The former strategy is characterized instead by flat wages and by employees' restricted access to the intellectual capital of the firm. The model may shed light in the theoretical explanation of observed industrial restructuring.

Two main policy implications may be drawn from the theory. First, the model suggests that restrictions to use stock option schemes and, more generally, restrictions to wage flexibility inside the firm -like collective bargaining arrangements- have welfare reducing effects. Incentive schemes and payment policies are an important instrument for the retention of the intellectual capital of the firm and therefore for the entrepreneur's ability to fully internalize the returns to innovative activities. There should be therefore welfare gains from achieving redistributive social policies through specialized instruments like income taxation alone, as opposed to a situation where several policy instruments (income taxation, collective bargaining) -some of which create allocative distortions- overlap.

The second policy implication relates to the importance of knowledge externalities, which occurs if the knowledge produced in firms has social value in addition to its private value within the firm. If knowledge externalities are sufficiently important, centralized configurations where employees do not access to the knowledge stock of the entrepreneur are inferior in terms of welfare to decentralized organizations, where knowledge is widely transferred. In sectors where knowledge externalities are believed to be sizeable, policy action should aim, with particular strength, at promoting competition and eliminating entry barriers. Competition policy facilitates the conditions to promote the "knowledge firm", since decentralization promotes a faster diffusion of knowledge while still contributing to the appropriability of the firm's intellectual capital.

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Appendix

Proof of Lemma 2:

Consider the game at $t = 2$. Incentive schemes and the number of employees in firm 1 in period 1 are given. For clarity we drop the time subindexes t. Consider an equilibrium with total product quantity $Q > Q^1$ and $M-1$ entrants, $i = 2, .., M$. Let $Q^i(M-1, Q^1)$ be the reaction function of entrant i. By definition: $Q = Q^1 + \sum_{i=2}^{M} Q^i(M-1, Q^1)$. Consider the payoff to a marginal M-th entrant $i = M + 1$. Clearly:

$$Q^i(M, Q^1)P(Q^1 + Q^{-i}(M, Q^1) + Q^i(M, Q^1)) - F(\theta) \leq 0$$

where $Q^{-i}(M, Q^1) = \sum_{i=2}^{M} Q^i(M+1, Q^1)$. Now consider the incumbent's alternative strategy: $\tilde{Q}^1 = Q = Q^1 + \sum_{i=2}^{M} Q^i(M-1, Q^1)$ It is straightforward to show that:

$$\tilde{Q}^1 = Q^1 + \frac{M-1}{M}(D - Q^1) > Q^1 + \frac{M-1}{M+1}(D - Q^1) = Q^1 + Q^{-i}(M, Q^1)$$

The last inequality means that by producing $\tilde{Q}^1$ the incumbent is deterring all entry, since $\tilde{Q}^1$ is greater than the quantity that deters a marginal entrant, which is equal to: $Q^1 + Q^{-i}(M, Q^1)$.

Now, under the original strategy the incumbent obtains less than under the deterring strategy $\tilde{Q}^1 = Q$, since: $Q^1 P(Q) < QP(Q)$. This contradicts the original equilibrium.

■

Proof of Lemma 3:

In what follows we drop the time subscript for all variables that refer to period 2. Define the following variables: $\overline{\pi}^1 \equiv \pi^1(0, Q^1)$, $\underline{\pi}^1 \equiv \pi^1(1, Q^1)$ where $\pi^1(E, Q^1)$ is defined as in the text. Moreover, let $R \equiv \pi^2(1, Q^1)$ and define: $\overline{w}^j \equiv w^j(\pi^1(0, Q^1))$, $\underline{w}^j \equiv w^j(\pi^1(1, Q^1))$

Let $s = 1, .., S$ be an index of the set of stakeholders S (employees plus non-employees) and let σ be a subset of S. Notice that the sufficient condition for the incumbent firm suffering information leakage is: $\min_{\{\sigma\}}\{\sum_{s\in\sigma}(\overline{w}^s - \underline{w}^s) - R\} < 0$. Since income is not destroyed, a necessary condition for the optimal incentive scheme is that it solves:

$$\max_{\{\overline{w}^s, \underline{w}^s\}} \min_{\sigma}\{\sum_{s\in\sigma}(\overline{w}^s - \underline{w}^s)\}$$

$$\sum_{s=1}^{S} \overline{w}^s = \overline{\pi}^1; \quad \sum_{s=1}^{S} \underline{w}^s = \underline{\pi}^1$$

We first prove the first claim for the case when there is one uninformed stakeholder (it is straightforward to extend it to an arbitrary number). With one uninformed stakeholder $s = 0$ there are $n_1^1 + 1$ stakeholders ($s = 0, .., n_1^1$). The optimality condition can be rewritten as:

$$\max_{\{\overline{w}^s, \underline{w}^s\}} \min\{\min_{s=1,..,n_1^1}\{\overline{w}^s - \underline{w}^s\}, \min_{s=1,..,n_1^1}\{(\overline{w}^0 - \underline{w}^0) + (\overline{w}^s - \underline{w}^s)\}\}$$

Let $A^0 \equiv (\overline{w}^0 - \underline{w}^0)$ and consider in the first place the case $A^0 > 0$. Then give the payoff of the uninformed stakeholder to $j = \arg\min_{s=1,..,n_1^1}\{\overline{w}^s - \underline{w}^s\}$. Clearly the solution is improved and $A^0 > 0$ cannot be optimal.
Consider the case $A^0 < 0$. Then redesign the incentive scheme in the following way: $\overline{v}^s = \overline{w}^s + \frac{1}{n_1^1}\overline{w}^0$, $\underline{v}^s = \underline{w}^s + \frac{1}{n_1^1}\underline{w}^0$ and the solution is clearly improved and $A^0 < 0$ is not optimal.
Finally if $A^0 = 0$ this implies no gains of giving stake to an uninformed agent when $\overline{w}^0 = \underline{w}^0 > 0$ (notice that when $\overline{w}^0 = \underline{w}^0 = 0$ the uninformed agent is being given no stake).

The second claim of the Lemma is that incumbent's firm equity is equally split among the set of employees $j = 1, .., n_1^1$ Given linearity, no income destruction and the first part of the claim, the candidate solution is then: $\overline{w}^j = \frac{1}{n_1^1}\overline{\pi}^1$ and $\underline{w}^j = \frac{1}{n_1^1}\underline{\pi}^1$. If this is not a solution, there is a solution $\{\overline{v}^j, \underline{v}^j\}_{j=1}^{n_1^1}$ with:

$$\min_j\{\overline{v}^j - \underline{v}^j\} > \min_j\{\overline{w}^j - \underline{w}^j\} = \frac{1}{n_1^1}(\overline{\pi}^1 - \underline{\pi}^1)$$

Let $j' = \arg\min\{\overline{v}^j - \underline{v}^j\}$. Clearly: $\overline{v}^{j'} - \underline{v}^{j'} > \frac{1}{n_1^1}(\overline{\pi}^1 - \underline{\pi}^1)$. But since j' is the solution it is clear that:

$$\sum_j(\overline{v}^j - \underline{v}^j) > \overline{\pi}^1 - \underline{\pi}^1$$

The last inequality contradicts that $\{\overline{v}^j, \underline{v}^j\}_{j=1}^{n_1^1}$ is a solution.
■

Proof of Lemma 4:
Recall that $F_o < (\frac{D}{4})^2$ so that we are ruling out the trivial case where communication is blocked at the first-best solution of the incumbent firm. Since $r(\theta_1^1, Q_2^1) = 0$, θ_1^1 can be made arbitrarily small without increasing costs. Q_2^1 satisfies:

$$r(0, Q_2^1) = 0 \Leftrightarrow Q_2^1 = D - 2\sqrt{F_o} > D - 2\sqrt{(D/4)^2} = D/2 = Q_2^1\,(*) \qquad (6)$$

■

Proof of Lemma 5:
Consider the first order condition of (5) with respect to θ_1^1 and Q_2^1:

$$\frac{\partial V}{\partial \theta_1^1} = \frac{(Q_1^1)^2}{2(\theta_1^1)^2} r(\theta_1^1, Q_2^1) - \frac{(Q_1^1)^2}{2\theta_1^1} \frac{\partial r(\theta_1^1, Q_2^1)}{\partial \theta_1^1} \tag{7}$$

$$\frac{\partial V}{\partial Q_2^1} = \frac{(Q_1^1)^2}{2\theta_1^1} \frac{D}{2(Q_2^1)^2} + \frac{(Q_1^1)^2 (F_o - \theta_1^1)}{2\theta_1^1} \frac{(-1)(D - 2Q_2^1)}{\frac{1}{2}((D - Q_2^1)Q_2^1)^2} + \frac{\partial \pi_2^1(0, Q_2^1)}{\partial Q_2^1} \tag{8}$$

Consider in the first place the case: $F_o - \overline{\theta} > 0$. Define $z_2 \equiv Q_2^1 - D/2$. It is clear that the last two terms of (8) are symmetric functions of z_2. Since the first term in (8) is always positive, an interior solution satisfies the first claim. The second claim is straightforward since by definition $r(\theta_1^1, Q_2^1) > 0$.

■

Proof of Proposition 1: Consider the case $F_o = \hat{F}_o$. The traditional firm clearly achieves total profits arbitrarily close to first-best profits. The knowledge firm achieves profits strictly smaller than first-best profits since $r(\theta_1^1, Q_2^1) > 0$. Moreover, in the interval $(\overline{F}'_o, \hat{F}_o)$, where $\overline{F}'_o \equiv D^2/4$ the traditional firm profits are constant as a function of F_o. Finally, the derivative of total profits with respect to F_o at $\overline{F}'_o$ is zero and it is negative only for values of F_o strictly lower than $\overline{F}'_o$, since:

$$\frac{\partial V}{\partial F_o}|_{\overline{F}'_o} = \frac{\partial \pi_2^1(0, Q_2^1(*))}{\partial Q_2^1} \frac{\partial Q_2^1}{\partial F_o} = 0 \tag{9}$$

The knowledge firm's profits strictly decrease as F_o decreases in $(\overline{F}'_o, \hat{F}_o$ since $\frac{\partial V}{\partial F_o} > 0$ where V is defined in (5). Therefore there is an interval $(\overline{F}'_o, \hat{F}_o$ with $\overline{F}_o < \overline{F}'_o$ where the traditional firm strategy dominates the knowledge firm strategy.
Consider now the case $F_o = 0$. Traditional firm's profits are: $\pi_1^1(*)$, since $\pi_2^1(0, Q_2^1) = 0$ when F_o=0. The knowledge firm's profits are bounded above by:

$$\max_{Q_1^1} \pi_1^1(0, Q_1^1) - \frac{1}{2\overline{\theta}(Q_1^1)^2 r(\overline{\theta}, Q_2^1(1))} > \pi_1^1(*) \tag{10}$$

which proves the claim.

■

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