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# Intellectual Property Rights and Efficient Firm Organization

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**Abstract**

I provide a justification of intellectual property rights as a source of static efficiency gains in manufacturing, rather than dynamic benefits from greater innovation. I develop a property-rights model of a supply relationship with two dimensions of non-contractible investment. In equilibrium, the first best is attained if and only if ownership of tangible and intangible assets is equally protected. If IP rights are weaker, the organization of the firm is distorted and efficiency declines: the final producer must either integrate her suppliers, which prompts a decline in their investment; or else risk their defection, which entails a waste of her expertise. My model predicts a greater prevalence of vertically integrated manufacturers where IP rights are weaker, and a switch from integration to outsourcing over the product cycle. Empirical evidence on the international supply chains of multinational companies bears out both predictions. As a normative implication, I find that IP rights should be strong but narrowly defined, to protect a business without holding up non-competing derivative innovations.

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# 1 Introduction

What is the rationale for intellectual property (IP) rights? The standard answer in economic theory is that they are a tool to promote innovation, through three main mechanisms. First, IP rewards inventors with monopoly profits, and this incentive should encourage investment in innovation (e.g., Schumpeter 1942; Nordhaus 1969; Tirole 1988; Reinganum 1989; Barro and Sala-i-Martin 2004; Bessen and Meurer 2008).[1] Second, the patent system promotes disclosure of inventions, which enables sequential innovation (e.g., Machlup and Penrose 1950; Horstmann, MacDonald, and Slivinski 1985). Third, IP rights support the development of a market for information, raising the profitability of innovation and enabling the rise of specialized R&D firms (e.g., Arrow 1962; Aghion and Tirole 1994; Arora, Fosfuri, and Gambardella 2001).[2]

Empirical evidence, however, increasingly casts doubt upon this long-standing conventional wisdom connecting IP and innovation (Gallini 2002; Bessen and Meurer 2008; Boldrin and Levine 2008b). Estimates of the value of patent protection have an order of magnitude of only 15 percent of expenditures on R&D (Griliches, Pakes, and Hall 1987; Lanjouw 1998; Schankerman 1998). Firms outside the chemical and pharmaceutical industry report that patents are a relatively unimportant way of protecting their profits from innovation (Levin et al. 1987; Cohen, Nelson, and Walsh 2000; Arundel 2001; Cassiman 2009). An extension of patent scope in Japan in 1988 did not induce an increase in either R&D spending or innovative output (Sakakibara and Branstetter 2001). A panel analysis of 60 countries over 150 years finds that increases in patent protection have had a negative impact on the number of patent applications filed by the country's residents, either domestically or abroad (Lerner 2002, 2009).

In the United States, patent protection has been strengthened since the creation in 1982 of the U.S. Court of Appeals for the Federal Circuit, with exclusive appellate jurisdiction over cases concerning patent validity and infringement. Compared to the regional circuit courts that previously heard such appeals, the Federal Circuit has shown a higher propensity to uphold the validity of patents; in particular, it has extended patentability to software and business methods.[3] Nevertheless, the creation of the Federal Circuit did not spur a surge in innovation and R&D (Jaffe 2000; Landes and Posner 2003; Hunt and Bessen 2004). On the contrary, innovators have been hindered by the large increases in patenting and patent litigation (Jaffe and Lerner 2004; Bessen and Meurer 2008). Bessen and Meurer (2008, p.

[1] The U.S. Constitution explicitly endorses this justification.

[2] Beyond utilitarian arguments about economic efficiency, legal scholars and philosophers have also justified IP rights as the ethically due reward for innovative creators (e.g., Merges 2011).

[3] *State Street Bank and Trust v. Signature Financial Group,* 149 F.3d 1368 (Fed. Cir. 1998).

141) conclude that the available evidence "implies that patents very likely provided a net *dis*incentive for innovation" outside of the chemical and pharmaceutical industries.[4] Boldrin and Levine (2008a, b) have advanced the radical view that IP should be abolished because it awards monopoly rights that inevitably cause deadweight losses, whereas its positive effect on innovation is neither empirically established nor logically necessary—endogenous investment in innovation is theoretically consistent with perfectly competitive markets.

In this paper, I propose a shift in the focus of our theory of IP. Its rationale need not be sought in incentives for innovation, just as we do not understand property rights on cars primarily as a tool to incentivize carmakers. Viewing IP rights through the same lens as property rights on physical assets may seem counter-intuitive, since knowledge assets are non-rival. Nonetheless, I establish formally that allocating and protecting ownership of intangibles, no less than of tangibles, is necessary to enable manufacturers to run an efficient supply chain in a world of incomplete contracts. When instead protection of IP is too weak, the efficient organization of production is hindered by the risk that a supply relationship could collapse into costly IP leakage. This problem is particularly salient for multinational corporations that contemplate cost-minimizing outsourcing deals with partners in developing countries (Kahn 2002). Far from being a particular concern of the most innovative firms, it is pervasive throughout the manufacturing sector. A perfect illustration comes from an industry that is neither particularly advanced technologically nor especially R&D intensive: footwear.

Since 1990, New Balance Athletic Shoe Inc., a U.S. manufacturer, had outsourced production of some of its cheapest and simplest shoes to a factory in China run by Horace Chang. In 1999, Chang unilaterally quadrupled production for sale in China; New Balance then terminated their relationship. Yet, Chang continued selling the shoes in competition with New Balance, both under their brand and with his own knock-off Henkee brand, not only in China but also in Europe and Japan. The breakdown of this relationship had an estimated cost of $10 million for the American company, which suffered not only competition from its former supplier, but also and more importantly disruption of its supply chain; legal costs as it vainly pursued a lawsuit in Chinese courts for a decade; and dilution of its brand value as too many of its cheaper and older China-made models reached the market, tarnishing a corporate image that hinges on the more advanced U.S.-made range. These costs largely represented net efficiency losses. Profits from Chang's sales would have failed to compensate them even within the partnership—which is why New Balance tried to veto

[4] The effect of strengthened IP protection on aggregate innovation is ambiguous in a theory of sequential development in which new inventions build upon existing ones (Scotchmer 1991; Gallini and Scotchmer 2002).

his production hike. They were further reduced once he could no longer rely on the value added by official retail channels.[5]

Conversely, extensive legal safeguards of IP rights underpin the efficient international supply chain organization of Apple Inc., by some measures the largest and most successful company in the world. The U.S. multinational itself focuses exclusively on retailing and product development. It outsources manufacturing to specialized suppliers such as Foxconn (Hon Hai Precision Industry Co. Ltd.) and Pegatron Corp., which also manufacture its competitors' products. This arrangement optimally exploits Apple's core competencies in design and customer-relationship management, as well as its suppliers' competitive advantage in cost-minimizing manufacturing. Such an efficient supply relationship hinges upon the effective enforcement of patents covering Apple's technology, copyright covering its software, trademarks covering its brand and the distinctive appearance of its products (or "trade dress"), and protected trade secrets covering its business strategy.

I develop a model which shows that IP rights underpin the efficient organization of manufacturing firms and therefore generate static productivity gains, distinct from the canonical dynamic benefits that would result from greater incentives to innovate. To highlight the distinction, I abstract completely from invention and assume instead that intangible assets as given ex ante. I focus on the organizational structure chosen to exploit them, following the property-rights theory of the firm (Grossman and Hart 1986; Hart and Moore 1990; Hart 1995). Specialized inputs can be either acquired from outside suppliers or produced internally. The supplier, whether a subcontractor or an employee, needs to make a relationship-specific investment. In a world of incomplete contracts, his incentives are determined by asset ownership.

My crucial assumption is that the supplier's investment has two dimensions: first, the amount of cost-minimizing effort; second, its objective, which can be either to cooperate with his downstream partner—like Foxconn with Apple—or to bypass her—like Chang with New Balance. In equilibrium, I find that the first best is attained if and only if IP rights are sufficiently strong. Then, outsourcing is both stable and efficiency maximizing. Ownership of physical productive assets protects the supplier from being held up by the downstream partner. At the same time, ownership of intangibles protects the latter from being cut out by the supplier. If instead IP rights are too weak, productivity falls. An outsourcing partnership may break down, leading to inefficient production by the supplier alone. Or else, to avoid this risk, vertical integration may be chosen instead; but then the supplier's incentives for

[5] The case received wide press coverage: e.g., in the *Wall Street Journal* (Kahn 2002), *Businessweek* (2005), *Fortune* (Parloff 2006), and the *New York Times* (Schmidle 2010). After a tortuous legal process, in 2008 a Beijing court found in favor of New Balance but awarded a mere $40,000 in damages (NTD 2008). Chang has stopped selling New Balance shoes, but his derivative brand lives on (www.henkee.com.cn).

cost-minimization are inefficiently blunted. Hence, I establish that efficiency is monotone increasing in the enforcement of IP rights.

The structure of my model is related to Aghion and Tirole (1994a, b), who apply the property-rights approach to develop a theory of the optimal organization of R&D. Their model highlights that efficient stand-alone research units are feasible only if they can securely own their inventions, and thus obtain legal protection from hold-up by their customers and financiers. Gans, Hsu and Stern (2002) present empirical evidence of such a pattern: in sectors with stronger IP rights start-ups are more likely to specialize in creating innovation and then licensing it. Rosenkranz and Schmitz (2003) extend the theoretical analysis to dynamic R&D alliances. They show that enforceable patents promote the disclosure of complementary know-how but stifle complementary non-contractible investments, and study the reallocation of patent rights in a research joint venture as this trade-off changes over time. These results provide a rationale for IP as a way of raising the productivity of innovation (Arora, Fosfuri, and Gambardella 2001; Arora and Merges 2004). Following Arrow's (1962) seminal contribution, they advance the theory of IP as a means to improve the allocation of resources for invention by facilitating trade in information.[6]

I extend and generalize the findings of this literature by showing that protection of IP does not benefit only innovative entrepreneurs and specialized research outfits whose output consists of ideas. Instead, more broadly, it is crucial to enable efficient outsourcing and sustain productivity for all firms that exploit any intangible asset in production—which is to say, for the entire modern manufacturing sector. More than the Arrovian view, my analysis bears out Kitch's (1977) insight that patents are useful not only for their reward function but also for their "prospect function," qualitatively similar to the role of property rights over natural resources: IP rights turn ideas into assets whose ownership can be clearly allocated. This possibility enables their efficient use in production and thus increases the efficiency of manufacturing, no less and possibly even more than the productivity of innovation.

My theory accounts for the observed cross-country organization of the supply chains of multinational corporations. The model predicts that vertical integration should be more prevalent in sectors and jurisdictions in which IP rights are less secure. Consistent with

[6] Arora (1995) shows that IP rights can also be leveraged to enable the sale of non-contractible know-how by bundling it with contractible patents. Gans, Hsu and Stern (2008) document empirically that firms are indeed more likely to license patented than unpatented technology. Nonetheless, ideas can be traded even without IP protection. They can be sold to one buyer under the threat of revelation to a competitor (Anton and Yao 1994), bundled with assets that cannot be expropriated (Arora 1996; Anton and Yao 2005), or kept secret while signalling their value through partial disclosure (Anton and Yao 2002, 2008). Entrepreneurs can connect agents with complementary know-how who could not trust each other directly (Biais and Perotti 2008), and firms can maintain a reputation for the safe internal circulation of innovative ideas (Hellmann and Perotti 2011).

this prediction, empirical evidence shows that stronger patent protection makes manufacturers more likely to establish a supply relationship by outsourcing rather than foreign direct investment (Lee and Mansfield 1996; Smith 2001; Antràs, Desai and Foley 2009).

Moreover, I develop a dynamic extension and find that imperfect IP protection accounts for an organizational product cycle with endogenous changes in the supply chain over time. A product is first manufactured by a vertically integrated firm at the beginning of its life cycle. Once the final good producer learns the appropriability of her technology, it may be safe to spin off a supplier and reap the ensuing reduction in production costs. My model thus accounts for the observed production pattern by which multinational firms first offshore manufacturing through FDI, and subsequently switch to arm's-length imports. (Mansfield, Romeo and Wagner 1979; Mansfield and Romeo 1980; Davidson and McFetridge 1984, 1985; Antràs 2005).

My theory and the available evidence jointly suggest that the most important justification of IP rights may be not as a tool to promote the creation of intangible assets, but rather as a mechanism that allows existing intangibles to be exploited efficiently. Such a shift in focus does not only provide a justification for IP that is robust to its seeming failure at fostering innovation. It also yields implications for the optimal design of IP rights. In particular, the classical view tends to favor broad patents, provided they can be licensed by incremental innovators (Gallini and Scotchmer 2002). Conversely, I show the optimality of narrow patent breadth in my property-rights framework, even when licensing is possible ex ante. Efficiency is maximized when the supplier is deterred from leaving the partnership and becoming a competitor, but instead encouraged to pursue spin-offs that do not directly compete with the parent business. Such differential incentives require ownership of intangible assets to be narrowly defined to protect the use of IP in the owner's business, without extending his rights to non-competing novel applications.

## 2 A Property-Rights Model of the Firm

A profitable business venture requires the cooperation of two agents with complementary skills, as well as two complementary assets.

A final producer $F$ is exogenously endowed with a unique profitable idea: an intangible asset $A_I$ that defines the characteristics of a final product whose potential sale revenues are normalized to unity. Concretely, we can picture $F$ as a U.S. multinational such as New Balance or Apple. Then $A_I$ consists of the manufacturing specifications of a product such as New Balance Classics shoes or the iPhone.

Furthermore, $F$ is endowed with specific expertise that is indispensable to exploit the full revenue-generating potential of his idea. Without the $F$'s personal contribution, revenues are reduced to $1-\eta$. In our examples, $\eta$ denotes the fraction of revenues that is accounted for by New Balance's or Apple's retail channels, after-sale customer service, and ongoing refinement of their products. We can also think of $\eta$ as the value of an entrepreneur's human capital. This value is fully revealed during the operation of the partnership, but it is not precisely known at the beginning. Instead, it is perceived as a random variable with a common-knowledge distribution $\Phi(\eta)$ on $[0,1]$.

Production of the final good requires a specialized input produced by a supplier $S$ using a tangible asset $A_T$. We can think of $S$ as a Chinese manufacturer such as Chang or Foxconn, and of $A_T$ as their manufacturing plant in China. Ex ante, there is a competitive pool of potential suppliers. However, in order to produce the specialized input required by $F$, the selected partner $S$ must make a relationship-specific investment. This investment involves two distinct decisions.

First, the supplier must decide what specialization he wants to acquire, in the manner described by Rajan and Zingales (2001) in a model of organizational hierarchy without any property rights. On the one hand, $S$ can cooperate and learn how to produce the specific input that complements $F$'s expertise. This input is worthless to anyone but $F$, but it allows her to produce the final good and sell it for its maximum unit revenue. On the other hand, $S$ can choose instead to defect and learn how to become a substitute for $F$, producing a different input that is specialized to the intangible asset $A_I$ but designed to bypass $F$'s expertise. This defecting input can be turned into a final product identically by $F$ or by anyone else (in particular by $S$), but its sales revenues are reduced to $1-\eta$. This assumption captures the value of specialization and the division of labor, reflected in the inevitable imperfection of $S$ as a substitute for $F$.

In Chang's case, the choice of defection took place when he made plans and procured materials to produce large quantities of Classics shoes for direct sale, instead of adhering to the production and distribution schedule originally agreed upon with New Balance. Subsequent meetings between U.S. headquarters and Chang could not restore the partnership after he had sunk the decision of quadrupling production in his factory. New Balance did not want such a large quantity of shoes to be brought to market, whether through official retail channels of otherwise. Conversely, Chang had by then become committed to selling his excess output.

In addition to choosing a specialization, $S$ must exert effort to minimize the cost of manufacturing intermediate inputs using the tangible asset $A_T$. An ex ante investment of $e \geq 0$ yields an ex post cost $c(e)$, described by a positive, strictly decreasing and convex function with

$$c(e) > 0,\ c'(e) < 0 \text{ and } c''(e) > 0 \text{ for all } e > 0, \tag{1}$$

satisfying the boundary conditions

$$\lim_{e\to 0} |c'(e)| > 2 \text{ and } \lim_{e\to\infty} |c'(e)| = 0, \tag{2}$$

which ensure that the choice of $e$ always has an interior solution.

The function $c(e)$ describes the cost of producing the specialized input selected through the first half of the investment decision—either the cooperating or the defecting input. Regardless of the choice between the two specializations, $S$ always retains the outside option of using $A_T$ to produce generic intermediates. These inputs cannot be used with $A_I$ to produce the distinctive final good, but they can be sold on their own for a market price $1-\alpha$. The parameter $\alpha \in (0, 1 - \lim_{e\to\infty} c(e)]$ captures the value of IP in $A_I$. Its magnitude represents the revenue lost by Chang when switching production from New Balance shoes to original Henkee models. It also maps onto the difference between the profitability of iPhones and that of other cell phones that Foxconn manufactures, e.g., on behalf of Nokia.

The supplier's investment is strictly specific to the physical asset $A_T$ and to his human capital: without either of them it is impossible to produce a specialized intermediate, and therefore to exploit the intangible asset $A_I$. This implies in particular that $F$ cannot compete with $S$ if he has chosen to defect instead of cooperating because she cannot recruit an alternative supplier.[7] The investment is also specific to $S$'s relationship with $F$ and $A_I$, but not as strictly. It generates unambiguously higher surplus within a cooperating partnership ($\alpha > 0$, $\eta > 0$), but it retains some value outside of it. The production cost $c(e)$ is identical for specialized and generic inputs.

The first-best investment choice requires $S$ to invest in complementing $F$ and to exert effort

$$e^* = \arg\max_e \{1 - c(e) - e\} \text{ such that } |c'(e^*)| = 1. \tag{3}$$

However, investment cannot be governed by a complete contract because of the complexity and unpredictability of the supply relationship. The parties cannot directly contract upon the investment level because it is unobservable. Ex-post costs and profits cannot be part of an enforceable contract because they are unverifiable by courts or arbitrators. Finally, a long-term supply contract cannot be written because the precise characteristics of the

[7]Likewise, Rajan and Zingales (1998) assume that a successful defector always enjoys a monopoly. In reality, $F$'s inability to compete due to the disruption of her planned supply chain could be only temporary. New Balance could not immediately replace Chang, and may thus have had to cede him a significant segment of the market for lower-value shoes, particularly in China. However, it did eventually wrest back control of worldwide sales of New Balance Classics shoes.

specialized input are initially uncertain.

Ex ante, the only incentive device available is the allocation of property rights (Grossman and Hart 1986; Hart and Moore 1990; Hart 1995). Both $F$ and $S$ sufficiently wealthy that each could purchase both assets. Restrictive covenants that limit the owner's freedom to use an asset are prohibitively costly, so ownership assigns complete control rights—if it is granted effective legal protection.

Enforcement of property rights over $A_T$ is perfect. Enforcement of property rights over $A_I$ depends instead on the quality of the IP regime. If $F$ owns $A_I$, $S$ may nonetheless choose to defect and infringe upon her IP, as Chang did with New Balance. In this case, he is liable to pay $F$ compensation whose expected value equals $\sigma$. The parameter $\sigma \in [0, 1]$ measures the strength of IP protection. This specification has an immediate interpretation in terms of lost profits damages, but it can be interpreted more broadly as a reduced-form representation of a broader variety of legal remedies.[8]

The relationship unfolds according to the following timeline:

1. $F$ recruits $S$ from the pool of potential suppliers. The parties negotiate the ownership of $A_I$ and $A_T$.

2. The value of $F$'s expertise $\eta$ is realized and observed by both parties. $S$ makes a non-contractible relationship-specific investment. He chooses his specialization (cooperating or defecting) and exerts effort $e$.

3. The intermediate input is produced. $F$ and $S$ bargain over its transfer price. The outcome of their negotiation is modelled by the Nash bargaining solution.

4. Property rights are enforced and payoffs are realized.

The two parties are risk neutral, they have symmetric information throughout, and they form rational expectations concerning subsequent stages of the partnership game. The equilibrium outcome can be computed by backwards induction.

In stage 3, joint surplus within the partnership and outside options if the partnership breaks down depend on the allocation and enforcement of property rights in stage 1, as well as on the realization of $F$'s expertise and on $S$'s investment choices in stage 2. Let $a_T$ and $a_I$ be binary variables denoting whether $S$ owns respectively $A_T$ and $A_I$ and can therefore use either asset if the partnership breaks down. Let his specialization be $s \in \{F, S\}$, where $s = F$ denotes cooperation and $s = S$ defection.

[8] The analysis would not be materially affected if some of the legal costs were a deadweight loss rather than a transfer from $S$ to $F$.

If $S$ has chosen to cooperate, joint surplus in the partnership is

$$\Pi(\eta, e, F) = 1 - c(e). \tag{4}$$

If the partnership breaks down, $F$ cannot produce the final good without a specialized input supplied by $S$. Thus his outside option is nil. $S$ also cannot produce the final good because he lacks access to $F$'s expertise. Thus, his outside option is nil if he does not own the tangible asset ($a_T = 0$). If instead $S$ owns $A_T$ ($a_T = 1$) he can produce generic intermediates outside the partnership and earn profits $1 - \alpha - c(e)$. The Nash bargaining solution implies that $S$'s payoff is then

$$\pi_S(a_T, a_I, \eta, e, F) = \frac{1 + a_T}{2}[1 - c(e)] - \frac{\alpha}{2} a_T. \tag{5}$$

If $S$ has chosen to defect ($s = S$), joint surplus in the partnership is reduced. $F$'s expertise can no longer be exploited, so the partnership must choose between producing a sub-par final good (losing revenue $\eta$) or a generic intermediate (losing revenue $\alpha$). So long as $S$ owns $A_T$, however, his outside options expand. Not only is he capable of producing generic intermediates; after defecting, he can also produce specialized intermediates and the final good without $F$'s expertise. If he does so without owning $A_I$ ($a_I = 0$), however, he is liable to pay damages $\sigma$ when IP rights are enforced in stage 4. Thus his outside option is $a_T[1 - \min\{\alpha, \eta + \sigma(1 - a_I)\} - c(e)]$.

Since defection unambiguously reduces joint surplus, it can be attractive only when it expands $S$'s outside options, namely when $\eta + \sigma(1 - a_I) \leq \alpha$.[9] Then joint surplus is

$$\Pi(\eta, e, S) = 1 - \eta - c(e). \tag{6}$$

$S$'s outside option is $a_T[1 - \eta - \sigma(1 - a_I) - c(e)]$, while $F$'s outside option is represented by the expected damages that he receives for infringement of his IP rights: $\sigma a_T(1 - a_I)$. The Nash bargaining solution implies that $S$'s payoff is then

$$\pi_S(a_T, a_I, \eta, e, S) = \frac{1 + a_T}{2}[1 - \eta - c(e)] - \sigma a_T(1 - a_I). \tag{7}$$

In stage 2, $S$ makes his investment choice anticipating these payoffs. Therefore he chooses specialization and effort that solve his unilateral optimization problem:

$$(e(a_T, a_I, \eta), s(a_T, a_I, \eta)) = \arg\max_{e \geq 0, s \in \{F, S\}} \{\pi_S(a_T, a_I, \eta, e, s) - e\}. \tag{8}$$

[9] If instead $\eta + \sigma(1 - a_I) > \alpha$ then joint surplus is $\Pi(\eta, e, S) = 1 - \min\{\alpha, \eta\} - c(e)$, $S$'s outside option is $a_T[1 - \alpha - c(e)]$ and $F$'s outside option is nil, so $S$'s payoff is $\pi_S(a_T, a_I, \eta, e, S) = \{(1 + a_T)[1 - c(e)] - \min\{\alpha, \eta\} - \alpha a_T\}/2$.

In stage 1, it is natural to assume that $F$ has full bargaining power and can capture the entire expected surplus from the relationship, since her profitable idea is unique while potential suppliers are in competitive supply. However, the division of bargaining power ex ante is immaterial. Any efficient bargaining procedure (such as the Nash bargaining solution) leads the parties to choose the asset allocation

$$(a_T^*, a_I^*) = \arg \max_{(a_T, a_I) \in \{0,1\}^2} \int_0^1 \Pi\left(\eta, e\left(a_T, a_I, \eta\right), s\left(a_T, a_I, \eta\right)\right) d\Phi\left(\eta\right). \tag{9}$$

# 3 Equilibrium Firm Structure

The productivity benchmark is provided by a legal system that perfectly protects IP. Formally, protection is perfect for $\sigma = 1$ because then expected compensation equals the full amount of lost revenues, removing any incentive to violate IP rights. Then the following result obtains (all proofs are provided in the appendix).

**Lemma 1** *Suppose that the legal system fully protects an agent's exclusive right to use the intangible asset $A_I$ ($\sigma = 1$). Then the first best is achieved by a non-integrated partnership in which the final producer $F$ owns $A_I$, while the input supplier $S$ owns the physical capital $A_T$.*

The lemma highlights how the optimal allocation of perfectly enforced property rights attains the first best. The underlying intuition is straightforward: so long as IP is effectively protected, the optimum can be reached by using ownership of the two assets to provide separate incentives for the two dimensions of investment.

The allocation of the intangible asset $A_I$ incentivizes the efficient choice of specialization ($s = F$). The final good can be produced only when the owners of the two assets cooperate (or coincide). If $F$ owns $A_I$ it is futile for $S$ to try substituting for her human capital. This would reduce potential sale revenues, without removing the need to negotiate with $F$, who controls the indispensable IP. As a consequence, $S$ makes the efficient choice to complement $F$ provided he doesn't own and cannot appropriate $A_I$. Hence, Apple can entrust Foxconn with the detailed specifications of its patented products, knowing that Foxconn will reliably produce them rather than developing competing imitations. The latter strategy would be unprofitable because Apple is notoriously aggressive and successful in pursuing the enforcement of its IP rights.

At the same time, the allocation of the tangible asset $A_T$ incentivizes the provision of cost-minimizing effort $e$. If $A_T$ belongs to $S$, he can use it to produce either a specialized or a generic input at identical cost $c(e)$. Since he can undertake generic production without

$F$'s consent, ownership of $A_T$ is all $S$ needs to internalize the full benefit of his investment. As a consequence, $S$ exerts the efficient effort $e^*$ provided he owns $A_T$. Indeed, Foxconn is famous for the ruthless efficiency of its manufacturing operations. It invests in the cost-minimizing management of its factories without fear of being held up by Apple, because the investment also pays off in its relationship with alternative customers such as Microsoft, Nokia, or Sony.[10]

At the opposite extreme, if $\sigma = 0$ there is no protection of IP rights. Then the only asset to be allocated is $A_T$, and the consequences for productivity are the following.

**Lemma 2** *Suppose the legal system does not protect property rights over intangibles ($\sigma = 0$).*

*If the final producer $F$ owns the physical capital $A_T$, the input supplier $S$ efficiently invests in cooperating with her. However, the equilibrium amount of his cost-reducing investment is suboptimal ($\bar{e} < e^*$).*

*If the input supplier $S$ owns the physical capital $A_T$, he provides the first best level of effort ($e^*$). However, he inefficiently invests in substituting the final producer $F$ whenever the value of her human capital is lower than her share of ex-post surplus ($\eta < \alpha/2$).*

Without secure IP rights, no party can have exclusive control rights over $A_I$. This failure to extend property rights to intangible assets entails a reduction in the range of available incentive schemes. Incentives for both dimensions of investment are determined by ownership of tangible assets ($A_T$) alone. The availability of a single asset to incentivize two decisions introduces a costly trade off that a strong IP regime can avoid. Granting $S$ ownership of $A_T$ gives him beneficial incentives for cost minimization. On the other hand, when IP is weak, it detrimentally increases his temptation to defect from the partnership. The lemma establishes that it may prove impossible to reconcile this tension and induce optimal investment along both dimensions.

Owning $A_T$ enables $F$ to prevent $S$'s defection by hiring him as an employee. When $F$ has residual control over $A_T$, $S$ needs to cooperate with her, or else he cannot produce anything and his investment is wasted. This need for cooperation rules out a defecting specialization, consistent with Teece's (1986) observation that the ownership of manufacturing capabilities is key to securing market positions that cannot be reliably protected by IP rights.[11] However,

[10] The textbook treatment of the property-rights theory assumes instead that not only the total value of the relationship-specific investment $e$ (i.e., $r - c(e)$) but also its marginal value ($|c'(e)|$) must be strictly higher within the relationship (Hart 1995). Under this alternative assumption, the first best can be attained only with complete contracts. Lemma 1 would then describe the second best. All subsequent results would represent a comparison between the second and the third best, but would otherwise remain qualitatively unchanged.

[11] More generally, even employees' cooperation need not be perfectly assured. Thus, Rajan and Zingales (2001) study how managerial hierarchies are structured to avoid employee defection. The trade off described

binding $S$ to $F$ as an employee also subjects him to the classic hold-up problem (Klein, Crawford, and Alchian 1978). After $S$'s investment is sunk, $F$ can appropriate part of its value in ex-post bargaining. Thus, $S$ cannot internalize the full benefit of his own investment, while he must bear its entire cost. As a consequence, the equilibrium effort provision is reduced below the optimal level ($\bar{e} < e^*$). This underinvestment has a cost

$$C = c(\bar{e}) + \bar{e} - c(e^*) - e^* > 0. \tag{10}$$

If instead $S$ owns $A_T$, his effort level is efficient, as in Lemma 1. On the other hand, his cooperation with $F$ is no longer assured. If he chooses to defect, $S$ can avoid sharing the ex-post surplus, at the cost of foregoing the gains from specialization and the value of $F$'s human capital. From $S$'s ex-ante perspective, the choice of specialization presents a meaningful trade off between reducing joint surplus and increasing his own share of it. When $F$'s human capital ($\eta$) is relatively unimportant compared to the value of $A_I$ ($\alpha$), the supplier chooses defection. Thus Chang chose to ramp up production and break away from New Balance to maximize his sale revenues, although joint surplus would have been higher in a continued partnership that limited Chang's output in order to maximize overall brand value. Defection is always suboptimal from the ex-ante point of view of stage 1. The cost of the distortion is a reduction of total surplus, while the ex-post advantage to $S$ is purely distributional. Contract incompleteness, however, prevents $S$ from committing to the efficient investment in complementarity.

Lemma 2 implies that vertical integration is optimal in the absence of IP protection ($\sigma = 0$) if and only if

$$C < \int_0^{\alpha/2} \eta d\Phi(\eta), \tag{11}$$

namely if underinvestment due to the hold up problem costs less than the expected value of $F$'s human capital wasted because of defection. This condition is assumed to hold throughout, so vertical integration under $F$'s leadership is among the equilibrium organizational forms.

The equilibrium structure of the firm depends on the appropriability of the intangible asset $A_I$ and on its legal protection. The latter is measured by the strength $\sigma$ of IP rights; the former by the possibility of using $A_I$ without $F$'s human capital, which is captured by the parameter $\eta$. Ex ante, appropriability is only imperfectly predictable: formally, $\eta$ is realized in stage 2 but unknown in stage 1 when asset ownership is allocated. The ensuing uncertainty gives rise to instances of partnership breakdown on the equilibrium path, such

by lemma 2 remains so long as ownership of complementary physical assets helps induce employees to cooperate instead of defecting, though it may not be infallible.

as the one involving New Balance and Chang.

The following proposition characterizes both the ex-ante and the ex-post organization of the firm in equilibrium.

**Proposition 1** *Legal protection of IP is perfectly effective when the expected penalty for infringement is sufficiently large compared to the value of intangibles ($\sigma \geq \alpha/2$). Then the firm is organized as a non-integrated partnership and the supplier $S$ exerts optimal effort ($e^*$)*

*Legal protection of IP is completely ineffective if its strength $\sigma$ falls below a minimum threshold $\bar{\sigma} \in (0, \alpha/2 - C)$. Then the firm is vertically integrated under the final producer $F$, and the supplier $S$ exerts suboptimal effort ($\bar{e}$).*

*When IP protection is partially effective ($\bar{\sigma} < \sigma < \alpha/2$), $S$ owns the physical capital $A_T$ and exerts optimal effort ($e^*$). Ex post, the firm operates as a non-integrated partnership with probability $p \in (0, 1)$. With probability $1 - p$, instead, $S$ defects, prescinds from $F$'s expertise and produces as an integrated firm.*

The first result is a straightforward extension of Lemma 1. By defecting, distorting his specialization, and substituting away from $F$'s human capital, $S$ gains his partner's share of the ex-post surplus ($\alpha/2$) at the cost of an efficiency loss ($\eta$) and a legal cost ($\sigma$). Perfect enforcement of IP rights is thus obtained when expected damages are at least equal to $F$'s profit share, so that $S$'s temptation to defect is removed with probability one.

When instead enforcement of IP rights is imperfect, $F$ must choose between relying on partial legal protection or self-protecting through the ownership of $A_T$. The second option ensures that production takes place within a high-quality, high-cost vertically integrated firm headed by $F$. The first choice instead involves ex-ante uncertainty. On the one hand, legal remedies and the value of $F$'s contribution might prove sufficient to sustain the first-best non-integrated partnership. On the other, $S$ might find it profitable to break away from $F$ and run his own low-quality, low-cost vertically integrated firm.

The IP regime is completely ineffective when it is dominated by private self-protection. If legal protection is too weak ($\sigma < \bar{\sigma}$), firm organization and equilibrium outcomes are the same as if it were nil.

When legal protection is imperfect but nonetheless preferable to costly self-protection ($\bar{\sigma} \leq \sigma < \alpha/2$), the eventual structure of the firm is realized only ex post. Letting $S$ own $A_T$ can lead either to a non-integrated partnership between $S$ and $F$, or to autarkic production by $S$ alone in an integrated firm that carries out internally production of both the specialized input and the final good. In this case, ex post $F$ might license the intangible asset $A_I$ to $S$

at price $\sigma$, avoiding lawsuits but not the efficiency loss ($\eta$) that is irreversibly triggered by $S$'s defection.

The model delivers unambiguous comparative statics on the prevalence of vertical integration as a function of IP protection.

**Corollary 1** *The probability that the firm operates as a non-integrated partnership is monotone increasing in the strength of IP protection ($\partial p/\partial \sigma > 0$) and monotone decreasing in the value of intangibles ($\partial p/\partial \alpha < 0$).*

*The threshold $\bar{\sigma}$ of IP protection for which the probability of vertical integration jumps to one is increasing in the value of intangibles ($\partial \bar{\sigma}/\partial \alpha > 0$) and decreasing in the importance of the supplier's investment ($\partial \bar{\sigma}/\partial C < 0$).*

Intuitively, more valuable intangible assets are more difficult to protect. Thus, when control of $A_I$ allows an agent to capture a greater share of profits IP rights must be stronger to have any effectiveness ($\partial \bar{\sigma}/\partial \alpha \geq 0$). Moreover, even if an arm's length relationship is attempted, it is more likely to fall prey to defection when the value of the knowledge assets it exploits is higher ($\partial p/\partial \alpha < 0$).

The threshold for effective IP rights is higher when self-protection through vertical integration is more efficient ($\partial \bar{\sigma}/\partial C \leq 0$). If the hold-up problem is mild and generates little underinvestment (low $C$), then vertical integration under $F$ is an attractive strategy, and marginal improvements to a weak IP regime fail to provide a convincing alternative.[12]

The key empirical prediction that emerges from the model is that vertical integration should be more common in sectors and countries whose IP protection is weaker. This prediction is borne out by empirical evidence on the supply-chain strategies of multinational corporations. The threat of IP leakage is a major concern for companies considering outsourcing to developing countries (e.g., Kahn 2002). Lee and Mansfield (1996) surveyed 100 major U.S. firms representative of six manufacturing industries. Consistent with Proposition 1, they find that vertical integration is one way of reducing the risk of IP leakage. For every sector and each of the 14 developing countries considered, the fraction of respondents reporting that "IP protection is too weak to permit them to transfer their newest or most effective technology to wholly owned subsidiaries" is smaller than the fraction that considers such protection insufficient to allow technology licensing to independently-owned foreign firms.

More formally, Smith (2001) estimates the effect of patent protection on the composition of bilateral exchange between the U.S. and fifty foreign countries. Consistent with Corollary 1, stronger IP rights in the destination country significantly increase licensing relative to

[12] If the maintained assumption in equation (11) failed to hold, then $F$-integration would always be dominated and $\bar{\sigma} = 0$. All other results in the proposition would remain unchanged.

affiliate sales and exports, though their absolute effect is positive for all forms of exchange. Antràs, Desai and Foley (2009) analyze the cross-border activities and foreign direct investment decisions of U.S. multinationals. They find strong, robust evidence that stronger patent rights (and investor protection, more broadly defined) are associated with greater reliance on arm's length technology transfer rather than direct investment, lower equity holdings in foreign affiliates, and a lower financing of their assets by the parent company. In keeping with the theoretical prediction of the model, IP protection significantly predicts the choice of outsourcing over operation through a vertically integrated subsidiary.

The link between IP rights and the organization of manufacturing supply chains, described by Proposition 1 and Corollary 1 and supported by empirical evidence, entails the core insight of the model.

**Corollary 2** *The ex-ante expected value of the firm is increasing in the strength of IP protection ($\partial \mathbb{E}\Pi / \partial \sigma \geq 0$). First-best efficiency is attained if and only if $\sigma \geq \alpha/2$.*

Even in the absence of R&D activities or any purposeful efforts to innovate, productive efficiency is monotone increasing in the strength of IP protection ($\partial \Pi / \partial \sigma \geq 0$). Existing intangible assets can always be exploited securely through vertical integration. But only a strong IP regime raises allows firms to outsource supply-chain operations to efficiently specialized subcontractors. Manufacturing productivity is higher when the supplier has keener incentives to exert cost-reducing efforts, but at the same time is deterred from wastefully and imperfectly duplicating the expertise of the final-good producer. When the sustainability of an efficient arm's length relationship is uncertain ($\bar{\sigma} < \sigma < \alpha/2$), any marginal strengthening of IP rights in the range has an immediate positive impact by raising the probability of cooperation and reducing the likelihood of defection.

Corollary 2 establishes that better enforcement of IP rights yields static productivity gains. This result contrasts with the classic theory of IP rights, which stresses their dynamic benefits from fostering innovation, but their static losses from reducing competition. The two theories are contrasting but complementary. My finding that IP enforcement raises firm productivity implies that it heightens the value of the intangible asset $A_I$. This increase would foster higher investment in innovation if the model were extended to include costly creation of $A_I$.

# 4 Organizational Dynamics

The boundaries of the firm are rarely constant over the life cycle of a product, as Coase (1937) already recognized. Proposition 1 accounts for the potential breakdown of arm's-length partnerships. Further organizational dynamics emerge when we analyze the effects of gradual learning about appropriability ($\eta$).

Consider a two-period repeated version of the baseline model in section 2. The first period, representing the initial phase of the product cycle, remains as above. First $F$ and $S$ allocate property rights; then $\eta$ is realized and $S$ makes the investment decision; finally the parties produce the specialized input and the final good, bargaining over the division of surplus unless $S$ has defected. In the second period, representing the phase of product maturity, these three stages are repeated. First the firm can be reorganized by transferring assets; then $S$ invests; finally production and bargaining take place. The difference is that the realization of $\eta$ is known since the beginning of the second period, so the allocation of property rights over $A_T$ and $A_I$ can be re-optimized taking it into account.

Ineffective protection of IP rights then implies the following evolution of the structure of a vertically integrated firm.

**Proposition 2** *Suppose that legal protection of IP is so weak that the firm initially operates as a vertically integrated company under the final producer $F$ ($\sigma \leq \bar{\sigma}$).*

*With probability $p$ the firm vertically disintegrates once the product reaches maturity. Ownership of the physical asset $A_T$ is transferred to the supplier $S$ and the firm turns into the first-best efficient arm's-length partnership.*

*With probability $q \in (0, 1)$ a buy-out occurs once the product reaches maturity. Ownership of both assets $A_T$ and $A_I$ is transferred to the supplier, who assumes the leadership of the integrated firm.*

In a weak IP regime, the firm initially seeks self-protection against the threat of $S$'s defection by vertically integrating under $F$'s ownership. This strategy affords insurance against the realization of appropriability. Attempting an arm's length relationship is initially risky due to the possibility of its collapse. Once the value of $F$'s human capital is known ($\eta$ is realized), such insurance is no longer necessary. It becomes clear which organizational structures are sustainable and which are not, and the constrained optimum can be chosen without residual uncertainty.

If the value of $F$'s human capital ($\eta$) is high, $S$ is not subject to the temptation to defect. Thus, it is safe and profitable for the firm to vertically disintegrate. $F$ retains ownership of $A_I$ but sell $A_T$ to her supplier, who can now be fully trusted to invest in complementarity. Reorganization then attains the first best, yielding an endogenous decline in production costs.

If instead $F$'s human capital turns out to be relatively unimportant (low $\eta$), the first best is unattainable because weak IP rights are insufficient to protect a highly appropriable intangible asset. The second-best organization for product maturity is then necessarily a form of vertical integration. Both assets are owned by the same agent, and both stages of production are carried out within a single firm. The optimal integrated firm, however, can be either led by $F$, or instead owned and operated by $S$ alone. The second part of Proposition 2 considers the transition from $F$-integration to $S$-integration.[13]

The comparative statics for the two transitions are again unambiguous.

**Corollary 3** *The probability of vertical disintegration is decreasing in the value of intangibles ($\partial p/\partial\alpha < 0$) and increasing in the strength of IP protection ($\partial p/\partial\sigma > 0$). The probability of a buy-out is increasing in the relative importance of the supplier's investment ($\partial q/\partial C > 0$).*

This efficiency-maximizing transformation from vertically integrated firm to arm's length partnership takes place with the same probability $p(\alpha, \sigma)$ that describes the stability of a non-integrated partnership in Proposition 1. In both cases, it is the probability that appropriability is sufficiently low (high $\eta$) for IP rights $\sigma$ to protect an asset with value $\alpha$. Naturally, it is higher when when legal sanctions are stronger ($\partial p/\partial\sigma > 0$) and $A_I$ less valuable ($\partial p/\partial\alpha < 0$).

A buy-out, instead, is a switch from a high-cost, high-quality configuration to a low-cost, low-quality alternative. Thus this type of reorganization is the more likely when the cost of $S$'s underinvestment is higher, and thus more likely to outweigh the value of $F$'s human capital in the cost-quality trade-off ($\partial q/\partial C > 0$).

Both kinds of reorganization entail efficiency gains as the partnership reoptimizes its structure in response to new information.

**Corollary 4** *Reorganization yields an efficiency gain $\Delta \geq 0$. Ex ante, the expectation of this gain is increasing in the quality of legal enforcement ($\partial\mathbb{E}\Delta/\partial\sigma > 0$), decreasing in the value of the intangible asset ($\partial\mathbb{E}\Delta/\partial\alpha < 0$), and increasing in the importance of the supplier's investment ($\partial\mathbb{E}\Delta/\partial C > 0$).*

Both organizational changes entail an endogenous decrease in production costs, as the supplier increases his effort to the first-best level ($e^*$). The ensuing efficiency gains increase with the cost of underinvestment ($\partial\mathbb{E}\Delta/\partial C > 0$), which is the cost of vertical integration under $F$ in the initial phase of the product cycle. The expected gain from reorganization is also higher when IP is less valuable ($\partial\mathbb{E}\Delta/\partial\alpha < 0$) because then a mature product is less

[13] The opposite transition can occur for intermediate IP protection ($\bar{\sigma} \leq \sigma < \alpha/2$), when arm's-length contracting is attempted but break downs because $S$ defects in the first period. If the cost $\bar{c}$ of underinvestment is low, $F$ reacts to defection by purchasing $A_T$ and running an integrated firm herself once the product reaches maturity.

likely to need vertical integration to forestall defection. The same is true when legal remedies are more effective at deterring $S$'s defection ($\partial \mathbb{E}\Delta/\partial\sigma > 0$).

Just as Corollary 2 showed that IP rights underpin efficient firm organization at the beginning of the product cycle, Corollary 4 establishes that they enable efficient reorganization as the product reaches maturity. This result reinforces the finding that a strengthening of the IP regime carries productivity benefits, whether or not it stimulates greater innovation. While marginal improvements to an ineffective IP regime ($\sigma < \bar{\sigma}$) do not raise efficiency in the early life of a product, they have the potential to do so during its maturity.

Proposition 2 and its corollaries extend the empirical predictions of the theory from the cross-section to the time-series dimension. The model implies that manufacturing in countries and sectors with weak IP protection should take place within the boundaries of a vertically integrated firm at the beginning of the product cycle. When the market reaches maturity, instead, arm's-length supply relationships become more common. The predicted pattern of gradual outsourcing is broadly consistent with the real-world dynamics of multinational activity in developing countries.

At a macroeconomic level, the rise of the Korean electronic industry bears out the predicted switch from integration to outsourcing (Antràs 2005). The sector entered international markets in the late 1960s and early 1970s when U.S. and Japanese companies set up subsidiaries in Korea. These affiliates were typically fully owned, and accounted for more than 70% of exports. As the industry reached maturity, in the 1980s, domestic firms achieved greater prominence, mostly as licensees and subcontractors of foreign multinationals.

The Chinese semiconductor industry similarly took off in the 1990s through the direct entry of foreign multinationals (Li 2011). The sector was heavily regulated by the Chinese government, which treated it as a strategic priority and severely limited the establishment of wholly foreign-owned entities. Nonetheless, the first successful fabrication plants were joint ventures run by NEC and Philips as captive subsidiaries supplying their foreign parents; while Intel and Motorola operated wholly-owned test and assembly facilities in China. Conversely, the last decade has witnessed the rise of domestic Chinese companies such as SMIC, now the world's fifth-largest semiconductor foundry. These enterprises operate as specialized contract manufacturers (so-called "pure foundries") that aggressively pursue licensing and outsourcing agreements with major foreign firms (e.g., Fujitsu and Infineon in the case of SMIC). Yet the switch to arm's length contracting is not universal, and some of the largest firms such as Intel and Samsung have continued to run vertically integrated foundries.

Suggestive evidence at the firm level also supports the prediction that companies first transfer technologies to their subsidiaries. They license it externally only when it is more mature and thus, presumably, less valuable in relative to the rest of the parent's company assets and expertise. Mansfield, Romeo and Wagner (1979) surveyed senior R&D executives at thirty U.S. companies. They report that the transfer to foreign subsidiary is the dominant way of exploiting innovation internationally in the first five years since its commercialization. Licensing then grows more important in the following five years. Mansfield and Romeo (1980) document the international technology-transfer decisions of thirty-one U.S. manufacturers. The lag between the introduction of a technological innovation and its transfer is on average less than six years when the recipient is a subsidiary, but more than twelve when it is an arm's-length licensee. Davidson and McFetridge (1984, 1985) study 1,376 technology transactions by thirty-two U.S. multinationals. Their estimates indicate that internal transfers are more likely for newer and more innovative technologies.[14]

# 5 Optimal Patent Breadth

The previous sections have established the static productivity benefits of a strong IP system. Consistent with the property-rights theory of the firm, IP provides a solution to the problem of contract incompleteness, and enables a manufacturing firm to exploit intangible assets via the efficient organization of production. Productively pursuing a given business opportunity, however, is the main but not the only economic role of a firm. Existing companies are also powerful incubators of new entrepreneurial ventures. Surveying a set of fast-growing privately held start-ups included in the 1989 *Inc.* 500 list, Bhidé (2000) finds that the seed idea is typically encountered during previous employment. Nonetheless, the typical spin-off does not compete directly with its parent company. On the contrary, entrepreneurs who exploit derivative ideas usually aim at serving unexploited niche markets, avoiding head-on competition with the established incumbents they previously worked for.

To analyze this phenomenon formally, assume that at time 1 a new opportunity arises for the supplier $S$ with exogenous probability $\iota \in [0,1]$. In addition to the relationship-specific investment $e$, he can then make an investment $i \geq 0$ to develop a derivative idea. This idea exploits $S$'s human capital and the intangible asset $A_I$ to generate a new business that generates profits $n$. The probability that the development of the idea is successful (conditional on the opportunity having arisen) is described by a concave function $v(i)$ with

$$v(i) \in [0,1], \; v'(i) > 0 \text{ and } v''(i) < 0 \text{ for all } i > 0, \tag{12}$$

[14] Davidson and McFetridge (1985) also find that internal transfers are less likely in countries with higher GNP per capita and those with a democratic form of government. Consistent with proposition 1, it is resonable to expect countries with higher income and better political institutions to have stronger IP regimes, although the authors' analysis includes no explicit measure of IP protection.

satisfying the Inada conditions

$$\lim_{i \to 0} v'(i) = \infty \text{ and } \lim_{i \to \infty} v'(i) = 0, \tag{13}$$

which ensure that the choice of $i$ always has an interior solution.

The two investments $e$ and $i$ are not competing. The spin-off does not require the operation of $A_T$ to produce specialized inputs, and it does not preclude $S$ from producing them while simultaneously pursuing a derivative idea. Consistent with Bhidé's (2000) findings, the spin-off is a market expansion that does not harm the profitability of the original firm.

However, the derivative idea builds upon and leverages the original intangible asset $A_I$. It represents a case of cumulative innovation, whose legal standing hinges on the scope or breadth of IP protection (e.g., Scotchmer 1991; Gallini and Scotchmer 2002). If $S$ develops a spin-off without having the right to use $A_I$, his derivative business may be found to infringe upon $F$'s intellectual property. $S$ would then be forced to pay compensation. The expected value of the award equals $\omega n$, with the parameter $\omega \in [0, \sigma]$ providing a concise measure of patent breadth.[15]

In stage 1, when the partnership is formed and the ownership of assets is decided, IP can also be licensed. If the owner of $A_I$ chooses to grant a license for its use to the other party, then both can exploit it simultaneously, given the non-rival nature of intangible assets. If $F$ owns $A_I$ but her supplier $S$ holds a license to use it, then he is free to develop a derivative idea without running the risk of being sued for infringement.

As in the baseline model in section 2, complexity and upredictability preclude complete contingent contracts, in keeping with the property-rights theory. All investments, $i$ as well as $e$, are unobservable. All revenues, costs, and profits are unverifiable. The precise characteristics of the derivative idea are uncertain ex ante, and thus cannot be part of a contract until investment $i$ has been sunk, concretizing the nature of the spin-off. The complexity of restrictive covenants makes them prohibitively costly, so ownership and licensing can only assign complete control rights. As a consequence, particular uses of assets cannot be contracted upon ex ante (Hart 1995). Thus, if $S$ is granted a license to use $A_I$, he is equally entitled to use it to develop a derivative idea, and to use it to produce a lower-quality imitation of the original product.

The optimal structure of the firm when spin-offs are possible ($\iota > 0$) admits the following characterization.

[15]It seems logical that the IP system should not and could not offer stronger protection against cumulative innovation than outright imitation: hence $\omega \leq \sigma$. The formal analysis would be unchanged if we also allowed $\omega \in [\sigma, 1]$.

**Proposition 3** *Legal protection of IP is completely ineffective if its strength $\sigma$ falls below a minimum threshold $\tilde{\sigma} \in [\bar{\sigma}, 1]$. Then the firm is vertically integrated under the final producer $F$, and the employee $S$ is granted a license to use the intangible asset $A_I$. He exerts suboptimal effort ($\bar{e}$) within the firm, but optimal effort ($i^*$) to develop a spin-off.*

*When IP protection is effective ($\sigma > \tilde{\sigma}$), $S$ owns $A_T$ but does not hold a license to use $A_I$. He exerts optimal effort ($e^*$) within the firm, but suboptimal effort ($\bar{\imath} < i^*$) to develop a derivative idea. The efficient non-integrated partnership is preserved with probability $p \in (0, 1]$.*

The proposition present new results while replicating those of Proposition 1. The key novelty is that IP rights that are both sufficiently strong and sufficiently broad create a tension between the asset allocation that maximizes productivity in the original venture and the one that maximizes the probability of a successful spin-off.

Investment in the derivative idea is suboptimal ($\bar{\imath} < i^*$) if $S$ does not hold a license to use $A_I$. In a world of incomplete contracts, however, granting $S$ a license ex ante means forfeiting legal protection against defection from an efficient arm's-length partnership. Then $F$ needs to protect his original idea using vertical integration instead, at the cost of sub-optimal investment within the partnership ($\bar{e} < e^*$).

The role of IP strength is qualitatively unchanged from Proposition 1. The second-best organization is the same that underpins the first best with an optimal IP system: the original firm is organized as an arm's-length partnership, and to maximize its robustness $S$ is denied a license ex ante. When enforcement is too weak, the firm resorts to vertical integration. When it is stronger, a non-integrated partnership is attempted instead. It is sustained with the same probability $p$ as in the original proposition, reaching certainty if $\sigma \geq \alpha/2$.

The minimum enforcement of IP rights required to induce an attempt at arm's length contracting rises ($\tilde{\sigma} > \bar{\sigma}$) because now vertical integration has an advantage that partially countervails suboptimal investment ($\bar{e}$) in efficient production of specialized inputs. As an employee, the supplier cannot steal his employer's business because he doesn't control the tangible asset $A_T$. Thus, he can be allowed instead to control the intangible asset $A_I$ through a license, incentivizing at least efficient effort ($i^*$) in developing a spin-off.

This new trade-off also underpins the comparative statics that are added to those of Corollary 1.

**Corollary 5** *The threshold $\tilde{\sigma}$ of IP protection for which the probability of vertical integration jumps to one is increasing in the likelihood of a derivative idea ($\partial\tilde{\sigma}/\partial\iota \geq 0$), in the value of a spin-off ($\partial\tilde{\sigma}/\partial n \geq 0$), and in the breadth of IP rights ($\partial\tilde{\sigma}/\partial\omega \geq 0$), as well as decreasing* *in the importance of S's investment within the partnership ($\partial\tilde{\sigma}/\partial C \leq 0$), and increasing in the value of $A_I$ ($\partial\tilde{\sigma}/\partial\alpha \geq 0$).*

Vertical integration is more likely to be chosen when spin-offs are more important, either because derivative ideas are more likely to emerge ($\partial\tilde{\sigma}/\partial\iota \geq 0$) or because they are more valuable ($\partial\tilde{\sigma}/\partial n \geq 0$). Outsourcing also becomes less appealing when IP rights are broader, increasing the hold-up problem for spin-offs that are not covered by a licence ($\partial\tilde{\sigma}/\partial\omega \geq 0$). Hence, the IP system deteriorates into uselessness not only as IP strength weakens, but also as IP scope broadens.[16]

The last result introduces the main finding of this section.

**Corollary 6** *The probability of a spin-off is decreasing in patent breadth ($\partial\bar{\iota}/\partial\omega < 0$). The aggregate value ($V$) of the partnership and its potential spin-off is monotone increasing in the strength of IP protection ($\partial V/\partial\sigma \geq 0$) and decreasing in its breadth ($\partial V/\partial\omega \leq 0$). The first best can be attained if and only if IP rights are simultaneously perfectly strong ($\sigma \geq \alpha/2$) and perfectly narrow ($\omega = 0$).*

IP rights must be strong in order to protect $F$'s original business, but at the same time they must be narrow in order to preserve $S$'s incentives to develop derivative ideas. The first best can be attained if and only if IP protection removes all temptation for $S$ to defect from an arm's-length partnership ($\sigma \geq \alpha/2$), but also all chances for $F$ to hold up a profitable spin-off ($\omega = 0$). Any weakening of the strength of IP protection, but also any broadening of its scope, has a negative impact on aggregate efficiency, which is captured by the aggregate value ($V$) of the original partnership and its potential spin-offs ($\partial V/\partial\sigma \geq 0 \geq \partial V/\partial\omega$).

Any marginal increase in IP breadth above the optimum destroys value by heightening the hold-up problem for derivative ideas. This friction reduces the likelihood of a successful spin-off ($\partial\bar{\iota}/\partial\omega < 0 \Rightarrow \partial V/\partial\omega < 0$). Moreover, as in Proposition 1, any marginal decline in IP strength below the optimum destroys value by making outsourcing more prone to collapse, thereby reducing partnership profits ($\partial p/\partial\sigma > 0 \Rightarrow \partial V/\partial\sigma > 0$).

The findings of Corollary 6 contrast with the conventional analysis of the optimal design of IP rights in the context of cumulative innovation. When IP rights are motivated by the goal of awarding innovators sufficiently large monopoly rents, the mainstream view tends to favor broad patents (Gallini and Scotchmer 2002). The underlying rationale is that the

[16] If the maintained assumption in equation (11) failed to hold, then when IP rights are ineffective ($\sigma \leq \tilde{\sigma} \in [0,1]$) $S$ would be granted both ownership of $A_T$ and a license to use $A_I$. His investments would both be optimal ($e^*$, $i^*$), but the partnership would survive only with probability $p - \delta$, for an increased risk of defection $\delta > 0$ increasing in the strength of IP protection ($\partial\delta/\partial\sigma \geq 0$). The threshold would be independent of marginal changes in the prohibitive cost of vertical integration ($\partial\tilde{\sigma}/\partial C = 0$), and it would depend ambiguously on $\alpha$. All other results in this section would remain unchanged.

initial innovator should share in all the profits his idea enables, indirectly as well as directly. Wide patent scope is then particularly crucial when cumulative innovation dissipates the original innovator's own profits. Yet, the desirability of broad patents also emerges, if less starkly, from models in which sequential innovations generate non-competing profit sources, as in the case considered here (Green and Scotchmer 1995; Matutes, Regibeau, and Rockett 1996; Schankerman and Scotchmer 2001). Green and Scotchmer (1995) acknowledge that IP breadth can have the countervailing downside of creating a harmful hold-up problem ex post, but show that this drawback is removed by ex-ante licensing.[17]

The same mechanism is at work in the present model: investment in derivative innovation is suboptimal with ex-post bargaining ($\bar{\imath} < i^*$), but optimal with ex-ante licensing ($i^*$). Yet, once we see IP as an instrument to alleviate the problem of contract incompleteness, the overall conclusion is overturned. Broad IP rights are ineffective blunt tools that can only solve one hold-up problem by creating another (achieving $e^*$ but $\bar{\imath} < i^*$, or $i^*$ but $\bar{e} < e^*$). Thus, the scope of IP should be narrowly defined to cover a specific business opportunity, so it can be protected without holding up sequential innovators.[18]

In fact, in this framework a narrower scope of IP rights increases rather than reducing the ex-ante value accruing to the original entrepreneur $F$. In stage 1, she controls access to the unique intangible asset $A_I$, as in Rajan and Zingales's (2001) analysis of defection and Boldrin and Levine's (2008a) model of imitation. Ex ante, she can therefore not only reap the profits she can derive from $A_I$ directly, but also internalize the value that $S$ can create through a spin-off after working with $A_I$. As a consequence, $F$'s ex-ante value $V$ increases with her partner's incentives for value creation, and thus falls with the likelihood that he will be held up due to the breadth of her IP rights ($\partial V / \partial \omega \leq 0$). Needless to say, these preferences are not time-consistent for $F$, who ex post would instead prefer a broadening of his IP right and the ability to hold up $S$ after his investment is sunk.

Evidence from the U.S. software industry lends suggestive support to this theoretical finding (Bessen and Meurer 2008). Since their introduction in the mid-1990s, patents on

[17] Without ex-ante licensing, in some models broad patents remain optimal (Chang 1995), while in others the opposite is true (Denicolò 2000). Models focusing on imitation instead of cumulative innovation have also found both cases in which optimal patents are broad and short-lived, and others in which they are narrow and long-lived (Gilbert and Shapiro 1990; Klemperer 1990; Gallini 1992). Overall, the literature has not reached firm unambiguous conclusions, but the tentative consensus is that broad patents are likely to be efficient if innovation is cumulative and licensing is possible ex ante (Gallini and Scotchmer 2002).

[18] Broad IP scope would be less detrimental given less contract incompleteness. In the limit, it would become harmless if the parties could write complete contingent contracts over the potential uses of $A_I$, instead of merely defining its owner and licensees. In reality, however, even more uncertainty surrounds cumulative innovation than the operation of a supply chain, and complete contingent contracts seem if anything costlier, more complex, and less likely for IP licensing than for outsourcing (Merges and Nelson 1990; Bessen and Meurer 2008).

software have proved to have particularly broad and vague scope, liable to be reinterpreted and expanded in court due to the abstract nature of the underlying claims. Consistent with ex-ante expectations of inefficiency, from the 1960s up to the 1990s prominent companies in the sector opposed software patents. So did a majority of software developers in Oz's (1998) surveys.

Thus, Bessen and Meurer (2008) advance the legal argument that patents, and especially software patents, should have much clearer and sharper boundaries than they currently do. Their limits should be defined precisely at the time of filing, and the patent should provide unambiguous notice to subsequent entrants. The model provides formal support for this view, and points to a conceptual economic formulation. According to Proposition 3 patents should only protect the market that the patent owner is currently serving. While in the real world the distinction between competing imitations and non-competing spin-offs may not be as clear-cut as in the model, the overall principle stands. For an innovation to be deemed infringing, it should not only be found to be derivative of a patented one. Instead, it should be proven to be simultaneously derivative and materially competing with the original product.

# 6 Conclusions

Empirical evidence increasingly calls into question the notion that stronger legal protection of IP stimulates innovation by guaranteeing higher profits for innovators (Bessen and Meurer 2008). Do IP rights have an economic justification if they fail to provide the dynamic benefits of greater innovation? In this paper, I have shown that they yield static efficiency gains because they underpin the efficient organization of manufacturing firms, even if innovation is taken to be exogenously given.

The organization of production is chosen in equilibrium to incentivize relationship-specific investments that cannot be governed by complete contingent contracts (Williamson 1971). In my analysis, the fundamental incentive device is ownership of productive assets, following the property-rights approach (Grossman and Hart 1986). Intuitively, the range of feasible organizational structures increases with the set of assets over which secure property rights can be assigned, and so does the efficiency of the attainable outcomes. Therefore, it is crucial that the legal system should guarantee secure ownership of intangibles as well as tangibles.

In my model, investment has both a cost and a quality dimension. I have shown that a strong IP system sustains an arm's-length supply relationship that achieves the first best on both dimensions. Under outsourcing, ownership of physical assets induces a supplier to make an efficient cost-minimizing investment. At the same time, his temptation to defect from the partnership with the final good producer is quashed by the expected punishment of IP infringement.

When legal protection of IP is weaker, the efficiency of manufacturing supply chains falls as a trade-off emerges between higher quality and lower costs. An outsourcing partnership is liable to fall victim to defection, forfeiting the contribution to quality of the downstream partner's expertise. Hence, she is likely to choose instead to protect her position through ownership of physical assets, ensuring her employees' loyalty but sacrificing their investment in cost reduction. Furthermore, firm structure then becomes dynamic. As a product reaches maturity and the manufacturer learns how appropriable the associated IP is, it may be feasible to switch from vertical integration to outsourcing, reaping an endogenous decrease in production costs without sacrificing quality.

The predictions of my theory are borne out by empirical evidence on the organization of manufacturing supply chains by multinational companies. Across countries, stronger patent rights are associated with a higher prevalence of arm's-length outsourcing relationships, relative to the establishment of foreign subsidiaries (Antràs, Desai and Foley 2009). Moreover, multinationals transfer technologies abroad considerably sooner after their domestic introduction when the recipient is a subsidiary than when it is an independent partner (Mansfield and Romeo 1980).

My results highlight an alternative economic rationale for IP rights, separate from their classic roles as a reward for innovators, an incentive for disclosure, and an underpinning of the market for information. The justification I have provided is a complement rather than a substitute of these established theories. In particular, my model implies that a robust IP system raises efficiency in exploiting intangibles, and thereby increases their value. This increase should incentivize the creation of knowledge assets just as a market for ideas does (Arrow 1962).

Nonetheless, my analysis casts IP in a different light than the standard account focusing on incentives and efficiency in the innovation sector. In my framework, the main function of IP rights is not to increase inventors' profits, but rather to solve the problem of contract incompleteness in the organization of production. This finding is consistent with Kitch's (1977) intuition that the patent system serves not only a reward function but also and perhaps mainly a "prospect function," enabling legal ownership of ideas and thereby facilitating efficient market activity in all sectors that use intangible assets, and not only in those that produce them.

I have formalized this insight in a model of the choice between outsourcing and vertical integration, but its applicability is broader. My theory emphasizes that legal IP rights are valuable because they provide an efficient publicly-provided substitute for inefficient private self-protection strategies that firms could adopt to safeguard their intangible assets against imitators. I have focused on ownership of physical assets and the cost of blunted incentives for employees' investments. Other distortive choices could be analyzed from the same point of view. E.g., fear of imitation could force an entrepreneur to limit the number of partners she can trust and cooperate with, stunting the growth of her firm. Strong IP rights would then prove necessary to enable efficient firm size, just as this paper has shown they are necessary to enable efficient firm organization.

By refocusing the justification of the IP system, my analysis yields a new perspective on its optimal design. In particular, I have found that IP rights should be strong but narrowly defined. Broad patents are inefficient because they encompass both the original use of an intangible asset, and the potential derivative applications of the same idea. Even if they can be licensed ex ante, they can solve one hold-up problem only at the cost of creating another. Narrow scope is necessary for IP rights to protect an entrepreneur's original business without enabling her to hold up potential spin-offs.

More broadly, a property-rights view of IP as a substitute for complete contingent contracts suggests a reassessment of the prominence of different legal instruments. The traditional emphasis on patents may need reconsidering, and the often neglected law of trade secrecy ought to receive greater attention, as Landes and Posner (2003) have argued. In fact, patent law itself may benefit from moving closer to trade-secrecy doctrines. For instance, my framework lends support to Bessen and Meurer's (2008) case for extending to patents the independent-invention defense, with a view to improving notice and defining clearer and narrower patent boundaries.

# A Appendix

## A.1. Proof of Lemma 1

Consider a non-integrated partnership in which the final producer $F$ owns $A_I$, while the input supplier $S$ owns the physical capital $A_T$: $a_T = 1$ and $a_I = 0$.

Then $S$'s payoff when he chooses cooperation ($S = F$) is

$$\pi_S(1, 0, \eta, e, F) = 1 - \frac{\alpha}{2} - c(e). \tag{A1}$$

If instead he chooses defection, his ex post payoff is

$$\pi_S(1, 0, \eta, e, S) = 1 - \frac{\alpha}{2} - c(e) - \frac{1}{2}\min\{\alpha, \eta\} \tag{A2}$$

because perfect enforcement of IP rights ($\sigma = 1$) implies that $S$ can never profitably infringe on $F$'s ownership of $A_I$ after defecting: $\alpha \leq \eta + \sigma$ for all $\alpha \leq 1$ and all $\eta \geq 0$.

For any effort choice $e$, cooperation is privately preferable to defection:

$$\pi_S(1, 0, \eta, e, F) \geq \pi_S(1, 0, \eta, e, S) \text{ for all } e \tag{A3}$$

For any specialization choice, the privately optimal effort is the first best

$$\max_{e \geq 0} \pi_S(1, 0, \eta, e, s) = \max_{e \geq 0}\{1 - c(e) - e\} = e^* \text{ for all } s. \tag{A4}$$

Hence, the privately optimal decision coincides with the first best

$$s(1, 0, \eta) = F \text{ and } e(1, 0, \eta) = e^* \text{ for all } \eta. \tag{A5}$$

## A.2. Proof of Lemma 2

If $S$ invests in complementing $F$ his ex post payoff $\pi_S(a_T, a_I, \eta, e, F)$ is independent of $a_I$ and $\sigma$. If instead $S$ invests in substituting $F$ his ex post payoff is also independent of $a_I$ when $\sigma = 0$, and equals

$$\pi_S(a_T, a_I, \eta, e, S) = \frac{1 + a_T}{2}[1 - \min\{\alpha, \eta\} - c(e)]. \tag{A6}$$

If $S$ does not own $A_T$ his payoffs are

$$\pi_S(0, a_I, \eta, e, F) = \frac{1}{2}[1 - c(e)] \geq \pi_S(0, a_I, \eta, e, S) = \frac{1}{2}[1 - \min\{\alpha, \eta\} - c(e)]. \tag{A7}$$

Thus, his privately optimal specialization is $s = F$, but his privately optimal effort level is

$$\bar{e} = \arg\max\left\{\frac{1}{2}[1 - c(e)] - e\right\} < e^* \text{ such that } |c'(e)| = 2. \tag{A8}$$

If $S$ owns $A_T$ his payoffs are

$$\pi_S(1, a_I, \eta, e, F) = 1 - \frac{\alpha}{2} - c(e) \text{ and } \pi_S(1, a_I, \eta, e, S) = 1 - \min\{\alpha, \eta\} - c(e). \tag{A9}$$

Thus, his privately optimal effort level is $e(1, a_I, \eta) = e^*$, but his privately optimal specialization is

$$s(1, a_I, \eta) = \begin{cases} S & \text{if } \eta < \alpha/2 \\ F & \text{if } \eta \geq \alpha/2. \end{cases} \tag{A10}$$

## A.3. Proof of Proposition 1 and Corollaries 1 and 2

When $F$ owns $A_T$, $S$'s ex-post payoffs $\pi_S(0, a_I, \eta, e, F)$ and $\pi_S(0, a_I, \eta, e, S)$ are independent of $\sigma$ as well as $a_I$ and $\eta$. As in Lemma 2, vertical integration always induces $S$ to choose the efficient complementary specialization but suboptimal effort. Joint surplus is certain ex ante and equals

$$\Pi(\bar{e}, F) = 1 - c(\bar{e}) - \bar{e}. \tag{A11}$$

If $S$ owns $A_T$ and chooses cooperation, his ex-post payoff $\pi_S(1, a_I, \eta, e, F)$ is also independent of $\sigma$, $a_I$ and $\eta$. If instead he chooses defection, his ex-post payoff is

$$\pi_S(1, a_I, \eta, e, S) = \begin{cases} 1 - \eta - c(e) - \sigma(1 - a_I) & \text{if } \eta \leq \alpha - \sigma(1 - a_I) \\ 1 - \frac{\min\{\alpha, \eta\} + \alpha}{2} - c(e) & \text{if } \eta > \alpha - \sigma(1 - a_I). \end{cases} \tag{A12}$$

If $S$ owns both $A_T$ and $A_I$, his payoff from defection is

$$\pi_S(1, 1, \eta, e, S) = 1 - \min\{\alpha, \eta\} - c(e). \tag{A13}$$

Then, as in Lemma 2, he chooses efficient effort, but suboptimally chooses defection whenever $\eta < \alpha/2$. If instead $S$ owns $A_T$ but $F$ owns $A_I$, $S$'s payoff from defection is

$$\pi_S(1, 0, \eta, e, S) = \begin{cases} 1 - \eta - c(e) - \sigma & \text{if } \eta \leq \alpha - \sigma \\ 1 - \frac{\min\{\alpha, \eta\} + \alpha}{2} - c(e) & \text{if } \eta > \alpha - \sigma. \end{cases} \tag{A14}$$

In this case, too, $S$ chooses efficient effort, but suboptimally chooses defection whenever

$$\eta \leq \frac{\alpha}{2} - \sigma. \tag{A15}$$

Intuitively, it is optimal for $F$ to own $A_I$ so as to reduce the likelihood of inefficient defection when $S$ owns $A_T$.

For $\sigma \geq \alpha/2$, ownership of $A_T$ is optimally allocated to $S$ and the firm operates as a first best non-integrated partnership earning profits

$$\Pi^* = 1 - c(e^*) - e^*. \tag{A16}$$

For $\sigma < \alpha/2$, assigning ownership of $A_T$ to $S$ and of $A_I$ to $F$ generates expected value

$$\mathbb{E}\Pi\left(\eta, e\left(1,0,\eta\right), s\left(1,0,\eta\right)\right) = 1 - c\left(e^*\right) - e^* - \int_0^{\alpha/2-\sigma} \eta d\Phi\left(\eta\right), \tag{A17}$$

such that

$$\Pi\left(\bar{e}, F\right) > \mathbb{E}\Pi\left(\eta, e\left(1,0,\eta\right), s\left(1,0,\eta\right)\right) \Leftrightarrow \int_0^{\alpha/2-\sigma} \eta d\Phi\left(\eta\right) > C, \tag{A18}$$

The function

$$\Lambda\left(\sigma\right) = \int_0^{\alpha/2-\sigma} \eta d\Phi\left(\eta\right) \tag{A19}$$

is monotone decreasing on $(0, \alpha/2)$:

$$\Lambda'\left(\sigma\right) = -\left(\frac{\alpha}{2} - \sigma\right)\phi\left(\frac{\alpha}{2} - \sigma\right) < 0. \tag{A20}$$

It takes values

$$\Lambda\left(0\right) = \int_0^{\alpha/2} \eta d\Phi\left(\eta\right) > C \tag{A21}$$

by the maintained assumption that $F$-integration can be optimal, and

$$\Lambda\left(\frac{\alpha}{2} - C\right) = \int_0^{C} \eta d\Phi\left(\eta\right) < C\Phi\left(C\right) < C. \tag{A22}$$

Thus we can define a threshold

$$\bar{\sigma} \in \left(0, \frac{\alpha}{2} - C\right) \text{ such that } \int_0^{\alpha/2-\bar{\sigma}} \eta d\Phi\left(\eta\right) = C. \tag{A23}$$

such that ownership of $A_T$ is allocated to $F$ in the second best if $\sigma \leq \bar{\sigma}$. By the implicit-function theorem,

$$\frac{\partial\bar{\sigma}}{\partial\alpha} = \frac{1}{2} \text{ and } \frac{\partial\bar{\sigma}}{\partial C} - \frac{1}{\left(\alpha/2 - \bar{\sigma}\right)\phi\left(\alpha/2 - \bar{\sigma}\right)} < 0. \tag{A24}$$

For $\bar{\sigma} < \sigma < \alpha/2$, ownership of $A_T$ is allocated to $S$ in the second best. The non-integrated partnership survives with probability

$$p = 1 - \Phi\left(\frac{\alpha}{2} - \sigma\right) \in (0,1) \text{ such that } \frac{\partial p}{\partial\alpha} < 0 \text{ and } \frac{\partial p}{\partial\sigma} > 0. \tag{A25}$$

The ex ante expected value generated by the partnership is

$$\mathbb{E}\Pi\left(\sigma\right) = \begin{cases} \Pi\left(\bar{e}, F\right) & \text{for } \sigma \leq \bar{\sigma} \\ \mathbb{E}\Pi\left(\eta, e\left(1,0,\eta\right), s\left(1,0,\eta\right)\right) & \text{for } \bar{\sigma} < \sigma < \alpha/2 \\ \Pi^* & \text{for } \sigma \geq \alpha/2, \end{cases} \tag{A26}$$

a continuous function of $\sigma$ with (weakly) positive derivative

$$\frac{\partial \mathbb{E}\Pi}{\partial \sigma} = \begin{cases} 0 & \text{for} \quad \sigma < \bar{\sigma} \\ \left(\frac{\alpha}{2} - \sigma\right) \phi \left(\frac{\alpha}{2} - \sigma\right) & \text{for} \quad \bar{\sigma} < \sigma < \alpha/2 \\ 0 & \text{for} \quad \sigma > \alpha/2. \end{cases} \tag{A27}$$

## A.4. Proof of Proposition 2 and Corollary 3

Firm structure in the first period is described by Proposition 1. In the second period, after the realization of $\eta$ is observed, three outcomes are possible:

1. If $\eta \geq \alpha/2 - \sigma$, an efficient arm's-length partnership is sustainable.
2. If $C \leq \eta < \alpha/2 - \sigma$, the second-best firm structure is vertical integration under $F$'s ownership.
3. If $\eta < C$, the second-best firm structure is vertical integration under $S$'s ownership.

If $\sigma < \bar{\sigma}$,$F$ owns $A_T$ and employs $S$ in the first period. Then in the second period:

1. With probability $p(\alpha, \sigma) = 1 - \Phi(\alpha/2 - \sigma)$, $F$ sells $A_T$ to $S$ and achieves a sustainable first-best arm's-length partnership.
2. With probability $\Phi(\alpha/2 - \sigma) - \Phi(C)$, firm organization is unchanged.
3. With probability $q(C) = \Phi(C)$, such that $\partial q / \partial C > 0$, $F$ sells both $A_I$ and $A_T$ to $S$.

## A.5. Proof of Corollary 4

The expected gain from reorganization is

$$\mathbb{E}\Delta = \left[1 - \Phi\left(\frac{\alpha}{2} - \sigma\right)\right] C + \int_0^C (C - \eta)\, d\Phi(\eta) > 0, \tag{A28}$$

such that

$$\frac{\partial \mathbb{E}\Delta}{\partial \sigma} = C\phi\left(\frac{\alpha}{2} - \sigma\right) > 0, \tag{A29}$$

$$\frac{\partial \mathbb{E}\Delta}{\partial \alpha} = -\frac{C}{2}\phi\left(\frac{\alpha}{2} - \sigma\right) < 0 \tag{A30}$$

and

$$\frac{\partial \mathbb{E}\Delta}{\partial C} = 1 - \Phi\left(\frac{\alpha}{2} - \sigma\right) + \Phi(C) > 0. \tag{A31}$$

## A.6. Proof of Proposition 3 and Corollary

The second best is selected ex ante from three possible combinations of asset ownership and licensing.

1. If $S$ owns $A_T$ and holds a license, then he chooses to defect when $\eta < \alpha/2$, so the arm's-length partnership is preserved with probability

$$1 - \Phi\left(\frac{\alpha}{2}\right) = p - \delta \text{ for } \delta = \Phi\left(\frac{\alpha}{2}\right) - \Phi\left(\min\left\{0, \frac{\alpha}{2} - \sigma\right\}\right), \tag{A32}$$

such that

$$\frac{\partial \delta}{\partial \sigma} = \begin{cases} \phi\left(\frac{\alpha}{2} - \sigma\right) & \text{for} \quad \sigma < \frac{\alpha}{2} \\ 0 & \text{for} \quad \sigma > \alpha/2. \end{cases} \tag{A33}$$

This yields expected profits

$$\mathbb{E}\Pi_L = \Pi^* - \int_0^{\alpha/2} \eta d\Phi(\eta). \tag{A34}$$

Moreover, $S$ invests efficiently in a spin-off and generates expected value

$$\Omega^* = \max_{i \geq 0} \{nv(i) - i\}. \tag{A35}$$

The total value of $A_I$ is then

$$V_L = \Pi^* - \int_0^{\alpha/2} \eta d\Phi(\eta) + \iota \Omega^*. \tag{A36}$$

2. If $S$ owns $A_T$ and does not hold a license, then he chooses to defect when $\eta < \alpha/2 - \sigma$, yielding expected profits

$$\mathbb{E}\Pi_S = \Pi^* - \int_0^{\min\{0, \alpha/2 - \sigma\}} \eta d\Phi(\eta). \tag{A37}$$

Moreover, since he is held up by $F$, he invests suboptimally in a spin-off:

$$\bar{\imath} = \arg\max_{i \geq 0} \{(1-\omega) nv(i) - i\} \text{ such that } v'(\bar{\imath}) = \frac{1}{(1-\omega) n} \tag{A38}$$

such that

$$\bar{\imath} = i^* \Leftrightarrow \omega = 0 \text{ and } \frac{\partial \bar{\imath}}{\partial \omega} = \frac{1}{(1-\omega)^2 v''(\bar{\imath})} < 0 \text{ for all } \omega > 0. \tag{A39}$$

This investment yields expected value

$$\bar{\Omega} = nv(\bar{\imath}) - \bar{\imath} \tag{A40}$$

such that

$$\bar{\Omega} = \Omega^* \Leftrightarrow \omega = 0 \text{ and } \frac{\partial \Omega}{\partial \omega} = \frac{\omega}{1-\omega} \frac{\partial \bar{\imath}}{\partial \omega} < 0 \text{ for all } \omega > 0, \tag{A41}$$

while

$$\frac{\partial\bar{\Omega}}{\partial n} = v\left(\bar{\imath}\right) + \frac{\omega}{1-\omega}\frac{\partial\bar{\imath}}{\partial n} = v\left(\bar{\imath}\right) - \frac{\omega}{\left[\left(1-\omega\right)n\right]^{2} v''\left(\bar{\imath}\right)} > 0 \text{ for all } \omega > 0. \tag{A42}$$

The total value of $A_I$ is then

$$V_S = \Pi^* - \int_0^{\min\{0,\alpha/2-\sigma\}} \eta d\Phi\left(\eta\right) + \iota\bar{\Omega}. \tag{A43}$$

3. If $S$ does not own $A_T$ and holds a license, then he exerts suboptimal effort yielding profits $\Pi^* - C$. Moreover, since he holds a license, he invests efficiently in a spin-off and earns $\Omega^*$. The total value of $A_I$ is then

$$V_F = \Pi^* - C + \iota\Omega^*. \tag{A44}$$

A fourth configuration is possible but dominated: $S$ might neither own $A_T$ nor hold a license. An employee, however, should always be granted a license. $S$ cannot defect if he doesn't own $A_T$, so the only effect of a license is to remove the distortion of $i$.

If $\sigma$ is sufficiently low that

$$\int_0^{\min\{0,\alpha/2-\sigma\}} \eta d\Phi\left(\eta\right) > C - \iota\left(\Omega^* - \bar{\Omega}\right), \tag{A45}$$

then in the second best $S$ does not own $A_T$ and holds a license. The total value of $A_I$ is $V_F$ independent of $\sigma$ and $\omega$.

If $\sigma$ is sufficiently high that

$$\int_0^{\min\{0,\alpha/2-\sigma\}} \eta d\Phi\left(\eta\right) < C - \iota\left(\Omega^* - \bar{\Omega}\right), \tag{A46}$$

then in the second best $S$ owns $A_T$ and does not hold a license. The total value of $A_I$ is $V_S$, strictly increasing in $\sigma < \alpha/2$ and decreasing in $\omega$.

Thus we can define a threshold

$$\tilde{\sigma} = \bar{\sigma} \text{ iff } \omega = 0,\ \tilde{\sigma} = 1 \text{ iff } \iota\left(\Omega^* - \bar{\Omega}\right) \geq C, \tag{A47}$$

and

$$\tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right) \text{ such that } \int_0^{\alpha/2-\tilde{\sigma}} \eta d\Phi\left(\eta\right) = C - \iota\left(\Omega^* - \bar{\Omega}\right) \text{ for } 0 < \iota\left(\Omega^* - \bar{\Omega}\right) < C \tag{A48}$$

such that ownership of $A_T$ is allocated to $F$ in the second best if and only if $\sigma \leq \tilde{\sigma}$.

## A.7. Proof of Corollary 5

By the implicit-function theorem,

$$\frac{\partial \tilde{\sigma}}{\partial \alpha} = \frac{1}{2} > 0 \text{ for } \tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right), \tag{A49}$$

$$\frac{\partial \tilde{\sigma}}{\partial C} = -\frac{1}{\left(\alpha/2 - \tilde{\sigma}\right) \phi\left(\alpha/2 - \tilde{\sigma}\right)} < 0 \text{ for } \tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right), \tag{A50}$$

$$\frac{\partial \tilde{\sigma}}{\partial \iota} = \frac{\Omega^* - \bar{\Omega}}{\left(\alpha/2 - \tilde{\sigma}\right) \phi\left(\alpha/2 - \tilde{\sigma}\right)} > 0 \text{ for } \tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right), \tag{A51}$$

$$\frac{\partial \tilde{\sigma}}{\partial n} = -\frac{\iota}{\left(\alpha/2 - \tilde{\sigma}\right) \phi\left(\alpha/2 - \tilde{\sigma}\right)} \frac{\partial \bar{\Omega}}{\partial n} > 0 \text{ for } \tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right), \tag{A52}$$

and

$$\frac{\partial \tilde{\sigma}}{\partial \omega} = -\frac{\iota}{\left(\alpha/2 - \tilde{\sigma}\right) \phi\left(\alpha/2 - \tilde{\sigma}\right)} \frac{\partial \bar{\Omega}}{\partial \omega} > 0 \text{ for } \tilde{\sigma} \in \left(\bar{\sigma}, \frac{\alpha}{2}\right). \tag{A53}$$

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