Intellectual Property Rights and Efficient Firm Organization

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November 2009
Preliminary Draft

Abstract

Evidence from policy reforms has shown that a strengthening of patent protection has no significant positive impact on innovation and R&D. Are intellectual property rights justified, if not to provide incentives to innovators? I present a new rationale grounded in the theory of the firm. In a world of incomplete contracts and relationship-specific investments, the efficient organization of production is achieved by allocating property rights. If ownership of intangible assets is not sufficiently protected by the legal system, the structure of the firm is distorted: an entrepreneur must either integrate his suppliers, or risk being displaced by them. In either case efficiency falls, even if innovation is entirely exogenous. My model predicts a greater prevalence of vertical integration where intellectual property rights are weaker. It also accounts for a product cycle in which an integrated firm spins off its suppliers and achieves lower costs after learning the appropriability of its technology.

1 Introduction

What is the economic rationale for intellectual property rights? The standard answer is that they reward innovators with monopoly profits, thereby providing incentives for innovation whose social benefits are greater than the deadweight losses caused by monopoly pricing (Schumpeter 1942; Nordhaus 1969; Tirole 1988; Reinganum 1989; Gallini and

*E-mail: gponzetto@crei.cat. I am grateful to Philippe Aghion, Gino Gancia, Edward Glaeser, Oliver Hart, Elhanan Helpman, Andrei Shleifer, Jaume Ventura, and seminar participants at CREI and Universitat Pompeu Fabra for helpful comments. Financial support from the Spanish Ministry of Science and Innovation (grant ECO2008-01666), the Barcelona GSE Research Network and the Government of Catalonia is gratefully acknowledged.

Scotchmer 2002; Barro and Sala-i-Martin 2004). But recent research increasingly casts doubt upon this long-standing conventional wisdom (Gallini 2002).

Empirical estimates of the value of patent protection have an order of magnitude of only 15 percent of expenditures on research and development (Griliches, Pakes, and Hall 1987; Lanjouw 1998; Schankerman 1998). Surveys have found that firms outside the pharmaceutical industry consider patents a relatively unimportant way of protecting the profits due to invention, both in the United States (Levin et al. 1987; Cohen, Nelson, and Walsh 2000) and in Europe (Arundel 2001; Cassiman 2009). Direct evidence from reforms of patent law also invites skepticism. An extension in patent scope in Japan in 1988 did not induce an increase in either R&D spending or innovative output (Sakakibara and Branstetter 2001). Since the early 1980s, patent protection has also been strengthened in the United States, particularly with the creation in 1982 of the U.S. Court of Appeals for the Federal Circuit. This specialized court has appellate jurisdiction over all cases concerning patent validity and infringement, and has proved more favourable to patent holders than the regional courts that previously heard such appeals. In general, it has shown much higher propensity to uphold the validity of patents. In particular, it has extended patentability to business methods.[1] Nevertheless, there is at best no robust evidence that innovation and R&D have increased since the creation of the Federal Circuit (Jaffe 2000; Landes and Posner 2003). On the contrary, the large increases in patenting and patent litigation over the last few decades may have hindered innovative activity (Jaffe and Lerner 2004). A panel analysis of patent policy for 60 countries over 150 years finds that protection-increasing changes in a country's laws have a negative impact on the number of patent applications filed by the country's residents, either domestically or abroad (Lerner 2009).

Theoretically, it has long been known that the effect of strengthened intellectual-property protection on aggregate innovation is ambiguous in a setting of sequential development in which new inventions build upon existing ones (Scotchmer 1991; Gallini and Scotchmer 2002). More recently, Boldrin and Levine (2008) have shown formally that market power is not a requirement for investment in innovation: a share of its returns can also be internalized by price-taking firms in a perfectly competitive environment with capacity constraints. An increasing awareness is emerging, particularly among legal scholars (Landes and Posner 2003; Heald 2005), that the most important justification of intellectual property may not be as a way of providing rewards for innovation, but rather as a mechanism to reduce the social losses that would result if entrepreneurs had to rely exclusively on secrecy.

In this paper, I show that intellectual property rights are necessary to enable the efficient organization of production. The focus is on firm boundaries and the decision to acquire inputs from outside suppliers or to produce them internally (Coase 1937;

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

Williamson 1971, 1975, 1985). The different efficiency properties of market transactions and vertical integration are explained endogenously, following the property rights theory of the firm developed by Grossman and Hart (1986) and Hart and Moore (1990). In a world of incomplete contracts, the fundamental source of incentives is the ownership of complementary assets, which increases an agent's bargaining power ex post, and therefore his willingness to make relationship-specific investment ex ante. The standard analysis assumes that property rights are well defined and effectively enforced for all relevant assets. But in the absence of a strong intellectual property regime, it may not be possible for any party to own intangible assets. This further reduces the range of available incentive devices, and therefore prevents the second best organization of production.

In my model, an entrepreneur is endowed with the blueprint for producing a profitable final good. Its exploitation requires the cooperation of a supplier, who makes a non-contractible investment in producing a specialized intermediate. This exposes him to the classical hold-up problem: after the investment is sunk, its benefits do not accrue to the investor alone, but must be shared with the final-good producer. Underinvestment is alleviated by granting ownership of tangible assets to the investing party.

However, the supplier does not only decide how much effort to exert. As in Rajan and Zingales's (2001) model of managerial hierarchy, he also faces a choice between investing in the relationship with the entrepreneur, or instead in imitating his idea and producing independently an inferior version of the final good. If the legal system is perfectly effective in preventing imitation, the optimal investment in complementary skills is assured in a non-integrated partnership. But if enforcement of intellectual property rights is imperfect, such a relationship becomes unstable. Intangible assets cannot be fully protected by secrecy within the partnership. An entrepreneur's idea must be revealed to the supplier if he is to invest in producing a specialized input, and this creates a risk of expropriation.

An independent supplier may choose to bypass the specialized producer of the final good. This involves a loss of aggregate efficiency, and possibly some legal costs; but it eliminates the need to share surplus with the entrepreneur ex post. Therefore, the strategy is sometimes privately optimal, leading to a breakdown of the partnership and a switch to integrated production by the supplier. To avoid this outcome, the entrepreneur can himself organize a vertically integrated firm. This choice, too, entails an efficiency loss, since the hold-up problem reduces the relationship-specific investment of an employee to a lower level than that of an outside partner. The underlying problem is that, as Teece (1986) particularly stresses, in a weak intellectual property regime ownership of complementary physical assets also grants control rights over intangibles.

The analysis yields the prediction that vertical integration should be more prevalent in sectors and jurisdictions in which intellectual property rights are less securely protected. Furthermore, I develop a natural dynamic extension of the model and find that imperfect legal protection of intangible assets accounts for changes in the structure of the

firm over the life cycle of a product. At first, an innovative final good is produced by an integrated firm. Once the entrepreneur acquires knowledge about the appropriability of his technology, it can be safe to spin off a supplier , thereby attaining a reduction in production costs. The model thus predicts a switch from vertical integration to outsourcing. Evidence on the strategies of multinational corporations is consistent with both empirical predictions (Mansfield, Romeo and Wagner 1979; Mansfield and Romeo 1980; Davidson and McFetridge 1984, 1985; Lee and Mansfield 1996; Antràs, Desai and Foley 2009).

Most important, I find that efficiency is monotone increasing in the enforcement of intellectual property rights in a framework in which innovative activity and the creation of intangible assets are completely exogenous. This is in contrast with the focus of the existing literature, which has concentrated on innovation and idea-creation even when its analysis of the patent regime has moved beyond the classic view of its role as a reward mechanism for innovators.

The most established alternative view, dating back at least to the nineteenth century (Machlup and Penrose 1950) views patenting as a way to induce disclosure of the inventor's private information. In a context of sequential innovation, disclosure is socially valuable but privately costly. It can occur voluntarily as a signal of competitiveness, to obtain better financing terms (Bhattacharya and Ritter 1983) or to dissuade rivals (Horstmann, MacDonald, and Slivinski 1985; Anton and Yao 2003, 2004). Patents, however, can provide added incentives by awarding a temporary monopoly (Scotchmer and Green 1990), by allowing a firm to extend a patent race (Lichtman, Baker and Kraus 2000; Baker and Mezetti 2005; Bar 2006), or by exposing it to the threat of patenting of a subsequent invention (Johnson 2005; Ponce 2007a, b) or a simultaneous one (Kultti, Takalo, and Toikka 2007). The disclosure argument comes closer to the present analysis when it takes invention as given and considers the problem of imitation. In that setting, the case for intellectual property rights is weak. Patents might dissuade wasteful efforts to reverse-engineer a trade secret (Denicolò and Franzoni 2004a, 2004b, 2006). But such efforts could identically be directed at inventing around a patent (Gallini 1992; Bessen 2005), and they could be avoided by the original inventor through licensing (Gallini 1984; Maurer and Scotchmer 2002; Cugno and Ottoz 2006). Boldrin and Levine (2004) consider the resources an innovator may waste to maintain secrecy. They show that the patent system can be a complement rather than a substitute to private rent-seeking, and conclude that it is likely to do more harm than good.

The difficulty of sustaining a market for information, emphasized by Arrow (1962), has also received considerable scrutiny. Intuitively, stronger intellectual property rights enable firms to specialize in research and development. Innovation may increase when it is outsourced rather than having to be carried out within integrated producers (Arora, Fosfuri, and Gambardella 2001; Arora and Merges 2004). Patents also provide incentives for universities to search for profitable buyers of their scientific discoveries, which may

be more efficient than having firms search for relevant knowledge (Hellmann 2007a). However, ideas can be traded even if they are not protected by intellectual property rights: 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). An entrepreneur can enlist outside help to develop an innovation, by acting as the nexus connecting two agents with complementary skills, neither of which could trust the other directly (Biais and Perotti 2008). Hellmann and Perotti (2009) suggest that firms can play the role of incubators by establishing a reputation for the safe internal circulation of innovative ideas.

The opposite problem of corporate innovation when employees can leak or steal information is considered by Anton and Yao (1995), Baccara and Razin (2007), and Hellman (2007b). Rajan and Zingales (2001) describe the optimal structure and evolution of a hierarchy that prevents the leakage of a profitable idea. Baccara (2007) models the creation and diffusion of technology when contractors and consultants hired by a firm spread its know-how to competitors, while Demski et al. (1999) explore how consulting firm organize internally to minimize such leakage. Aghion and Tirole (1994a, b) use the property rights theory of the firm to analyze the production of innovation as a relationship between a research unit and its financier. I complement these analyses by highlighting the pivotal role of intellectual property rights in allowing the efficient organization of all firms that use intangible assets, even without being involved in research and development.

2 Intangible Assets in the Property Rights Theory

The transaction costs literature (Coase 1937; Williamson 1971, 1975, 1985) recognizes that the world is so complex and unpredictable that it would be impossible or prohibitively costly to write contracts that specify ex ante in perfect detail all the consequences of all possible contingencies. Instead, production involves the cooperation of many agents bound by incomplete contracts, whose terms are progressively specified and renegotiated. The haggling involved in this process may be the source of considerable costs. Mitigating them is the purpose and raison d'être of the firm as an economic institution.

A crucial source of inefficiency is the hold-up problem (Klein, Crawford, and Alchian 1978). The parties have the ability to make specific investments that generate value in the context of their relationship, but have limited use outside of it. Incomplete contracting prevents them from devising ex ante an optimal incentive scheme that rewards each agent for his own investment. Instead, the surplus generated is shared ex post through bargaining. As a consequence, each party is reluctant to invest, fearing the others will hold him up once the investment is sunk.

The property rights theory of the firm (Grossman and Hart 1986; Hart and Moore

1990) shows that, absent complete incentive contracts, asset ownership is the second best incentive device. The owner of an asset has residual control rights over it: whenever its usage is not specified by an previous contract, he can decide how to use it and exclude others from using it. This ability grants him bargaining power and allows him to internalize a grater share of the surplus ex post. The efficient organizational structure sets incentives for relationship-specific investment by allocating optimally among the parties the assets employed in the operation of the firm.

The second best incentive mechanism therefore relies on effective enforcement of property rights over all relevant means of production. This is a natural assumption for tangible assets such as plots of land, production plants, or inventories. It is less obviously satisfied in the case of intangible assets such as product designs, brands, or client lists, whose protection depends on the prevailing intellectual property regime. Its weakness may prevent the efficient organization of the firm and exacerbate the hold-up problem in production.

This fundamental intuition can be formalized in a stylized model that includes two agents with complementary skills, and two complementary assets, on the lines of Hart's (1995) textbook treatment of the property rights approach. A final-good producer F can generate revenue r by using an intangible asset A_I, say the design of a distinctive product, and a specialized input. This intermediate is produced using a tangible asset A_T, say a manufacturing plant, thanks to relationship-specific investment by a supplier S

The production process is divided into two stages. Ex ante, at time 1, S makes an investment that enables production of the specialized input. Ex post, at time 2, the intermediate is produced. The investment is unobservable, and thus cannot be contractually determined. Ex post costs, revenues and profits are also unverifiable and thus cannot be part of an enforceable contract. However, the parties have rational expectations, and given the absence of uncertainty they can correctly predict at time 1 all outcomes at time 2.

Incomplete contracting is captured by the assumption that ex ante the precise characteristics of the specialized input are uncertain. As a consequence, a long-term supply contract cannot be written. Uncertainty is resolved at time 2, and only then can the parties bargain over the price of the intermediate. The outcome of their negotiation is represented by the Nash bargaining solution.

Ex ante, the only incentive device available is the allocation of property rights. At time 0, before S invests, the parties negotiate ownership of A_I and A_T. F and S have symmetric information at time 0, and they are sufficiently wealthy that each could acquire both assets. By the Coase theorem, they agree on the asset allocation that maximizes expected joint surplus. Restrictive covenants that limit the owner's freedom to use an asset are assumed to be prohibitively costly, so ownership assigns complete control rights.

S's investment involves two distinct decisions. As in Rajan and Zingales (2001), the

supplier must first decide whether to become a complement to F's human capital, or instead to attempt to become a substitute. As a consequence of this choice, S invests in enabling A_T to produce one of two mutually exclusive specialized inputs. The first allows F, with A_I, to produce a high-quality final good that generates revenues r. The second makes it possible to use A_I to produce a low-quality final good that generates revenues $(1-\eta)\,r$. The high-quality version of the final good relies crucially on F's human capital, whose value is captured by $\eta \in (0,1)$. Instead, the low-quality version can also be produced directly by S. The value of the division of labour and the inevitable imperfection of S as a substitute for F is captured by the fall in revenues associated with the choice of a product that can be produced autarkically. Regardless of the choice of specialization, A_T can also be used to produce generic intermediates that cannot be used with A_I to produce the distinctive final good, but which can be sold for a market price $(1-\alpha)\,r$, with $\alpha \in (0,1)$ capturing the value of A_I.

The second investment decision concerns the effort and expenditure devoted to improving efficiency in manufacturing, which determines the cost of producing intermediates using A_T. An ex ante investment of $e \geq 0$ yields an ex post cost $c(e)$, a positive, strictly decreasing and convex function with

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

satisfying the boundary conditions

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

which ensure an interior solution to the choice of e for all configurations of asset ownership.

This function describes identically the cost of producing a specialized or a generic input. S's investment in complementing F is relationship-specific in an absolute sense: it generates unambiguously higher surplus for the partnership than outside of it. However, unlike Hart (1995), I do not make the additional assumption that its marginal product must be strictly higher within the relationship. The investment is also strictly specific to the physical asset A_T and to S's human capital: without either of them, it is impossible to produce a specialized intermediate, and therefore a final good using A_I.

The first best investment choice maximizes the ex ante aggregate value of the partnership. This requires S to invest in complementing F and to provide effort

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

In this setting, perfect enforcement of intellectual property rights suffices to attain the first best despite incomplete contracting and relationship-specific investment. All proofs are provided in the appendix.

Lemma 1 *Suppose that the legal system protects an agent's exclusive right to use the intangible asset A_I and produce the related final good. Then the first best is achieved by a non-integrated partnership in which the final producer owns the right to A_I while the input supplier owns the physical capital A_T.*

The intuition behind this result is straightforward. When intellectual property is effectively protected, non-integration implies that the final good can only be produced when the owners of the two assets cooperate. Therefore, if A_I belongs to F it is pointless for S to try substituting for F's human capital. This would reduce potential sale revenues, without removing the need to negotiate with F, who controls an indispensable intangible asset. At the same time, ownership of A_T suffices to let S internalize his entire investment, because the owner of the plant has the same cost of producing a specialized intermediate for the partnership or a generic one for the market.

The optimum is achieved by using the two assets to provide separate incentives. The allocation of the intangible asset A_I directs the quality choice and incentivizes the efficient specialization. Ownership of the tangible asset A_T regulates the cost choice and induces the optimal provision of effort. Without secure property rights to the idea, however, physical capital acquires two contrasting roles. On the cost side, it still provides beneficial incentives to increase investment. On the quality side, however, it detrimentally increases S's temptation to break the partnership. It is not necessarily possible to reconcile the two and induce optimal investment along both dimensions.

In particular, if S retains ownership of A_T his cooperation with F is no longer assured. Them the gains from specialization and F's human capital risk being dissipated.

Lemma 2 *Suppose the legal system does not protect property rights over intangibles.*

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

If the final producer owns the physical capital A_T, the input supplier efficiently invests in high-quality production. However, the equilibrium amount of cost-reducing investment is suboptimally low ($\bar{e} < e^*$).

At time 1, S's investment is distorted in anticipation of having to share with F ex post the surplus generated by the partnership. When he owns A_T, S fully internalizes the marginal return to his investment, so he does not respond to the hold-up problem on the quantity margin, by underinvesting. However, he can avoid being held up by switching to a low-quality product and eliminating the need to cooperate with F. From S's point of view at time 1, the choice involves a meaningful trade-off between reducing joint surplus and increasing his own share of it. When F's human capital (η) is not sufficiently

important compared to the value (α) of A_I, the supplier distorts the quality decision and produces output of low quality. Needless to say, this choice is jointly suboptimal from the ex ante perspective of time 0: 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 ex ante.

Alternatively, F can acquire residual control of A_T and bind S to himself by hiring him as an employee. However, this organization blunts the supplier's incentives for cost-reducing investment. This result exhibits the standard consequences of the hold-up problem. If S does not own A_T, he cannot fully internalize his own investment, and therefore suboptimally reduces its quantity. On the other hand, the necessity of cooperating with F, which is the very reason for underinvestment, also removes the temptation to distort the quality decision. The cost of underinvestment equals

$$\bar{c} = c(\bar{e}) + \bar{e} - c(e^*) - e^* > 0. \tag{4}$$

Weak intellectual property rights threaten the feasibility of vertical specialization and the organization of production through arm's length transactions in a non-integrated relationship. Consistent with Teece's (1986) observation, I find that direct ownership of manufacturing capabilities becomes the key to a secure market position. The final good producer must either head an integrated company and have an employee manufacture the specialized input, or face the risk that his supplier will abandon the partnership, expropriate F's intellectual assets, and seize the market with a low-quality good produced by an integrated firm of his own.

To analyze the solution to this problem and the prevalence of different organizational forms as a function of the legal environment, I characterize enforcement by a single parameter $\sigma \in [0,1]$. If S infringes upon F's rights over A_I, he is liable to pay compensation whose expected value equals σr. This formulation has an intuitive interpretation in terms of lost profits damages, but it should be interpreted more broadly to encompass all sorts of legal remedies. The specification captures without loss of generality any amount of expected compensation, since $\sigma = 1$ is more than sufficient to deter any violation. In addition, the analysis would not be materially affected if we assumed that some the legal costs are a loss for the partnership rather than a transfer from S to F: such a loss would be avoided in any case by efficient bargaining at time 2.

Moreover, I assume that the appropriability of A_I, namely its ability to be used without F's human capital, is a random variable η with support $[0,1]$ and probability distribution $\Phi(\eta)$ with continuous density $\phi(\eta) > 0$ for all $\eta \in [0,1]$. The distribution Φ is common knowledge, but η is unknown at time 0 when the assets are allocated and the partnership organized. Its realization is only revealed at time 1 when S makes the

investment decision. The parties are assumed to be risk neutral, so expected surplus is maximized at time 0.

Proposition 1 *If the expected penalty for infringement is sufficiently large compared to the value of intangibles ($\sigma \geq \alpha/2$), legal protection of intellectual property is perfectly effective. Then the firm is organized as a non-integrated partnership and attains first best efficiency.*

Legal protection is ineffective if the penalty for infringement is lower than a threshold $\bar{\sigma}(\alpha, \bar{c}) \in [0, \alpha/2)$. The threshold is increasing in the value of intangibles ($\partial\bar{\sigma}/\partial\alpha \geq 0$) and decreasing in the importance of the supplier's investment ($\partial\bar{\sigma}/\partial\bar{c} \leq 0$). Facing ineffective legal protection ($\sigma < \bar{\sigma}(\alpha, \bar{c})$), the firm is vertically integrated under the ownership of the final producer, and the supplier exerts suboptimal effort ($\bar{e}$).

When legal protection has partial efficacy ($\bar{\sigma}(\alpha, \bar{c}) \leq \sigma < \alpha/2$), the supplier owns the physical capital and exerts optimal effort (e^*). Ex post an efficient non-integrated partnership with the final good producer is preserved with probability $p(\alpha, \sigma)$. Otherwise the supplier produces final output of inefficiently low quality as an integrated firm. The probability of non-integration is decreasing in the value of intangibles ($\partial p/\partial\alpha < 0$) and increasing in the extent of legal protection ($\partial p/\partial\sigma > 0$).

The ex ante expected value generated by the partnership is increasing in the extent of legal protection of intellectual property ($\partial\Pi/\partial\sigma \geq 0$).

The first result is immediate. By distorting the quality choice an substituting away from F's human capital, S gains his partner's ex post share of first best surplus ($\alpha/2$) at the cost of an efficiency loss (η) and a legal cost (σ). Perfect enforcement is thus obtained when expected damages are at least equal to F's ex post payoff, so that S's temptation to defect is removed with probability one.

When enforcement 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 could prove sufficient to sustain the first-best non-integrated partnership. On the other, there is a risk that S will break away from F to run his own low-quality, low-cost vertically integrated firm.

The intellectual property regime can be considered ineffective when it is dominated by private self-protection. When legal protection is too weak ($\sigma < \bar{\sigma}$), firm organization and equilibrium outcomes are identical as if it were nil ($\sigma = 0$). Greater sanctions a necessary to protect a more valuable asset ($\partial\bar{\sigma}/\partial\alpha \geq 0$). Naturally, what needs protection is not the total revenue that the intangible asset can produce (r), but only the value it adds compared to the alternative use of the complementary factors of production (αr). The test for the effectiveness of intellectual property rights is also more stringent when the

alternative technology for private self-protection is itself more effective. In the model, this is the case when it imposes a lower efficiency cost ($\partial\bar{\sigma}/\partial\bar{c} \leq 0$). In fact, only when the cost of underinvestment ($\bar{c}$) is sufficiently low and the value of intangibles (α) is sufficiently high can F-integration provide an attractive protection strategy ($\bar{\sigma} > 0$).

When self-protection is too costly and legal protection imperfect, the eventual structure of the firm is realized ex post. Allocating ownership of A_T to S can lead either to a non-integrated partnership between S and F, or to autarkic production by S alone in an integrated firm that effectively licenses F's intangible asset A_I and carries out internally production of both the intermediate input and the final good. The latter option is the more likely the more valuable and the less protected intellectual property is ($\partial p/\partial\alpha < 0$ and $\partial p/\partial\sigma > 0$).

The analysis thus predicts that vertical integration should be more common in sectors or countries in which the intellectual property regime is weaker. Consistent with this prediction, studies of foreign direct investment document the role of vertical integration as a response to weak intellectual property rights. Lee and Mansfield (1996) present a survey of 100 major U.S. firms representative of six manufacturing industries: for each sector and each of the 14 developing countries considered, the fraction of respondents reporting that "intellectual property protection is too weak to permit them to transfer their newest or most effective technology to wholly owned subsidiaries" is smaller than the fraction of firms that consider such protection insufficient to allow technology licensing to independently-owned foreign firms. Antràs, Desai and Foley (2009) exploit a comprehensive dataset on the activities and foreign direct investment decisions of U.S. multinationals: the data show greater use of arm's length technology transfer to countries with higher investor protection. Although the emphasis is on credit-market development, their econometric analysis also finds that an explicit measure of patent protection significantly predicts the choice of outsourcing over operation through a direct affiliate.

The proposition concludes by formalizing the main insight on the benefits of intellectual property rights. By enabling the assignment of exclusive control rights to intangible assets, they expand the range of available incentive devices, and allow firms to organize in a way that mitigates the problem of non-contractible investment. As a consequence, efficiency is monotone increasing in the legal protection of intangibles ($\partial\Pi/\partial\sigma \geq 0$). This results departs radically from the standard analysis of intellectual property, because in my model there is no research and development, nor any innovation, but merely intangible assets that are exogenously given. In fact, it is not necessary to interpret A_I as the outcome of an innovative activity.

In my model, as usual, the value of a firm that exploits an intangible asset is increasing in its legal protection. In the classic framework this is only desirable to stimulate creation of intangible assets, and comes at the cost of granting the firm a monopoly power that reduces efficiency ex post. Instead, I have focused on dynamics within the firm that leave

both its stock of intellectual property and its market power unchanged. Abstracting from the usual considerations of which intangible assets can be exploited, and who can exploit them, I have investigated how they can be exploited. My finding is that they can be used more efficiently if they are the object of secure property rights.

3 Intellectual Property and Organization Dynamics

Proposition 1 explains the allocation of asset ownership and the initial organization of the firm. In the real world the boundaries of the firm are rarely constant over the life cycle of a product, as Coase (1937) already recognized. Imperfect legal protection of intellectual property rights can also explain such a dynamic evolution of organizational structure.

The analysis can be developed in a straightforward extension to a two-period setting. In the first period, the sequence of actions is the same described in the baseline model. First F and S allocate property rights, exchanging lump-sum payments as necessary. Then η is realized, and S makes the investment decision. Finally the parties bargain over the division of surplus, and produce the intermediate input and the final good. In the second period, the same stages are repeated: first the firm can be reorganized by transferring assets; then S invests; finally negotiation and production take place. The difference is that the realization of η is known since the beginning of the period, so the allocation of property rights over A_T and A_I can be re-optimized taking it into account.

Proposition 2 *Suppose that legal protection is ineffective ($\sigma < \bar{\sigma}(\alpha, \bar{c})$) and the final producer initially owns the tangible asset A_T.*

After an initial period of operation as a vertically integrated firm, with probability $q(\bar{c})$, which is increasing in the relative importance of the supplier's investment ($\partial q/\partial \bar{c} > 0$) a buy-out occurs: ownership of both assets is transferred to the supplier, who assumes the leadership of the integrated firm. With probability $p(\alpha, \sigma)$ (such that $\partial p/\partial \alpha < 0$ and $\partial p/\partial \sigma > 0$) a spin-off occurs: ownership of physical capital is transferred to the supplier, and the firm operates as a non-integrated partnership.

Re-organization generates an efficiency gain $\Delta \geq 0$. The ex ante 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 ($\partial \mathbb{E}\Delta/\partial \bar{c} > 0$).

In a weak intellectual property regime, vertical integration under F's ownership is initially chosen as a form of insurance against the risk of defection by S. Once the value of F's human capital has become observable through the realization of η, 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.

F-integration may remain optimal even after information revelation, but this need not be the case.

If F's contribution to partnership value is sufficiently low, it is suboptimal to try protecting it despite the weakness of the legal environment: instead, F sells A_T and A_I to S. The firm remains vertically integrated, since both assets are owned by the same agent, and more important both stages of production are carried out within the boundaries of the firm. With a buy-out, the firm switches from producing high quality output at a high cost to being a low-quality, low-cost producer. It profits from doing so because the decline in quality is smaller than the reduction in cost. Thus this reorganization is the more likely to be optimal, the higher the cost increase associated with underinvestment ($\partial q/\partial \bar{c} > 0$).

If instead the value of F's human capital is sufficiently high, S is not subject to the temptation of producing without it. As in proposition 1, overcoming the temptation is easier when legal sanctions are stronger ($\partial p/\partial \sigma > 0$) and when A_I is less valuable ($\partial p/\partial \alpha < 0$). Then F can retain ownership of A_I, but sell A_T to his supplier, having ascertained that he can be trusted with investing in complementarity. The spin-off allows the attainment of first best efficiency: the non-integrated partnership achieves simultaneously high quality and low costs.

The model therefore predicts a dynamic pattern in which vertical integration is followed by outsourcing. Empirical evidence on the technology-diffusion strategies of U.S. multinationals is consistent with this prediction. Recently developed innovations tend to be transferred internally to subsidiaries, while licensing to outside partners becomes more likely for more mature technologies (Mansfield, Romeo and Wagner 1979; Mansfield and Romeo 1980; Davidson and McFetridge 1984, 1985).[2]

Finally, the model implies again that stronger legal protection of intellectual property is beneficial. The mechanism is the same as in proposition 1. Higher sanctions are more likely to deter S from distorting the quality dimension of investment, and therefore to allow the organization of an efficient non-integrated partnership ($\partial \mathbb{E}\Delta/\partial \sigma > 0$). For the same reason, the expected gain from reorganization is decreasing in the value of A_T, which makes deterrence harder ($\partial \mathbb{E}\Delta/\partial \alpha < 0$). The gain increases with the cost of underinvestment ($\partial \mathbb{E}\Delta/\partial \bar{c} > 0$), because that coincides with the cost of self-protection that vertical integration under F incurs.

On the other hand, once spin-offs are brought into the picture, the model can show how over-zealous protection of existing intangible assets may prove detrimental in a setting of incomplete contracting. The issue is the promotion or hindrance of spin-offs that do not continue operating as suppliers of the original firm, but rather pursue new busi-

[2] Antràs (2005) presents an alternative explanation for these dynamics when intellectual property rights are not a concern. In his model, both the headquarters and the supplier make relationship-specific investments. An exogenous evolution of technological reduces over time the relative importance of headquarter investment, prompting a corresponding reduction in its asset ownership.

ness opportunities. This mechanism of firm creation lies at the heart of entrepreneurship. Bhidé (2000) surveys a set of fast-growing privately held start-ups included in the 1989 *Inc.* 500 list, and concludes that the seed idea was typically encountered during previous employment. Nonetheless, the typical spin-off does not compete directly with its parent company. On the contrary, entrepreneurs exploiting derivative ideas usually aim at serving unexploited niche markets, avoiding head-on competition with longer-established incumbents.

To extend the analysis in this direction, suppose that F is an entrepreneur endowed with an idea A_I that enables him to earn a profit. In stage 0, F recruits S from a competitive pool of potential suppliers. Thus F has full bargaining power and can capture the entire ex ante surplus from the relationship.

In stage 1, a new opportunity arises for S: in addition to investing in specializing to F and A_I, he can develop a derivative idea. The two investments are not mutually exclusive, since the latter does not require the operation of A_T to produce specialized intermediate, but merely the combination of S's human capital and F's intangible asset to produce a new one.An idea-generating investment of $i \geq 0$ yields an derivative idea whose expected present value $v(i)$ is a positive, strictly increasing and concave function with

$$v(i) \geq 0,\ v'(i) > 0 \text{ and } v''(i) > 0 \text{ for all } i < 0, \tag{5}$$

satisfying the boundary conditions

$$\lim_{i \to 0} v'(i) > 2 \text{ and } \lim_{i \to \infty} v'(i) = 0. \tag{6}$$

which ensure an interior solution to the choice of i.

The original intangible asset A_I is accorded legal protection whose breadth $\omega \in [0,1]$ is measured by the probability that S's derivative idea will be found to infringe. In that case, its exploitation requires S to bargain with F in order to obtain a license. The outcome of this negotiation is again modelled by the Nash bargaining solution.

Proposition 3 *Investment in the development of derivative ideas is monotone decreasing in the breadth of legal protection of the original one ($\partial i / \partial \omega < 0$). Its level is optimal when intellectual property rights are perfectly narrow ($\omega = 0$).*

The value V of the original idea is monotone decreasing in the breadth of its legal protection ($\partial V / \partial \omega < 0$) and is maximized by perfectly narrow intellectual property rights ($\omega = 0$).

Just as the intellectual property regime can solve the hold-up problem, it can create one where none existed. The first part of the proposition directly mirrors Green and Scotchmer's (1995) analysis. They focus on the division of profits in sequential innovation, and highlight that investments that increase aggregate profits are always made if

contracting is possible ex ante, before the investment occurs; but not necessarily if it happens ex post, when the second innovator has sunk his costs. In a world of incomplete contracts, ex ante agreements are impossible, so negotiation must take place ex post, if at all. Thus the development of derivative ideas is the more intense, the lower the likelihood that the development has to bargain with the owner of the original asset.

However, the second part of the proposition departs from the usual results in the literature on cumulative innovation, surveyed by Gallini and Scotchmer (2002). The consensus favours broad patents, provided that they can be licensed by second-generation products. The main concern, albeit not the only one, is to provide sufficient rewards for the original innovator (Chang 1995). In the present setting, these incentives are increased rather than reduced by narrow protection. The crucial difference is that, as in Rajan and Zingales (2001) and Boldrin and Levine (2008), in my model the original producer F controls access to the intangible asset. This allows him to internalize not only the profits he can derive from it directly, but also the value that other agents can create from it after working with it. As a consequence, it is in his own interest not to be able to hold up his partners ex post, so that their incentives for value creation are maximized.

4 Conclusions

The firm emerges as an economic institution to organize production efficiently in a world in which transactions cannot be governed by complete contracts. The property rights approach highlights that ownership of productive assets is the key device to provide incentives for investment under incomplete contracting. It follows that the range of feasible organizational structures, and the quality of the outcomes they are able to attain, is at least weakly increasing in the set of assets to which control rights can be assigned.

In this perspective, I have shown that clearly defined and effectively enforced intellectual property rights are desirable even if they are not necessary, or possibly not useful, to stimulate innovation. They increase efficiency by allowing firms to exploit optimally their existing intangible assets. In particular, they ensure that ownership of physical capital and intellectual property can be separated, so that the two may be used to provide different incentives for relationship-specific investment.

In my model, investment has a quality and a cost dimension. A strong intellectual property regime suffices to compensate for the incompleteness of contracts, and sustains a non-integrated partnership that achieves the optimum on both dimensions. When legal protection is weaker, vertical integration is more common, and efficiency falls as a trade-off emerges between higher quality and lower costs. Organizational structure also becomes dynamic. Innovative products are initially manufactured by integrated firms. Subsequently, a switch to outsourcing may take place, entailing an endogenous decrease in manufacturing costs.

These results present a new rationale for intellectual property rights, complementary to their well-known roles as a reward for innovators, an incentive for disclosure, and an underpinning of the market for information. While I have focused on one justification alone, all are present in the real world. Their relative importance, whose assessment goes beyond the scope of the present work, has implications for the optimal design of intellectual property law.

As a first step in the direction of a broader analysis, I have found that intellectual property rights should be narrowly defined if their main role is internal to the firm. The entrepreneur controls access to his know-how, and this suffices to let him internalize the gains resulting from derivative ideas developed by his associates. Overly broad legal protection reduces the value of the original idea by creating a hold up problem ex post.

More broadly, my findings suggest a reassessment of the respective prominence of different legal instruments. The economic literature has placed the most emphasis on patents as grants of monopoly power. However, if protection of intangibles is most important within the firm, pride of place would go to the law of trade secrecy, and to such elements as non-compete clauses and non-disclosure agreements. Patents would be a substitute to be used when a secret cannot be protected by contracts due to their incompleteness.

A Appendix

A.1. Proof of Lemma 1

Suppose that S invests in complementing F. Ex post, joint surplus in the partnership is $r - c(e)$. If the relationship breaks down, neither F nor S can produce the final good. However, S can produce generic intermediates and earn $(1-\alpha) r - c(e)$. Hence his payoff in bargaining is

$$\pi_S^F(e) = \left(1 - \frac{\alpha}{2}\right) r - c(e), \tag{A1}$$

and the optimal investment level is $\arg\max\left\{\pi_S^F(e) - e\right\} = e^*$.

Suppose instead that S invests in substituting F. Ex post, joint surplus in the partnership is $(1 - \min\{\eta, \alpha\}) r - c(e)$. If the relationship breaks down, again the final good cannot be produced but S can produce generic intermediates. His bargaining payoff is

$$\pi_S^S(e) = r - c(e) - \frac{1}{2}(\alpha + \min\{\eta, \alpha\}) r < \pi_S^S(e) \text{ for all } e \geq 0,. \tag{A2}$$

since $\eta > 0$ and $\alpha > 0$. Thus the complementary investment is privately optimal.

A.2. Proof of Lemma 2

Let S own A_T, and suppose he invests in complementing F. Ex post, joint surplus in the partnership is $r - c(e)$. If the relationship breaks down, neither F nor S can produce the final good. However, S can produce generic intermediates and earn $(1-\alpha) r - c(e)$. Hence his bargaining payoff is

$$\pi_S^F(e) = \left(1 - \frac{\alpha}{2}\right) r - c(e), \tag{A3}$$

and the optimal investment level is e^*.

Suppose instead that S invests in substituting F. Ex post, he earns the full surplus

$$\pi_S^S(e) = (1 - \min\{\eta, \alpha\}) r - c(e), \tag{A4}$$

with or without F's cooperation. Again the optimal investment level is e^*.

However, $\pi_S^S(e) > \pi_S^F(e)$ if and only if $\eta < \alpha/2$.When this inequality is satisfied, it is privately optimal for S to invest in substituting F if he owns A_T.

Let F own A_T, and suppose that S invests in complementing F. Ex post, joint surplus in the partnership is $r - c(e)$. If the relationship breaks down, no production can take place, since F lacks access to S's human capital and S lacks access to the physical capital A_T. Ex post bargaining give S a payoff

$$\pi_S^F(e) = \frac{1}{2}[r - c(e)], \tag{A5}$$

and the optimal investment level is

$$\bar{e} = \arg\max\left\{\pi_S^F(e) - e\right\} < e^* \text{ such that } |c'(e)| = 2. \tag{A6}$$

Suppose instead that S invests in substituting F. Ex post, joint surplus in the partnership is $(1 - \min\{\eta, \alpha\}) r - c(e)$. If the relationship breaks down, again no production

takes place. S's bargaining payoff is

$$\pi_S^S(e) = \frac{1}{2}\left[\left(1 - \min\{\eta, \alpha\}\right) r - c(e)\right] < \pi_S^F(e) \text{ for all } e \geq 0, \tag{A7}$$

since $\eta > 0$ and $\alpha > 0$. Thus the complementary investment is privately optimal whenever F owns A_T.

A.3. Proof of Proposition 1

Assigning ownership of A_T to F generates a certain value of

$$\Pi_F = r - c(\bar{e}) - \bar{e}. \tag{A8}$$

If instead S owns A_T, his decision depends on the realization of η: he always provides optimal effort e^*, but he chooses to produce the high quality good if and only if $\eta \geq \alpha/2 - \sigma$. Thus from the time-0 perspective assigning ownership of A_T to S generates expected value

$$\mathbb{E}\Pi_S = r - c(e^*) - e^* - r\int_0^{\alpha/2-\sigma} \eta d\Phi(\eta). \tag{A9}$$

The ex ante expected value generated by the partnership is $\Pi = \max\{\Pi_F, \mathbb{E}\Pi_S\}$ such that $\Pi/\partial\sigma \geq 0$.

It is optimal for A_T to be owned by F if

$$\int_0^{\alpha/2-\sigma} \eta d\Phi(\eta) > \frac{\bar{c}}{r} \tag{A10}$$

namely if

$$\sigma < \bar{\sigma}\left(\alpha, \frac{\bar{c}}{r}\right) \in \left[0, \frac{\alpha}{2}\right) \text{ such that } \frac{\partial\bar{\sigma}}{\partial\alpha} > 0 \text{ and } \frac{\partial\bar{\sigma}}{\partial(\bar{c}/r)} < 0 \text{ if } \bar{\sigma} > 0. \tag{A11}$$

For $\sigma \in [\bar{\sigma}(\alpha, \bar{c}/r), \alpha/2)$, ownership of A_T is allocated to S, and this leads to non-integrated with probability

$$p(\alpha, \sigma) = 1 - \Phi(\alpha/2 - \sigma) \text{ such that } \frac{\partial p}{\partial\alpha} < 0 \text{ and } \frac{\partial p}{\partial\sigma} > 0. \tag{A12}$$

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

A.4. Proof of Proposition 2

After the realization of η is observed, non-integration is known to be sustainable whenever $\eta \geq \alpha/2 - \sigma$: since it yields the first best outcome, it is always chosen if it is feasible. When $\eta < \alpha/2 - \sigma$ only integration is possible: F-integration is optimal for $\bar{c}/r < \eta < \alpha/2 - \sigma$ (an interval that may be empty) and S-integration for $\eta < \bar{c}/r$. The two are indifferent for $\eta = \bar{c}/r$, which is in any case non-generic.

In the first period, F owns A_T and employs S if $\bar{c}/r < \int_0^{\alpha/2-\sigma} \eta d\Phi(\eta)$. With probability $p(\alpha/2 - \sigma)$, F sells A_T to S and the firm switches to efficient non-integration. With

probability $q(c) = \Phi(\bar{c}/r)$, such that $\partial q/\partial \bar{c} > 0$, F sells both A_I and A_T to S.

The expected gain from the reorganization is

$$\mathbb{E}\Delta = \left[1 - \Phi\left(\frac{\alpha}{2} - \sigma\right)\right]\bar{c} + \int_0^{\bar{c}/r} (\bar{c} - r\eta)\, d\Phi(\eta) > 0, \tag{A13}$$

such that $\partial \mathbb{E}\Delta/\partial \sigma > 0$, $\partial \mathbb{E}\Delta/\partial \alpha < 0$, and $\partial \mathbb{E}\Delta/\partial \bar{c} > 0$.

A.5. Proof of Proposition 3

The first best level of investment is

$$i^* = \arg\max \{v(i) - i\} \text{ such that } v'(i) = 1, \tag{A14}$$

while actual investment is

$$i(\omega) = \arg\max \left\{ \frac{2-\omega}{2} v(i) - i \right\} \leq i^* \text{ such that } v'(i) = \frac{2}{2-\omega} \tag{A15}$$

which implies $\partial i/\partial \omega < 0$ for all $\omega \in (0,1)$ and $i(\omega) = i^*$ if and only if $\omega = 0$.

Having all the bargaining power ex ante, F internalized the entire surplus

$$V(\omega) = \pi + v(i(\omega)) - i(\omega) \text{ such that } \frac{\partial V}{\partial \omega} < 0 \text{ for all } \omega \in (0,1).$$

where $\pi > 0$ is the profit from exploiting A_I directly, taking into account the optimal choice of firm organization

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