DYNAMIC HYBRID PATENT STRATEGIES: FIGHT OR COOPERATE?

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Abstract

We address a research gap at the interplay between competition and cooperation in the context of patent strategies. We advocate a dynamic notion of strategy involving a menu of patent strategies enabling the firm to switch among compete, cooperate or wait (patent sleep) modes. We examine the optimality of different strategies based on contingencies related to industry demand and dynamism and whether innovation is radical or incremental, identifying the circumstances under which strategic patenting is best used to compete or to cooperate. Dynamic hybrid strategies obtain, involving switching from one type of compete mode to another or from competition to cooperation as demand rises or as the innovation advantage gets small. In high demand initially give-up strategies may switch to competing and then, at higher demand l, to cooperation. In contrast to disruptive technologies, a dynamic switch can occur in either direction and is more valuable in a more uncertain environment.

Key words: patent strategies, strategic patent use, technology commercialization strategy, competition, cooperation, real options, option games, disruptive technologies

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In the extant economics and strategy literature, competitive rivalry and cooperation have been viewed as distinct (even opposing) strategy paradigms, leading researchers and managers to focus on one or the other distinct mode of inter-firm interaction (e.g., Lado, Boyd and Hanlon, 1997). However, rising evidence from academia and business practice provides numerous situations where firms engage in *both* competition *and* cooperation concurrently or they may alternate among these modes in sequential stages over time or in different market circumstances. Some firms cooperate in one sphere, such as in R&D alliances or in cross licensing their patents,[1] while competing fiercely in the marketplace (e.g., Intel and AMD, Samsung and Fujitsu, Facebook and Yahoo). Others collaborate to strengthen their competitive position vis-à-vis other rivals, substitutes or third entrants, or to share upstream resources (e.g., Coca-Cola and Pepsi). Yet, most scholarship on cooperation (e.g., Dyer and Singh, 1998; Lavie, 2006; Kale and Singh, 2009) is not integrated with competition strategy (e.g., Barney, 1986a; Chen, 1996; Silverman and Baum, 2002), leaving the interplay of cooperation and competition as a yet-unfilled research gap.

Classic arguments in favor of competition vs. cooperation (and within each favoring strategic commitment or flexibility) have sound theoretical justifications. A key question therefore is, under what circumstances should competition or cooperation inform strategy decision-making? The interplay among competitive rivalry and cooperation is fundamental in both economics and business strategy, even though scholars avoided addressing it under uncertainty (Wernerfelt and Karnani, 1987).[2] The competition vs. cooperation dilemma needs to deal with the why, how and under what circumstances firms are better off cooperating rather than competing in uncertain and dynamic environments. The Appendix table catalogues various real world business examples of technology licensing or patent use strategy where firms sometimes chose to compete, while at other times to cooperate or follow a hybrid strategy. The chosen patent use or technology commercialization strategy (TCS) in these examples depends on contingency factors such as the degree of innovation (incremental or radical) and the level

[1] Cooperative cross-licensing is common. Intel and AMD kept patents out of fighting through *cross-licensing* since 1976. "Anything that we patent they can use, and anything they patent we can use. We don't have to design around each other's patents," commented John Greenagel of AMD. Since 1990 Samsung and Fujitsu engage in cross-licensing giving access to each other's microchip technologies. Defending against lawsuit by Yahoo in March 2012 –after purchasing 750 patents from IBM and 650 from Microsoft -- Facebook filed a countersuit forcing Yahoo to cross license. Since 2003 Microsoft signed more than 500 agreements with customers, partners and competitors, including cross-licensing with Nikon.

[2] Wernerfelt and Karnani (1987) note: "Since strategy is concerned with the future, the strategic context of a firm is always uncertain… under uncertainty there is a tradeoff between focus [commitment] and flexibility…. this analysis is further complicated by the presence of competition…the literature on strategic planning has avoided discussing the trade-offs involved in confronting uncertainty." One way is "for competitors to cooperate with each other in dealing with uncertainty."

and volatility of market demand. We focus on the context of strategic use of patents as it allows the competition or cooperation mode to be chosen endogenously depending on above contingency factors.

We thus examine patent use strategies depending on contingencies in innovation strength and market demand characteristics while accounting for dynamic competitive interactions. These strategies involve different choices (switching) across time periods. We particularly focus on the tension between strategic use of patents to strengthen one's relative position to exploit more of the technology space for own advantage e.g., via costly offensive bracketing of the rival's patent in high demand (or raising a defensive patent wall around own patent in medium demand) in pursuit of asymmetric Cournot profits vs. the collaboration benefits of sharing a larger market pie involving monopoly rents. We show that in case of large or radical innovation in high demand the innovator might be better off to accept a smaller share of a larger market pie rather than aim for a bigger share of a smaller pie resulting from higher bracketing costs and the ensuing price war. More generally, we revisit the notion of dynamic business strategy within the context of strategic use of patents to incorporate endogenous strategic interactions, emphasizing that path-dependent asset accumulation (Dierickx and Cool, 1989) often involves not only a tradeoff between commitment and flexibility under uncertainty but also dynamic shifts among competing and cooperative strategy modes. Our approach thus complements resource-based view (RBV) and dynamic capabilities (Teece, Pisano and Shuen, 1997) to also account for strategic interactions and hybrid or pivot strategies (Marx, Gans and Hsu, 2014).

Our study seeks to fill a research gap at the competition-cooperation interplay (see Figure 1) and the patent strategies literature using the methodology of "option games", which combines real options analysis (Dixit and Pindyck, 1994; Trigeorgis, 1996) and basic game theory (see Smit and Trigeorgis (2004), Chevalier-Roignant and Trigeorgis (2011)).[3] This methodology enables us to quantify how the tradeoff between strategic commitment (games) and flexibility (options) affects the interplay of rivalry and cooperation and specifically how to balance the tension between seeking a dominant share of a likely smaller market pie resulting from aggressive positioning vs. a smaller (equal) share of a larger pie resulting from an accommodating stance.[4] We address the above intertwined competition-cooperation and commitment-flexibility dilemmas in the context of strategic use of patents (Rivette and Kline, 2000; Arundel and Patel, 2003; Somaya, Kim and Vonortas, 2010), analyzing optimal pivot or switch strategies under both exogenous market demand and endogenous strategic (rival) uncertainty in an integrated dynamic strategy framework using option games.

[3] "Option games" is a simplified, discrete-time variant of stochastic game theory. It recently gained acceptance in both academia and practice (e.g., Smit and Trigeorgis, 2009; Ferreira, Karr and Trigeorgis, 2009).

[4] The commitment-flexibility tradeoff relates to the choice between commitment (a.k.a. specificity, focus or efficiency), e.g., involving early market entry to accumulate knowledge and capabilities, exploit economies of scale, preempt rivals or gain first-mover advantages, and flexibility from waiting (to make more informed decisions when market uncertainty is resolved), staging or altering scale to adapt to market developments.

Inter-firm cooperation was previously looked down as a form of collusion that restricts competition (Porter and Fuller, 1986).[5] Cooperative relationships among firms, such as (cross)licensing agreements (Grindley and Teece, 1997; Arora and Fosfuri, 2003; Fosfuri, 2006), joint ventures (Harrigan, 1988; Chi, 2000; Kumar, 2005; 2011) and strategic alliances and networks (Gulati, 1998; Gulati, Nohria and Zaheer, 2000; Kogut, 2000), gained more importance rather recently. This emerging cooperation literature has generally followed a separate path, focused on the motivation and rationale for collaboration (Lavie and Rosenkopf, 2006), partner selection (Beckman, Haunschild and Phillips, 2004; Gulati, Lavie and Singh, 2009), alliance management (Hoffmann, 2005; 2007), performance (Reuer and Koza, 2000; Zollo, Reuer and Singh, 2002), and value appropriation (Gulati and Singh, 1998; Lavie, 2007). In the technology commercialization strategy (TCS) literature (Teece 1986, Gans and Stern 2003), an innovator entrant's choice was seen as rather static (one-time) and binary: either compete against incumbents in the product market or cooperate via licensing of the technology permanently, depending on environmental, competitive and organizational factors. This binary ("either or") mode led to the prediction that disruptive technologies bring about the exit of incumbents (Christensen 1997). This may no longer be the case if hybrid (switch) strategies are considered. Furthermore, a static binary commitment strategy, e.g., of competing on the direct to consumer product in speech recognition technology can be quite myopic if it ignores the option to later switch to collaboration via OEM licensing agreements. As Michael Phillips, cofounder of Vlingo, noted: "Even if you are losing money on the direct to consumer product [i.e., negative NPV] that is okay because you will make it up on the OEM licensing deals [i.e., on the switch option]."

Only rather recently scholars began to appreciate the intricate and potentially beneficial interactions that may arise when firms choose to switch from competitive to cooperative strategies, e.g., recognizing that competition in the product market in the first stage may help resolve uncertainty about the value of technology or otherwise establish credibility that may facilitate cooperation later on (Arora, Fosfuri, and Gambardella, 2001; Marx, Gans and Hsu, 2014), or that it may provide learning benefits (Gavetti and Rivkin, 2007) --just as early cooperation may enhance learning and knowledge/technology transfer that can strengthen firms' long-term competitive positions (Hamel, 1991; Khanna, Gulati and Nohria, 1998; Kale and Singh, 2007). Early attempts to balance rivalry and cooperation (e.g., Perlmutter and Heenan, 1986; Hamel, Doz and Prahalad, 1989; Jorde and Teece, 1989; Hill, 1997) were followed by more recent streams on coopetition (Branderburger and Nalebuff,

[5] Early research in economics and strategy focused on inter-firm rivalry, especially relating competitive advantage to industry structure (e.g., Porter, 1980; Rumelt, 1991), firms' product-market positioning and inimitable idiosyncratic resources (Wernerfelt, 1984; Barney, 1986b), asset accumulation (Dierickx and Cool, 1989), and (dynamic) capabilities (Prahalad and Hamel, 1990; Teece, Pisano and Shuen, 1997). Firm performance is shaped by competitive dynamics driving firm heterogeneity and power asymmetry (Peteraf, 1993; Makadok, 2001).

1996; Dagnino and Rocco, 2009), coopetition networks and horizontal alliances (Gnyawali et al., 2006; Luo, Slotegraaf and Pan, 2006), and an emerging competition-cooperation research on pivoting strategies (Hoffmann, 2007; Marx, Gans and Hsu, 2014).

The most prominent and closest work to ours is that of Marx, Gans and Hsu (2014) that consider a two-stage commercialization strategy (TCS) for disruptive technologies involving a start-up innovator competing in the product market at first to establish the value of its technology and later switching to a cooperative strategy via licensing once the uncertainty is resolved or the incumbent's integration costs decline. This is a sequential across-time switch from competition to cooperation driven by two special characteristics of disruptive technologies: (i) uncertainty about the future value of the entrant's innovation (making the incumbent reluctant to cooperate at first) and (ii) initially high costs of integration with the incumbent's existing product line or infrastructure that decline over time (hence giving an incentive for the incumbent to wait-and-see). These are based on assumptions that the organizational effects of such innovations are competence-destroying (Tushman and Anderson 1986) and that these technologies are initially less compatible, poorly-performing and costly to integrate, but that they improve over time (Christensen 1997). The initial competition mode and later strategy switch to cooperation is driven critically by these features, and not by the uncertainty of the innovation or of market demand. The above drivers do not provide a justification for opposite-type switches, i.e., from collaboration to competition (about 4-5% of Marx, Gans and Hsu's (2014) ASR sample), as was the case with Nuance Communications that in 2002 decided to switch from collaboration licensing its technology to selling prepackaged applications directly on its own. We complement the above work showing that strategy switching motives are broader (relating to the dilemma between commitment and flexibility and the tension of getting a bigger share of a smaller pie under rivalry vs. a smaller share of a bigger pie under cooperation under certain contingencies), and go beyond the above specific features of disruptive technologies. In our broader setup switches among competitive and collaborative modes can be bi-directional and can reverse as the level and volatility of demand shift. That is, while reduced technological uncertainty is a precondition that enhances the value of switching from competition to collaboration (only) in disruptive technologies, in our setup the role and impact of uncertainty is different, with higher demand uncertainty favoring switching in either direction even for incremental (non-disruptive) innovation.

Another recent related contribution is the work on patenting strategies by Mihm, Sting and Wang (2015). The authors examine a related set of issues guiding firm patent strategy, focusing on how firms manage the tradeoff between knowledge/patent protection weighted against knowledge leakage from patent application disclosures. Using simulation they examine how business environment and firm contingencies affect the strategy whether to patent or not. By contrast, we use option games methodology to analyze how different firm, competitive and environmental contingencies affect how to use patents strategically (rather that to use a patent or not), focusing on a different tension: whether to commit resources and compete aggressively to dominate the market or to share in a flexible collaborative manner a potentially larger market pie. Although the motives and contingencies associated with patenting (or not) and patent use strategies bear some similarity (e.g., protection, defensive/offensive blockade and exchange motives or competitive behavior/strategic interaction contingency), they are also quite different. In their simulations, no firm chooses to participate in a patent exchange (collaboration), they simply "indicate the value of patent exchange (mutually shared patents or cross-licensing) once game outcomes are realized" by exogenously augmenting their simulation results (p. 2670). In our case, collaboration is an endogenous conscious strategic choice. Their value payoff is profit-based (though not having a specified functional form), whereas ours accounts for future option value, which rises with demand uncertainty. Volatility exacerbates switch patterns between competition and collaboration. While their analyzing innovation leader would consider the patented solutions of its competitor, ours would explicitly factor in the benefits of collaboration and consider switching patent use strategy. While in their framework "patent exchange is unlikely when a leader competes with a follower because only the leader would benefit from the exchange" (p. 2681), we show that collaboration via cross-licensing may be attractive to an innovation leader with large technological advantage in case of high demand and volatility if the costs and damage from a patent fight war (including loss of option value from pre-mature option exercise akin to prisoner's dilemma) exceed the benefits of market domination. Their results are based on simultaneous-move games over predefined strategies, while ours account for a dynamic timing leader-follower advantage with switch options among competitive and collaborative strategies.

Despite the previous advancements, the rivalry-cooperation interplay remains under-researched (Chen and Miller, 2014). We extend research at the competition-cooperation interplay, advocating a more *dynamic* notion of strategy in the context of strategic IP use involving a menu of patent strategies enabling the firm to switch among compete, cooperate or wait (patent sleep) modes. We examine the optimality of different patent strategies based on demand realization, uncertainty and industry dynamism and whether innovation is incremental or radical (without adopting the specific assumptions of being "disruptive" above), identifying general circumstances when strategic patenting is best used to compete, such as defending oneself by building a *patent wall* around one's core patent or go on attack *bracketing* the rival's patent, or to cooperate via licensing out or cross-licensing of patented technologies. When firms should compete or cooperate depends on firm, competitive and environmental contingent circumstances. Dynamic *hybrid* patent strategies involve switching from one type of competitive rivalry to another or from competition to cooperation (and vice versa) as demand

and volatility rises or when the innovation advantage is small. The assumptions of "disruptive" technologies (a la Christensen 1977) relied on by Marx, Gans and Hsu (2014) are not needed for driving our switching strategies in the IP use context (but uncertainty is). We abstract away from motives such as the need to prove the technology or facing high upfront and later declining integration costs, focusing instead on the role of the level (state) and uncertainty in industry demand. Switching can be justified in either direction (e.g., from cooperation to competition), besides being in a wait-and-see mode. Further, switching does not need to take place in sequential stages over time (e.g., when future value is proven or integration costs drop) as in Marx, Gans and Hsu (2014), as here it may be precipitated by shifts in demand states or volatility, as well as rival offensive or defensive moves. The article thus helps advance and extend our understanding of *dynamic* or *hybrid* pivot strategies expounding more general conditions when is best to compete or to cooperate and provides guidance on how to *flexibly* use IP as a general strategy tool (beyond TCS).

Our article contributes to the strategy field, the patent strategies literature and the competition-cooperation interplay in several ways. First, it helps better understand the interplay between rivalry and cooperation and the contingent circumstances favoring switch from one to the other within an integrated dynamic patent strategy framework. We add to the emerging competition-cooperation interplay literature an analysis of the conditionality of the optimal strategy on several moderating factors, such as market demand and volatility regimes and the incremental or radical nature of innovation. We also contribute to TCS, which has mostly taken a static view of the commercialization process, the flexibility of innovative firms to switch strategy, providing a broader rationale for the existence of pivoting strategies documented in Marx, Gans and Hsu (2014). We show that switching can occur contemporaneously in either direction depending on demand and volatility conditions, even when innovation is incremental and the assumption of disruptive technologies concerning sequential decline in technological uncertainty or the cost of adoption does not hold. Finally, we contribute to a firm-level contingency theory of strategic patent use involving hybrid strategies illustrating how real options and *option games* can be used to help integrate flexibility (option) aspects in dynamic environments with strategic commitment (game-theoretic) behavior to identify the best switching strategy and balance the tension of striving to dominate under an aggressive commitment strategy vs. sharing larger collaborative benefits, going the "extra mile" in long-dated strategic planning efforts to integrate competition and cooperation under uncertainty.[6]

[INSERT FIGURE 1 ABOUT HERE]

[6] In their call for further research to address this "very complex problem," Wernerfelt and Karnani (1987) note: "we feel that the cooperation option is very timely and of increasing importance. While stochastic game theory is difficult … we feel that the importance of the topic may justify going that extra mile."

POSITION IN PATENT/ STRATEGY LITERATURE

Figure 1 summarizes the development of the competition (upper part) and cooperation research streams (lower part) in the broader strategy literature. The IP/licensing stream (our application context) spans both literatures. The methodological developments of IO/game theory, real options and option games are shown in white circles. Competition is higher along the vertical axis. The strategic commitment (games) vs. flexibility (options) dimension is captured along the horizontal axis, with the latter being more important in an uncertain/dynamic environment (lower right). A research gap at the interplay between competition and cooperation is identified in the middle space (numbered as (10)).

In intellectual property (IP) and technology commercialization strategy (TCS) (***Stream* (9)**), patent licensing acquired importance as a means of inter-firm cooperation and technology transfer.[7] Strategy scholars examined strategic uses of patenting, such as preemptive strategies and (cross) licensing. Preemptive patenting improves the appropriability of returns to R&D for incumbents with strong market power (Ceccagnoli, 2009). A firm's decision to license out to rivals is also influenced by imitation, first-mover advantages and transaction costs (Hill, 1992). The slower the diffusion of technology, the longer the innovator can exploit first-mover advantages by keeping the technology proprietary (Lieberman and Montgomery, 1988). But when rivals have strong incentives to imitate, licensing is more appealing to enable early standard-setting or rent appropriation via royalty payments and reduce damage from preemption. A firm's rate of technology licensing is driven by the degree of competition, market share and product differentiation (Fosfuri, 2006). Licensing out foregoes the ability to preempt the rival, so it is advised only if innovation advantage is small or incremental. Contract design deals with market imperfections, including market and technical (success) uncertainties, appropriability, costs of technology transfer, agency and hold-up problems (Davis, 2008). Licensors pursue different strategies with exclusivity structures to address contractual challenges (Somaya, Kim and Vonortas, 2010). Firms avoid licensing out patents when they pursue a proprietary strategy (Teece, 1986). In TCS, technology appropriability and complementary assets favor a cooperating strategy via licensing (Arora and Ceccagnoli, 2006), while size and prior market power reduce the propensity to license (Gambardella, Giuri and Luzzi, 2007). IP strategy became "more proactive" (Grindley and Teece, 1997) with cross-licensing enabling "freedom-to-manufacture" against infringement (Teece, 2000).

[7] Early I.O. focused on number of licensees and industry structure (Arrow, 1962; Katz and Shapiro, 1986), value sharing (Kamien and Tauman, 1986), likelihood of licensing (Gallini, 1984; Gallini and Winter, 1985) or (non)exclusivity (Katz and Shapiro, 1985, 1986; Kamien and Tauman, 1986; Anand and Khanna, 2000).

Our application context here is patent strategies. Unlike traditional use to commercialize or license out an innovation, *strategic patenting* focuses on extending use of patents beyond exclusive exploitation (Rivette and Kline, 2000; Cohen, Nelson and Walsh, 2000; Arundel and Patel, 2003; Reitzig, 2004; Somaya, 2012). Besides conventional uses (1) to commercialize or (2) to license out a technology (Arora and Ceccagnoli, 2006), patents can be used strategically for various objectives: (3) fight *defensively* by building a patent wall around one's own patent for protection or (4) *offensively* by blocking a rival's patent; (5) in infringement lawsuits (possibly forcing later collaboration), exchange (e.g., cross-licensing) or other cooperative uses (e.g., in a patent pool). As in Mihm, Sting and Wang (2015), we focus on protection (preemption), blockade (fight defensively or offensively) and collaboration via exchange motives. Early treatments assumed predictable conditions. Recent work extended real options "downward" in Figure 1 to capture flexibility in technology sourcing, but ignored strategic commitment or game theoretic factors.[8]

In what follows we delineate between different TCS strategies using commitment vs. flexibility and the strength of innovation (incremental or radical) to inform the decision whether to compete or cooperate. Our article extends the previous strategy literature "vertically" (as well as "horizontally") to help address the identified research gap at the interplay between competition and cooperation [**(10)** in Figure 1] utilizing *option games* in the context of strategic patent use, while also balancing commitment and flexibility. In addressing the dilemma of when to use a patented innovation strategically to compete or to cooperate, our approach offers new insights on path dependence and value appropriation under different demand or volatility regimes and illustrates conditions where collaboration is preferable in dynamic environments with endogenous market structure.

THE STRATEGIC PATENT USE MODEL

In this section we develop a framework employing a dynamic notion of competitive strategy in the context of patent use. Dynamic strategy here refers to the ability to switch among strategic modes (e.g., compete, collaborate, wait or exit) under different contingent circumstances, focusing on future states of demand (high, medium or low), volatility and industry dynamics, and the relative advantage of the new innovation (acquired via a new patent by innovator firm A) i.e., whether it is radical or incremental compared to the old technology (exploited via an existing patent by incumbent rival firm B). We abstract away from motives such as the need to prove the value of the technology or facing high upfront

[8] Strategic use of intangible resources and inter-firm cooperation was recently analyzed using game theory/I.O. models. Alliances are amenable to game-theoretic modeling exhibiting prisoner's dilemma-type payoffs (Parkhe, 1993). Arend and Seale (2005) examine how partners cooperate, defect or exit at each stage of an alliance, while Arend (2009) examines how reputation affects cooperation. Goyal and Netessine (2007) analyze a three-stage game (involving technology, capacity and production) assessing the value of product flexibility and competitive impact on a firm's choice of technology intangibles. Ross (2014) provides a game theoretic model of how optimizing firms choose the level and nature of risk strategies.

and later declining integration costs, focusing instead on the level and uncertainty in industry demand, besides strategic patent use motives (e.g., rival preemption or blockade).

Basic setup

We consider three outcomes (types) of a patented process innovation resulting in no, small (incremental) or large (radical) cost advantage.[9] If the entrant's new technology has negligible advantage over the incumbent's existing technology, and the two rivals are otherwise ex ante symmetric in market power, competitive strategy is best exercised in a collaborative mode (e.g., via licensing out or cross-licensing patents). This is in line with prior literature suggesting that cross-licensing is appropriate when patent portfolios are roughly equivalent and conforms with what we see in the world of practice.[10] [11] But if innovation is radical an aggressive compete mode may dominate (at least initially). For example, under high demand (with enough profits for both firms to be in the market), either competition (e.g., via patent bracketing) or collaboration may take place; under moderate demand (with room for only one firm to produce), the firm with the stronger technology can strengthen its core patent advantage (e.g., by forming a patent wall around it) driving out the rival to exploit a monopoly position.[12] Under low demand (insufficient for either firm to produce profitably, but with higher future demand potential) and large technological disadvantage the rival may exit, with the innovative firm maintaining a growth option on future monopoly profits.

In-between, if the innovation is incremental (small advantage), a hybrid or more-flexible strategy may be best. Under normal (medium or low) demand a cooperative outcome may result whereby entrant firm A licenses out its incrementally superior technology to incumbent firm B. However, if demand or volatility is very high the marginally weaker competitor may put up a fight,

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[9] We here focus on *process* innovation under quantity competition. The analysis may be extended to a *product* patent that allows selling a product at a higher price. If it is under Bertrand price competition, the results may differ. Process and product patents are used in different ways in a firm's appropriability strategy (see Cohen, Nelson and Walsh, 2000). The distinction between "small" vs. "large" innovation advantage relates to the innovator's ability to disrupt the process or preempt the rival. Large advantage is related to *radical* or *disruptive* process innovations, while small advantage is associated with *incremental* process innovations. *Radical* process innovations reduce the innovating firm's marginal costs giving it a monopoly position. *Small* process innovations result in marginal cost advantage without undercutting rivals. If cost savings from innovation is s, the marginal price is θ and marginal production cost c, the criterion for distinguishing large (radical) from small process innovation is: if $s \geq \theta - c$, the innovation is large, else it is small (Arrow, 1962).

[10] If the incumbent technology owner has a dominant market share it may still be induced to cross-license for the freedom to invent or to prevent other potential third entrants. If the new technology has no real advantage over the old one, adopters might require some discount or incentives to switch.

[11] Some model aspects should be interpreted with caveats. Cross-licensing might be influenced by product nature and complexity. It might also be used to assure freedom to invent among roughly equal rivals (Grindley and Teece, 1997). Licensing may also depend on other factors related to industry structure (Fosfuri, 2006). The model is simplified.

[12] Under moderate demand, collaborative activity may sometimes also result, such as by two incumbents developing a patent protection or a joint patent against new entrants. In 1999, facing external threat, IBM and Dell signed a 7-year cross-licensing deal. Dell held only 40 patents on its direct sales business model vs. IBM's thousands on its hardware components. Dell agreed to buy parts from IBM, which was licensed to use Dell's design technology in its own PCs. The cross-licensing strategies proved complementary.

resulting in a competition equilibrium outcome (e.g., patent bracketing). Therefore, the notion of strategy is extended to incorporate compete (fight), cooperate, wait (patent sleep) or exit modes that may prevail under different scenarios depending on the relative innovation advantage and other factors.

We consider a situation where two patent-holding firms, entrant firm A and incumbent firm B, are involved in a two-stage strategic patent use game. The timing of the game is as follows:

I. At time 0 (beginning of stage I), firm A acquires a new core patent resulting from earlier innovative activity that may be superior to the existing technology held by incumbent firm B. In the base case, the two firms are of equal market power (prior to the new patent by firm A) so firm A potentially gets an asymmetric advantage over B; the case that incumbent firm B has more prior market power is considered in the extension.

II. At time 2 (after two subperiods, beginning of stage II), each firm makes a decision on its best patent strategy vis-à-vis its rival (i.e., to compete, cooperate or wait), depending on firm A's relative innovation advantage and the state of industry demand (High, Medium or Low).

New entrant firm A can extract significant strategic value if its innovative process is protected effectively by a superior patent relative to incumbent firm B´s existing technology. We assume no uncertainty about the value of the new technology and perfect legal protection.[13] Firm A´s patent is a legal resource converting its R&D activity into a proprietary investment giving it distinct technological advantages over its rival. If market demand is favorable, the firm may exploit the new patented technology on its own, making a technology commercialization investment (I = \$80 m). At time 2, either firm may use its respective patent in a strategic way. It may follow a defensive patent strategy (e.g., building a patent wall around its own core patent) or engage in an offensive fight with its rival ("bracketing" each other´s core patents). If demand is highly uncertain or demand conditions are not favorable, firm A may wait and keep its patent "sleeping" (or it may pursue a cooperative cross-licensing patent strategy) reconsidering the situation next period.

The situation is more complicated when market demand uncertainty is exacerbated by strategic competitive uncertainty. If firm A faces an incumbent firm B with an old technology after the same product market, each firm's patent strategy may also depend on its rivals' patent-use moves.[14] When the competitive setting involves such strategic uncertainties, firms may be better off to flexibly exploit patents as *strategic leveraging options.* When competition is endogenous, a game-theoretic treatment

[13] Imperfect patent protection impacts the size of patent advantage as the size will be scaled down. If the size shifts from the disruptive (large) type to the incremental (small) one, the result may also differ qualitatively. The analysis may further be extended to account for asymmetric information (where the average cost advantage accounting for the probabilities of successful or ineffective patent enforcement is used in a player's reaction function) and the use of mixed strategies.

[14] If firm A is a potential market entrant, it may not know the precise market structure upon entry and the reaction of the incumbent rival (or future competitors). Even as an incumbent, it may not anticipate the patent entry mode and response of potential entrants to its action in the first place.

is required. Firm A must consider *both* how its investment decision affects its rival and how it may be impacted by rival reactions. A number of issues need to be addressed. What type of patent strategy (cooperative or competing, defensive or offensive) should firm A pursue in stage II depending on its relative innovation advantage (determined by the strength of its own innovation and/or the relative prior market power of incumbent firm B), the state and volatility of demand and the nature of competition? Should it compete to exploit innovation advantages for its own use or should it share them with its rival? Should the strategy change in different circumstances and if so, how?

If the firm follows a standard DCF approach to valuing the patent, its static value is obtained by discounting its expected future cash flows (net of investment outlay, I, of \$80 m) back to the current time (t = 0) using the cost of capital (k = 20%).[15] Expectations are taken assigning appropriate probabilities to the occurrence of each scenario at the end of period 2. The static NPV of the patent, assuming immediate investing, is thus estimated at \$20m (= $V - I$ = 100 – 80). This analysis ignores the dynamics and options resulting from the second-stage patent game among the two firms.

The basic strategic patent-use game

The patent will have higher value if recognized that during the second stage it can be strategically used against (or to benefit) competition. This involves ascertaining the degree of technological advantage (radical or incremental) and the nature of competition in the industry, accounting for rivals' strategic moves under different demand realizations. Assuming rationality of players in strategic interaction permits deriving each player´s payoff values in industry equilibrium.[16] In selecting one of the patent strategies, firm A must account for the type of innovation (incremental or radical), the market power of the incumbent and the state and volatility of demand (low, medium or high). The same applies to firm B. Each firm decides which strategic move to make. Different combinations of the above factors may produce different types of industry equilibria. Several equilibrium patent strategies may result involving the above compete, cooperate or wait strategy modes depending on demand (high, medium or low) and the size of technological advantage (no, small, large), as seen in Figure 2. In the base case

[15] In the basic two-stage strategic patent use game with an underlying market value (binomial) evolution under High (H), Medium (M) or Low (L) demand scenarios, the new patent gives firm A the exclusive right to build capacity for commercializing its new technology by making an investment of I = \$80 m by period 2 (end of stage I). The PV of expected cash inflows from patent exploitation is V_0 = \$100 m, and is expected to fluctuate with annual volatility σ = 0.60 (or 60%) moving up by a multiplicative factor u (= e^{σ}) = 1.8 or down by 0.6 (=1/1.8) each period, ranging by period 2 (end of stage I) from a low (L) value of V^{--} = 36, to a medium (M) value V^{+-} = 108, to a high (H) value of V^{++} = 324.

[16] The menu of alternative patent strategies includes: 1. abandon or exit (under very low demand); 2. wait or sleep (under low demand); 3. cooperate (e.g., via licensing out or cross-licensing); and 4. compete (fight defensively or offensively). These patent strategies embed four types of options (with patent value as underlying asset): 1. option to abandon or exit; 2. option to sleep (wait-and-see); 3. option to extend patent potential cooperatively (via licensing-out or cross-licensing); 4. option to expand patent potency through a defensive patent wall (*clustering/fencing*) or via handicapping the opponent by filing complementary patents to exploit or fill gaps around the rival´s core patent (*bracketing*).

rivals have equal a priori market power. In subsequent robustness we consider incumbent firm B having larger market power.

The combination of three states of demand for each of three relative technological size advantage scenarios results in 9 subgames, each potentially involving different equilibria and optimal patent strategies. These subgames are numbered from 1 to 9 in the figures. In brief, if there is no significant innovation cost advantage resulting from firm A's patented innovation and the firms are otherwise a priori symmetric in market power, they are more likely to cooperate, cross-licensing their patents to each other.[17] At the other end, if firm A's innovation brings about a large (radical) advantage, a compete mode (commercializing the innovation and producing in-house) is more likely.[18] The precise strategy depends on the level of demand, with high demand potentially involving more offensive strategies (e.g., bracketing), intermediate demand involving raising a defensive patent wall by the firm with stronger patent (or by both against third entrants) to reinforce their advantage and potentially drive the rival(s) out, while in low demand letting the patent sleep.

[INSERT FIGURE 2 ABOUT HERE]

We next put more structure on the 9 subgames to access the value payoffs and strategy equilibria depending on demand (H, M or L) and the size of innovation advantage (no, small, large). The two patent holders compete in the same industry as a duopoly behaving rationally. Each pursues a set of patent strategies at time 2 resulting in a given value payoff. Patent use choices during stage II take the generic form "*sleep*" (wait-and-see) versus "*invest*." Investing under a cooperative mode (e.g., in the left region) involves licensing-out one's patent to the rival (who lets its own patent sleep) or cross-licensing patents (both firms invest). One or both firms may let their patent sleep (sleep-sleep scenario). Keeping one's patent sleeping amounts to deferring the strategic decision to (cross-license or fight) to next period ($t = 3$). Holding a sleeping patent is a wait-and-see option. This option is more valuable when demand is volatile. Letting the patent sleep (during stage II) results in continuation (or call option) value (C). In such a wait-and-see strategy, if both firms let their patents sleep a stronger patent position for firm A allows it to appropriate a larger share (s %) of total continuation value (i.e., sC). Firm B captures the remaining, smaller portion, $(1 - s)C$. In general, the driving force of the sharing terms of end-of-period collaboration between the firms here is the relative market power based on the cost advantage or size of innovation of firm A´s patent relative to firm B´s. If firm A's innovation is

[17] In many cross-licensing situations, firms may be in an asymmetric position in terms of relative IP value contributed. The mechanism of balancing royalty payments views the net-taking firm paying a fee to the other (see Grindley and Teece, 1997). An asymmetric distribution of patent value a priori may change the results. In the asymmetric case that incumbent firm B has more market power, a fight mode involving a bracketing war (rather than cooperation) may result in lower demand states. See later robustness analysis and discussion surrounding Figure 9A.

[18] In the in-between case of small innovation advantage, hybrid strategies may result, e.g., involving fight via offensive bracketing at high demand and switch to cooperation via licensing out patented technology at low or medium demand.

large (radical), firm A appropriates most (s = 75%) of NPV or C (and firm B gets 25%); if small (incremental), firm A gets 60% (and firm B 40%). If there is no cost advantage from the patent, market value sharing is 50-50. The continuation value represents an option on stage II-total market value (V), which evolves according to the assumed binomial tree.[19]

Under a compete mode, investing involves a defensive patent clustering strategy via a patent wall around one's *core* patent (to keep the opponent out) or each firm pursuing an offensive patent bracketing strategy to block its opponent from exploiting its patent (both firms invest). The patent strategy implementation cost is the base commercialization cost (I = \$80 m), though it may be delayed, increased or reduced depending on strategy choice (sleep, compete or collaborate). Cooperation results in enlarged market value pie (by 20%). This is captured by a strategy (cooperate or fight) mode multiplier (m), which for the cooperative mode is $c = 1.2$, amplifying the underlying market value to mV ($=1.2V$).[20] By contrast, a fighting mode results in a reduced market value pie (by 30%) due to ensuing costly patent wars. That is, in case of fighting $mV = fV = 0.7V$.[21] In Figure 6 we provide sensitivity of Expanded-NPV to the fighting and cooperation multiple (m) choices. Again, one or both firms may let their patents sleep instead of investing. If both firms postpone a fight, the continuation

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[19] In the extension, we conduct robustness when incumbent firm B has asymmetric prior market power. In this case we make the following alternative assumptions. If firm A's patent advantage is large, it fully offsets firm B's initial market power so 50-50 market sharing results. If there is no advantage, firm B appropriates most (s = 75%) of NPV or C (and firm A 25%); if small advantage, firm B receives 60% (and A 40%). This is summarized in the right column in Figure 4.

[20] The cooperation mode multiple can be justified as follows. Consider a Cournot duopoly with linear (inverse) demand function: $p(Q) = \theta - bQ$, where Q is total industry quantity and θ is stochastic demand (marginal price). Suppose if firms A and B collaborate they produce the monopoly quantity and share it based on their relative market power (s_i), i.e., $c = \frac{s_i \Pi^M}{\Pi_i^C}$, with profits for firm i (A or B) under monopoly (M) and Cournot competition (C) given by:

$$\Pi^M = \frac{(\theta - cost)^2}{4b}, \quad \Pi_i^C = \frac{(\theta - cost)^2}{9b} \text{ (cost symmetry)}, \quad \Pi_i^C = \frac{(\theta - 2cost_A + cost_B)^2}{9b} \text{ (cost asymmetry)}$$

where $cost_A$, $cost_B$ are marginal costs for firm A and firm B ($cost_A = cost_B = cost$ under symmetry). The cooperation multiple can then be calculated under no, incremental (small) or radical (large) innovation advantage by firm A (with related market power shares as described earlier). In the symmetric case of no innovation advantage ($s_i = 0.5$) where firms A and B face the same variable unit production *cost,* the cost multiplier c reduces to 9/8 or 1.13. Accounting for the asymmetric cases (where firm A enjoys an incremental or radical cost-leader advantage) via simulation of θ in the linear (inverse) demand function yields an average cooperation multiplier of 1.2 across the scenarios (θ drops out in the no innovation advantage case). Similar results apply to the case of prior asymmetric market power by incumbent firm B.

[21] To estimate the fight multiple, we follow Epstein (2003) who accesses an appropriate damages award in the context of lost profits analysis associated with patent infringement. This method, called PERLS, improves the conventional market share rule by integrating lost sales estimates with the effect of price erosion via an adjustment for the price elasticity of demand. Similar to infringement, a patent fight with a rival results in sales reduction and a price erosion, negatively affecting profitability. The PERLS model adapted for the case of patent fighting is:

$$Lost\ Profits\ from\ Patent\ Fighting = \mu Sales \frac{s}{1-s} + \delta Sales + \delta Sales \frac{s}{1-s} + \varepsilon \frac{Sales}{1-s} * \frac{\delta}{1+\delta}(\delta + \mu)$$

where μ: innovative firm A's profit margin; *Sales*: innovating firm A's sales after patent fight; s_A = s: innovative firm A's market share; s_B = (1-s): incumbent firm B's market share; δ: price erosion (due to patent fighting); ε: market price elasticity of demand. For reasonable parameters, we estimate lost profits from patent fighting (compared to a "but-for" situation in the absence of fighting) at -31% under no innovation advantage, -30% under incremental innovation, and -18% under radical innovation. This is robust to firm A's sales. Based on an average of the above scenarios (equal to 26.4%), fighting reduces total market value by roughly 30% (with fight multiple 0.7).

value refers to the next-period ($t = 3$) equilibrium in which firms A and B receive a declining market value because of intensified rivalry. Each firm´s payoff corresponds to the present value of expected future cash inflows generated by its specific patent strategy.[22] An options game valuation of firm A's patent strategy depends on the equilibrium solution found for each of the investment subgames composing the overall options game. The equilibrium outcome values in High, Medium and Low demand (E_H, E_M and E_L) constitute the payoffs in the end-of-period nodes of the binomial option tree. These are weighted by the respective (risk-adjusted) probabilities and discounted back at the riskless rate (r). Firms choose their patent strategy simultaneously.

[INSERT FIGURE 3 ABOUT HERE]

The resulting value payoffs (for firm A, firm B) in each of the 9 subgames are summarized in normal form via the 2 x 2 matrices of Figure 3, depending on demand (High, Medium, Low) and the size of innovation advantage (no, small, large). [These subgame payoffs are described in more detail in Supplementary Appendix]. Three benchmark *subgames (1, 3* and *5)* are highlighted (in circle) and explained at length. The other subgames are variations on these. *Subgame 1* illustrates a typical value payoff structure of a game in which firm A uses its patent in a cooperative mode (e.g., licensing out or cross-licensing). This game is likely to occur when firm A has no real innovation advantage. *Subgame 3* represents a payoff structure when firm A uses its patent in a fight mode (e.g., defensive via a patent wall or offensive via bracketing). The latter fight modes are prevalent in situations where firm A´s innovation is radical (large). For example, under medium demand (M) where there is room for only one of the firms to operate profitably, firm A may solidify its advantage by building a defensive patent wall around its core patent that enables it to drive the rival out and earn monopoly profits.[23] If demand is high (whether firm A´s advantage is large or small), the rival may have a fighting chance and go on the offensive to identify gaps around firm A´s core patent to limit its advantage; firm A may pursue a similar offensive strategy, resulting in a patent bracketing war. *Subgame 5* presents a more complex situation where a hybrid strategy is preferable [described in Supplementary Appendix].

[INSERT FIGURE 3 ABOUT HERE]

SUBGAME EQUILIBRIA/NUMERICAL RESULTS

We next discuss the *equilibrium outcomes* in different states of demand under a cooperative, compete or wait mode for a given size of technological advantage. Figure 4 summarizes the main assumptions and inputs used. If the firms cooperate, underlying market value (V) is enlarged by a cooperation

[22] Information is common knowledge, from the set of strategic actions to value payoffs. Although both firms A and B have a *core* patent, we take the view of patent-advantaged firm A and assess the *expanded* NPV of its patent strategy.

[23] If innovation advantage is small (incremental), it may not drive out the rival and cooperating strategy via licensing may be preferable at intermediate demand.

multiple ($m = c = 1.2$) to $1.2V$; if they compete, the fight multiple (or erosion factor) m here is $f = 0.7$, resulting in reduced value of $0.7V$. Relative market power shares (s for firm A, 1 – s for firm B) in sharing the total market value (adjusted NPV) or the continuation option value (C), depending on the size of technological advantage (no, small, large), are: 0.5, 0.5 (no); 0.6, 0.4 (small); 0.75, 0.25 (large advantage).[24] Investment (technology commercialization) cost is I = \$80 million (m), cost of capital (k) is 20% and risk-free interest (r) is 8%. Building a defensive patent wall by firm A raises costs by 20% to $w_A I$ ($w_A = 1.2$) and strengthens its market position, increasing its market value to $w'_A (mV)$ ($w'_A= 1.2$).[25] If the firms engage in an offensive patent bracketing war, costs are increased to bI (b = 1.3). In certain situations a firm (e.g., firm A) may pay a fee as % of market value (F% of V) to the other firm to license in its technology provided the former agrees not to operate in the market (the licensing fee schedule F is shown in Figure 4). Demand fluctuates stochastically in each period, with total market value (V), starting at V_0 = \$100 m, moving up or down by factors $u = 1.8$ and $d = 0.6$, with a risk-adjusted probability of up move $p = 0.4$. The implied volatility σ (= ln u) is 60%. At $t = 2$, if demand is high (moves up twice) $V^{++} = 324$, if demand is medium (after one up and one down move) $V^{+-} = 108$, and if demand is low (following two down moves) $V^{--} = 36$.

[INSERT FIGURE 4 ABOUT HERE]

Given these assumptions, inputs and the payoff value expressions for the various subgames described in Figure 3A (top), we obtain the numerical results for the nine subgames shown in Figure 3B (bottom panel). Each of the four "strategic" patent-use scenarios within each subgame is associated with a pair of payoff values for (firm A, firm B) derived from the above analysis [see Supplementary Appendix]. Each subgame involves two main choices by firm A or B: invest now or wait (sleep). "Invest" choices by firm A or B are cooperative in case of no patent advantage (symmetric players) or small advantage under low demand (involving licensing or cross-licensing); are of a fighting nature for large advantage (building a patent wall or bracketing), and may be hybrid for small advantage under intermediate demand (e.g., licensing vs. bracketing). The Nash equilibrium outcome for each subgame is shown as a shaded box, with the prevailing patent strategy listed below it. These outcomes and patent strategies are consistent with the theoretical predictions of Figure 3A.

To illustrate, consider first the simple symmetric case of no patent advantage involving a cooperative mode under high demand at end of stage I ($V^{++} = 324$) in the leftmost top matrix (***subgame 1***) in Figure 3B (bottom). If both firms let patents sleep (upper-left box), each firm appropriates the deferral (wait-and-see) option value according to their (equal) market power, resulting in payoffs (157,

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[24]The assumed relative market shares if incumbent firm B has prior market share power (under no, small or large patent advantage by firm A) are: 0.25, 0.75 (no); 0.4, 0.6 (small); 0.5, 0.5 (large advantage).

[25] Building a patent wall by weaker firm B raises its costs by 30% to $w_B I$ ($w_B = 1.3$) and increases its market value share to $w'_B (mV)$, where $w'_B = 2.2$.

157). If both firms invest cross-licensing their patents (lower-right box), they share the *Expanded* NPV ($mV^{++} - I$ = 1.2*324 – 80 = 308.8) at t = 2 resulting in a (154, 154) payoff. If firm A licenses its patent to B for a fee F (= 50% of V^{++}) and leaves the market to its rival, firm A receives F = 162 and firm B 147 (308.8 – 162). The symmetric diagonal case results in payoffs (147, 162). Given these payoff outcomes, summarized in *subgame 1* of Figure 3B, the resulting Nash equilibrium is ***cross-licensing*** (lower-right shaded box). Each firm has a dominant strategy to invest (license), regardless of its rival's decision (for firm A, 162 > 157 if firm B sleeps and 154 > 147 if it invests; for firm B, 162 > 157 if firm A sleeps and 154 > 147 if it invests).[26] The Nash equilibrium is invest-invest (154, 154) with each firm licensing to the other (cross-licensing). Under no cost advantage involving symmetric firms, both firms collaborate via cross-licensing with no incentive to deviate. ***Subgames 4 and 7*** under Medium and Low demand result in similar invest-invest *cross-licensing* Nash equilibria --but with lower values for the collaborating firms, namely (25, 25) and (2, 2). In 2014 Google and Samsung signed a 10-year cross-licensing agreement enabling each to access each other's patent portfolios on products and technologies in response to Rockstar Consortium (Apple, Microsoft and Sony) suing rivals. The above is summarized as follows: when there is no substantive innovation advantage and rivals are roughly symmetric, collaboration (e.g., via patent exchange or cross-licensing) is a natural equilibrium outcome regardless of industry dynamism (across demand states). This is in line with prior literature which seems to suggest that patent exchange or cross-licensing is appropriate when patent portfolios or the players are roughly equivalent. For instance, Mihm, Sting and Wang (2015) show that this is the case when both firms are R&D leaders (following a symmetric active patenting strategy) or when both are R&D imitators. Such collaboration under symmetry is also what we tend to see in the world of practice (e.g., see examples of Google and Samsung, IBM and Dell or Philips and Sony in the Appendix).

Consider now the situation involving *radical* innovation under a *competing* mode instead, again under High demand (***subgame 3***). When both firm patents sleep (upper-left box), each firm appropriates the continuation value of the wait-and-see option (C) according to their (asymmetric) market power (s = ¾ for firm A and 1 – s = ¼ for firm B), resulting in payoffs (98, 33).[27] When both firms invest by fighting via bracketing, they share the reduced (from fighting) total market value according to their market power, with each incurring a larger cost from bracketing (by b = 1.3) the

[26]A dominant strategy is indicated by an arrow or a black dot (tip of an implied arrow) over the higher payoff choice; Nash equilibrium is reached when a pair of black dots is obtained in a cell or when the arrows point the flow to a position (box) that once reached there is no incentive to deviate from it. The resulting equilibrium is indicated by a shaded box.

[27] End-of-period payoff (upper-node value V^{+++} in next period 3) on which continuation values are calculated is max(0.70V^{+++} - 1.3I, 0). Here fighting, delayed to next period, causes market value erosion (by 30%) and investment costs are larger by b = 1.3 because of intense patenting around the rival's product (bracketing). The time-2 value of 98 is the average (using risk-neutral probabilities) of subsequent-period upper and lower payoffs given a fight strategy.

other's patent (e.g., $NPV_A = ¾(0.7*324 – 1.3*80) = ¾(122.8) = 92$). This results in a (92, 31) payoff (lower-right *bracketing* box). If one firm (e.g., firm A) engages in patent clustering (building a patent wall) while the rival keeps its patent sleeping (off-diagonal boxes), the former captures an enhanced share (e.g., firm A receives $s(w_A) = ¾(1.2)$ or 90%) of net market value ($V^{++} – I = 324 – 80 = 244$) or 220, with the rival receiving the remainder (8).[28] This results in payoffs of (220, 8) or (68, 152) along the diagonal, depending on whether it is firm A or B that preempts the opponent via raising a patent wall. The Nash equilibrium is derived similarly (as in *subgame 1* above), as each firm has a dominant strategy to invest regardless of the opponent's decision (for firm A, 220 > 98 and 92 > 68; for firm B, 152 > 33 and 31 > 8). The resulting equilibrium is the bottom-right, invest-invest ***bracketing*** strategy (92, 31). Under reciprocating competition in high demand, firms feel induced to fight via patent bracketing -- even though they are better off to let their patents sleep. The fear of the rival investing in a patent wall and strengthening its position if it lets its own patent sleep puts pressure on both firms to invest aggressively bracketing each other's patent, analogous to the prisoner's dilemma.

The other two cases involving *radical* (*large*) innovation at intermediate (M) or low (L) demand levels (***subgames 6 and 9***) are interesting in themselves. Although they involve similar payoffs they result in different types of equilibria, with *subgame 6* at medium demand resulting in an invest-sleep *patent wall* strategy (34, 0), and *subgame 9* at low demand in a *sleeping* strategy by both firms with payoff (9, 0) in the top-left box. In ***subgame 6*** involving medium demand there is room for only one firm to operate profitably so firm A can strengthen its technological advantage by investing in a protective patent wall earning monopoly profits (valued at 34) driving its rival out (0). Here, firm A has a dominant strategy to invest, regardless of its rival's decision (34 > 9 and 3 > -29). Knowing that firm A is better off to invest and fight regardless, firm B waits (sleeps) rather than engage in a costly bracketing fight (0 > -17), resulting in the ***patent wall*** outcome (34, 0).

In ***subgame 9*** involving low demand, it is not profitable for either firm to operate, with firm B (being at large cost disadvantage) exiting (truncating value to 0). Firm A lets its superior patent sleep, maintaining an option to become a monopolist should the market recover (with continuation value 9). Each firm has a dominant strategy to let its patent sleep (or abandon) independently of its rival's move (for firm A, 9 > -5 and -14 > -20; for firm B, 0 > -1 and 0 > -7). Given low demand ($V^{--} = 36$), both firms lose value if they fight via patent clustering (wall) or a bracketing war. There is just one dominant ***sleeping*** strategy equilibrium in the upper-left box (9, 0), with the disadvantaged firm abandoning the market and the advantaged firm maintaining an option to be a future monopolist.

Proposition 1: When a pioneer firm's innovation is radical, competition *is more likely. The precise strategy may differ across demand regimes. It may range from offensive fighting*

[28] Firm B receives $(1 - s\, w_A)V – (1 - s)w_A\, I$ or 10% of 324 – 30% of 80 = 8.

> *(bracketing) in high demand or dynamic industries, to defensive patent wall by the advantaged firm to drive out its rival in medium demand, to a wait-and-see strategy (patent sleep) with an option on future monopoly in a low demand regime.*

As a classic example of defensive patent wall following radical innovation, in the late 1960s Xerox blocked rivals by patenting every feature of its copier technology "xerography". When IBM tried to enter in 1972, Xerox sued blocking entry with hundreds of patents. FTC forced Xerox to license to entrants at nominal cost, with prices and market share later dropping to half. In 1990, after BIC's challenge with disposable razors, Gillette launched *Sensor* cartridge razors (emphasizing comfort over price) protected by a patent wall. *Sensor* became the best-selling cartridge razor in US. A wall of 35 and 70 patents defended later launches of MACH3 and Fusion in 1998 and 2006. By contrast, as an example of patent sleep, in 1989 Endovascular Technologies (EVT) patented its Ancure stent system and kept the patent sleep in the low-demand coronary market. In 1997 Guidant (new entrant) responded to (incumbent) Johnson & Johnson (J&J)'s patent infringement suit by acquiring EVT and its dormant stent technology. In 6 months Guidant sold $350 m worth of devices.

The case of *small* (incremental) innovation under high demand in ***subgame 2*** is similar to *subgame 3*, with the share of firm A being lower (s = 60% rather than ¾) assuming bracketing war neutralizes or eliminates firm A's small patent advantage, rendering the bracketing outcome symmetric (61, 61). Each firm again has a dominant strategy to invest, resulting in a symmetric ***bracketing*** equilibrium under a *fight* mode. However, under low or medium demand the firm switches to a *cooperative* mode, yielding different equilibrium outcomes, namely an invest-sleep ***licensing*** equilibrium in the lower-left box. The *hybrid* case of ***subgame 5*** at intermediate demand is particularly interesting as investing may take the form either of a cooperative licensing strategy or of a costly bracketing fight. Firm B is better off to wait and avoid investing in a costly fight, with firm A agreeing to cooperatively license its marginally superior patented technology to firm B for a fee (F) while still producing itself directly (and capturing half the market value). This leads to the following:

> *Proposition 2: In case of incremental* (small) *innovation advantage, the firm may be better off to pursue a* flexible hybrid strategy*, switching from a compete mode (e.g., bracketing the rival's patent) at high demand to collaboration (licensing) at lower/medium demand levels.*

The circumstances around the above proposition involving dynamic switching strategies are a novel aspect of this paper as they give rise to pivoting from competition to collaboration under incremental innovation simply as a result of shifts in market demand or volatility conditions, without relying on the specific assumptions of sequential (staged) resolution of uncertainty about the value of the technology and gradual decline in the costs of technology integration that characterize the potentially disruptive technologies that are the focus in Marx, Gans and Hsu (2014). In the latter setup firms pay a cost to resolve the uncertainty of the technology, which is assumed to decline over time for disruptive technologies. We assume away uncertainty in the value of the technology and the cost of its integration and instead focus on uncertainty in industry demand. As a result, in our setup the above switching can be in the reverse (i.e., from a collaborative to a compete mode) if demand or volatility shifts are opposite, something that is not explainable under the disruptive innovation theory. Whereas in Marx, Gans and Hsu (2014) firms start by competing in the market entry stage and switch over time across stages as the uncertainty of the technology or the cost of its adoption decline, switches in our setup can occur contemporaneously across demand states and the value of switching increases with industry demand uncertainty. That is, whereas in the disruptive innovation setup reduced technological uncertainty is a precondition that enhances the value of switching from competition to collaboration (only), in our setup higher demand uncertainty favors switching in either direction even for incremental (non-disruptive) innovation, with the role and impact of uncertainty being opposite. In industry practice, facing high demand and volatility Yamaha used patent bracketing in the 1990s to fence in rivals in the watercraft market obtaining 100 patents with feature improvements around the competing jetski design. In 2001 it claimed (incumbent) Bombardier's products infringed on its patents. In 2002 the two settled. Facing low/medium demand, by contrast, Genentech opted to cooperatively license its patent on synthetic insulin to Eli Lilly (the incumbent) in the 1970s, enhancing both firms' advantage in the industry as post-innovation monopoly profits exceeded the combined Cournot duopoly profits.

VALUE OF PATENT STRATEGY

A strategic patent investment involves a portfolio of patent options (e.g., to exit, sleep, license in or out, cross-license, fight through raising a patent wall or a bracketing war). Each of these options has the base economic value of the commercialized patent as underlying asset. The resulting time-$t = 2$ equilibrium payoffs in each state of demand (E_H, E_M and E_L) for a given technological or competitive advantage (C = No, Small or Large) are then weighted by their respective (risk-adjusted) probabilities and discounted back to the present ($t = 0$) for 2 periods at the riskless interest rate r within a backward binomial option valuation process. Using risk-neutral probabilities for each up and down move of $p = 0.4$ (and $1 - p = 0.6$) and a risk-free rate $r = 0.08$, yields an *expanded* net present value (E-NPV) for the patent strategy of firm A of \$32 m in case of *no* competitive advantage involving a cooperative mode (cross-licensing); \$31 m in case of *small* (incremental) advantage involving a hybrid strategy (fighting via bracketing under high demand and cooperating via licensing under medium or low demand); and \$29 m in case of *large* (radical) advantage involving a fight stance (bracketing under H demand, raising patent wall to preempt and gain monopoly rents under M demand while sleeping under L demand):

No Competitive Advantage/Cooperative Mode:

$$\textit{Expanded}\ \mathrm{NPV}_0 = \frac{p^2E_H + 2p(1-p)E_M + (1-p)^2E_L}{(1+r)^2} = \frac{0.16x154 + 0.48x25 + 0.36x2}{(1+0.08)^2} = 32;$$

Small Competitive Advantage (Incremental Innovation)/Hybrid Strategy:

$$\textit{Expanded}\ \mathrm{NPV}_0 = \frac{0.16x61 + 0.48x46 + 0.36x12}{(1+0.08)^2} = 31;$$

Large Competitive Advantage (Radical Innovation)/Fight Mode:

$$\textit{Expanded}\ \mathrm{NPV}_0 = \frac{0.16x92 + 0.48x34 + 0.36x9}{(1+0.08)^2} = 29.$$

These results are summarized in Figure 5A. Compared to the static NPV of $20 m (that assumes investing now while ignoring the interplay between competition and collaboration), firm A's patent options portfolio (estimated from above *Expanded* NPV – static NPV) is worth $12 m under the cooperative strategy (involving cross-licensing) when there is *no* advantage (symmetry); $11 (=32 – 20) m under the hybrid strategy in *small* (incremental) innovation; and $9 m under a fight mode in case of *large* (radical) innovation. The fight mode in this case, despite firm A's patented innovation advantage, results in lower value due to value destruction from ensuing patent war.

In case of large or radical innovation, firm A might recognize that in high demand (H) it might be better off to cooperate (via cross-licensing), obtaining a smaller (½) share of a (20%) larger market pie (resulting in 154 as in *subgame 1*), rather than fight offensively shouldering higher bracketing costs to obtain a higher share (¾) of a fiercely contested and consequently (30%) smaller pie (resulting in value of 92). Such a hybrid patent strategy, switching from a compete mode via raising a defensive patent wall to strengthen its patent advantage in medium demand (with room for just one firm) to a cooperative relationship via cross-licensing in high demand (effectively replacing 92 by 154 in the last equation for *Expanded* NPV above), results in a higher E-NPV of $38 m (up from $29 m), almost doubling the value of the patent options portfolio to $18 m.[29] This hybrid patent strategy under radical innovation is more valuable ($38 m) than the cooperative strategy under no advantage involving symmetric firms ($32 m) or the hybrid strategy under small patent advantage ($31 m). Figure 5B illustrates graphically how the value of the patent strategy (E-NPV) varies with the degree of innovation advantage (asymmetry) measured by the market concentration (Herfindahl-Hirschman Index or HHI) at different levels of volatility (σ) under the compete, cooperate and hybrid strategies in our asymmetric duopoly. The cooperation and hybrid strategies are at a higher (elevated) value level.

[INSERT FIGURE 5 ABOUT HERE]

[29] In 1979 Philips and Sony, following their "videotape format war" of the 1970s, rather than engaging in a (new) battle, switched to a cooperative strategy adopting the same industry standard and agreeing to co-license the technology to any firms willing to produce CD players.

ROBUSTNESS AND EXTENSIONS

We next consider robustness to alternative specifications and extension to the case of asymmetric (stronger) prior market power by rival firm B. We first examine the tradeoff between compete and cooperate modes for high demand and extend our investigation considering a broader menu of patent strategies at more extreme levels of demand or involving higher volatility in dynamic industries, highlighting the value of hybrid strategies with flexibility to switch among various compete, collaborate, sleep or exit modes. Figures 6A and B highlight the tradeoff between the cooperate vs. compete strategies arising in high demand states in case of radical innovation examining the sensitivity of *Expanded* NPV to the fight erosion or cooperation multiple ($m = f$ or c). In Figure 6A, at the fight erosion multiple of $f = 0.7$ in the base case (with cooperation multiple of $c = 1.2$), the compete strategy results in a lower E-NPV than the cooperate (cross-licensing) strategy ($29 m vs. $38 m). However, as the fight multiple rises above a certain cutoff level $f^* = 0.96$ (i.e., as the degree of damage from an ensuing patent war diminishes), the compete strategy results in a higher value. If there is no value erosion from a bracketing war ($f = 1$), E-NPV = $40m. For $f > f^*$ a pure fight strategy is preferable when firm A's patent is superior, while for $f < f^*$ a hybrid pivoting strategy involving a switch from competition to cooperation via cross-licensing when demand gets very high is optimal instead. A hybrid strategy is also optimal when innovation is incremental.

Figure 6B illustrates the sensitivity of E-NPV to *cooperation* multiple (c) assuming *large* innovation advantage under a cooperate/ hybrid strategy. Again, when c = 1.2 (as in base case) cooperation results in higher value (38) than compete (29) when $f = 0.7$. In fact, cooperation always dominates fighting for $f = 0.7$. At the cutoff fight multiple $f^* = 0.96$ (upper horizontal dotted line) competing and cooperation result in the same value (38) when c equals $c^* = 1.2$. For $f^* = 0.96$ cooperation is beneficial when the cooperation multiple exceeds $c^* = 1.2$, while fighting dominates when $c < 1.2$. Figure 7A extends the sensitivity analysis of E-NPV to the cooperation multiple (c) under different innovation advantage cases. The case where c = 1.2 (vertical line) corresponds to the base case of Figure 5A. Even under a large technological advantage, a rigid fight strategy results in lower value of 29 m. Above a cutoff level of 1.1, having a small advantage under a hybrid strategy is preferable to a rigid fight strategy, as collaboration via (cross) licensing in the low and medium states enhances value. Below a cutoff level of c = 1.17, having a small advantage results in a higher value than having no advantage, but at a higher cooperation multiple no advantage might lead to higher value as it induces collaboration via cross-licensing in all demand scenarios whereas under small advantage a fight bracketing strategy may ensue in the high demand regime (as in Figure 2). A deliberate hybrid cooperation strategy under large advantage here seems best.

[INSERT FIGURES 6 AND 7 ABOUT HERE]

Figure 7B presents sensitivity of *Expanded* NPV to volatility (σ) under no, small and large innovation advantage. The base level of σ = 60% confirms the E-NPV values found in the middle column of Figure 5A. The conflict between competition and collaboration in high demand states leads to the value discontinuity or gap between the rigid fight strategy and the dynamic switch (cooperative) strategy E-NPVs under radical innovation. E-NPV values decline at lower volatility levels as expected. At σ = 15%, values coincide with those shown in the left E-NPV column in Figure 5A. An interesting discontinuity in the E-NPV values is observed around a critical volatility level of about σ* = 38%. This discontinuity arises due to a shift in certain equilibrium subgames as volatility declines below a critical threshold level. Under radical innovation, in low demand the equilibrium strategy is to sleep (wait) under high volatility; but as σ declines below σ*, the value of the wait-and-see option declines while the attractiveness for the advantaged firm to fight and drive the weaker rival out given low demand and low recovery prospects rises. But at very high demand, cooperation is attractive under high volatility in dynamic industries, partly deriving from the option to jointly appropriate the value of open innovation and optimizing future decisions under demand uncertainty, avoiding the prisoner´s dilemma of both firms investing prematurely under the pressure of competitive rivalry. As volatility declines below a certain level, however, there is a switch from cooperative to competitive equilibrium involving a shift from the wait (sleep) mode to a rigid fight mode.[30] Figure 8A confirms, in case of large innovation advantage, that at low σ a rigid, fight only strategy (e.g., raising a defensive patent wall to strengthen the patent´s large advantage) may be best. However, as the cone of uncertainty rises a wider menu of strategic choices opens up, including sleep/exit at the low end and cooperation at high (as well as middle) demand. At high volatility (σ = 90%), characterizing more dynamic industries, optimal patent strategies span the whole range from exit, sleep, defensive fighting (raising patent wall), offensive competition (bracketing), and cooperation (cross-licensing).

[INSERT FIGURE 8 ABOUT HERE]

Figure 8B provides a summary and an extension (including the case of small and no advantage) of the various cooperate vs. compete patent strategies that may be optimal when a broader range of demand states is possible under highly volatile markets in the base/symmetry case. The case of large (radical) innovation (rightmost column) corresponds to the high volatility case (rightmost column) of Figure 8A above. Here, higher demand volatility allows adding Very High (VH) and Very Low (VL) demand states at the two extremes, besides High (H), Medium (M) and Low (L) demand after time

[30] In moderate or high demand if patent advantage is small and volatility is high, future high rewards may induce a weaker rival to fight aggressively and enter a bracketing war; as volatility declines, however, the possibility of high rewards declines and the weaker rival may face a patent wall by the stronger patent holder or shift to cooperation.

period $t = 4$. As previously, in determining the equilibria for each of the various cooperate or compete subgames, the firm should select the type of patent *strategy S* (e.g., sleep or exit, licensing out, cross-licensing, raising patent wall, or bracketing) and associated options to optimally exercise depending on different market demand (or volatility) conditions and the size of its technological advantage. The optimal patent strategy is a function of the size of competitive/innovation advantage C (No, Small, Large), the cooperative or competitive strategy mode *m (c*ooperate, *c, or f*ight, *f)*, and demand level regime *D* (e.g., VH, H, M, L or VL).[31] Under large technological advantage (L) strategic patent use by firm A may span the entire menu of available options depending on prevailing market demand conditions: ***abandon or exit*** when demand is very low (VL);[32] ***sleep*** or "wait and see" when demand is low (L); expand/strengthen the patent through a patent wall to preempt the rival and gain monopoly position at medium demand (M), while at times cooperate with the rival to preempt third entrants; engage in offensive fighting via ***bracketing*** in high demand (H); and potentially switch to a cooperative mode (***cross-licensing***) at very high levels of demand (VH), allowing room for both rivals to profit. In general, under radical innovation, the optimal patent strategy of firm A may vary or switch among defer or exit, and compete or cooperate, depending on the level of demand and other conditions such as volatility and industry dynamism. Under volatile conditions, patent strategy should be dynamic, able to adapt and switch among various compete, cooperate or sleep modes. Patent strategy is generally hybrid when the innovation advantage is marginal, with small variations in demand, e.g., from High to Medium, necessitating a strategy switch from a compete mode (e.g., bracketing) to a cooperate mode (licensing). This may also be the case when innovation is radical, with cooperation possibly prevailing unless the market is limited. These dynamic switches among cooperate, compete or sleep modes bring about value discontinuities and non-trivial tradeoffs not fully recognized in traditional analyses. The above insights can be summarized via the following proposition.

> *Proposition 3: Cooperation can prevail in volatile regimes even when innovation is radical under high demand when the (smaller) share of joint benefits exceeds the dominant share of a reduced market pie from a costly patent war. At high demand, initially give-up strategies may switch to competition and then, at higher demand in volatile regimes, to cooperation. Volatility exacerbates these switch patterns between competition and collaboration.*

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[31] For a given competitive/innovation advantage C (C = N, S or L), patent strategy *S* is a function of strategy mode *m* and demand regime *D*, namely *Patent Strategy*$_m^D$(*S*|C). For no or small innovation advantage where a cooperative mode typically prevails, firm A can leverage its patent via exercising one of the following options depending upon demand conditions: option to extend the patent through *Patent Strategy*$_c^D$ (*cross-licensing*|C = No), D = VH, H, M or L; option to extend through *Patent Strategy*$_c^D$ (*licensing-out*|C = Small), for D = M or L; or option to or abandon it through *Patent Strategy*$_c^D$ (*sleep* or *abandon*) for D = VL (regardless of the size of innovation advantage).

[32] In Figure 8B a fight mode extends to the very low demand scenario forcing exit by a disadvantaged rival. If firms are roughly ex post symmetric, a collaborative strategy may result (e.g., patent pool) particularly if incumbent firms A and B jointly face third-party entrants.

That is, even with a superior innovation, the firm should still consider the full menu of compete and cooperate strategies, potentially switching among sleep, compete and collaborate modes as demand changes in pursuit of a dynamic competitive strategy.

Asymmetric Prior Market Power

In 2009, GlaxoSmithKline, an incumbent with large prior market share power, and Nuevolution, a smaller entrant with a radical technology to efficiently identify potent drug leads, entered into a cooperative cross-licensing agreement despite their initial power asymmetry. GSK obtained access to Nuevolution's lead discovery technology, while the later gained access to GSK's big pharma capability. We next consider the asymmetric situation when incumbent firm B has larger *prior* market share power and examine how an asymmetric distribution affects the interplay between competition and cooperation.[33] Suppose incumbent firm B has a 75% market share dominance. If firm A's new patented technology has only a small advantage, the initial asymmetry in favor of incumbent firm B will be reduced only partly (shares will adjust to s = 40% for firm A and 1 – s = 60% for B). The incumbent's initial market power advantage is eliminated, however, if firm A's patented innovation is radical, reverting back to an ex post symmetric situation (50-50), as was the case with GSK and Nuevolution. Suppose the relative market shares for firms A and B in the power asymmetry case (under no, small or radical patent advantage by firm A) are: 0.25, 0.75 (no); 0.4, 0.6 (small); 0.5, 0.5 (large advantage). In Figures 9A and B, the circles indicate subgames that shift between compete and cooperation modes and vice versa in this asymmetry case, compared to the symmetric base case discussed earlier. Previous symmetry games 4 and 7 that under no patent advantage were earlier characterized by cooperation (cross-licensing) under moderate and low demand, now change into compete games involving bracketing due to asymmetry resulting from incumbent firm B´s prior market power; similarly, subgame 8 involving small innovation advantage under low demand previously characterized by cooperation (licensing out) now turns into a bracketing fight. By contrast, the previous asymmetry due to firm A´s large advantage in subgame 6 that led to a fight (patent wall) is now offset by the incumbent´s prior advantage so resulting symmetry now supports cooperation (cross-licensing). Some cases that were previously symmetric, characterized by cooperation, now become asymmetric turning into competition, and vice versa. What matters is the *relative* overall competitive advantage or

[33] It is unlikely to find cross-licensing cases where firms are in a purely symmetric position. Sometimes the weaker firm will pay a fee to the other. A legitimate question is, what would compel the old technology owner to cross-license if it has a dominant market share? If the new technology has no advantage, buyers of the old patented product will likely require some inducement to switch to the new (but not superior) technology. The old technology owner may be induced to cross-license for reasons such as freedom to invent, a high fee, or collaborate to prevent entry by new entrants (third parties).

asymmetry, not just the absolute patent advantage. Figure 19B shows the revised outcomes and resulting equilibria in the changed subgames.

[INSERT FIGURE 9 ABOUT HERE]

SUMMARY, DISCUSSION AND IMPLICATIONS

We identified a research gap at the core of business strategy (Figure 1) that has struggled with the classic dilemma of "competition vs. cooperation", failing to adequately address the interplay of these two modes of inter-firm interaction. Utilizing a new application context in strategic management involving the strategic use of patents in "proactive" business strategy (Grindley and Teece, 1997; Cohen, Nelson and Walsh, 2000; Reitzig, 2004; Somaya, 2012), we addressed this gap, analyzing the dilemma of when firms should compete or cooperate. We also accounted for how the "commitment vs. flexibility" tradeoff (Wernerfelt and Karnani, 1987) affects the interplay of competition and cooperation. We captured the tradeoff between strategic commitment (fight/preempt) and flexibility (wait/stage/ally) via the use of a novel strategic tool, option games. Our work supports Lado, Boyd and Hanlon's (1997) finding that successful firms "possess enhanced *strategic flexibility* by either holding or striking a wide variety of *strategic options*" and responds to a key research challenge posed by Somaya (2012): "it would be valuable to incorporate the strategies and actions of rival and partner firms … actions initiated by rival firms may lead to competitive dynamics that have yet to be systematically investigated… it would be worthwhile to explore when firms are and are not better off pursuing "weak," nonproprietary [collaborative] patent strategies to enhance the value creation potential of their innovation." Our findings are compared subsequently with those in the competitive strategy, TCS/(cross)licensing, strategic alliances and related literatures.

Our work extends recent contributions using real options in technology and strategy (e.g., McGrath and Nerkar, 2004; Oriani and Sobrero, 2008), especially those with a game theoretic perspective (Camerer, 1991; Ferreira, Karr and Trigeorgis, 2009), by illustrating how a patent strategy can be designed and valued and examining the optimality of different competitive, cooperative or hybrid strategies. The optimal patent strategy is moderated not only by the strength of patent innovation advantage in line with extant licensing literatures (e.g., Somaya, 2012) but also by the level and volatility of demand. Extending related literature on strategic alliances (e.g., Teece, 1986; Kogut, 1991; Gulati, 1998; Chi, 2000; Arend and Seale, 2005; Somaya and Vonortas, 2010) and licensing strategies (Anand and Khanna, 2000; Fosfuri, 2006; Davis, 2008), we analyze the circumstances under which firms should collaborate or fight in using their IP assets strategically under uncertainty.

In line with Rumelt (1984), Wernerfelt and Karnani (1987), and Marx, Gans and Hsu (2014), we promote a dynamic notion of strategy that involves the use of a menu of patent strategies enabling the firm to switch among compete (fight), cooperate, or wait (patent sleep) modes that may prevail under different future demand or volatility scenarios. The above dynamic strategy is conditioned on the strength of innovation advantage and on prior (potentially asymmetric) market power, consistent with extant literature (e.g., Arrow, 1962; Fosfuri, 2006; Ceccagnoli, 2009). We confirm that radical innovation generally increases the benefit (and lowers the critical demand threshold at which it pays) to *fight* to attain proprietary benefits. The greater the advantage of the newly patented over the existing technology, the greater are the incentives to fight, e.g., bracketing each other's patents or erecting a defensive patent wall (e.g., Nestlé's coffee machine *Nespresso*). This is analogous to the classic result in the licensing literature (e.g., Arrow, 1962; Hill, 1992; Wang, 1998) that drastic innovation should be kept proprietary, while patented technologies with incremental advantage might be shared via licensing out to capture royalty fees or as a defense against imitation. However, beyond known opportunistic factors, competitive forces and the strength of patented innovation advantage, we emphasize important strategic drivers such as interactions among industry players and the role of market uncertainty, showing that the above result is moderated by such factors as the level and volatility of demand. We find that patent strategies seem to be well-ordered for small innovation advantage at increasing levels of demand, with fighting becoming more attractive when demand gets higher (e.g., Yamaha and Bombardier's patent bracketing war), whereas collaboration is preferred in low or moderate demand (as in Genentech's licensing with Eli Lilly). This complements Hill (1992).

The dilemma between competition and collaboration in high demand regimes requires special attention as it may lead to value discontinuities and tradeoffs in dynamic industries. Radical innovation under moderate or high demand often induces a compete mode (e.g., via patent wall or bracketing strategies), in line with first-mover advantage motives (Lieberman and Montgomery, 1988). But our rationale here is distinct and complementary to Hill's (1992) preference for licensing out to prevent imitation. It confirms and complements Hill's (1997) intuition that in an unpredictable and dynamic environment, a firm seeking to establish its new technology as an industry standard should switch between pure competitive (e.g., sole provider) strategies, assertive cooperation stances with sequential rival preemption (aggressive multiple licensing) and more sit-back collaboration strategies, depending on rival technologies, barriers to imitation and availability of internal complementary resources.

The above may also help explain why, contrary to traditional prescription when innovation is radical, *cooperation* might prevail in dynamic environments that entertain the prospect of *very* high levels of demand. This novel result merits further consideration. Our option games analysis of dynamic patent strategy suggests that if the firm follows a cooperating strategy (e.g., via cross-licensing of patents with rivals) it might significantly enlarge its strategic patent value share by enlarging the industry pie. The joint benefits from cooperation enlarging the market pie may exceed the value from a higher share of a smaller market pie from winning a competitive battle net of higher fight costs. Under high demand one can also anticipate scenarios where there is fierce fighting to take advantage of monopoly rents (a typical Microsoft stance), as well as other scenarios where collaboration might occur (e.g., via cross licensing) to jointly appropriate the value of open innovation and exploit larger joint rents, as in Intel and AMD's cross-licensing agreement. This complements Teece (2000). Under specific circumstances, collaboration may also prevail at moderate demand if incumbent firms fear competition from new entrants. Cross-licensing may raise a wall protection around incumbent oligopolists (e.g., IBM and Dell's cross-licensing agreement). Radical innovation may induce patent sleeping or rival exit under very low demand, as in EVT's selloff of its sleeping patented coronary stent technology to Guidant.

The above analysis reveals severe limitations of traditional NPV that treats the size of the market pie as given. In option-games analysis, firm decisions are contingent on both market demand and the incorporation of rival reactions into one's strategic patent moves. The size (and sharing) of the market pie is a function of the (competing, cooperating or hybrid) strategies pursued by the firm and its rivals, moderated by the demand level and volatility. When a firm pursues a compete strategy this may potentially lead to lower overall value due to ensuing patent wars even when it has considerable innovation advantage. In such a case the *expanded* net present value of the patent strategy may be lower. Hence, the value of a patent strategy may be enhanced by a combination of favorable market conditions and via a cooperating stance (e.g., cross-licensing of patents) under high demand and volatility. Even in low demand with an incremental innovation advantage, the value of the associated patent strategy may be enhanced via licensing in anticipation of future collaboration.

Market uncertainty can be value-enhancing as it not only increases growth option value but it also induces firms to switch to collaboration strategies. This hidden upside potential from higher market uncertainty in dynamic industries can be exploited through a richer menu of strategic choices by cooperating firms. This is generally the case when firms are roughly symmetric with equivalent technologies (e.g., Google and Samsung). This is in line with Fosfuri (2006), though for different reasons. If the innovator holds a marginal patent advantage, Fosfuri (2006) argues the incentive to license is low as there is low profit dissipation. We find that licensing out may be justified even under low or medium demand.[34] Also, we find upside potential from collaboration may hold under very high demand or volatility conditions even when firms are asymmetric, as initially give-up strategies may switch to fighting and then, at higher demand, to cooperation. Hybrid strategies may thus result,

[34] Fosfuri (2006) notes that firms with larger prior market share have a weaker incentive to license as they would suffer higher profit dissipation. Our finding, that in the asymmetric situation (when incumbent firm B has larger prior market power whereas innovator firm A has an incremental innovation advantage) under medium demand licensing is preferable for firm A, is in the same direction.

involving switching from one type of fight mode to another or from competition to cooperation as demand rises or as the patent advantage gets smaller. Volatility exacerbates and brings out these peculiar switching patterns between competition and collaboration modes. This is particularly relevant in emerging or dynamic technology industries characterized by change (Ang, 2008).

Our strategic options lens is complementary to property rights theory (Anand and Khanna, 2000) suggesting that firms should avoid licensing a superior technology to reduce the risk of imitation. We give more weight to the benefits of collaboration in enhancing the value of the relevant market by fostering exchange of technologies and encouraging industry innovation. Such collaboration benefits may be lost when taking an aggressive stance that erodes market value. Fighting may be justified in some cases, however, when the firm has a radical advantage, in line with Arrow (1962) and Hill (1992). But this holds if the market value erosion from fighting is limited or market demand is constrained enabling the firm with radical technology to drive the rival out and gain a monopoly position (e.g., Gillette *Sensor*'s patent wall). Our preemptive patenting strategies under moderate demand and the moderating role of market power asymmetry are consistent with Fosfuri (2006) and Ceccagnoli (2009). A different strategy, however, may be appropriate if demand or the rewards of winning a fight are so high that the rival may not be driven out and causes substantial damage fighting back. A careful scanning of rival behavior is warranted. Our analysis also enriches Davis (2008) in providing a more dynamic analysis of an IP vendor's licensing strategies. This may enable licensing parties to negotiate better contracts adjusted in a contingent manner in line with option analysis.

Our findings also support Chen's (1996) competitor analysis based on firm-specific factors. The collaboration strategy under no innovation advantage corresponds to Chen's (1996) high market commonality and resource similarity reducing the chance of attacking due to high-risk multi-market overlap and capability for retaliation. The compete strategy under radical innovation represents relationships in which inter-firm discrepancy in market focus and resource endowments is so strong that the firm is better off initiating a challenge. Our view also enriches Chen and Miller (2014) by accounting not only for a competitive but also for a cooperative stance among firms. Our main results are consistent with the findings of Marx, Gans and Hsu (2014) on pivoting strategies and the practical entrepreneurial practices in Ries (2011), whereby startups are encouraged to introduce a minimum viable product to obtain customer feedback to decide whether to persevere or switch. This reveals a richer set of situations under which firms should compete or cooperate in using their IP assets under uncertainty, enriching our understanding of patent strategy and IP management (Somaya, 2012).

Our study also offers important *managerial* implications for an adaptive strategy for IP managers and business strategists. Our practical option-games framework enables practitioners and scholars to move from concepts and propositions to dynamic strategy formulation through use of tools that can quantify strategy development and adaptability, enabling pivoting among competing and collaborative modes. Our framework also helps advance the use of game theory in management practice (Lado, Boyd and Hanlon, 1997; Branderburger and Nalebuff, 1995; Ross, 2014). Our Expanded-NPV criterion enables managers to integrate flexibility and commitment within a holistic framework that addresses the dilemma between competition and cooperation, providing more precise insights on path dependency. Besides expected rents from preset capabilities, operations and strategies, our criterion also quantifies the dimension of cooperation. Application of "option games" to strategic patenting gives managers a tool to assess the value of patent strategies under *both* demand and strategic uncertainty. Managers can assess how dynamic patent strategy depends on the level and volatility of demand and on radical or incremental innovation. They can thus address the optimality of different competitive or cooperative strategies using demand and the degree of innovation advantage as driving factors of patent strategy while accounting for rival reactions.

In assessing the *expanded* NPV of a core patent strategy today, managers must anticipate which set of contingent patent-use strategies they might pursue in the future. This decision depends on some well-known factors, such as the strength of the patented new technology, relative prior market power and anticipated rival reactions. What matters is the *relative* overall competitive advantage arising out of firm heterogeneity or asymmetry (Peteraf, 1993). However, it has been less obvious how the optimal strategy may also depend on the demand and volatility regimes. New and more subtle variables, such as demand regimes, volatility or investment exercise timing and staging may help explain more subtle differences in strategic investment behavior. In terms of implications for patent management, it is of import to maintain a flexible IP portfolio strategy and attract the right collaborations (Grindley and Teece, 1997). Creating and managing cooperative relationships, leveraging ("borrowing") resources outside firm boundaries (Capron and Mitchell, 2012) within a broader alliance portfolio that is "evolving from adapting to shaping and exploiting, according to the state of strategic uncertainty" (Hoffman, 2007) is a critical dynamic capability requiring requisite complementary assets and absorptive capacity (Anand, Oriani and Vassolo, 2010). Management should thus be flexible to dynamically switch among wait-and-see, compete or cooperate strategy modes as market circumstances warrant. This is the essence of competitive strategy, being in "constant search for ways in which the firm's unique resources can be redeployed in changing circumstances" (Rumelt, 1984). When one goes the "extra mile" (Wernerfelt and Karnani, 1987) to combine real options and games under uncertainty, the complex interplay between competition and collaboration may begin to unravel.

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Appendix. Real world business examples of competitive and cooperative patent use strategy

Innovation	Demand	Volatility	Mode	Strategy	Real-world Business Example
Panel A. Cooperate					
Negligible (no)		Medium/ High	Cooperate (against externals)	Cross-License	In 2014 **Google** and **Samsung** sign a 10-year cross-licensing agreement enabling each to access each other's patent portfolios on products and technologies in response to Rockstar Consortium (Apple, Microsoft and Sony) suing rivals.
Panel B. Cooperate/Compete (Hybrid)					
Incremental (small)	Low/ Medium	High	Cooperate	License	In 1970s **Genentech** cooperatively licenses its patent on synthetic insulin to **Eli Lilly** (incumbent) enhancing both firms' advantage in the industry as post-innovation monopoly profits exceeded combined duopoly profits.
Incremental	High	High	Compete (fight)	Patent Bracketing	In 1990s **Yamaha** fences in rivals in the watercraft market obtaining 100 patents with feature improvements around the competing jet ski design. In 2001 it claimed **Bombardier**'s products infringed on its patents. In 2002 the two settled.
Panel C. Compete					
Radical (large)	Low	Medium	Wait	Patent Sleep	In 1989 **EVT** patents its Ancure stent system and keeps the patent sleep (in low-demand coronary market). In 1997 **Guidant** (new entrant) responds to (incumbent) Johnson & Johnson (J&J)'s patent infringement suit acquiring EVT and its dormant stent technology. In 6 months Guidant sold $350 m worth of devices.
Radical	Medium	Low (stable)	Compete	Patent Wall	In late 1960s **Xerox** blocks rivals by patenting every feature of its copier technology "xerography". When IBM tries to enter in 1972, Xerox sues blocking entry with hundreds of patents. FTC forced Xerox to license to entrants at nominal cost, with prices and market share later dropping to half.
Radical	Medium	Medium	Compete (preempt)	Patent Wall	In 1990, after **BIC**'s challenge with disposable razors, **Gillette** launches *Sensor* cartridge razors (emphasizing comfort over price) protected by a patent wall. *Sensor* became the best-selling cartridge razor in US. A wall of 35 and 70 patents defended later launches of *MACH3* and *Fusion* in 1998 and 2006.
Radical	Medium/ High	High (unpredict.)	Cooperate (against external threat)	Cross-Licensing	In 1999 **IBM** and **Dell** sign a 7-year cross-licensing deal. Dell held only 40 patents on its direct sales business model vs. IBM's thousands on its hardware components. Dell agreed to buy parts from IBM, which was licensed to use Dell's design technology in its own PCs. The cross-licensing strategies proved complementary.
Radical	Very High	High (unpredict.)	*Switch to* Cooperate (not fight)	Cross-Licensing	In 1979 **Philips** and **Sony**, following their "videotape format war" of the 1970s, rather than engaging in a (new) battle agree to adopt the same industry standard and co-license the technology to firms willing to produce CD players.
Panel D. Asymmetric Market Power					
Radical	Medium/ High	Medium	Cooperate	Cross-Licensing (asymmetry)	In 2009, **GlaxoSmithKline** (incumbent with market power) and **Nuevolution** (innovating firm) enter into a cross-licensing agreement involving technologies to efficiently identify potent drug leads. GSK obtains access to Nuevolution's lead discovery technology, and the later gains access to GSK's big pharma capability.

Figure 1. Literature categorization: streams positioning on competition vs. cooperation interplay

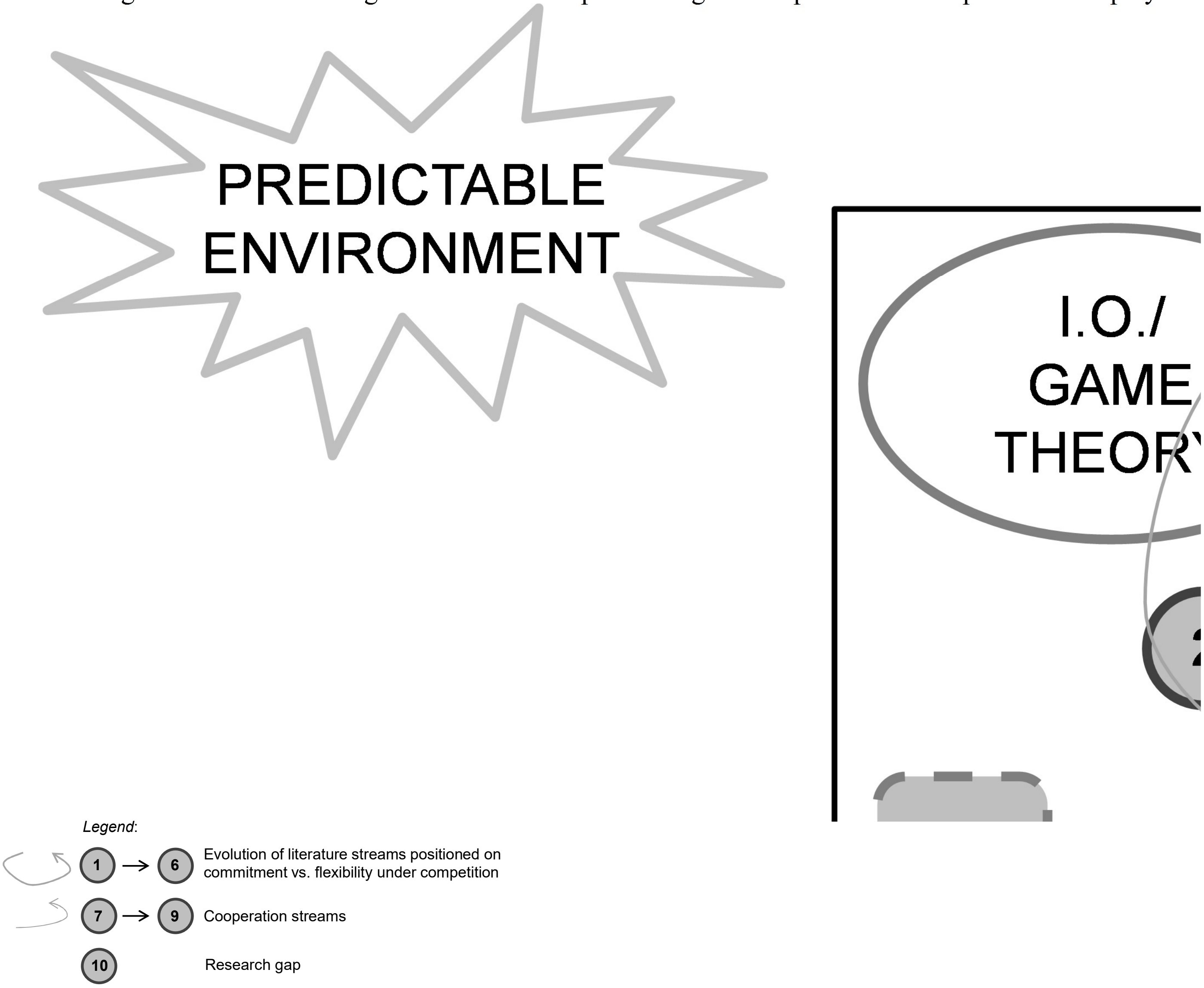


Figure 2. Patent strategies contingent on innovation advantage and state of demand/industry dynamism

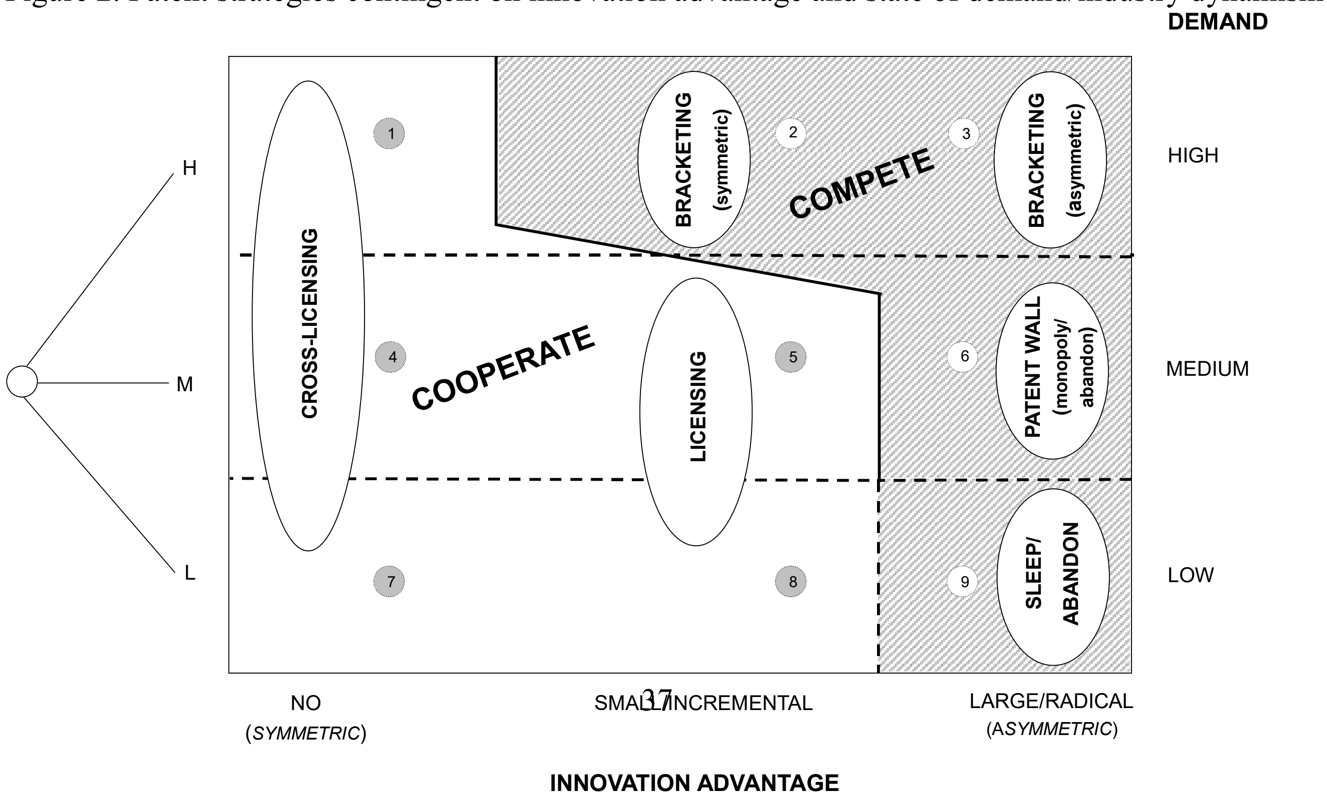
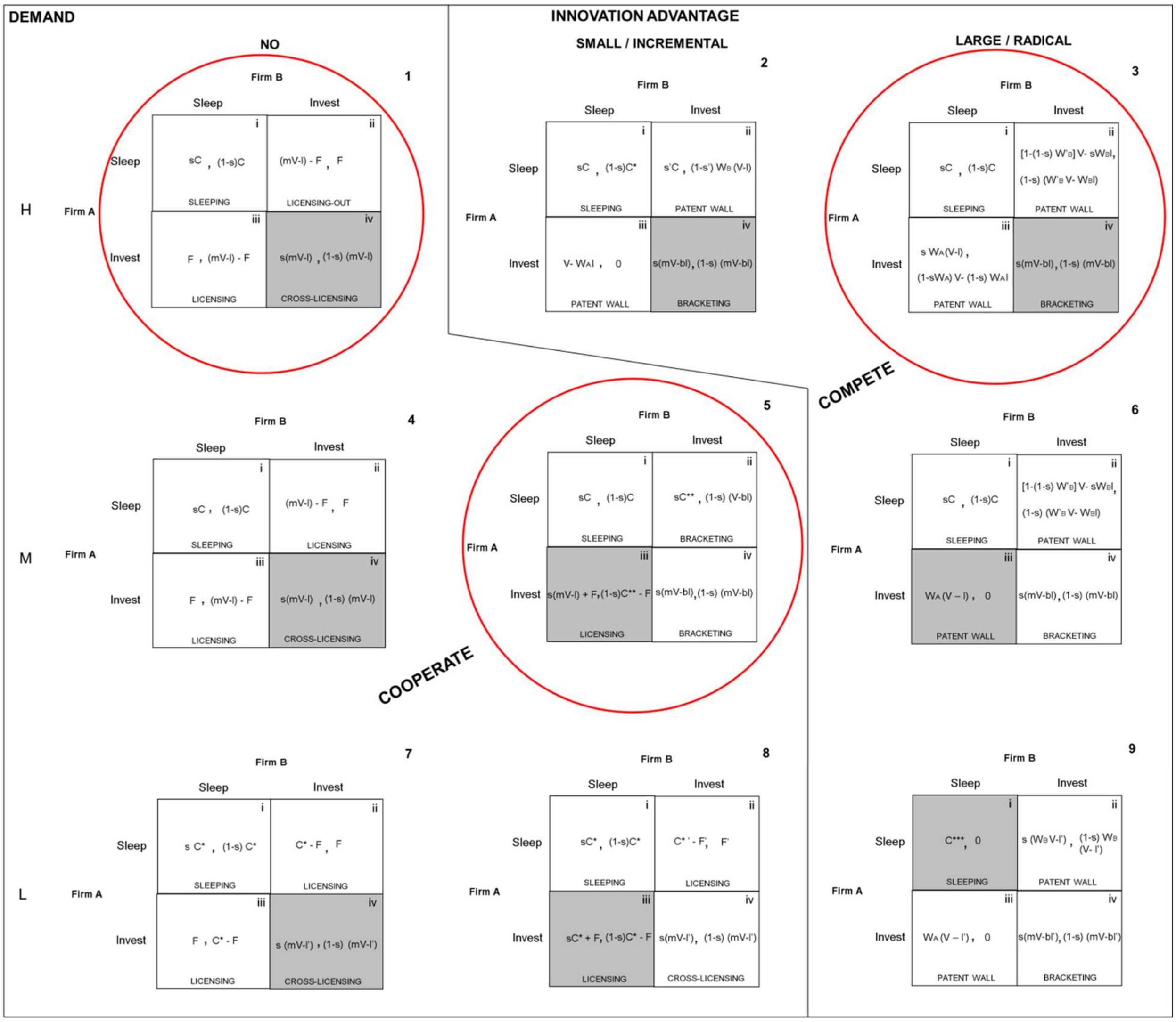


Figure 3. Value payoffs for various subgames depending on demand and innovation advantage



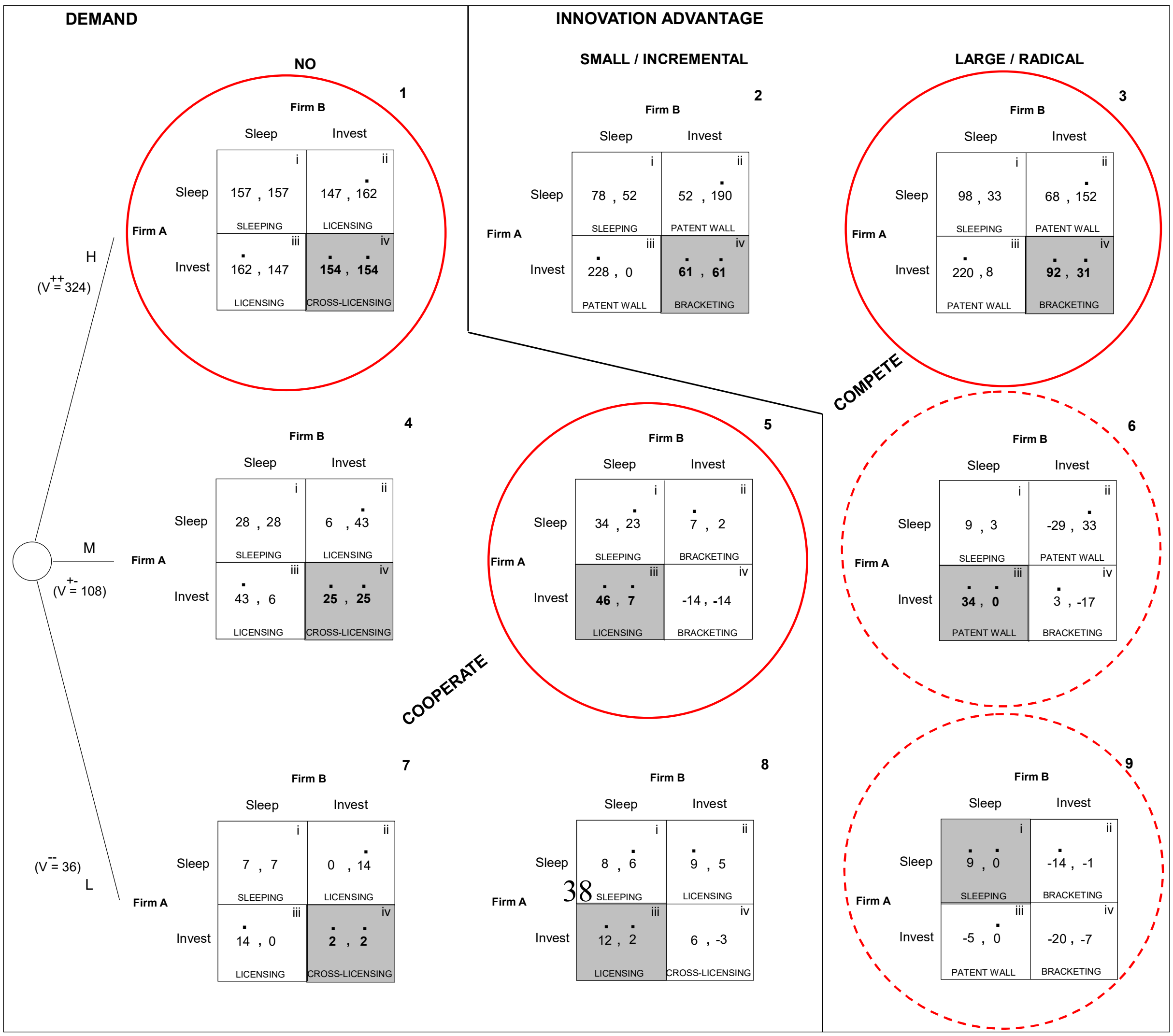


Figure 4. Summary of main assumptions and input parameters

Cooperation/Fight multiple (*m*)

Cooperation (*c*)	1.20
Fight (*f*)	0.70

Market power share (s)

	FIRMS			
	Symmetric		Asymmetric	
INNOVATION ADVANTAGE	A	B	A	B
No	50%	50%	25%	75%
Small/Incremental	60%	40%	40%	60%
Large/Radical	75%	25%	50%	50%

Patent Wall multiplier (*W*)

	FIRM	
	A	B
Cost Multiplier (W I)		
W_A	1.2	
W_B		1.3
Value Multiplier (W' V)		
W'_A	1.2	
W'_B		2.2

Bracketing Cost multiplier (*b*)

	FIRM	
	A	B
Cost Multiplier (*b*)	1.3	1.3

Licensing Fee (*F*)

	INNOVATION ADVANTAGE		
	No	Small	Large
HIGH DEMAND (H)	50%		
MEDIUM/LOW DEMAND (M/L)	40%		
MEDIUM DEMAND (M)		20%	
LOW DEMAND (L)			15%

Other valuation inputs

Investment cost (*I*): $ 80 million

Base volatility (σ): 60%

Cost of capital (k): 20%

Riskless interest rate (r): 8%

Figure 5A. Value of patent strategy (Expanded-NPV) under No, Small or Large innovation advantage

COMPETITIVE ADVANTAGE	PATENT STRATEGY			E-NPV Low σ (15%)	E-NPV Base σ (60%)	E-NPV High σ (90%)
No	COOPERATE (cross-license)			29	32	34
Small/Incremental	HYBRID	H	Compete (bracket)	24	31	32
		M/L	Cooperate (license)			
Large/Radical	COMPETE	H	Compete (bracket)	19	29	32
		M	Compete (patent wall/preempt)			
		L	Sleep			
	HYBRID	H	Cooperate (cross-license)	34	38	39
		M	Compete (patent wall/preempt)			
		L	Sleep			
Ignore competition; invest now					20 (=NPV)	

Note: base fight multiple 0.7; cooperation multiple 1.2.

Figure 5B. Value of patent strategy (E-NPV) for varying degrees of innovation advantage (asymmetry) reflected in market concentration index (HHI) and different volatility under compete, cooperate and hybrid strategy (asymmetric duopoly)

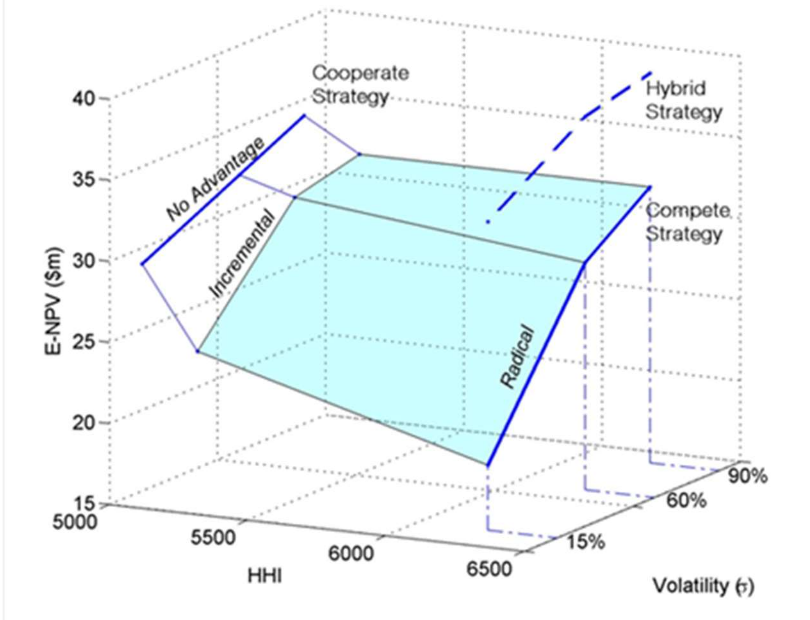


Figure 6A. The compete vs. cooperate tradeoff:

Sensitivity of E-NPV to *fight erosion* multiple
(under large or radical innovation advantage)

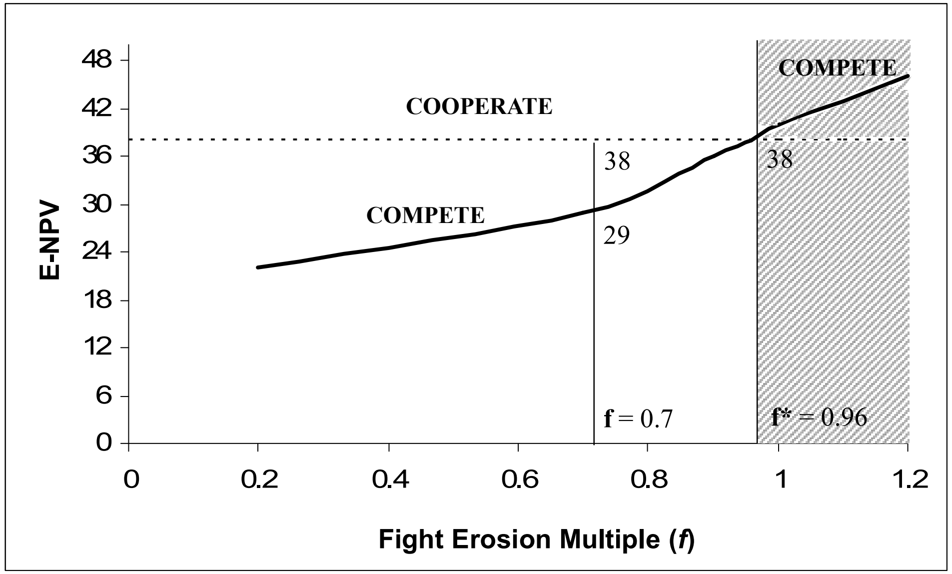


Figure 7A. Sensitivity of E-NPV to *cooperation multiple* for different degrees of innovation advantage

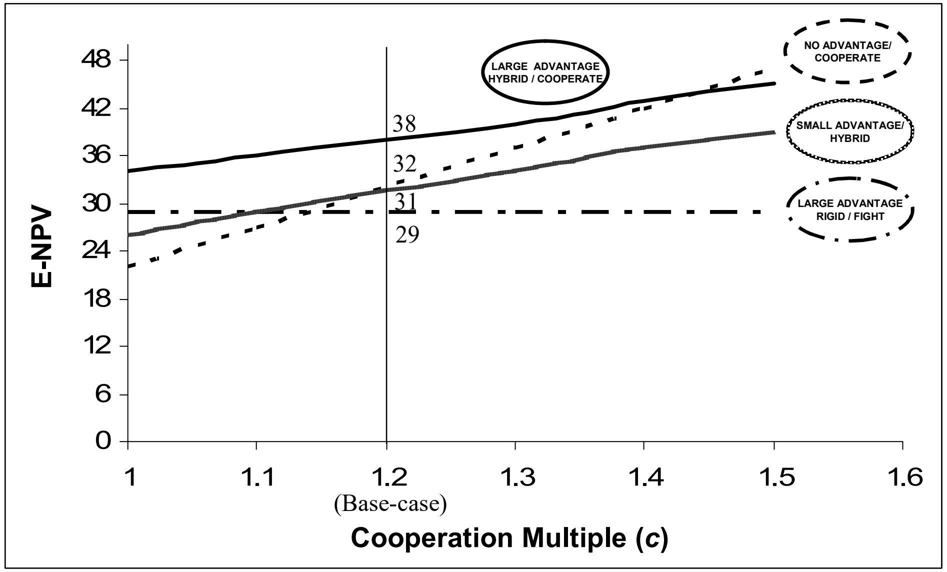


Figure 6B. Sensitivity of E-NPV to *cooperation* multiple

(under large advantage/cooperation stance)

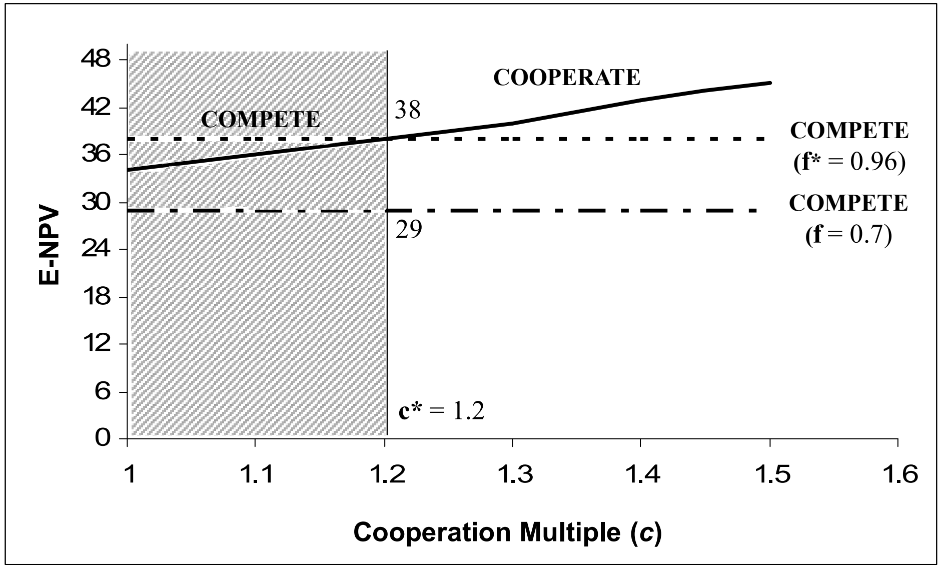


Figure 7B. Sensitivity of E-NPV to *volatility* under No, Small or Large innovation

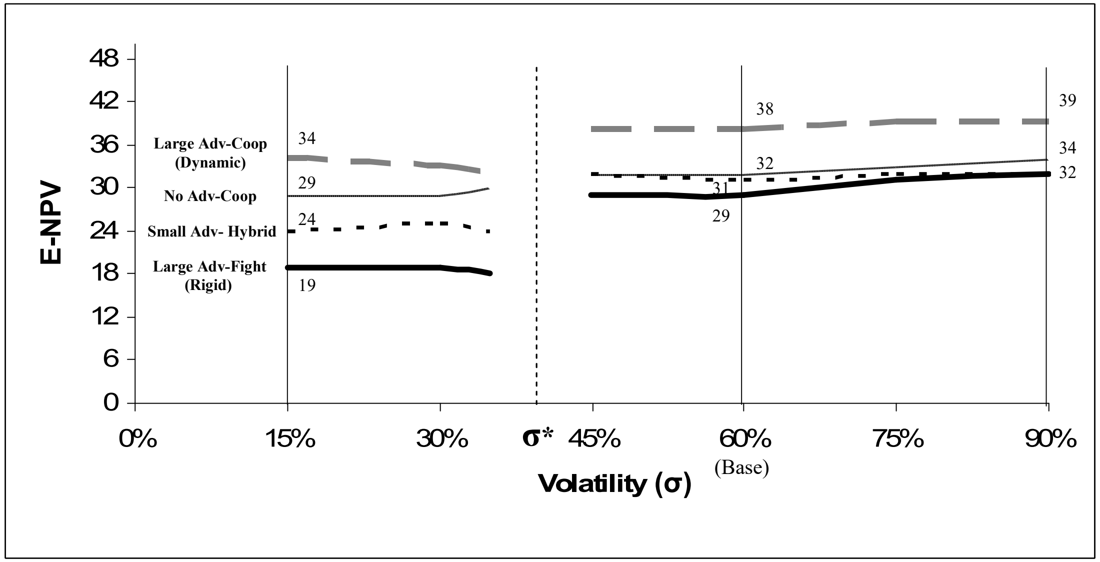
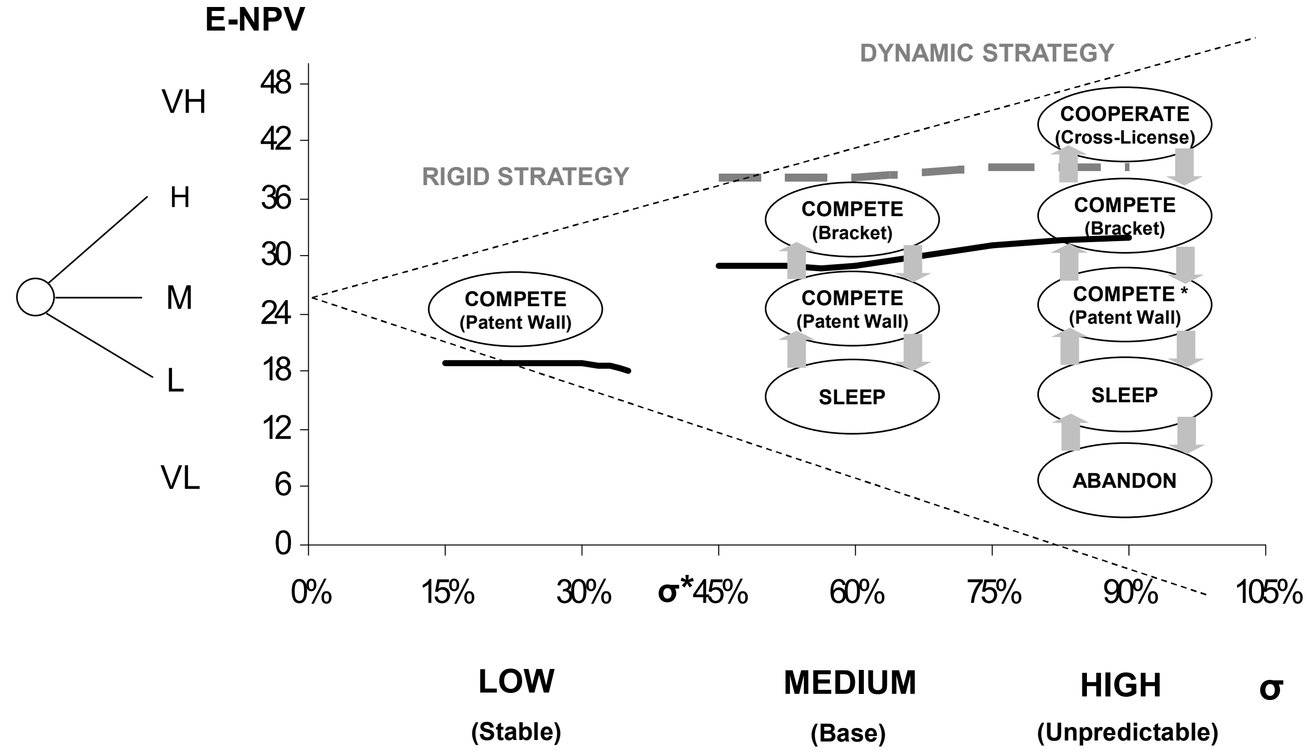


Figure 8A. Summary and extension of patent strategies for a broader range of demand uncertainty (under large innovation advantage) – Symmetry case



* Sometimes cooperate (e.g., cross-licensing against third rivals)

Figure 8B. Summary and extension of *compete vs. cooperate* strategies (for a broader range of demand/uncertainty) under No, Small or Large innovation advantage – Symmetry case

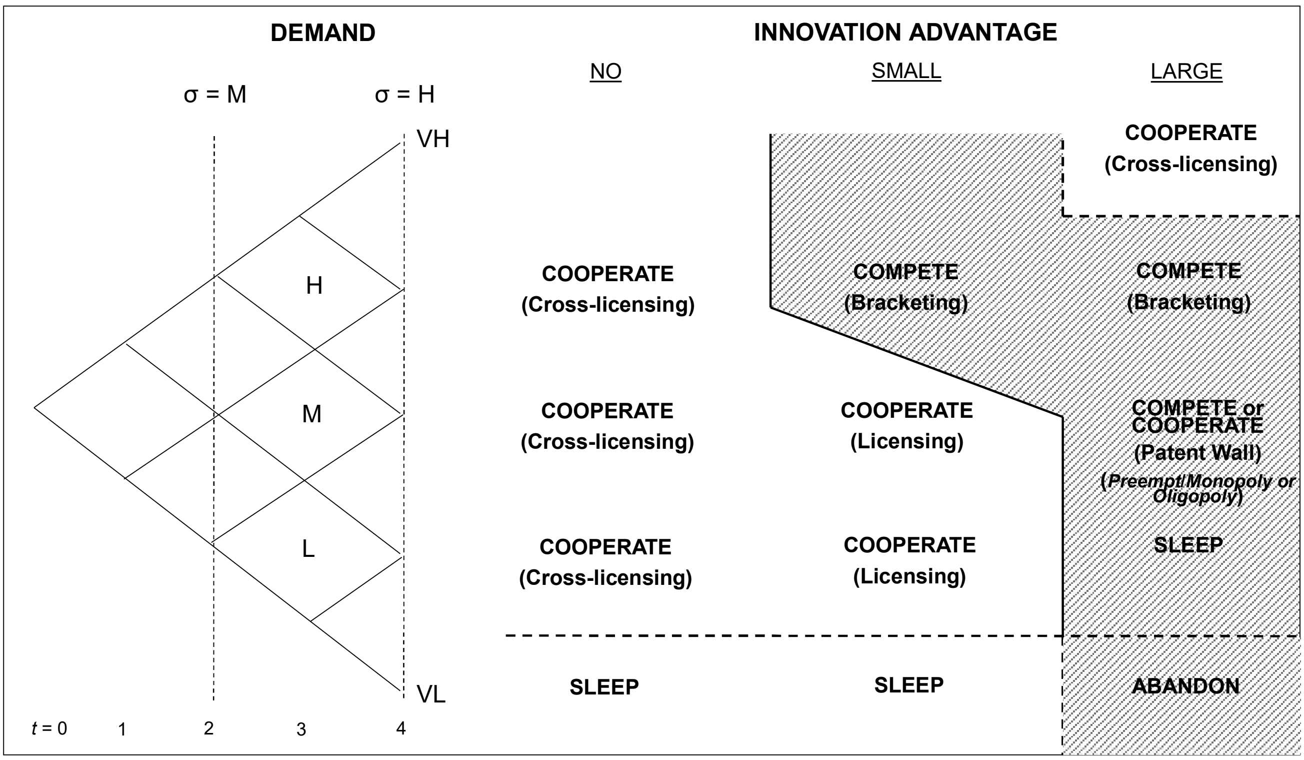
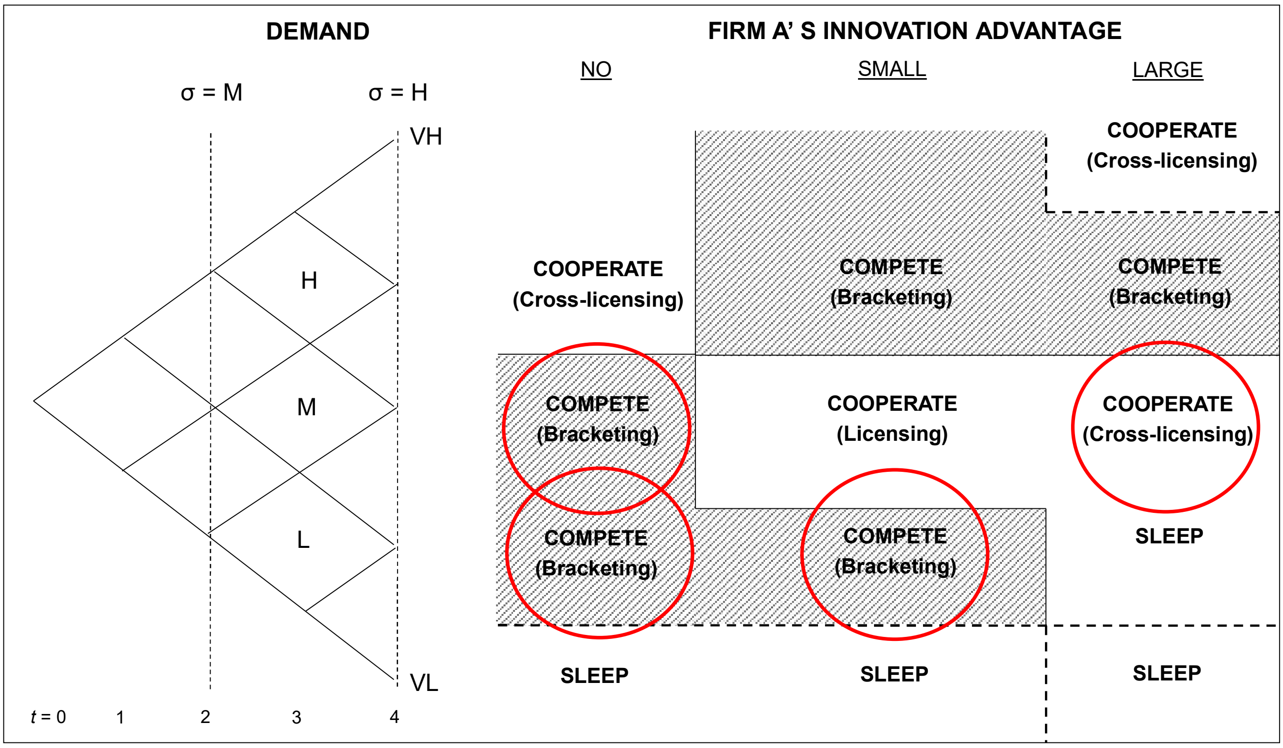


Figure 9A. Changes in *compete vs. cooperate strategies* when incumbent firm B has more prior market power – Asymmetry case



Note: Circles indicate subgames that shift between compete and cooperation modes in asymmetry case (compared to symmetry).

Figure 9B. Revised subgame outcomes and equilibria when incumbent firm B has more market power – Asymmetry case