Endogenous Spillovers, Increased Competition and Re-organization Waves

Diego Rodriguez Palenzuela *†

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Abstract

We consider an entrepreneur that is the sole producer of a cost reducing skill, but the entrepreneur that hires a team to use the skill cannot prevent collusive trade for the innovation related knowledge between employees and competitors. We show that there are two types of diffusion avoiding strategies for the entrepreneur to preempt collusive communication i) setting up a large productive capacity (the *traditional firm*) and ii) keeping a small team (the *lean firm*). The traditional firm is characterized by its many "marginal" employees that work short days, receive flat wages and are incompletly informed about the innovation. The lean firm is small in number of employees, engages in complete information sharing among members, that are paid with stock option schemes. We find that the lean firm is superior to the traditional firm when technological entry costs are low and when the sector is immature.

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†Correspondence address: Diego Rodriguez Palenzuela / Department of Economics / Universitat Pompeu Fabra / Ramón Trias Fargas 25-27 / 08005 Barcelona / Spain/e-mail: dieguez@upf.es

1 Introduction

This paper relates to two branches of the literature, one of them empirical and the other one theoretical. On the empirical side we take into consideration the claim that an important firms' reorganization process has been taking place, mainly in R&D intensive sectors and mainly in the US[1]. We do not attempt here to summarize this literature. A brief but very informative account of the recent business transformation can be found in Rajan and Zingales (98) and references thereupon. Rajan and Zingales call to the firm that emerged from the corporate restructuring process the *New Corporation* (NC), as opposed, say, to the traditional corporation (TC). The NC is typically less integrated (more prompt to subcontract activity to other firms). A leading feature of the NC are its *flat hierarchies*: the authority chain or informational distance between production employees and managers is shorter in the NC than in the TC. An additional feature of the NC is its wide-spread use of managers and employees stock options and its small size[2]. Importantly, Rajan and Zingales point to increased competition as the leading factor explaining trends in corporate restructuring.

We are concerned as well in this paper with the theoretical literature on firms' boundaries. Possibly the most fruitful approach so far to understand the determinants horizontal and vertical integration of firms goes under the heading of incomplete contracting theory. The Grossman-Hart-Moore (GHM) theory of the firm points to contract renegotiation and the ex ante allocation of property rights as the determinants of asset-specific investments. In particular, property rights are allocated so as to maximize agents welfare, subject to a renegotiation constraint. Summaries of the GHM to the theory of corporate governance can be found in Hart (95) and Zingales (98).

Without taking stock in the theoretical debate on the foundations of the incomplete contracts theory[3], we take here a different route to model the determinants of firms' boundaries determination. We depart of incomplete contracts theory by assuming perfect commitment to contracts and the verifiability of corporate profit streams. Instead, the key ingredient in our model is the ability of firm's members to collude with non-members. Such collusion

[1] See for instance Piore and Sabel's (86) "The Second Industrial Divide".

[2] See for instance Ferguson and Morris (1993) for a description of the typical Silicon Valey firm, the paradigm of the NC.

[3] For the state of the art on a very lively debate see specially Maskin and Tirole (98), Hart and Moore (98) and Segal (98).

is possible if intellectual property rights are absent or imperfectly protected and if the intellectual capital accounts at least partially for the market power of the firm.

We argue that, even if we think of imperfect commitment as a very relevant factor in organizations's design, still some interesting implications can be drawn from models of complete contracts when collusion among firm members and non-members is possible (and in particular if collusion takes the form of trade of information for rents).

We build a simple model in this spirit. The structure of our model is as follows: there is an entrepreneur who introduces a process innovation that reduces the cost of producing good A. In order to benefit from it, the entrepreneur builds a team of collaborators that become (fully or partially) informed about the new process. Contracts are used to avoid leakages of information in the short run (about product A). In particular, contracts are used to avoid communication relating the new process between collaborators and outsiders[4]. This has value for the entrepreneur since such communication leads to entry by the latter and finally to competition in market A.

But innovation is cumulative and it leads to a subsequent application: product B that can only be discovered by agents with knowledge of product A. There are two considerations to make. First, although trade secret law protects intellectual property rights related to current innovations, it is difficult for an innovator to avoid leakages of information that relate potential future innovations (product B). Second, the entrepreneur is negatively affected by leakages of information between collaborators and outsiders for appropriating the returns to innovation from the subsequent product, B. The contractual failure follows from the inability to restrict communication between collaborators and potential entrants.

We find that only two distinct strategies emerge for the entrepreneur to limit spillovers: keeping a small team size (the *lean firm* strategy) and overinvesting in physical assets (productive capacity) -the *traditional firm* strategy-, so as to preempt communication between members and non-members. Keeping a small team size implies that, by giving equity to employees, they have lower incentives to collude with outsiders. Since equity is finite, employees keep the knowledge secret only if the team is small enough. Keeping

[4] We will see that in the short run it remains the issue of avoiding diffusion of information between the entrepreneur and non-members. It is realistic to assume that if communication is a moral hazard variable, the entrepreneur -who is informed about the innovation from the beginning- is a candidate to sell collusively information also from the beginning.

a small team has a clear disadvantage: the employees work at a marginal cost higher than the socially efficient one.

Predating communication means that the entrepreneur creates a large productive capacity, so as to eliminate the benefits of entry. Indeed, with a large enough capacity the entrepreneur does not need to give equity to employees, and therefore has no restrictions in setting a large size of her team. With a large team the benefits of low marginal costs when producing little output per employee are realized: the benefit of predating communication through capacity is that production costs are low. The cost is that the necessary capacity is generally an overinvestment with respect to the first-best, what reduces profits.

Our leading result is that increases in industrial competition (decreases in technological entry costs) shift the preferences of the entrepreneur from the traditional firm's "predating communication" strategy to the lean firm's "keeping a small team size" strategy. More precisely, when technological entry costs to the industry are high, the entrepreneur organizes a *traditional* firm. The traditional firm has the following characteristics: the size of the entrepreneur team is large, but employees produce small amounts, are paid flat wages, and are endowed with a smaller skill level than the entrepreneur. Employees do not hold equity of the firm.

On the other hand when technological entry costs are zero, the entrepreneur sets up a *lean firm*. In the lean firm the size of the entrepreneur's team is smaller and employees produce more output than in the traditional team (additionally, employees work more than in the socially optimal allocation). Moreover, in the lean firm employees hold firm's equity.

Moreover, we find that the lean firm is relatively more efficient at protecting rents from future technological developments within the firm, relative to current developments. The traditional firm instead compromises future developments in order to protect current rents from innovations. Our model implies in particular that in growing sectors (where innovation is intense and future innovations have more value than current ones) we expect agent to implement the lean firm strategy, whereas in decaying sectors (where future innovations are less important than current ones), the traditional firm strategy is preferred.

Two more remarks should be made before we introduce our model. One is that what we call the traditional firm corresponds to a corner solution of the entrepreneur's program. Even if entry costs shrink slowly with time, only when they reach a sufficiently small level the entrepreneurs switches to the interior solution (that is, there is a discontinuity in the firm organization variables and entry costs). The second remark is that even if entry costs are fixed, we show that the transition from the traditional to the lean firm follows if the skill level of the entrepreneur is higher than a certain treshold. In particular, if the entrepreneur brings to the industry little knowledge, she sets up a traditional firm, but if she brings a high enough skill level she starts up a lean firm: it is both reductions in entry costs and technological progress that explain the transition from the traditional to the lean firm.

Finally, our model provides a simple potential explanation of the increased wage gap between high skill and low skill workers. The argument is that increased competition and the accumulation of knowledge produce a shift from the traditional firm to the lean firm strategies in a subset of sectors. In lean sectors workers are (for the endogenous reasons stated above) more skilled, work more hours and have greater marginal productivity (and earnings) than in traditional sectors.

The last few years have witnessed an increased interest in model of endogenous R&D spillovers. Most of the theoretical literature has focused on endogenous spillovers arising from employees' turnover across firms. In Rodriguez-Palenzuela (98a) (R-P (98a)) spillovers arise through collusive trade between firm's members and non-members (turnover does not need to occur for knowledge to diffuse across firms). The leading difference[5] between this paper and R-P (98a) is that in the latter paper physical assets are not introduced: the entrepreneur can not engage in the strategic investment of physical assets in order to protect intellectual property rights. In this paper we analyze precisely this latter role of the control of physical assets, together with the strategic role of other corporate organization variables like payment systems and the employee size of the firm.

The rest of the paper is organized as follows. Section 2 presents the model. In section 3 we first derive the firm's organization when secrecy can be achieved contractually. We then introduce the possibility of collusion. We show that there is a corner solution (that we label the traditional firm) and an interior solution (that we label the lean firm). We characterize the two solutions in propositions 1 and 2. In section 4 we compare the profits

[5] Other minor differences are that in this paper the number of team members is discrete and that collusive communication between a team member and a non-member is frictionless (absence of deterministic and stochastic communication costs). Otherwise the 2-stage structure and other features of the models is very similar.

of the traditional firm and the lean firm as a function of entry costs and the skill level introduced by the entrepreneur. We characterize the optimal organization in proposition 3. All proofs are contained in an Appendix.

2 The Model

There is a countably infinite number of agents indexed by $i \in \mathbb{N}$. The game is divided in two main stages:

Initial product stage (A):

We consider an entrepreneur (henceforth $i = 0$) who is the only agent that has done an innovation at an initial stage. Innovating means that $i = 0$ has a skill $\overline{\theta}$ that allows her to produce good A.

The entrepreneur (and more generally, any agent informed about θ) can diffuse the innovation to other agents. We assume that information sellers can engage in a given point in time in two types of communication, that we label *network* or *contractual* and *collusive* communication [6]. Contractual communication means that the entrepreneur trains any number of network members in the skill θ. Collusive communication means that the information seller informs about θ to one[7] agent that does not have an employee status (a non-member).

Communication (contractual or collusive) has no direct costs and it means that an agent i with skill level θ_i transfers knowledge to a less informed agent j with θ_j^0, and as a result of that the skill level of j is increased to a value $\theta_j^1 \in \left(\theta_j^0, \theta_i\right]$. For an agent with skill level θ the cost of producing q units of output (A or B) is simplified to: $c(\theta, q) = \frac{1}{2\theta}q^2$.

We assume that at this initial product stage the collaborators (except the entrepreneur) are not able to communicate information on the skill θ (alternatively, we assume that the entrepreneur is able to preclude such communication).

Follow-up product stage (B):

[6] This is so in general. Yet notice that at stage A the entrepreneur is the only agent that is eligible to sell information.

[7] *One* agent stands for a normalization of a *fixed* but finite number of agents. Collusive communication is more costly than contractual communication in that under collusive communication it is no longer feasible to communicate information about the skill to an arbitrarily large number of agents.

After product Q^A has been sold, there is a discovery of a second application of skill θ. We call this second application *product* B. As opposed to the initial product stage, at the follow-up product stage all agents that had a positive level of the skill θ (and not just the entrepreneur), are able to engage in contractual *and* collusive communication with uninformed agents[8] (we assume in particular that informed agents make *take it or leave it* offers to uninformed agents). Communication is subject to additional restrictions that we introduce bellow.

After diffusion of information on the skill, production and trade of Q^B takes place. We (realistically) assume that incumbent firms (those that produced positive amounts of the initial product A) have a first mover advantage over new firms, that did not produce good A: initially incumbent firms produce good B; subsequently, informed agents that did not produce before decide on entry, firm organization and production of good B. Entry costs $F(\theta)$ depend on the skill level of the entrant. For tractability we assume a linear relationship between entry costs and skill level: $F(\theta) = \max\{0, F_o - f\theta\}$, with $f > 0$.

Finally the market for good B meets. The demand for goods A and B is given by the inverse demand function: $P^m(Q^m) = D^m - \beta Q^m$, for $m = A, B$. At the trade stages agents sink their production from previous periods.

Before introducing the exact timing of the game, we make more precise our assumptions on contractibility, communication and firm organization. We model generically the sale of information by an informed individual (with $\theta > 0$) to less informed individuals. To be precise, let the sequence $i \in \{i\}_{i=0}^{\infty}$ be an index of individuals in the economy and let $n \in \{n\}_{n=0}^{\infty}$ be an index of networks[9] or firms.

At certain points in time informed individuals can engage simultaneously in contract and collusive communication. Collusive communication between seller i and buyer j involves a skill level $\theta(i, j, t)$ transmitted from i to j and a price p_{ij}^t, paid by j to i at time t.

Contract communication in network n involves a subset of N_n^t individuals $\{i_n^t\} \subset \{i\}_{i=0}^{\infty}$, that are the *members* of network n as of time t. Network n

[8] We are capturing the idea that researchers in the firm are diffusing information not related to the *current* R&D project (product A), but related to a *future* product not yet developed (product B). This justifies why trade secret law is assumed to be ineffective.

[9] We use subscripts for networks and superscripts for time periods. For instance, if individual i is a member of network n as os time t, we write i_n^t.

involves as well a set of transfers w between members. The transfers w are possibly contingent on time t. Finally, the network contract defines a profit sharing rule $b\left(i_n^t, \pi_n^t\right)$, where π_n^t are the profits of network n as of time t. $b\left(.,.\right)$ is the fraction of profits to which i_n^t is entitled, as a function of realized profits[10].

A network contract C_n is a set that specifies all contractible variables relating n : the identity of members in all networks, the profit sharing rule, monetary exchanges and quantities to be produced:

$$C_n = \left\{ \left\{ i_n^t \right\}, b\left(i_n^t, \pi_n^t\right), w\left(i_n^t, i_n^s, t, \left\{ i_{n'}^t : n' \neq n \right\}\right), q_{i_n^t}^{t1} \right\}_{s,t=A1}^{B3}.$$

Notice that contract C_n does not depend on any spot[11] communication agreement $\left(\theta\left(ij\right), p_{ij}^t\right)$, nor does it depend on other network n' characteristics, except for the membership list of network n'. Notice that we impose no restrictions on contract C_n.

In summary, we have:

Definition1 : *"Agent i's communicates" means that, as of time t, i sets up contract $C_{n(i)}$, engages in network communication through network $n\left(i\right) = \left\{ i_{n(i)}^t \right\}$ and possibly in collusive communication with agent j.*

The exact timing of decisions is as follows:

$t = A1$: the first entrepreneur "communicates" as defined above[12]. Production takes place.

$t = A3$: trade of good A takes place in the final market[13].

$t = B1$: informed agents "communicate". Firms that produced good A produce good B.

$t = B2$: new firms decide to enter and produce good B. Trade for good B takes place.

$t = B3$: trade of good B takes place in the final market.

[10] We are assuming that cotracts that depend on profits of other firms are not feasible.

[11] C_n does not include either network communication. The contract regulates the members' decisions on information diffusion both inside and outside the firm.

[12] As a result of this there is a set of individuals Ω_{A1} informed about θ as of period $A1$, where $\Omega_{A1} = \left\{ i_{n(0)} \right\} \cup \left\{ j_0 \right\}$

[13] Notice that there is not a $t = A2$ stage. This is to make clear the difference between the A-stage and the B-stage. Only at the B-stage (spcifically at $t = B2$) entry by competitors is possible.

Finally we assume that agents are not liquidity constrained, so that teams are organized so as to maximize members' joint surplus. We are assuming that agents can disentangle the knowledge that produces skills from the knowledge relating the value of those skills: if an agent has skill level θ she can proof to another agent that her skill level is θ without increasing the skills of the other agent. That is, we assume away problems of adverse selection. Finally, collusive trades are unrestricted, except by the assumptions laid above.

3 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 in the model just presented above.

3.1 Verifiable Communication

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

$$\max_{\{C_0\}} \sum_{m=A,B} \left\{ P^m \left(Q_0^m\right) Q_0^m - \sum_{\{i_0^{m1}\}} \frac{q\left(i_0^{m1}\right)^2}{2\theta\left(i_0^{m1}\right)} \right\} \tag{1}$$

It is straightforward to show:

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

- *only one network (the entrepreneur's network $n = 0$)*[14],
- *full information sharing in $n = 0 : \theta\left(i_0^t\right) = \overline{\theta}$ for all $i \in \left\{i_0^t\right\}$,*
- *$q^*\left(i_0^t\right)$ is arbitrarily small and $N_0^t = \left|\left\{i_0^t\right\}\right|$ is arbitrarily large (total costs tend to $c_q\left(\overline{\theta}, 0\right) Q = 0$), and*

[14] Strictly speaking, the entrepreneur is indifferent between forming a single network and outsourcing production to arbitrarily many firms, as long as these firms sell the output exclusively to the entrepreneur before the latter sells in the final market.

- *the optimal quantity Q_{0*}^m is given by revenue maximization:*

$$\textit{for } m = A, B : Q_{0*}^m \frac{dP^m\left(Q_{0*}^m\right)}{dQ_{0*}^m} + P\left(Q_{0*}^m\right) - c_q\left(\overline{\theta}, 0\right) = 0 \Leftrightarrow Q_{0*}^m = \frac{D^m}{2\beta}$$

The first-best contract (for the coalition of the entrepreneur and her employees) is mute on the allocation of stake $b\left(i_0^t, \pi_0^t\right)$ and transfers $w\left(.,.\right)$ among team members. The important point is that when the entrepreneur has the possibility to restrict communication between members and non-members, she uses this possibility to avoid entry and competition in the final market.

3.2 Collusion with outsiders

For expositional clarity we have taken the view that the collusive transactions between members of the initial team and non-members have not direct costs[15].

Consider in the first place the entrepreneur's objective function. From the absence of liquidity constraints the entrepreneur maximizes her team's surplus plus the income from members' information sales (B) at $t = B1$. This is given by:

$$\max_{\{C_0\}} \sum_{m=A,B} \left\{ P^m\left(Q^m\left(C_0\right)\right) Q_0^{m1} + \sum_{\{i_0^{m1}\}} \left(p_{\left(i_0^{m1}\right)j}\left(C_0\right) - \frac{q\left(i_0^{m1}\right)^2}{2\theta\left(i_0^{m1}\right)} \right) \right\} \qquad (2)$$

where $Q^m\left(C_0\right)$ is the total supply[16] of product m $(m = A, B)$ in the market, that depends on the entrepreneur's contract through its effect on endogenous entry.

Notice that there are two main differences between expression (2) and entrepreneur's objective function under verifiable communication in (1). The first difference is that in (2) the amount supplied by the initial team Q_0^m and total market supply $Q^m\left(C_0\right)$ are not necessarily the same. The second one is that under collusion (and no liquidity constraints) the entrepreneur

[15]See Rodriguez-Palenzuela (98) for the analysis of a similar setting with both exogenous and endogenous transaction costs in collusive markets.

[16]In particular: $Q^m\left(C_0\right) = Q_0^{m1}\left(C_0\right) + Q_{-0}^m\left(C_0\right)$ where $Q_{-0}^m\left(C_0\right)$ is the total quantity produced by firms other than the entreprenur's firm..

captures the gains from member $i_{\mathbf{0}}^{m1}$ collusion with non-member j, given by the term $p_{\left(i_{\mathbf{0}}^{m1}\right)j}\left(C_{\mathbf{0}}\right)$ in (2). These two differences arise from collusive communication between members of the entrepreneur's network and non-members. Communication ultimately determines entry. The entrepreneur affects entry conditions through her network contract $C_{n=\mathbf{0}}$.

We first show that there are two types of solutions, that we spell-out bellow: corner solutions and interior solutions. After showing some properties of the equilibrium that are common to both corner and interior solutions in lemmas 1 to 3, we analyze separately the properties of each of these solutions in propositions 1 and 2. Finally, in Proposition 3 we provide conditions under which each of the two types of solution is preferred for the entrepreneur.

The following definitions will be useful:

Definition 1 *The entrepreneur sets up network $n = 0$ as a* traditional firm *if in equilibrium $b\left(i_{\mathbf{0}}^{t}, \pi_{\mathbf{0}}^{t}\right) = 0$ for all $i_{\mathbf{0}}^{t} \neq 0$ (stake is zero for members different to the entrepreneur), in all periods.*

Definition 2 *The entrepreneur sets up network $n = 0$ as a* lean firm *if in equilibrium $b\left(i_{\mathbf{0}}^{t}, \pi_{\mathbf{0}}^{t}\right) > 0$ for all employees.*

Before solving for the different types of solutions[17], we first look at the continuation game at $t = B2$. For a firm $n\left(j\right)$ that enters at $t = B2$, the reaction function is given by:

Lemma 1 *Consider a network $n\left(j\right)$ formed by individual j with skill level $\theta\left(j\right) > 0$ at $t = B2$. If j expects that all other firms will supply $Q_{-n(j)}^{B3}$ units of the good, the optimal reaction and profits are respectively:*

$$\begin{aligned} Q_{n(j)}^{B3}\left(Q_{-n(j)}^{B3}\right) &= \frac{D^{B}}{2\beta} - \frac{1}{2}Q_{-n(j)}^{B3} \\ \pi_{n(j)}^{B3}\left(Q_{-n(j)}^{B3}\right) &= \beta\left(Q_{n(j)}^{B3}\left(Q_{-n(j)}^{B3}\right)\right)^{2} - F\left(\theta\left(j\right)\right) \end{aligned}$$

We now show that as of period $t = B1$ existing networks strictly prefer to deter communication between members and non-members.

[17] We show bellow that in equilibrium there are no cases out of Definition 1 and Definition 2.

Lemma 2 : *At the equilibrium of the continuation game at $t = B1$ quantities Q_n^{B1} are set up so that at $t = B2$ there are no gains of collusive communication between members of all existing networks and non-members. Moreover, at $t = B1$ and $t = B2$ production is cost-efficient: for $t = 1, 2 : N_n^{Bt} \to \infty$.*
Proof: in the Appendix

Lemma 2 says simply that no gains of collusive trade at $t = B2$ are left as of stage A. How does network n preempt communication (and entry) at $t = B1$ between its members and non-members?. Notice that for a member i_n to be able to communicate to non-members (potential entrants) he must be already informed as of $t = B1$: it must be that he was a member of n already at the initial (product A) stage. The candidates to communicate with non-members are the informed members in $\Omega_n^{A1} \equiv \left\{ i_n^{A1} \in \left\{ i_n^{A1} \right\} : \theta\left(i_n^{A1}\right) > 0 \right\}$.

From the entrant's payoffs in Lemma 1, $\pi_{n(j)}^{B3}$:

Lemma 3 : *the condition for member $i_n^{A1} \in \Omega_n^{A1}$* not *communicating with entrant*[18] *j is:*

$$b\left(i_n^{A1}, \pi_n^{B3}\right) Q_n^B P\left(Q_{-n(j)}^B\right) \geq b\left(i_n^{A1}, \pi_n^{B3}\right) Q_n^B P\left(Q_{-n(j)}^B + Q_{n(j)}^B\right) + \pi_{n(j)}^{B3}$$

where $\theta(j) = \theta\left(i_n^{A1}\right)$.

The left hand side of the previous expression is i_n^{A1}'s stake in team n (costs are sunk at the communication stage $B1$) when i_n^{A1} refrains from selling information. The right hand side is that stake when i_n^{A1} communicates $\theta\left(i_n^{A1}\right)$ to j, plus the gains from j's entry, that are captured by the information seller. The "secrecy" condition reduces to:

$$b\left(i_n^{A1}, \pi_n^{B3}\right) \geq \frac{\beta\left[Q_{n(j)}^{B3}\left(Q_{-n(j)}^{B3}\right)\right]^2 - F\left(\theta\left(i_n^{A1}\right)\right)}{Q_n^{B3}\left[P\left(Q_{-n(j)}^{B3} + Q_{n(j)}^{B3}\right) - P\left(Q_{-n(j)}^{B3}\right)\right]} \tag{3}$$

Notice that the reaction function $Q_{n(j)}^{B3}\left(Q_{-n(j)}^{B3}\right)$ of entrant $n(j)$ is continuous but non-differentiable at a particular value of competitors production level, $\widehat{Q}_{-n(j)}$. This causes that we find two types of solutions, characterized by whether the productive capacity of the entrepreneur's firm is at the non-differentiability point or to whether it is bellow that point.

[18] It will be clear below that we do not neet to consider collusive trade between members of two networks.

3.3 Corner solution: the *traditional* firm

Consider in the first place the solution to (2) when the constraint (3) is binding for all $i_n^{A1} \in \Omega_n^{A1}$ and $b\left(i_n^{A1}, \pi_n^{B3}\right) = 0$ for $i_n^{A1} \neq 0$. We first consider the case where the entrepreneur did not engage in collusive communication at $t = A1$: if there is entry by one firm at $t = B2$, the relevant market supply for the entrant is that of the original firm, Q_0^{B1}:

$$b\left(i_0^{A1}, \pi_0^{B3}\right) = \frac{\beta\left[Q_1^{B1}\left(Q_0^{B1}\right)\right]^2 - F\left(\theta\left(i_0^{A1}\right)\right)}{\beta Q_0^{B1} Q_1^{B2}\left(Q_0^{B1}\right)} = 0 \tag{4}$$

The output level $\widehat{Q}_0^{B1}$ of the entrepreneur's firm that satisfies condition (4) and the corresponding profits π_0^{B3} are:

$$\begin{aligned}
\widehat{Q}_0^{B1} &\equiv \left\{\frac{D^B}{\beta} - 2\left(\frac{F\left(\widetilde{\theta}\right)}{\beta}\right)\right\} \\
\pi_0^{B3}\left(\widehat{Q}_0^{B1}\right) &= 2\left(\frac{F\left(\widetilde{\theta}\right)}{\beta}\right)^{\frac{1}{2}}\left[D^B - 2\left(\beta F\left(\widetilde{\theta}\right)\right)^{\frac{1}{2}}\right]
\end{aligned}$$

where: $\widetilde{\theta} = \max\left\{\theta(i) \mid i \in \{i_0^{m1}\} \text{ and } i \neq 0\right\}$. It is the employee with skill level $\widetilde{\theta}$ the one that is relevant because this is the one that has maximal gains of trade with potential entrants. The traditional firm sets total output so as to preempt communication between members and non-members while it gives them no stake in the firm. This condition determines the output that is produced in the traditional firm. The number of employees N_0^{B3}, the knowledge and quantity allocation $(\theta(x), q(x))$ are given by the solution to:

$$\begin{aligned}
\max_{\left(C_0, \theta\left(\left\{i_0^{A1}\right\}\right)\right)} \pi_0 &= \pi_0^{A3} + \pi_0^{B3}\left(\widehat{Q}_0^{B1}\right) \\
&= \sum_{m=A,B}\left\{Q_0^{m1}\left(D^m - \beta Q_0^{m1}\right) - \sum_{i_0^{m1} \in \left\{i_0^{m1}\right\}} \frac{q\left(i_0^{m1}\right)^2}{2\theta\left(i_0^{m1}\right)}\right\} \\
\text{subject to} &: \sum_{i_0^{m1} \in \left\{i_0^{m1}\right\}} q\left(i_0^{m1}\right) = Q_0^{m1}
\end{aligned}$$

$$
\begin{aligned}
&: \quad \theta\left(i_{\mathbf{0}}^{m1}\right) \in \left[0, \overline{\theta}\right] \\
&: \quad Q_{\mathbf{0}}^{B1} = \widehat{Q}_{\mathbf{0}}^{B1}
\end{aligned}
$$

Proposition 1 *If* $\frac{D^B}{2\beta} > 2\left(\frac{F\left(\theta=\overline{\theta}\right)}{\beta}\right)^{\frac{1}{2}}$*, in the entrepreneur's "traditional" firm (that gives no stake to employees), there is:*
1) imperfect information sharing: $\theta\left(\left\{i_{\mathbf{0}}^{A1}\right\}\right) < \overline{\theta}$ *for* $i_{\mathbf{0}}^{A1} \neq 0$
2) the number of employees at $t = A1$ *is (arbitrarily) large* $N_{\mathbf{0}}^{A1} \to \infty$
3) The entrepreneur is claimant to all firm's profits and does not engage in collusive communication at $t = A1$
Moreover, if $\frac{D^B}{2\beta} > 2\left(\frac{F(\theta=0)}{\beta}\right)^{\frac{1}{2}}$*, in addition there is:*
4) "overproduction": $Q_{\mathbf{0}}^{B1} = \widehat{Q}_{\mathbf{0}}^{B1} > Q_{\mathbf{0}*}^{B1}$
5) Profits in the traditional firm converge to:

$$
\pi_{\mathbf{0}} = \pi_{\mathbf{0}}^{A3} + \pi_{\mathbf{0}}^{B3} = \pi_{\mathbf{0}*}^{A3} + 2\left(\frac{F(0)}{\beta}\right)^{\frac{1}{2}}\left(D^B - 2\left(F(0)\,\beta\right)^{\frac{1}{2}}\right)
$$

(Profits decrease with entry costs, and are equal to zero when entry costs are zero, $F(\theta) = 0$*).*

Proof in the Appendix.

The condition $\frac{D^B}{2\beta} > 2\left(\frac{F\left(\theta=\overline{\theta}\right)}{\beta}\right)^{\frac{1}{2}}$ in proposition 1 says simply that the quantity that maximizes monopoly profits when costs are nil is not sufficient to preempt communication while giving no knowledge, nor stake to employees[19]. In summary, proposition 1 says that there is always a level of production $\widehat{Q}_{\mathbf{0}}^{B1}$ that reduces market prices sufficiently so as to preempt all gains from communication between members and non-members, even if members hold no stake in their own firm. Since employees have no stake, the equity costs of hiring employees is nil. The traditional firm hires *many marginal* workers so as to benefit from decreasing returns to scale (cost reduction).

Notice that the effect of the traditional firm is to distort the allocation for producing $Q_{\mathbf{0}}^{B1}$ in order to produce $Q_{\mathbf{0}}^{A1}$ efficiently (that is $\pi_{\mathbf{0}}^{A3} = \pi_{\mathbf{0}*}^{A3}$ but:

[19] When $\widehat{Q}_0^{B1}$ is smaller or equal to the first-best quantity Q_{0*}^{B1} the first-best is trivially achieved. Notice that for $\widehat{Q}_0^{B1} \leq Q_{0*}^{B1}$ it has to be that $F(\theta)$ be sufficiently *high*.

$\pi_0^{B3} < \pi_{0*}^{B3}$). Moreover, the traditional firm engages in imperfect information sharing so as to increase $F\left(\theta\left(i_0^{A1}\right)\right)$and therefore to decrease $\pi_1^B\left(\theta\left(i_0^{A1}\right)\right)$ as much as possible.

3.4 Interior solutions: *the lean firm*

We now explore solutions to (2) where the restriction $b(x) \geq 0$ is not binding. To keep the analysis simple we take the extreme case of zero entry costs (that we have shown give zero profits to the traditional firm for any skill level θ). We show that the lean firm yields positive profits from product A and first-best profits (see result 1 above) from product B even when entry costs are nil.

Since $F(\theta) = 0$ for all θ, if there is not communication with non-members of the initial team in equilibrium, it must be that

$$b\left(\theta\left(i_0^{A1}\right), \pi_0^{B3}\right) = \frac{\beta\left(Q_1^{B3}\left(Q_0^{B3}\right)\right)^2}{\beta Q_0^{B3} Q_1^{B3}\left(Q_0^{B3}\right)} = \frac{Q_1^{B3}\left(Q_0^{B3}\right)}{Q_0^{B3}} \equiv \widetilde{b}\left(Q_0^{B3}\right) \qquad (5)$$

that does not depend on $\theta(x)$. It is then clear that in the lean firm the entrepreneur gives all the information to the employees, since endowing them with knowledge decreases costs but has no costs in terms of equity, that is: $\theta\left(i_0^{A1}\right) = \overline{\theta}$ for all i_0^{A1}. The solution to the entrepreneur's program satisfies:

Proposition 2 *Under zero entry costs, the lean firm (where employees hold positive equity) satisfies:*
1) profits are given by:

$$\max_{\left\{Q_0^{A1}, Q_0^{B1}\right\}} \pi_0 = P^A\left(Q_0^{A1}\right) Q_0^{A1} - \frac{1}{2\overline{\theta}}\left(Q_0^{A1}\right)^2 \frac{Q_1^{B2}\left(Q_0^{B1}\right)}{Q_0^{B1}} + P^B\left(Q_0^{B1}\right) Q_0^{B1}$$

2) complete information sharing: $\theta\left(i_0^{A1}\right) = \overline{\theta}$,
3) there is "underemployment" in the production of $Q_0^{A1} : N_0^{A1} < N_{0*}^{A1}$
4) employees "overproduce" : $q\left(i_0^{A1}\right) > q^*\left(i_0^{A1}\right)$,
5) the transfer function w satisfies the following stock-option condition: at time $t = A3$ members of $n = 0$ choose between a lump-sum transfer $w_0 = \frac{\pi_{0*}^{A3}}{N_0^{A1}}$ *and a fraction of firm $n = 0$'s stock* $b_0^{A3} = \frac{1}{N_0^{A1}}$ *and the entrepreneur does not engage in collusive communication at $t = A1$.*

Proof: in the Appendix.

The lean firm is not as cost efficient as the traditional firm even if there is complete information sharing (costs are strictly positive in the lean firm). This is because in this case it is not feasible for the entrepreneur to hire an arbitrarily large team of members that produce small amounts. Bringing in more members dilutes stakes and makes secrecy impossible, since incumbents capacity is not large enough to preempt communication and since the possibility of collusion destroys the gains of "breaking the budget constraint".

Notice that as opposed to the traditional firm, the lean firm distorts the allocation to produce Q_0^{A1} away from the efficient allocation[20]. The complete information sharing property follows since entrants profits are independent of the type of member that sells information in this case (so that there are benefits but no costs of informing members). Instead, the entrepreneur's investment in secrecy takes the form of keeping a small team, where the members produce too much output in terms of the socially efficient output.

Interestingly, the optimal scheme is a (linear) stock-option scheme. The linearity of the scheme follows from agents ability to trade collusively without restrictions (this is also why there are no gains in giving stake to uninformed parties).

The stock vs. lump-sum payment option aspect of the optimal contract is less straightforward: there is a time interval (between $t = A1$ and $t = B1$) where only the entrepreneur is a candidate to collude with non-members. With a stock option contract for employees, the entrepreneur is kept as the residual claimant of the venture during that time interval, so that she has no incentives to reduce the market power of her own team.

4 Discussion

We saw in previous sections that the traditional firm is more efficient at reducing costs, since it benefits from the increasing marginal costs technology by hiring "many" marginal employees. 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

[20] That is, the lean firm engages in two allocative distortions with respect to the first-best in result 1: it produces Q_0^{A1} inefficiently and it produces too many units of Q_0^{B1}.

depends on entry costs being high. High entry costs facilitate the preemption of communication.

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

Our leading result is that when entry costs F are high the traditional firm is superior, but when entry costs are small (competition is *tough*) the lean firm is superior. Before comparing the two types of firm consider the following definition and lemma:

Definition 3 : *The maturity of the industry* μ *is given by:* $\mu \equiv \frac{D^A}{D^B}$.

Lemma 4:
1) The entrepreneur organizes only a lean firm or a traditional firm.
2) In all cases members are restricted to belong to only one network.

Proof: in the Appendix.

Statement 1 in lemma 4 says that there is no loss of generality for focusing in the lean and traditional firms: mixed organizations where only a fraction of the individuals hold equity are never optimal. Statement 2 is straightforward and it implies that membership contracts are exclusive: agents are restricted to belong only to one team, that is a verifiable characteristic.

The comparison of the two strategies in organization is given by:

Proposition 3:
Case 1: $D^A = D^B$:
1) There is a number $\varepsilon > 0$ *such that for* $F(\theta = 0) \geq \frac{1}{\beta}\left(\frac{A}{4}\right)^{\frac{1}{2}} - \varepsilon$ *the entrepreneur organizes a traditional firm.*
2) If $\underline{F}(\theta) = 0$*, the entrepreneur organizes a lean firm.*
3) If $\overline{\theta}$ *is sufficiently high the lean firm dominates the traditional firm.*

Case 2: $D^A \neq D^B$:
4) If the maturity of the industry $\mu = \frac{D^A}{D^B}$ *is high enough the traditional firm is preferred.*

5) If μ is low enough (the industry is very immature) the lean firm is preferred.

Proof: in the Appendix.

The rational for statements 1 and 2 in proposition 3 is clear from the discussion of propositions 1 and 2 above: high entry costs favor the "communication preemption strategy", whereas the profits from the "small team strategy" are robust to nil entry costs. Statement 3 follows since under high level skill θ the specific cost of the lean firm (high production costs of Q_0^{A1}) vanishes.

Statement 4 shows that, since the traditional firm distorts relatively more the market for the follow-up innovation, it is preferred when the initial innovation A is relatively more important. We interpret this finding as a relative advantage of the traditional firm in mature sectors. Statement 5 is the reverse of statement 4: since the lean firm distorts relatively more the allocation for producing Q_0^{A1}, it is preferred when follow-up market B is larger (when the industrial sector is *immature*).

We claim that proposition 3 can be interpreted as a plot for the transformation in business organization that we mentioned at the outset of the paper. For concreteness, consider the PC industry in the eighties. The industry was led at that time by IBM, that corresponds to the traditional firm of our model. A very large corporation, hierarchically organized and characterized by a culture of secrecy within the firm, that is, a culture of only partial information sharing inside the organization. Moreover, jobs in the lower ends of the hierarchy were paid with flat wages. Finally, IBM before the reforms of the early nineties followed a strategy of integration, that we interpret in the model communication preemptive strategy.

In contrast with the organization of IBM in the eighties, consider the organization of firms in very competitive, low fixed (entry) costs of Silicon Valley (the lean firm in our model). Firms are small and members work long days. Hierarchies are flatter, what we interpret as information sharing inside the firm. Employees are "empowered", what we read as meaning that they access to more sensible, strategic information and are given equity of the firm.

Moreover, the "suddenness" of organizational changes can be explained by the model since the model is compatible with marginal reductions in entry costs leading to discrete changes in organizations, from the corner solution to the interior solution. Finally, in the model the lean firm emerges under low entry costs and high skills brought by the entrepreneur. Since we think of increased competition and technological progress as historic trends, the model predicts naturally that the lean organization substitutes the traditional organization

In summary, we believe there are enough coincidences between the generally accepted view on firms reorganization and our model to take seriously our theory of firm's boundaries based on the absence of intellectual property rights. From the theoretical viewpoint, a virtue of our approach is that the internal organization of the firm and market structure are modeled simultaneously, under standard, generally accepted assumptions.

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Appendix

Proof of Lemma 2:
Say $\widetilde{Q}^{B1}$ is the equilibrium supply in market B as of $t = B1$. If at $t = B2$ there are gains of collusive trade between a member i_n^{A1} and a non-member, then the non-member enters with network n', produces $Q_{n'}^{B2}\left(\widetilde{Q}^{B1}\right)$ and gets: $\beta\left(Q_{n'}^{B2}\left(\widetilde{Q}^{B1}\right)\right)^2 - F\left(\theta\left(i_n^{A1}\right)\right) > 0$. Price for B is: $P\left(\widetilde{Q}^{B1} + Q_{n'}^{B2}\right) \equiv \overline{P}$. But $\widetilde{Q}^{B1}$ cannot be the equilibrium quantity since: $\left(Q_n^{B1} + Q_{n'}^{B2}\right)\overline{P} > Q_n^{B1}\overline{P}$.
The rest of the claim is straightforward since at stage B secrecy is not an issue anymore and production is efficient as in Result 1.
■

Proof of Proposition 1:
Consider first the case where, given f, $F(\theta = 0) \in \left(\frac{1}{\beta}\left(\frac{A}{4}\right)^2, \frac{1}{\beta}\left(\frac{A}{4}\right)^2 + f\overline{\theta}\right)$. Then the entrepreneur of the traditional firm can be arbitrarily close to the first-best in Result 1 by giving employees the level of knowledge $\widetilde{\theta}$ that satisfies: $F\left(\widetilde{\theta}\right) \equiv \frac{1}{\beta}\left(\frac{A}{4}\right)^2 \Rightarrow \widetilde{\theta} < \overline{\theta}$. Total costs are:

$$\lim_{N_0^{A1}\to\infty} \frac{Q_0^{A1}}{2\widetilde{\theta}N_0^{A1}} = \lim_{N_0^{A1}\to\infty} \frac{Q_0^{A1}}{2\overline{\theta}N_0^{A1}} = 0$$

Consider now the case where $F(\theta = 0) < \frac{1}{\beta}\left(\frac{A}{4}\right)^2$. Then to satisfy the zero stake $b\left(i_0^{A1}, \pi_0^{B3}\right) = 0$ for employees condition (4) it must be: $Q_0^{B1} = \widehat{Q}_0^{B1} > Q_{0*}^{B1}$ and $\theta_{i_0^{A1}}$ arbitrarily small.
■

Proof of Proposition 2:
1) follows directly from condition (5). 2) follows from derivating profits of network $n = 0$ with respect to $\theta\left(i_0^{A1}\right)$, $\frac{\partial\pi_0}{\partial\theta} = \frac{1}{\theta(i)^2}\frac{\left(Q_0^{A1}\right)^2 Q_1^{B2}}{Q_0^{B1}} > 0 \Rightarrow \theta(x) = \overline{\theta}$ for $x \in \left\{i_0^{A1}\right\}$. Since $b_0^{A1} > 0$ then N_0^{A1} is finite and production per employee is bounded away from zero (statement 4).

Statement 5): Consider first collusive communication at $t = B1$. We first show that under unrestricted collusion there are no gains of giving stake to an uninformed (about θ) agent. First notice that network $n = 0$ profits (and therefore incentive schemes) can take only two values: $R_0^m \equiv P^B\left(Q_0^B\right)Q_0^B$ and $R_0^c \equiv P^B\left(Q_0^B+Q_1^B\right)Q_0^B$. For an informed agent x of type $\theta(x)$ payment must satisfy:

$$\overline{b}_x R_0^m - \underline{b}_x R_0^c - \pi_1^c(\theta(x)) \geq 0 \tag{6}$$

where $\overline{b}_x$ $(\underline{b}_x)$ is x's fraction of gross high (low) profits in $n=0$. Let incentive schemes for an uninformed agent be $\left(\overline{b}_u, \underline{b}_u\right)$. But the uninformed agent that colludes with informed agent x obtain:

$$\begin{aligned} \overline{b}_x R_0^m - \underline{b}_x R_0^c - \pi_1^c(\theta(x)) + \overline{b}_u R_0^m - \underline{b}_u R_0^c &\geq 0 \Rightarrow \\ \overline{b}_u R_0^m - \underline{b}_u R_0^c &\geq 0 \end{aligned}$$

The uninformed agent can substitute incentives at the same rate as informed agents: $\frac{\overline{b}_u}{\underline{b}_u} = \frac{\overline{b}_x}{\underline{b}_x} = \frac{R_0^c}{R_0^m}$ and therefore cannot be used to relax the budget constraint.

The constraint (6) will be binding for all except possibly one agent:

$$\overline{b}_x R_0^m - \underline{b}_x R_0^c - \pi_1^c(\theta(x)) = 0 \Rightarrow \overline{b}_x = \underline{b}_x R_0^c / R_0^m + \pi_1^c(\theta(x)) / R_0^m$$

Without loss of generality, let $i=0$ be the agent for whom restriction (6) is possibly not binding. Since uninformed agents are not introduced: for $b=\overline{b},\underline{b}$: $b_0 = 1 - \sum_{x\neq 0} b_x$ and:

$$\begin{aligned} \overline{b}_0 R_0^m - \underline{b}_0 R_0^c - \pi_1^c\left(\overline{\theta}\right) &\geq 0 \\ &\Rightarrow \left(1 - \sum_{x\neq 0} \overline{b}_x\right) R_0^m - \left(1 - \sum_{x\neq 0} \underline{b}_x\right) R_0^c + \pi_1^c\left(\overline{\theta}\right) \geq 0 \\ &\Rightarrow R_0^m \geq R_0^c + \sum_x \pi_1^c\left(\overline{\theta}\right) = R_0^c + N_0^{A1}\pi_1^c\left(\overline{\theta}\right) \end{aligned}$$

But the last restriction will also be binding, since increasing N_0^{A1} always reduces costs, from which is clear that $\overline{b}_x = \overline{b} = \frac{1}{N_0^{A1}} = \frac{\pi_1^c\left(\overline{\theta}\right)}{R_0^m - R_0^c}$. But:

$$\begin{aligned} \underline{b}_x &= \left(\overline{b}_x R_0^m - \pi_1^c\left(\overline{\theta}\right)\right)/R_0^c = \underline{b} = \left(\frac{\pi_1^c\left(\overline{\theta}\right) R_0^m}{R_0^m - R_0^c} - \pi_1^c\left(\overline{\theta}\right)\right)/R_0^c \\ &= \left(\frac{\pi_1^c\left(\overline{\theta}\right) R_0^m}{R_0^m - R_0^c} - \frac{\pi_1^c\left(\overline{\theta}\right) R_0^m - \pi_1^c\left(\overline{\theta}\right) R_0^c}{R_0^m - R_0^c}\right)/R_0^c = \frac{\pi_1^c\left(\overline{\theta}\right)}{R_0^m - R_0^c} = \overline{b} \end{aligned}$$

That is, the optimal incentive scheme is linear in the lean firm.

Finally, we must prove that the entrepreneur does not engage in collusive communication at $t = A1$. Call $\overline{\pi}_0$ the total firm $n = 0$'s profits when $i = 0$ does not sell information at $t = A1$ and $\underline{\pi}_0$ and $\underline{\pi}_1$ the profits of firms $n = 0$ and $n = 1$ when $i = 0$ sells information at $t = A1$. Clearly: $\underline{\pi}_0 + \underline{\pi}_1 < \overline{\pi}_0$. Two things should happen in equilibrium: the employees should be willing to realize the stock option:

$$w_0 \leq b_0 \overline{\pi}_0, \text{ say: } w_0 = b_0 \overline{\pi}_0$$

and the entrepreneur $i = 0$ should prefer to keep the innovation secret:

$$\begin{aligned} \underline{\pi}_0 + \underline{\pi}_1 - \left(N_0^{A1} - 1\right) w_0 &\geq b_0 \overline{\pi}_0 \Leftrightarrow \\ \underline{\pi}_0 + \underline{\pi}_1 &\geq N_0^{A1} b_0 \overline{\pi}_0 = \overline{\pi}_0 \end{aligned}$$

so that the stock-option scheme is feasible.

■

Proof of Proposition 3:

Consider $F_* (\theta = 0) = \frac{1}{\beta} \left(\frac{A}{4}\right)^2$. From proposition 2, for this intercept of the entry cost mapping the traditional firm is arbitrarily close to the first-best profits in Result 1. Profits in the lean firm are bounded above by the first-best profit level. Consider a marginal reduction in $F(\theta = 0) = F_*(\theta = 0) - \varepsilon$. the effect of the reduction in the traditional firm is of second-order: $-\frac{\partial \pi_0^t}{\partial F(\theta=0)} = -\frac{\partial \pi_0^B}{\partial F} = -\frac{\partial \pi_0^B\left(Q_{0*}^{B1}\right)}{\partial Q_0^B} \frac{d\widehat{Q}_0^{B1}}{dF} = 0$ but the effect on profits in the lean firm is of first-order: $-\frac{\partial \pi_0^l}{\partial F(\theta=0)} = -\frac{\partial \pi_0}{\partial F} = -\frac{\partial \left\{ \max_{\left\{Q_0^{A1}, Q_0^{B1}\right\}} \pi_0 \right\}}{\partial F} = -\frac{1}{2\overline{\theta}} \frac{\left(Q_0^{A1}\right)^2}{\left(N_0^{A1}\right)^2} \frac{\partial N_0^{A1}}{\partial F(\theta=0)} < 0$ since $N_0^{A1} = \left(\frac{\pi_1^c\left(\overline{\theta}\right)}{R_0^m - R_0^c}\right)^{-1} < \infty$ and $\frac{\partial N_0^{A1}}{\partial F(\theta=0)} > 0$.

On the other hand when $F(\theta) = 0$ for all θ, in the traditional firm $\pi_0^{B3} = 0$ but in the lean firm profits from market A are bounded bellow by L_0:

$$\pi_0^l \geq L_0 \equiv \max_{Q_0^{A1}, Q_0^{B1}} P^A\left(Q_0^{A1}\right) Q_0^{A1} - \frac{1}{2\overline{\theta}} \left(Q_0^{A1}\right)^2 + P^B\left(Q_0^{B1}\right) Q_0^{B1} > 0$$

Then if $D^B \geq D^A$ the lean firm performs better than the traditional firm.

■