Promoting Competition by Coordinating Prices:
When Rivals Share Intellectual Property

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Abstract

The paper examines technology agreements and the standards process from which they emerge when members supply inputs to the alliance while simultaneously competing with it. Under this *overlapping ownership* structure, pool members are horizontally related. I show that strategic complementarity between the downstream products owned by a member and those arising from the collaboration is sufficient for a pool to be pro-competitive. Although patent pools are more efficient than uncoordinated pricing, consumers are better off if an outside firm rather than a pool member owns the non-pool competing product. Antitrust rules facilitating efficient IP agreements under overlapping ownership and their implications for the direction of technological change are derived.

1. Introduction

The 1980s marked a pivotal era in the history of the U.S. patent system. A series of changes altered incentives of innovators, the patent office and the courts in ways that conspired to strengthen intellectual property (IP) rights.[1] In response, innovators have been patenting at unprecedented rates while aggressively asserting their newfound rights with greater confidence and success against alleged infringers.[2]

Since innovation is a sequential process building upon previous discoveries, a strengthening of IP rights can serve to discourage, rather than promote, innovation.[3] In particular, since modern technologies typically comprise a multitude of components, each covered by a patent, innovators developing new drugs or consumer electronics can become entangled in a patent thicket, stacking up royalties and negotiation costs along the way. The alternative is to risk costly legal challenges or abandon research altogether.

But as patent thickets have grown, so too has the incentive for inventors to create adequate clearings for profitable exchange.[4] Private agreements between rational players are generally aimed at enabling the use and further development of new discoveries. When not anticompetitive, these private remedies can be efficient in reordering and redefining IP rights through bilateral licensing, standards organizations, copyright collectives and patent pools. In doing so, they can facilitate technology transfer, potentially countering some of the negative fall-out from an overreaching protection regime.[5]

This paper analyzes agreements that combine complementary patents essential to the design of a new product, owned by one or more players who are already active in the market with a competing product. The focus is on patent pools that coordinate prices on complementary components in support of a standard: the incentives to join them, the antitrust rules that constrain them, and their impact on the design of new products and consumer prices. With over $100 billion

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[1] The primary changes include (1) centralization of the appeal process into a single Court of Appeals for the Federal Circuit; (2) introduction of a new patent fee that has had the effect of turning the Patent Office into a profit center; (3) extension of patent rights to software, business methods and biotechnology. In response to these changes, patent applications and grants increased dramatically over the past twenty years, as have patent litigation cases. For example, see Jaffe and Lerner (2004) and Bessen and Meurer (2008), Boldrin and Levine (2008) for discussions of the changes and recommendations for improvement.

[2] See Lanjouw and Lerner (1998), Lanjouw and Schankerman (2001), Hall and Ziedonis (2001).

[3] Sincethe 1990s, attention in the economic literature has shifted from analysis of stand-alone innovations to sequential research in which later generations of improvements built built productively on previous discoveries (see for example, Merges and Nelson (1990), Scotchmer and Green (1990), Scotchmer (1991)). It is in this framework that the relationship between innovation and patent strength may no longer be positive and monotonic.

[4] See Heller and Eisenberg (1998), Shapiro (2001) and Ziedonis (2004) for a discussion of patent thickets.

[5] Scotchmer (1990) and Green and Scotchmer (1995) analyze private mechanisms between holders of IP rights and subsequent researchers for restoring efficient incentives and implications for patent policy; Merges (1999) and Shapiro (2001) consider private mechanisms such as patent pools and collectives for organizing patent rights among groups of IP owners.

of sales generated each year in the United States from products or devices that are based wholly or in part on technologies in patent pools (Clarkson (2003)), this type of strategic alliance among IP owners has been prominent in modern technology markets.

I examine technology-sharing agreements in which members are horizontally related through ownership in a competing product that does not rely on the pooled inputs but competes with products that do. The efficiency of patents pools is examined for this *overlapping ownership* structure: equilibrium prices, incentives to cooperate, and the selection of products at the standard-setting stage are determined, along with antitrust rules for identifying socially beneficial agreements.

Patent pools that combine complementary components supporting a standard have been deemed socially beneficial by antitrust authorities, as articulated in the *U.S. Department of Justice-Federal Trade Commission Guidelines on the Licensing of Patents* (hereafter, the *Guidelines*).[6] The reasons are clear: first, patentees of complements are vertically related and therefore would not be competitors in the absence of the agreement and second, coordination solves the classic complements problem, identified by Cournot (1838) and analyzed by Shapiro (2001) for patent pools. Indeed, this efficiency view is on solid economic ground when patentees are engaged solely in the input market or vertically integrated into production of the dedicated downstream product (Lerner and Tirole (2004), Kim (2004)). However, this view may be incorrect when members of the pool have a stake in products that complete with the pool's downstream products since, when ownership overlaps in this way, the patentees will be horizontally as well as vertically related. In this case, pool formation gives rise to a tension: While pricing of inputs will be more efficient in the pool, pricing of outside goods owned by pool members may soften competition.

The fact that competing firms cooperate in strategic alliances has been a concern throughout the history of patent pools but those concerns tend to be discounted when pools comprise complementary, essential and valid patents: For example, in the business review letter for the DVD pool, the Assistant Attorney General for the Department of Justice (DOJ) acknowledged that a pool could overextend its reach and "collude on prices outside the scope of the Portfolio license" and restrict competition;[7] however, his analysis focused on the relationship of the patents within

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[6] The US DOJ-FTC Guidelines notes that pools of complementary patents "may provide competitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions and avoiding costly infringement litigation."
[7] See the business review letter from Assistant Attorney General Joel Klein to Carey R. Ramos (June 10, 1999), regarding the formation of pools for the DVD-Rom and DVD-video formats.

the pool and not on competing goods owned by member patentees in the same market. Moreover, he noted that in the DVD pool "each of the Licensors is a leading manufacturer of consumer electronics equipment…" but did not explore the potential anticompetitive effects from this observation, concluding that the pooling agreement is "not likely to impede competition…for use in making DVDs, players, or decoders or for other products that conform to alternative formats, or in the markets in which DVDs, players and decoders compete." Even if not *explicitly* impeded, as this paper argues, competition may be tacitly compromised as pool members internalize the impact of their pricing decisions on the profitability of alternative formats in which they have a stake.[8]

In a simple but robust framework, I show that strategic complementarity between downstream products is generally sufficient to retain the efficiency of patent pools. Not all socially efficient pools will be privately profitable, however, especially if firms are asymmetric in their ownership structure and the downstream products are close substitutes. Anticipating this, patentees at the standard-setting stage will tend toward a more distant substitute relative to an environment in which pooling is not an option, further enhancing the efficiency of cooperative agreements. While it is shown that patent pools continue to be pro-competitive for a given ownership overlap by the cooperating firms, the converse is not true: An increase in the degree of overlap can result in higher prices, less differentiated products, and possibly hold-up of a new standard. Antitrust rules for IP agreements between horizontally related firms are derived using this framework.

1.1 Related Literature

In analyzing the private and social consequences of patent pools under overlapping ownership, this paper builds upon several ideas in the industrial organization literature. Especially relevant are the papers focusing on collaborative technology agreements, including patent pools, cross-licensing, research joint ventures.[9] In contrast to the previous literature on patent pools of complements, the patentees in this framework are horizontally related, created by an industrial

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[8] This concern, not previously analyzed, is noted in Layne-Farrar and Lerner (2008): "firms contributing complementary patents to the standard may be rivals, offering competing products in downstream markets…".

[9] See, for example, Gilbert (2004, 2009), Shapiro (2001), Kim (2004), Aoki (2004), Aoki and Nagaoka (2004), Schiff and Aoki (2007), Choi (2005, 2009), Lerner and Tirole (2004), Dequiedt, V. and Versaevel, B. (2006), Lerner, Stojwas and Tirole (2007), Layne-Farrar and Lerner (2008), Lampe and Moser (2010a,2010b), Gallini (2011a,b), Delcamp (2011), Baron and Pohlmann (2011) and Flamm (2011). Also, related are Gallini (1984), Fershtman and Kamien (1992), Arora et.al. (2001), who examine incentives to license and/or cross-licensing and D'Aprement and Jacquemin (1988), Motta (1992), Kamien, et. al. (1992) and Scotchmer (1998) on analyze research joint ventures. Also related are Merges (1996) and Aoki and Schiff (2008) who examine institutions for coordinating intellectual property rights and an analysis of market mechanisms that give rise to these institutions.

structure in which one or more participants in the agreement own products that (1) do not require a license from the pool to operate but (2) compete in the downstream market with products that do. Firms could also be horizontally related if only (1) or (2) held.[10] I turn now to those two alternative forms of overlap, summarize findings in the literature regarding them, and contrast them with the ownership structure examined here.

The converse of (1) occurs when patentees are vertically integrated into the downstream product served by the pooled inputs. Applying results from a rich literature that explores vertical integration in general markets, Lerner and Tirole (2004) and Kim (2004) analyze the case of patent pools with vertically integrated firms. First they identify two inefficiencies when input firms license independently: the complements problem (Cournot (1838), Shapiro (2001)) and raising rivals' costs (Salop and Scheffman (1983)). Then they show that when coordinating prices, pool members internalize the above effects, thereby reducing prices and foreclosure.[11] And so, a pool continues to be efficient within the setting of vertical integration.

Pool members in this paper are also integrated but in a different downstream product; in effect, integration is *diagonal* in that ownership crosses over from the upstream inputs in one vertical chain to a competing downstream product in another. Figure 1 illustrates this "diagonal" representation in which F1 owns both X, an input essential to the production of Z, as well as assets on the downstream product W that competes with Z. Unlike vertical integration in which F1 may have the incentive to foreclose rivals selling competing versions of Z, a patentee with diagonal (or overlapping) ownership in a competing downstream product may have the incentive to prevent entry of a competing standard by withholding its essential input X. This form of ownership overlap differs from vertical integration in another way. As Reisinger and Tarantino (2011) argue, a firm may not have the incentive to vertically integrate since in doing so, a supplier of a complementary and essential input may raise its price to offset the vertically integrated firm's lower price. In contrast, a patentee benefits by diagonally integrating into an outside competing good since it places upward pressure on the downstream prices.

The above discussion contrasts two market structures in which the patentees compete in the same market. Another way firms in a pool can be horizontally related is through competition in unrelated markets, that is, when (2) above is relaxed. In examining this problem, Bernheim and

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[10] Tepperman (2002) considers a similar ownership structure in context of unilateral licensing in which the licensee produces a substitute to the licensed good. In contrast, this paper explores multi-lateral agreements with vertical and horizontal features.
[11] Kim (2004) and Lerner and Tirole (2004) differ in the impact of vertical integration on the pooled price (the former showing it will fall; the latter than it will increase) but both show that pools with vertically integrated members in the dedicated downstream product will increase welfare for complementary patents.

Whinston (1990) reveal that firms confronting each other in a multi-market context can soften competition across markets; nevertheless, such coordination can be socially desirable if it allocates production toward efficient firms.[12] In contrast, this paper explores tacit cooperation between substitutes through explicit sharing of complementary inputs in a *related* market. Price effects in this paper work through the firm's incentives to internalize the impact of its price increase in one good on the demand for the other. Layering either the Lerner-Tirole vertical integration or the Bernheim-Whinston horizontal structure on top of the diagonal overlapping structure examined here would generate distinct effects on prices, incentives to cooperate and product choice.

Against this motif of the related and complementary literature, Section 2 offers several examples of IP cooperative agreements with overlapping ownership as well as of strategic alliances in non-IP markets. In Section 3, a simple environment with differentiated price-setting firms is introduced. Three organizational decisions are outlined: First the standard-setting process for developing a new product; second the decision to combine IP through a patent pool; and finally, the pricing game in which the new standard competes with the current product. Section 4 derives the equilibrium of the pricing game. If the downstream products are economic substitutes and strategic complements, then a pool of complements is shown to be efficient. Conditions under which the results on prices are robust to changes in several assumptions of the model are derived.

Section 5 explores the decision to join the agreement: If the pool is restricted to set prices only on the pooled components, then efficient pools may not form if downstream products are strong substitutes. In Section 6, the standard-setting process is analyzed, given future equilibrium pooling and pricing decisions. In a simple framework, the prospect of pooling is shown to encourage innovators to choose a more differentiated standard from that of the current product than if IP were uncoordinated. Section 7 offers insights into an antitrust policy that facilitates efficient pools and standards. Conditions under which expanding the scope of pools is socially desirable are derived for efficient pools that would otherwise be unprofitable. Section 8 concludes with a discussion of testable predictions and places the paper in context of the larger debate on the pros and cons of a system of proprietary IP.

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[12] Bulow, et.al. (1985) show that products owned by multi-product firms need not be substitutes in the same market for there to be price effects across those goods.

2. Examples of Cooperative Agreements with Overlapping Ownership

Many patent pools formed over the past century were inspired by anti-competitive motives: dominant firms competing in the same market combined their patents to fix prices and foreclose rivals (Gilbert (2004)). The negative effects of these collusive arrangements are well known. The focus here is on modern patent pools that combine complementary inputs toward supporting standards and reducing transactions costs.[13]

Many modern patent pools include firms that supply essential and complementary patents for a particular standard while offering competing products in the same market. Evidence of such overlapping ownership between competing products inside and outside the pool is shown in Tables 1-2 for DVD-ROM and DVD-video patent pool (DVD-6C) formed in 1999. Current membership is listed in Table 1. Note that the majority of members ranked among the top 20 semiconductor firms in 2000 during the years in which the U.S. Department of Justice and the European Commission approved the pool.

Several of the pool members were engaged in fierce competition as well as alleged anti-competitive behavior. For example, Toshiba and Sharp have competed vigorously in the flash memory market while being implicated along with Samsung and others by the U.S. Department of Justice and European Commission over price-fixing in the liquid crystal display market. And, as noted below, they also compete in the same market as DVD players. That is, while *products* in the DVD pool do not compete with each other, *members* of the DVD pool do, both in unrelated markets and in the same market. It is the latter variety that is the focus of this paper: when parties to the agreement own competing goods in the same market in which the pool operates.

Table 2 presents examples of products that compete with DVD products (drivers, discs, players) and for which DVD pool members previously had or currently have production capacity: Netflix movies on-demand (Samsung), VHS players and cassettes (JVC, Panasonic), film production (Time Warner), HD-DVD (Toshiba) and Blu-Ray (Samsung, Mitsubishi, Hitachi, Sharp). Although many of the products listed are either inferior or improved versions of the pooled products, they are nevertheless substitutes, and some were available at the time of pool formation.

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[13] Virtually all modern patent pools follow from standard-setting processes, but the reverse is not. Internet standards set by several bodies and research arms (such as the Internet Engineering Task Force or the Internet Society) and world-wide web protocols (as set by the World Wide Web Consortium), for example, have not evolved into a pool of software or related patents and copyrights. See Lin (2002) for a discussion of the relationship between standardization and patent pools.

Another example of the industrial structure explored here is the 3G Patent Platform Partnership. In that arrangement, five distinct competing platforms were approved, as was an umbrella "Management Company" intended to coordinate administrative costs but not to engage in pricing across platforms. The overlap in ownership arises since some companies were members of more than one platform. The Assistant Attorney General recognized the potential antitrust implications of this arrangement and addressed them specifically in his business review letter of 2002, noting that while the firms were entitled to participate in more than one Platform Company, they "should establish appropriate firewalls to safeguard against sharing of competitively sensitive information." This is a curious recommendation since it is not clear how companies with overlapping ownership can safeguard against using information on its own patents. Even if one disregards coordination at the mega-pool level, overlapping ownership across the five platforms can potentially soften competition.

Most information-communication technology pools are characterized by some degree of overlap. For example, some members of the RFID (Radio Frequency Identification) Consortium, formed in 2005, that includes tracing and identification technology with electronic tags, are involved in related, potentially competing products using Global Positioning System technology (LG Electronics and Motorola) and Location-Based Services (Motorola).   Sony and Phillips, both members of the CD-RW Pool formed in 1988 for audio data storage devices, are also members of the DVD-3C Pool formed in 1998 that supplies products arguably in the same market.   The MPEG-4 pool, also formed in 1998, focuses on digital audio and video data compression technology that supports DVDs, digital television, and interactive multimedia and graphic applications, and includes dozens of members, one of which is Microsoft with ownership in Windows Media Audio (an audio compression technology).[14]

Although patent pools are less common in biotechnology markets, they are beginning to emerge as a promising mechanism for sharing patents. In addition to pools formed in recent years to facilitate access to developing countries, MPEG LA has recently announced a for-profit diagnostic genetics patent licensing facility or clearinghouse. This "licensing supermarket" intends to aggregate patent rights, issue and negotiate non-exclusive licenses to diagnostic firms, researchers and labs, allocate royalties to its members and monitor use for potential infringement. In contrast to high technology pools, the diagnostic pool is not developed around a particular

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[14] Several MPEG members are also involved in the DVD-6C pool, but products from the pools are complementary rather than substitutes.

standard but, similarly, appears to be for the purpose of reducing transactions costs to users. An interesting development to watch is whether this alliance will be permitted to include substitutes, similar to copyright collectives, or be constrained to admit only patents essential to particular diagnostic tests or related products.[15]

Examples of cooperative agreements under overlapping ownership extend beyond the IP arena. For example, consider the airline industry. To travel from one country to another, consumers often require complementary flights from competing carriers. Traveling between cities in Canada and the United States (e.g. Vancouver to Miami) requires at least one stop where consumers must switch from a Canadian (e.g., Air Canada) to a U.S. carrier (e.g., United). Alternatively, Canadians may choose to take their winter vacation in Hawaii instead, where direct flights are available from either Air Canada or United. The question in the paper, applied to this context, is whether Air Canada and United should be allowed to coordinate prices on their complementary flights between Canada and U.S. cities when they compete with each other in the same market. In practice, there is considerable flexibility in agreements between airlines, especially within the various consortia in which they are members. Related to this is the much acclaimed partnership between rivals Toyota and Subaru to produce two new sports cars, the Scion FR-S and Subaru BRZ: effectively identical cars but with their respective brand names. While it is common for competitors in this industry to share production facilities to reduce production costs, the strategy of combining complementary assets for the purpose of creating a new product is a relatively new business model. In combining their respective design and engineering, the firms plan to introduce a joint product that may be competitive with their other, albeit less sporty and more functional, models. Similarly, software and hardware companies often partner in joint ventures; for example, the recent partnership between Nokia and Microsoft will combine their respective phone technology and software applications to create a global smartphone ecosystem, while both continue to compete in the related market for mobile phones with their brand-name products.

I now turn to the formal analysis of agreements that combine complementary patents and their impact on prices, incentives to cooperate, product selection and consumer welfare.

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[15] Patents are essential to a standard or product if there are no economic substitutes; that is, anyone implementing the standard would naturally infringe the patent.

3. The Framework

The analysis begins with a downstream good W, the assets of which are either owned by a monopolist or jointly controlled by more than one incumbent firm.[16] Two firms, F1 and F2, are deciding whether or not to develop a distinct but competing standard for supporting a new product Z. Only F1 and F2 have the technological expertise to make or acquire the N essential patents that are used in fixed proportions in the production of Z.[17] The N inputs are identical except for ownership: F1 owns *s* of the patents and F2 controls the remaining *1-s* components, and are assumed to have no uses outside production of the Z product.

Four ownership regimes are considered: (1) W is owned by neither F1 nor F2; (2) F1 (or equivalently F2) produces W jointly with a third firm not involved in the new standard and shares equally in the profits; (3) F1 (or equivalently F2) has a monopoly on W; and (4) Both F1 and F2 jointly control W. The vector $\Theta = (k_1, k_2)$ indexes the ownership regimes, where k_i is firm i's share of W, and takes on the values (0,0), (½,0), (1,0) or (½,½); and so $k_1 + k_2 \leq 1$. Without loss of generality, F1 is assumed to be the firm with the overlap in ownership regimes (2) and (3). In environments (2) and (4), F1 shares ownership of W with either a firm involved only in W or with a firm that also produces essential Z inputs; the structure in regimes (2)-(4) is referred to as *overlapping ownership* in the upstream Z inputs and the downstream W product.

The degree of overlap or integration is indexed by $\omega = 2(k_1 + k_2 + 2k_1k_2)$, which conveniently maps the Θ regimes {(0,0), (½,0), (1,0) and (½,½)} into respective values {0,1,2,3}. Higher values of ω are associated with higher degrees of integration (or overlap) by upstream patentees into W. Finally, for expositional clarity, F1 and F2 are referred to as "inside" firms, and firms involved only in W are "outside" firms.

3.1 Standard-Setting Process

The analysis follows three sequential decisions by F1 and F2. In the first, the innovators decide whether or not to engage in a cooperative standard-setting process and, if so, what type of standard (equivalently Z product) to introduce. At this stage, the decision variable is γ: the degree

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[16] For example, the owners of W may also supply essential inputs or engage in a strategic alliance; for example, one firm may own the patent on W but a second specific production capacity for W.

[17] It can be shown that pools are socially beneficial for a limited number of nonessential patents included in the pool. Economides and Salant (1992) analyze mergers when differentiated varieties of upstream inputs are available and identify conditions under which a merger of all firms may increase prices. Gilbert (2009) also considers the case of nonessential patents and argues that over-inclusion is not likely to harm competition as long as the pool includes at least one valid essential patent and patentees are free to license their components independently.

of product differentiation between the existing product W and the new product. If either F1 or F2 is already producing W, it may refuse to participate and simply exercise its outside option W. It is assumed that this is the only source of communication failure in the standard-setting process; that is, when total profits to F1 and F2 from introducing a new product are less than profits generated under a monopoly in W.[18] For acceptable γ, each firm develops its respective sets of complementary and essential inputs: sN for F1 and $(1\text{-}s)N$ for F2. Costs of developing a standard are discussed in a later section.

3.2 Pooling and Pricing Decisions

After securing their patents, the firms make a second organizational decision: either to operate independently, therefore producing and selling their respective bundle of inputs separately, or to pool their patents and coordinate the price of the full bundle of N inputs. In both cases, the inputs are sold to perfectly competitive downstream producers of Z.[19] Whether or not the firms pool their complementary patents will depend on the return to each firm from not cooperating.

In the pricing game following the pooling decision, the producers of Z and W compete in a differentiated Bertand game. Since components are identical within each firm's portfolio, so too will be the inputs prices sold by F1 and F2, respectively denoted by p_1 and p_2. The downstream price of Z (under the simplifying assumptions above) is then given by $p_z = N(sp_1 + (1 - s)p_2)$. And so in the no-pooling pricing game, F1 and F2 choose their respective prices p_1 and p_2 and the W owner chooses p_w. Under pooling, the price of Z is chosen jointly by F1 and F2, simultaneously with the W owner's independent choice of p_w. Demands for W and Z are respectively $q_w = g(p_z, p_w; \gamma)$ and $q_z = f(p_z, p_w; \gamma)$, where f and g are twice differentiable and $\frac{\partial f}{\partial p_z} < 0$ and $\frac{\partial g}{\partial p_w} < 0$. The W and Z downstream products are economic substitutes so that $\frac{\partial f}{\partial p_w}$ and $\frac{\partial g}{\partial p_z}$ are positive. Costs of production are assumed to be constant and symmetric and, for convenience, are set to 0.

The framework outlined above offers an analysis of cooperative IP agreements – both product and price coordination – by prospective members already operating in the relevant market.

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[18] That is, the process by which the firms choose γ abstracts from interesting coordination problems studied in the literature. For example, Farrell and Shapiro (1988) model delays in standard setting as a war of attrition. In more recent empirical research, Simcoe (2012) employs data from the Internet Engineering Task Force to measure coordination delays in the standard development process.

[19] That is, there is no mark-up by downstream producers and so an alternative interpretation of this market structure is that F1 and F2 are vertically integrated into the downstream Z market.

Efficiency results on pooling will depend on two important considerations, taken exogenously here. The first is the ownership structure – namely, the firms' overlap in W, indexed by ω. The second feature of the environment involves restrictions on cooperation, imposed by antitrust, which are described by Assumptions 1 and 2 below. The first restriction rules out horizontal collusion:

Assumption 1: When one or more patentees of complementary inputs produce a substitute that competes with products based on those inputs, then a merger of the patentees' assets is prohibited.

For example, suppose the ownership regime is ω=2 in which F1 owns *s* of the Z patents and also has a monopoly in W. Assumption 1 states that F1 and F2 cannot combine their assets through a merger. This may seem overly restrictive given that the Z inputs are vertically related; but since F1 produces a substitute to Z, the latter requiring inputs owned by F2, F1 and F2 are horizontally related as well. Therefore, a merger may be welfare-reducing relative to more benign technology sharing agreements, namely a patent pool, constrained by Assumption 2:[20]

Assumption 2: Pool members are restricted to set only the prices of the components approved for the pool.

Assumption 2 reflects the current antitrust approach toward patent pools. For example, in the business review letter for the MPEG pool, the Assistant Attorney General wrote: Patent pools must not "collude on prices outside the scope of the Portfolio license".[21] This restriction is referred to in this paper as "limited coordination". "Full coordination", prohibited under Assumption 2, would occur if parties to the agreement coordinated prices of all the goods owned by the pool members (including W as well as the Z inputs for ownership regimes ω>0).

In order to successfully exploit the benefits from technology sharing, it is further assumed that the patentees are required to expend effort to achieve efficiencies from the pool. This relationship is incorporated in the model through Assumption 3.

Assumption 3: Under a pool, the share of pooled profits to F1 and F2 (α and 1-α respectively) is proportional to the share of patents contributed to the pool (s and 1-s respectively).

Assumption 3 can be supported theoretically and empirically. Theoretically, a bilateral agency model operates in the background in which F1 and F2 must exert effort *ex post*, not observable by third parties, for the cooperative agreement to have value. For example, effort may

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[20] If an outside firm owned W and the Z inputs were pooled, then cross-licensing of W and the pooled patents at per unit royalties could facilitate horizontal collusion. That is, cross-licensing would be equivalent to a merger and therefore, by Assumption 2, would be contravened.

[21] Business review letter from Assistant Attorney General Joel Klein to Gerrard Beeney regarding the formation of the MPEG pool, June 26, 1997, p. 7.

take the form of information reports on each patent contributed to the pool.[22] If the marginal product of effort by each firm is proportional to the share of patents contributed to the pool, then a firm's *ex post* share of pool profits will be proportional to its patent contributions.[23]

Assumption 3 is also empirically consistent with actual profit allocation rules adopted by modern patent pools. As Layne-Farrar and Lerner (2008) report in their study of nine modern patent pools, the two most commonly used allocation rules are *patent-based* and *value-based*, as referred to in this paper. Under the first, members receive a share of the profits based on the number of patents contributed to the pool; $\alpha = s$ is a special case adopted in this paper. Under the second, the patentees receive a share of the pool's earnings in proportion to the *value* of their patents. In this model, the latter is set at the value of the respective patents in the uncoordinated (or no pool) equilibrium. That is, if p_1^{NP} and p_z^{NP} are the the respective equilibrium prices of F1's inputs and of the final good Z, then F1's share of the pool under the *value-based* rule will be $\alpha = s\left(\frac{Np_1^{NP}}{p_z^{NP}}\right).$

Patent pools are typically managed either by one of the members (as in the DVD pool in which Toshiba manages the pool) or by a new and separate entity (as in the MPEG pool in which MPEG-LA is the pool authority). Antitrust authorities have approved both arrangements.[24] Although Assumption 2 requires that the pool set only prices of the pooled components, it is assumed that when setting the royalty of the bundled license, the pool authority takes into account profits on all goods owned by its members (including outside products).[25] Finally, firms are allowed to make side payments, constrained by the *ex post* allocation rules.

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[22] Note that a contract in which F2 sells its output at a fixed fee and zero price to F1 would not provide incentives for F2 to make the required effort (for example, to produce high quality output). An alternative specification with demand uncertainty, unobservable to third parties, and limited wealth would also be consistent with Assumption 3; however, while preserving the results in this paper the latter framework would be more restrictive than the one adopted in this paper.

[23] For example, if profits to F1 and F2 are given by: $V(e_1,e_2)\alpha\pi_z(p_z,p_w) - \varepsilon\ Nse_1$ and $V(e_1,e_2)(1-\alpha)\pi_z(p_z,p_w) - \varepsilon\ N(1-s)e_1$, where e_i is the effort taken by firm i for each of its patents and $\varepsilon > 0$. Symmetry in effort levels is a reasonable assumption for similar patents (for example, effort might involve recording a description of each patent), in which case, the efficient effort levels satisfy: $\alpha/(1-\alpha) = s/(1-s)$. That is, the profit share is proportional to the patent contributions to the pool. The model in this paper is consistent with this bilateral agency problem for ε close to zero and profits evaluated at optimal effort levels. For expositional clarity, it does not explicitly appear in the formal model. See Neary and Winter (1995) for analysis of a related problem.

[24] Under Assumption 3 the pool members may prefer to appoint an external firm than either of the internal patentees since the latter may have the incentive to bias the prices in their favor. Under Assumption 3 if F1 has ownership in W, it will want to maximize only its share of profits from sales of Z plus its profits from W and F2 would want to maximize its share of the pooled profits. Both would yield lower industry profits than under an external pool authority, paid a fixed fee to manage the pool.

[25] If the pool authority cannot be instructed to maximize total profits of its members and maximizes only the profits generated by sales of the Z inputs, then the results in the paper are reinforced. Moreover, pools are required to allow independent licensing in which case the firms can license their components outside of the bundle. However, without alternative uses or substitutes for the Z inputs, as in this framework, individual prices set will be those implied by the bundle price.

3.3. Pricing of Inputs and Downstream Products

In the absence of a pool

In maximizing profits, the players involved in both the inputs for Z and the product W internalize the impact on profits of one good when setting the price of the other. In general, profits to each W and Z input firm can be written in terms of the ownership regime parameters: k_i and β_i where β_i, i = 1,2 is defined as:

$$\beta_i = \begin{cases} 0 \text{ if } k_i = 0 \\ 1 \text{ if } k_i > 0 \qquad \text{for } i=1,2 \end{cases}$$

Note that the pair (β_1, β_2) takes on the values (0,0) when outside firms own W (ω=0); (1,0) when F1 is the only Z firm involved in W (ω=1 or 2); and (1,1) when W is jointly owned by F1 and F2 (ω=3). Consider first the no pooling case in which the Z input firms independently set their prices. Let $\pi_z(p_z, p_w; \gamma)$ and $\pi_w(p_z, p_w; \gamma)$ represent the total profits in the market from the sales of Z and W, respectively, when the Z product type is γ. Then profits to each of the Z input firms and W firms are given by:

(1) *Profits of Firm 1:* $\qquad \pi_z(p_z, p_w; \gamma) - N(1-s)p_2 f(p_z, p_w; \gamma) + k_1 \pi_w(p_z, p_w; \gamma)$

(2) *Profits of Firm 2 :* $\qquad \pi_z(p_z, p_w; \gamma) - Nsp_1 f(p_z, p_w; \gamma) + k_2 \pi_w(p_z, p_w; \gamma)$

(3) *Joint profits of W firms:* $N(\beta_1 sp_1 + \beta_2(1-s)p_2)f(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)$,

where $p_z = N(sp_1 + (1-s)p_2)$.

Note that the individual profit functions for F1 and F2 are written in terms of the aggregate profits $\pi_z(p_z, p_w; \gamma)$ minus a term representing the value of the other patentee's inputs. This representation emphasizes the vertical relationship between the firms' patents and is convenient for deriving later results.

Under a pool of the Z inputs

When F1 and F2 pool their inputs, they choose one price – the price of the bundle of Z inputs (or equivalently the price of Z). Since all the inputs are essential, there is no opportunity for substitution. Moreover, in choosing the profit-maximizing price of the bundle, each patentee internalizes the impact of its prices on the demand for inputs owned by the other member. Consequently, the profits earned by the Z and W input firms are given by:

(4)   *Joint profits of F1 and F2:* $\pi_z(p_z, p_w; \gamma) + (k_1 + k_2)\,\pi_w(p_z, p_w; \gamma)$

(5)   *Joint profits of W firms:* $(\beta_1\alpha + \beta_2(1-\alpha))\,\pi_z(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)$

A final assumption regards the economic viability of Z and W. In particular,

Assumption 4. If F1 has a monopoly on W as well as on the full set of the N essential inputs for Z, then producing both W and Z is at least as profitable as closing down production of one good and producing the other as a monopolist.

Assumption 4 does not rule out the possibility that a patentee with overlap in W and *a subset* of the Z inputs may wish to withhold its patents or expertise to prevent the introduction of a competing standard. Assumption 4, therefore, acts a benchmark in indicating that if hold-up occurs, it is attributed to coordination constraints, rather than the intrinsic value of the new product.

4. Pricing game following product and pooling decisions

In this section, equilibrium prices of the differentiated Bertrand game are derived, following the product choice γ and the pooling decision, given by $\vartheta = $ P, NP, where P and NP denote environments in which the complementary inputs are, respectively, pooled or not. The results for each ownership regime ω are examined. Figure 1 illustrates the case in which F1 owns both an essential input to Z (shown as X) as well as the competing downstream product W (regime $\omega=2$). Note that in the absence of a pool, F1 chooses both prices of its X input and of downstream product W; F2 chooses the price of its Y component.

For a give k_i and β_i, i=1,2 defined above, (1)-(3) imply that equilibrium price under no pooling are:

(6) $p_1^{NP} = argmax\ [\pi_z(p_z, p_w; \gamma) - N(1-s)p_2 f(p_z, p_w; \gamma) + k_1\pi_w(p_z, p_w; \gamma)]$

(7) $p_2^{NP} = argmax\ [\pi_z(p_z, p_w; \gamma) - Nsp_1 f(p_z, p_w; \gamma) + k_2\pi_w(p_z, p_w; \gamma)]$

(8) $p_w^{NP} = argmax\ [N(\beta_1 sp_1 + \beta_2(1-s)p_2)f(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)]$

where $p_z = N(sp_1 + (1-s)p_2)$.

And so the equilibrium prices satisfy the following equilibrium conditions:

(9) $\quad p_1^{NP}: \quad \dfrac{\partial \pi_z}{\partial p_z} - N(1-s)p_2 \dfrac{\partial f}{\partial p_z} + k_1 \dfrac{\partial \pi_w}{\partial p_z} = 0$

(10) $\quad p_2^{NP}: \quad \dfrac{\partial \pi_z}{\partial p_z} - Nsp_1 \dfrac{\partial f}{\partial p_z} + k_2 \dfrac{\partial \pi_w}{\partial p_z} = 0$

(11) $\quad p_w^{NP}: \quad N(\beta_1 sp_1 + \beta_2(1-s)p_2) \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} = 0.$

If F1 and F2 decide to pool their inputs, the bundled price of the Z inputs will be set centrally by the pool authority where the objective is to maximize total profits of its members, including profits from W earned by its members. Equilibrium prices under a pool, from (4) and (5) therefore are given by:

(12) $\quad p_z^P := argmax \; [\pi_z(p_z, p_w; \gamma) + (k_1 + k_2)\,\pi_w(p_z, p_w; \gamma)]$

(13) $\quad p_w^P = argmax \; [(\beta_1 \alpha + \beta_2(1-\alpha))\,\pi_z(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)]$

And, these prices satisfy the following conditions:

(14) $\quad p_z^P: \quad \dfrac{\partial \pi_z}{\partial p_z} + (k_1 + k_2) \dfrac{\partial \pi_w}{\partial p_z} = 0$

(15) $\quad p_w^P: \quad (\beta_1 \alpha + \beta_2(1-\alpha)) \dfrac{\partial \pi_z}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} = 0$

Note that the equilibrium prices in (9)-(11) and (14)-(15) depend on ω and γ as well as $\vartheta =$ P, NP but the notation has been suppressed for convenience. To get a sense of the impact of overlapping ownership, first consider the benchmark case of no overlap, in which W is owned exclusively by outside firms. That is, $\omega = \beta_i = k_i = 0$, for i = 1,2. Denote the equilibrium price of the jth good in the no pooling and pooling equilibria as p_j^{NP} and p_j^P, j = Z, W. Then,

Proposition 1: If W is owned by an outside firm, then a sufficient condition for $p_j^{NP} \geq p_j^P$ is

$\dfrac{\partial^2 \pi_j}{\partial p_w \partial p_z} \geq 0$ *for j = W, Z. That is, if W and Z are strategic complements (and imperfect substitutes) then both prices of W and Z will be no greater under a pool than when the Z patents are not coordinated.*

Proof: Evaluating the pooling condition in (14) at the no-pool prices p_j^{NP} in (9)-(10) yields $-f(p_z^{NP}, p_w^{NP}; \gamma) < 0$, implying that the profit-maximizing price of Z under pooling – when the price of W is held constant at p_w^{NP} – is lower than p_z^{NP}. Similarly, evaluating (15) at the no-pool prices in (11) reveals that p_w^{NP} is profit-maximizing under a pool, given p_z^{NP}. But, as noted, the price of Z will fall under a pool, for $p_w = p_w^{NP}$. Since a reduction in the price of Z reduces $\dfrac{\partial \pi_w}{\partial p_w}$,

the decline in W's prices is reinforced if $\frac{\partial^2 \pi_w}{\partial p_w \partial p_z} \geq 0$; that is, if W and Z are strategic complements. Similarly, for strategic complementarity, a lower price of W reinforces the downward pressure on the price of Z. ∎

Consider now the environments of overlapping ownership in which at least one patentee has a direct stake in W; that is, ω > 0. Let $p_j^\vartheta(\gamma; \omega)$ be the equilibrium price for good j (= Z,W) for product type γ, ownership regime ω (= 1, 2 or 3) and pooling decision ϑ (= P or NP). Then, the results on the impact of a pool in complementary inputs is summarized below:

Proposition 2: *If the downstream products are substitutes and strategic complements then*
(i) $p_j^P(\gamma; \omega) \leq p_j^{NP}(\gamma; \omega)$ for j = W, Z under the value-based rule and under the patent-based rule
for $(\beta_1, \beta_2) = (1,1)$ for all ω > 0. However, for $(\beta_1, \beta_2) = (1,0)$, prices will be lower under
pooling if F1's share of patents is s ≤ ½ +ε, where ε is not too large. (ii) Both $p_j^P(\gamma; \omega)$ and
$p_j^{NP}(\gamma; \omega)$ are non-decreasing in the degree of overlapping ownership ω for j=Z,W.

Proof. As in the proof of Proposition 1, evaluating the pooling condition in (14) at the no-pool prices $p_j^{NP}(\gamma; \omega)$ from (9)-(10) yields: $-f(p_z^{NP}, p_w^{NP}; \gamma) < 0$, implying that the profit-maximizing price of Z under pooling – when the price of W is held constant at $p_w^{NP}(\gamma; \omega)$ – is lower than $p_z^{NP}(\gamma; \omega)$. (The $(\gamma; \omega)$ notation is suppressed for the remainder of the proof.) However, the parallel exercise for the W expressions in (11) and (15) requires consideration of the allocation rule for awarding profits shares, α. In particular, substitution of the no-pool equilibrium prices in (11) into (15) yields the expression:

$$\beta_1 (\alpha p_z^{NP} - Nsp_1^{NP}) + \beta_2((1 - \alpha)p_z^{NP} - N(1 - s)p_2^{NP}) \frac{\partial f}{\partial p_w}.$$

Under the value-based allocation rule, the above expression equals 0 since $\alpha = \frac{Nsp_1^{NP}}{p_z^{NP}}$ by definition. The same holds for the patent-based rule when $(\beta_1, \beta_2) = (1,1)$. And so the profit-maximizing price of W equals p_w^{NP} under a pool in Z inputs given p_z^{NP}. Under the patent-based rule for $(\beta_1, \beta_2) = (1,0)$, $\alpha = s$ and so the above expression equals 0 for ω=3, and is non-positive if $p_z^{NP} \leq Np_1^{NP}$ for ω=1, 2. From (9) and (10), it can be seen that a sufficient condition for this to be true is $s \leq \frac{1}{2}$, that is F1's patent share is no greater than ½. Therefore, the price of W will be lower under pooling, holding the price of Z at the no pooling value. But, as noted, p_z will fall under pooling. A lower p_z will reduce the marginal condition in (15) if Z and W are strategic complements. This can be seen by differentiating the left-hand side of (15) with respect to p_z which gives: $\frac{\partial^2 \pi_w}{\partial p_w \partial p_z} + \alpha \frac{\partial^2 \pi_z}{\partial p_z \partial p_w} > 0$, for strategic complements. And so, the profit-maximizing price of W will be lower under pooling. Similarly, a lower price of W reinforces the downward

pressure on the price of Z since the change in the left-hand side of (14) with respect to p_w is: $\frac{\partial^2 \pi_z}{\partial p_z \partial p_w} + \frac{\partial^2 \pi_w}{\partial p_w \partial p_z}$. Pairwise comparisons of (9)-(11) as well as (14)-(15) for various ω yield the second part of Proposition 2. ∎

Part (i) of Proposition 2 reveals that for strategic complements, a pool in the Z inputs reduces the prices of both competing downstream products. Strategic complementarity is a sufficient condition for pools to be pro-competitive, even when members are horizontally related, except when $(\beta_1, \beta_2) = (1,0)$ and profits are allocated according to the patent-based rule. In that case prices can increase under a pool if F1 holds a disproportionately large share of the Z patents since it may have a greater incentive to enhance its pool earnings by raising its price of W relative to the no pooling equilibrium.

The intuition for the other cases in (i) of the Proposition is straightforward: If an upstream patentee also owns W, it internalizes the positive impact of raising the price of W on the demand for Z, even when the patents are not pooled, thereby creating upward pressure on the prices of W and the Z components. Under a pool, the value of each additional unit of Z is lower so there is less incentive to increase the price of W in order to enhance the demand for Z. Reinforcing this effect is the reduction in the marginal profits on W from a decline in the demand for W when the price of Z falls. This downward pressure on W's price, in turn, reinforces the price reduction in Z; in particular, the conventional efficiency incentive for pooling is reinforced by the reduction in the price of an outside substitute.[26] Thus, both downstream prices are lower with a pool than without.

Part (ii) of the proposition implies that prices of downstream products are lowest when W is owned by outside firms and highest when both members of the Z pool share ownership of W; that is prices under a pool increase in the ownership overlap by pool members. Hence, while consumers prefer a pool to uncoordinated pricing for any ownership regime, they prefer the W assets to be owned by outside firms rather than pool members. This result will be central to the discussion of divestiture in Section 7.

4.1 The Outside Option

The above analysis assumes that in equilibrium, both Z and W are available, regardless of the ownership regime. Assumption 4 assures that this will be true either for ownership state ω=0 or ω=3 (no overlap or maximum overlap). However, this condition may not guarantee Z's

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[26] Note that the latter effect holds whether an outside or inside firm owns W.

economic viability under the two intermediate regimes in which only F1 either wholly or partially owns W.   In particular, there may exist a $\tilde{\gamma}$, such that for $\gamma \geq \tilde{\gamma}$, F1 will set a price of its Z input bundle (Nsp_1) sufficiently high so that Z is undesirable at W's monopoly price. Denote the latter by p_w^m. Then the "choke price" of Z, $\bar{p}_z$, for a given γ is: $f(\bar{p}_z, p_w^m; \gamma) = 0$. Given that the firm forfeits control of its input price under a pool, F1 can foreclose the Z market with a high price of its inputs only if the firms chose "no pooling" in the previous stage.[27] Simulations using a quadratic utility specification show that for the ownership in which F1 has full control of W, it will never assert its outside option. However, if it shares W with an outside firm, then $\tilde{\gamma} = .95$; that is for $\gamma > .95$, demand for Z will be zero in equilibrium. As will be shown later, anticipating this outcome at the pooling and product selection stages will affect the choice of the standard.

The hold-up strategy by a firm with IP rights on inputs essential to a standard may seem at odds with "FRAND" licensing obligations typically invoked by standard organizations. In particular, FRAND rules require patentees to license other members and users at "fair, reasonable and non-discriminatory" terms, with the intention of preventing members from exploiting their IP rights to enhance their relative position or jeopardize the standard's competitiveness. Even if such an obligation can be enforced, analysis of the outside option is nevertheless relevant in identifying the range of γ for which F1 prefers a monopoly on W alone to participating in both W and Z. As will be shown in sections 5 and 6 for the pooling and product decisions, F1 would refuse to participate in the standard-setting process for this product range, so there would never be a need to foreclose Z at the pricing stage. Before turning to these earlier stages, I first examine the robustness of the results in Propositions 1 and 2 to alternative assumptions.

4.2 Robustness Checks

When Cooperating Firms are Incumbent Rivals

In the basic framework presented above, the ownership regimes include situations in which zero, one or both firms are involved in a *single* downstream product outside of the pool. For $\omega = 2$ F1 has a monopoly in W, whereas when $\omega = 3$, both firms share the assets in W (for example through a strategic alliance). Even in the latter case, in which the degree of overlap is greatest, prices are lower under a pool than under uncoordinated pricing.

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[27] This emphasizes an important difference between "diagonal" and vertical integration: Foreclosure of rivals under the latter occurs when the lowers its downstream price; here it arises when the integrated firm increases the price of its outside good.

Alternatively, suppose *each* firm has a monopoly on its own brand of the competing good W, denoted respectively by W_1 and W_2. That is, both firms are rivals in the market prior to the introduction of the third product Z that requires their essential and complementary inputs. The no pooling equilibrium input prices are the same as in (9)-(10) where $k_i = \beta_i = 1, i = 1,2$, except that π_w is subscripted with 1 or 2 for W_1 and W_2 respectively in (9) and (10). Call these revised conditions (9)' and (10)'. Regarding the equilibrium prices of W_1 and W_2, (11) is transformed into two conditions given below:

(11)' $\quad p_{w1}^{NP}: \ Nsp_1 \frac{\partial f}{\partial p_{w1}} + \frac{\partial \pi_{w1}}{\partial p_{w1}} = 0$

$\qquad\quad p_{w2}^{NP}: \ N(1-s)p_2 \frac{\partial f}{\partial p_{w2}} + \frac{\partial \pi_{w2}}{\partial p_{w2}} = 0$

Next consider the equilibrium prices under pooling. The condition in (14) is revised to account for the second W product; as in the no pooling case, there are two equilibrium prices for W_1 and W_2:

(14)' $\quad p_z^P: \ \frac{\partial \pi_z}{\partial p_z} + \frac{\partial \pi_{w1}}{\partial p_z} + \frac{\partial \pi_{w2}}{\partial p_z} = 0.$

(15)' $\quad p_{w1}^P: \ \alpha \frac{\partial \pi_z}{\partial p_{w1}} + \frac{\partial \pi_{w1}}{\partial p_{w1}} = 0$

$\qquad\quad p_{w2}^P: \ (1-\alpha)\frac{\partial \pi_z}{\partial p_{w2}} + \frac{\partial \pi_{w2}}{\partial p_{w2}} = 0.$

The results for this model in which both F1 and F2 are incumbent rivals are summarized below:

Proposition 3: *If each input patentee has a monopoly on its own brand of W and W₁, W₂ and Z are economic substitutes and strategic complements then (i) under a value-based rule or for a patent-based rule with symmetric patentees, prices of downstream products will be lower under a patent pool relative to uncoordinated pricing. (ii) If the patent-based rule is in effect and W₁ and W₂ are symmetric, then the equilibrium price of the downstream product Wᵢ can be higher under a pool if owner i contributes a disproportionately larger share of essential patents to the pool.*

Proof: The proof follows the logic in Proposition 2. Comparison of the sum of (9)' and (10)' with (14)' reveals that for W_i prices held at the no pool level, the price of Z under a pool is less than that for uncoordinated pricing. However, comparison of (11)' with (15)' is more complex, with the results depending on the allocation rule implemented: Under the value-based rule (15)' vanishes at the equilibrium no pool prices given by (11)' and so the results are the same as in Proposition 2. As before, under the patent-based rule, the impact of a pool on prices depends on the relative patent contributions by F1 and F2 to the pool. Comparison of (11)' and (15)' reveals a parallel condition to the case of one W product: the price of W_i will be lower under a pool relative

to no pool, holding the price of Z at the no pool level if: $p_z^{NP} \leq Np_i^{NP}, i = 1,2$. If W_i (i = 1,2) demands are symmetric, then from (11)' $Nsp_1 = N(1-s)p_2$, implying that the above condition may not hold for the firm with the majority of patents. ∎

Recall that for a single brand of W in Proposition 2, F1's asymmetric ownership in the outside good increased the likelihood that the price of its input bundle exceeded that of F2, implying that it would receive over ½ of the Z profits in the no pooling equilibrium. Therefore, even if it had the majority of patents, its return under a patent-based rule could fall short of those from not pooling, giving it less incentive to raise its price of W under pooling. Here, the firms are symmetric in that each owns an outside good. So in the no pooling equilibrium, the prices of the firms' input bundles converge. [28] Hence, if F1 has the larger share of inputs, then the patent-based rule will compensate it more than would uncoordinated pricing; consequently, it will set the price of W_1 higher under pooling so as to increase the demand for Z. Working in the opposite direction is the downward pressure on the prices of W_1 and W_2 from a reduction in the price of Z when the inputs are pooled. Nevertheless, it remains a theoretical possibility that the price of at least one W brand can be higher under a patent-based rule when firms' patent contributions are asymmetric.

When W and Z are Complements

The case of complements is instructive to examine since it is an example of strategic substitutes; that is $\frac{\partial^2 \pi_i}{\partial p_i \, \partial p_j} \leq 0$. Although a pool results in a higher equilibrium price of W (since a lower price of Z increases the demand for W), it will be welfare-enhancing. The more interesting question is whether the prices of W and Z are higher or lower as the degree of overlap increases. Proposition 4 provides an answer.

Proposition 4: *If W and Z are economic complements and weak strategic substitutes, then their equilibrium prices under a pool will be lower if one or both firms own W compared to a pool with outside ownership of W.*

The result in Proposition 4, found by making pairwise comparisons of (14) and (15) for ownership regimes ω={0,2,3}, reveals that the efficiency of a patent pool in Z under overlapping ownership holds for complements as well as substitutes. However, in contrast to substitutes,

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[28] Note that in this environment *sNp₁ = (1-s)Np₂ = ½ pᵤ* in the no pooling equilibrium, regardless of the relative number of patents. Therefore, under the value-based rule, pool shares converge toward equality, consistent with Neary and Winter (1995).

prices of complements may be lower as ownership of W transfers from outside firms to one or both input patentees.

When Pool Membership Grows

Next the robustness of the results in Propositions 1 and 2 to the size of the pool is explored. Consider a situation in which each of N essential components is provided by a single upstream firm. Each of N_1 firms owns only a single input essential to Z while each of N_2 patentees owns a Z input and shares in the production of W, where $N_1 + N_2 = N$. Furthermore, M outside firms are involved in W. I abstract from bargaining issues by assuming that the pool is feasible only if all the firms agree to comply.[29] Let $\tilde{\pi}_i$ represent patentee i's profits from sales of its Z input. Then, the equilibrium prices in the absence of a pool satisfy:

(16) $\quad p_i^{NP} = argmax\,\{\tilde{\pi}_i(p_z, p_w; \gamma)\}$ $\qquad\qquad$ *for i = 1,...,N_1*

$\quad\quad p_j^{NP} = argmax\,\{\tilde{\pi}_j(p_z, p_w; \gamma) + \frac{\pi_w(p_z, p_w; \gamma)}{M + N_2}\}$ $\qquad$ *for j = 1,...,N_2*

$\quad\quad p_w^{NP} = argmax\,\{\sum_j \tilde{\pi}_j(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)\}.$

Under a pool, the equilibrium prices are:

(17) $\quad p_z^{P} = argmax\,\{\pi_z(p_z, p_w; \gamma) + \frac{\pi_w(p_z, p_w; \gamma)}{M + N_2}\}$

$\quad\quad p_w^{P} = argmax\,\{N_2 \alpha\, \pi_z(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)\}.$

Solving the problems in (16) and (17) yield the following results:

Proposition 5: *Suppose each of N firms owns an essential component required for the production of a downstream product Z, N_2 of which also share in the ownership of W with M outside firms. If W is a strategic complement of Z then (i) prices of Z and W will be lower under a pool than when the prices of the Z inputs are set by independent firms for any overlap N_2. Moreover, (ii) the equilibrium prices under a pool increase in the degree of overlapping ownership.* Proof in Appendix A.

Hence, the results in Propositions 1 and 2 are preserved as the pool increases in size. That is, as the number of essential patents grows so too do the private and social benefits from pooling.

Finally, the assumption of simultaneous pricing is altered to allow prospective members of a pool commit to input prices at the time of joining the agreement, in anticipation of the price

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[29] See Gaudet and Salant (1992) for analysis of a merger of complementary products when members believe they can hold out or unilaterally defect.

response by the W downstream owner. As shown in Appendix B, while the results of Propositions 1 and 2 are generally preserved, conditions are identified in which cooperative pricing with commitment can put upward pressure on prices. I now turn to the patentees' decision to pool or not to pool.

5. When does it pay to join a patent pool?

As the previous section reveals, a pool of complementary patents, in most cases, increases competition in the relevant market even when members are horizontally related through ownership in downstream competing products. However, since industry profits are not maximized when the pool is constrained to set only the prices of the patents approved for the pool (Assumption 2), they may be lower under a pool than under independent pricing of the patents. Consequently efficient pools may not form.

Two effects militate against incentives to form a pool. First, pooling complementary inputs induces a price reaction from a competing product that offsets some or all the gains from a pool (Schiff and Aoki, 2007).[30] Second, for patentees with outside ownership, a pool in the Z inputs will increase profits from sales of the inputs but at a cost of reducing profits on the outside competing product. As shown below for quadratic utilities, the latter cost is more acute the greater is the substitutability between the downstream products. Consequently, the incentives to join the pool depend on both the nature of the relationship between the products as well as the ownership environment.

Recall that γ denotes the degree of substitutability, with lower values representing a greater degree of differentiation (Singh and Vives, 1984). Then, since equilibrium prices of Z and W depend both on γ and the ownership structure ω, the incentive compatibility constraints for Firms 1 and 2 to join the pool are given by:

$$(18) \qquad \tilde{\pi}_i^P(\omega,\gamma) - \tilde{\pi}_i^{NP}(\omega,\gamma) \geq 0 \qquad for\ i = 1,2,$$

where $\tilde{\pi}_i^{\vartheta}(\omega,\gamma)$, ϑ = NP,P, includes firm i's total profits from sales of all its goods. Since transfers between firms are allowed, a necessary and sufficient condition for pool formation is:

$$(19) \qquad \tilde{\Pi}^P(\gamma,\omega) - \tilde{\Pi}^{NP}(\gamma,\omega) \geq 0,$$

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[30] See also Bulow, et. al. (1985) for an analysis of firms operating in multiple markets.

where $\widetilde{\Pi}^\theta(\omega, \gamma)$ is the sum of the pool members' profits.[31]

Consumer preferences are represented by the quadratic utility specification below, where W and Z enter symmetrically.

(20) $\quad U = q_w + q_z - \frac{1}{2}(q_w^2 + q_z^2) - \gamma q_w q_z$.

Maximizing the expression in (20), net of expenditures, with respect to q_w and q_z yields the following demand system:

(21) $\quad q_i = \frac{1-\gamma-p_i+\gamma p_j}{1-\gamma^2} \ \ for\ i,j = Z,W$.

Note that the range of products represented by this utility function extends from perfect substitutes $\gamma = 1$ (e.g., Z is an identical DVD player to W) to perfect complements at $\gamma = -1$ (e.g., Z is a high-quality disc used in the W player). Also included in the latter category of complements could be an improvement that requires the previous generation (e.g., Z is a chip imbedded in the W DVD player). Not represented is an improvement that replaces W (e.g., a faster and less costly chip), which would be a second dimension in product space.[32]

For illustration purposes, symmetry is imposed on the W and Z demands and on the patent shares contributed by the two firms; therefore $\alpha = \frac{1}{2}$ under both the value-based and patent-based allocation rules. The equilibrium prices of the downstream goods for three of the four ownership regimes are presented in Table 3. Note that if W and Z are substitutes, they are also strategic complements,[33] resulting in a reduction in prices under pooling for all ownership regimes. When $\gamma < 0$, W and Z are complements and strategic substitutes; as expected, the price of Z is lower and the price of W higher under a pool relative to uncoordinated pricing for all ownership regimes.

Figure 2 illustrates the joint private benefits, given in (19) for the following ownership regimes: outside firm ownership ($\omega = 0$); joint ownership between F1 and outside firm ($\omega=1$); monopoly on W by F1 ($\omega=2$); joint ownership by F1 and F2 ($\omega=3$). It also identifies critical values above which patent pools will not be profitable in each case: Only if the substitutability between downstream products is sufficiently low will a pool form, except in the case of full coordination

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[31] This assumes that F2 is held at its no-pool value and so the upfront fee to F1 would be $L = \frac{1}{2}\pi_z^P(p_z,p_w) - \tilde{\pi}_2^{NP}(p_z,p_w)$. If the profits were divided according to Nash bargaining, then the upfront fee would be equal to $L = \frac{1}{2}(\tilde{\pi}_1^{NP}(p_z,p_w) - \tilde{\pi}_2^{NP}(p_z,p_w) + \pi_w^{NP}(p_z,p_w) - \pi_w^P(p_z,p_w))$ and the range of γ for which pools are profitable would be smaller.

[32] Patent policy is analyzed for two dimensions of product differentiation and product improvement in Eswaran-Gallini (1996).

[33] For quadratic utility, $\partial^2 f/\partial p_z p_w = \partial^2 g/\partial p_w p_z = 0$ and so $\partial^2 \pi_z/\partial p_z p_w = \partial f/\partial p_w$ and $\partial^2 \pi_w/\partial p_z p_w = \partial g/\partial p_z$, implying that economic substitutes are also strategic complements.

(ω=3) when a pool is always profitable. For strong substitutes, the downward pressure on W is too great for the increase in the pool profits to compensate F1 for its loss on W. [34]

In addition to highlighting the importance of the relationship between the downstream products, Figure 2 also reveals the effect that pool members' ownership in W has on the incentive to pool. When only F1 is involved in W, the range of acceptable γ for forming a Z pool is small, relative to neither or both firms operating in the W market. That is, the critical value of γ beyond which pooling is not jointly profitable, denoted by $\bar{\gamma}$, is non-monotonic in the degree of overlap: $\bar{\gamma}$ initially falls in ω as ownership in W switches from outside firms (ω =0) to F1 (ω =1 or ω =2) and then rises again when both firms are engaged in the production of the outside good (ω =3).

To understand the relationship between ω and $\bar{\gamma}$, consider the marginal effects when ownership of W switches from an outside to an inside firm. At $\gamma = .77$, F1 and F2 are indifferent between forming a pool and not when $\omega = 0$: a pool raises profits on the Z inputs at the expense of the outside firm which in turn responds competitively by lowering its price and offsetting some of the gains from the pool. The same effects occur when F1 owns W but, in this case, F1 must be compensated for its loss in profits from reduced sales of W. If the firms are indifferent between forming a pool and not when $\omega = 0$, then when F1 has a stake in W, the status quo will be strictly preferred to a pool, hence, the reason for a decline in $\bar{\gamma}$. As ω increases further such that both firms are involved in the production of W, then full coordination is achieved and a pool will always be preferred to no pool.

These results parallel those found in the theoretical analysis by Aoki and Nagaoka (2004) and the empirical study in Layne-Farrar and Lerner (2008) on the disincentives for heterogeneous firms to join pools. There, heterogeneity is defined by productive activity *inside* the pool (within the vertical relationship); here, firms differ according to their ownership in *outside*, competing products. Moreover, the previous papers predict that, in light of the instability created by heterogeneous firms, pools will tend to attract patentees that make symmetric contributions from inside the pool. Similarly, a prediction arising from this model is that pooling is more likely to attract firms with symmetric contributions from outside the pool (e.g., ω=0 or ω=3).

But when pool members are asymmetric in their outside ownership (ω =1 or 2), pooling is less attractive: Even if symmetric in their patent contributions, they are asymmetric in their economic contributions to the pool, in that a patentee with overlap will internalize the impact of

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[34] If the pool maximized only the profits generated from the sales of the pooled components rather than total profits of its members (including W), then it would be unprofitable for a wider range of γ.

increasing the price of W on the demand for Z and thus generate higher pool profits to distribute among the members. But for strong substitutes, the pool may not generate sufficient gains to compensate F1 for its loss in the outside good W. More precisely, since F1 cannot be made the residual claimant of the pool, as restricted by Assumptions 2 and 3, pooling inputs will not be privately profitable when the new standard is strongly competitive with W.[35]

Also note that as the patent share of the firm with overlapping ownership increases, the pooling outcome for a patent-based allocation rule approaches the monopoly outcome. This suggests a pool will be more attractive when firms are asymmetric both in their patent contributions to the pool and in their ownership of competing products; that is, when firms are asymmetric both inside and outside the pool. Finally, recall from the earlier section that an increase in the number of essential components renders a pool more profitable. Therefore, the denser the patent thicket, the greater will be the incentive to join the pool and the greater the range of γ for which pooling is profitable.

Assumption 4 implies that profits under a pool exceed those under no pooling for $\gamma = 0$. Therefore, necessary and sufficient conditions for the existence of a critical value $\bar{\gamma}$, such that for all $\gamma > \bar{\gamma}$ no pooling is privately preferred to price coordination are (1) profits generated from a pool decline more steeply in γ than profits from independent pricing and (2) pool profits at $\gamma = 1$ are less than uncoordinated profits. That is, the equilibrium profits under pooling must cross the no pool profits at some $\gamma \leq 1$. General results can be found for two organizational regimes. First, for $\omega=3$ (full overlap), $\bar{\gamma} \geq 1$, that is, it always pays to form a pool: When both firms are involved in W and Z, they will internalize the impact of raising prices of Z inputs on the demand for W and vice versa, even when required by Assumption 2 to build a "fire wall" between the two pools.

The second case involves $\omega =2$ in which F1 has a monopoly in W. As γ approaches 1, profits under uncoordinated pricing rise above those for a pool. That is, while a pool is privately beneficial in allowing coordination of complementary inputs, the patentees delegate price control to the central authority for joint price determination. Even if each firm can also set independent prices for their respective inputs, it will be constrained by the pool price. Although the pool (as well as F1) internalizes the negative impact of a reduced Z (W) price on the demand for W (Z), profits will be dissipated. In contrast, under independent pricing, F1 can exercise its outside option (subject to FRAND rules) by setting its bundled price ($p_1 N s$) equal to $\bar{p}_z(\gamma, p_w^m)$, thus

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[35] The equal *ex post* shares in this example are made asymmetric through an upfront transfer.

making Z not economically viable and leaving it with a monopoly on W. This assures the existence of a (not necessarily unique) critical value $\bar{\gamma}$. This result is described in Proposition 6.

Proposition 6: *Under Assumption 4, if both pool members own the outside good, then a pool privately dominates uncoordinated pricing for all γ. However, for ownership regime in which one patentee (F1) has a monopoly on an outside good (W), a critical value, $\bar{\gamma} \leq 1$ exists for which uncoordinated pricing privately dominates pooling for all $\gamma \in (\bar{\gamma}, 1]$.*

5.1 Outside Option

As noted above, a patentee with overlap may have the incentive to raise the price of its inputs sufficiently high to foreclose Z from the market. However, it can do this only if no pooling was the organizational form chosen since, under a pool, patentees delegate price control to its manager. To analyze how this affects the pooling decision, I make a simplifying assumption:

Assumption 5: Equilibrium profits of the patentees under pooling and no pooling decline in γ.

That is, as W and Z become closer substitutes, total profits accruing to the two patentees fall. Under Assumption 5, two situations can arise when a critical value $\bar{\gamma} < 1$ exists. To examine these cases, consider the ownership regime $\omega=2$ in which F1 has a monopoly in W.[36] Let $\tilde{\gamma}$ be defined as before: the value above which F1 prefers a monopoly in W to production of both W and the Z inputs in the absence of a pool. Furthermore, let $\hat{\gamma}$ be the value above which F1 prefers a monopoly in W to production of both W and a pool in the Z inputs. Let π_w^m be monopoly profits from W: the value of its outside option, which is independent of γ. Figure 3 illustrates two cases: (1) for π_w^m above the intersection, in which the profits under pooling exceed those from no pooling for a given γ, $\tilde{\gamma}_h < \hat{\gamma}_h$; and (2) for π_w^m below the intersection in which profits from uncoordinated pricing is privately preferred to pooling for a given γ, $\tilde{\gamma}_l > \hat{\gamma}_l$.

The second case is shown in Figure 4. Note that it preserves the analysis developed in this section: for $\gamma < \bar{\gamma}$, pooling is chosen; for $\gamma > \bar{\gamma}$, the patentees choose not to pool. However, for sufficiently close products, $\gamma > \tilde{\gamma}_l$, F1 will exercise its outside option by setting the price of its input bundle equal to $Nsp_1 = \bar{p}_z(\gamma, p_w^m)$ and produce as a monopolist in W. Note that this case reveals three ranges of γ in which standards (1) lead to pools, (2) do not lead to pools and (3) fail to occur altogether.

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[36] The analysis is similar for $\omega=0$ and $\omega =1$.

The first case, illustrated in Figure 5, can also occur for relatively profitable W. As shown, the range in which F1 chooses to produce as a monopolist in W is now much larger, occurring for $\gamma > \hat{\gamma}_h$. For these products, F1 refuses to join a patent pool so that it can set the price of its essential inputs equal to the choke price $Nsp_1 = \bar{p}_z(\gamma, p_w^m)$. Pooling is chosen for $\gamma < \hat{\gamma}_h$ and no pooling (and foreclosure of Z) for $\gamma > \hat{\gamma}_h$. While this situation does not arise for quadratic preferences with symmetric products, it can occur in theory, when W is relatively profitable. Anticipating this outcome, the patentees will avoid products in the $(\hat{\gamma}, 1]$ range at the product-selection stage, analyzed in the next section.

6. Product Choice (or Standard-Setting)

In this section, innovators F1 and F2 coordinate on product selection of Z through a simple standard-setting process. Product type, designated by γ, is chosen jointly in anticipation of future pooling and pricing decisions.[37] As noted in the previous section, if products $\gamma > \tilde{\gamma}_l$ in Figure 4 (for relatively low profitability of W) or $\gamma > \hat{\gamma}_h$ in Figure 5 (for relatively high profitability of W) were developed and F1 had a monopoly in W, it would not pool and then subsequently attempt to price the competing product out of the market. Whether F1 in fact would be allowed to do this – that is, set non-FRAND prices – of course is irrelevant since such standards would never be developed in the first place. Knowing that it would be better off by producing W alone, F1 would refuse to supply its expertise or patents essential to the development of the standard. While recognizing that the equilibrium of this framework may simply be the status quo (in which only W is available in the market), I focus for the remainder of this section on problems in which $\tilde{\gamma}$ and $\hat{\gamma}$ are sufficiently large such that the standard process yields a new product in which both firms will want to engage.[38]

As noted earlier, the joint cost of developing a new product or standard is given by K(γ), where K'(γ) < 0.[39] Denote $V^\vartheta(\gamma; \omega)$ as the equilibrium joint profits of F1 and F2 earned on Z and W for ownership regime ω and product γ, arising from the pooling and pricing stages, where $\vartheta =$ P, NP. Then, F1 and F2 solve the following problem:

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[37] Fershtman and Kamien (1992) analyze firms' decision whether to produce one or both complementary components, X and/or Y when cross-licensing is anticipated. Here, F1 and F2 are assumed to have a comparative advantage in their respective inputs in order to focus on the relationship between the new and incumbent products when pooling is (or is not) anticipated.

[38] In a more complete analysis of the innovation decision, F1 and F2 would face competition from other firms producing W or new entrants into the market. This extension is discussed briefly in the Conclusions and is a topic for future research.

[39] This assumption implies that the cost of developing the Z standard increases in the degree of differentiation from W (or decreasing in γ) is invoked in order to generate internal solutions.

(22) $Maximize\ V^{\vartheta}(\gamma;\omega) - K(\gamma).$
           γ

Note that when pooling is an option, the derivative of (22) can be discontinuous at $\gamma = \bar{\gamma}$, if the firms switch from pooling to no pooling. So the analysis is conducted in two parts: First, the profit-maximizing γ is derived under P and NP, which denotes environments in which pooling is always or never chosen respectively *for all γ*. The results below reflect this constrained maximization problem. Second, the analysis is then refined to allow for the endogenous decision to combine (or not) patents, when pooling is available. In order to derive comparisons of product choice across ownership regimes, quadratic preferences are again adopted.

Result 1 (Quadratic Utility): Let $\gamma_{\omega}^{\vartheta}$ denote the product type chosen for ownership regime ω, when anticipating $\vartheta = NP, P$ for all γ. Then, (i) firms anticipating a pool will choose a more distant substitute or less compatible complement if F1 fully owns W ($\omega = 2$) than when both members share W ($\omega = 3$): $|\gamma_2^P| \leq |\gamma_3^P|$. (ii) Firms anticipating a pool will choose a closer substitute when ownership overlaps under regime $\omega = 2$ than when there is no overlap $\omega = 0$: $\gamma_0^P \leq \gamma_2^P$. (iii) Finally, the firms will choose a closer substitute or a less compatible complement under $\omega = 2$ and uncoordinated pricing than when both firms share in the ownership of W and Z inputs and pooling is anticipated; that is, $\gamma_3^P \leq \gamma_2^{NP}$. Proof in Appendix.

Result 1 implies that the degree of substitutability between Z and W chosen by the innovating firms, under various ownership regimes can be summarized by: $\gamma_0^P \leq \gamma_2^P \leq \gamma_3^P \leq \gamma_2^{NP}$. First, note from (i) and (iii) that if the Z input firms develop a substitute for W, it will be more differentiated when pooling is permitted for all γ than when it is not. For example, comparison $\gamma_2^P \leq \gamma_2^{NP}$ implies that if pooling is illegal then the product chosen for a given cost of development will be closer to the current standard than if the patentees anticipate price coordination. The reason contrasts with the explanation given previously in the literature: there, firms have the incentive to develop bargaining chips that will be more valuable in later settlements (Hall and Ziedonis (2001)). Here, they distance themselves, not due to fear of reprisal, but in order to soften competition in the market intensified by the anticipated pool.

The above analysis is based on either pooling being anticipated or not for all γ. As noted above, when the pooling decision is endogenous (rather than exogenously imposed), it may not be the equilibrium outcome for γ sufficiently large. Since larger γ may be profitable when

development costs fall steeply in γ, then the joint profit function will become discontinuous at the critical value $\bar{\gamma}_\omega$, defined as the product type at which firms switch from pooling to no pooling for ownership regime ω. Then, for $\gamma > \bar{\gamma}_\omega$, the firms will locally prefer γ_ω^{NP} and no pooling to γ_ω^P and pooling. It will also be the preferred choice globally if the net joint profits, evaluated at γ_ω^{NP}, exceed profits in (22) evaluated at $\bar{\gamma}_\omega$; otherwise, the latter choice – pooling with a more differentiated product – will be chosen. That is, the choice of γ when pooling is an option never supports a closer standard than when prices cannot be coordinated.

Also implied by Result 1 is that the new standard will be closer to W when pooling is anticipated, the greater is the degree of overlap. This may seem counterintuitive but is attributed to the fact that firms with greater overlap are better positioned to dampen the competitive effect through their price-setting decisions; therefore, they choose a closer (and less costly-to-develop) substitute. More precisely, when F1 owns W, it discounts the negative effect that a reduction in the price of W has on the demand for Z since F1 receives only α of the profits generated by the pool. Therefore, it sets a price too low relative to the private first-best under ω=3. Anticipating this price-setting behavior, the firms agree to develop a substitute that is more differentiated than if the pool were allowed to coordinate both the prices of W and the Z inputs. Note that in developing a new standard, the firms with overlap create competition for their outside product but the cost of doing so is less when they can coordinate both prices than when they cannot.[40]

To understand the claim in (iii) of Result 1, consider the impact of no pooling for ω=2 on product choice. Again, F1 does not take into account the full benefit of a demand increase in Z for an increase in the price of W and so sets W too low relative to a pool that is fully coordinated (ω=3). It also does not internalize the full impact of an increase in the price of its Z inputs on the reduction in the demand for F2's inputs and sets the price of its inputs too high. For quadratic utility, the latter dominates the former effect; and so the firms choose a higher γ (more competitive product) relative to the fully coordinated outcome.

The three dimensions of choice – product selection, pool formation, and pricing – are influenced by antitrust. In the next section, the normative issues arising form the framework are explored, with particular attention to the role that antitrust policy plays in promoting efficient agreements between horizontally related firms.

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[40] This result contrasts with Arrow's "replacement effect" (1962) in which Z is effectively a vertical improvement of W. Here, rather than replacing the current product, the new standard competes for market shares in an expanded market.

7. Antitrust Rules for IP Cooperative Agreements

7.1 Antitrust and the Pooling-Pricing Decisions

As shown, a pool of complementary inputs can be beneficial from a consumer perspective but not profitable from the firms' perspective. This outcome has implications for antitrust policy. In particular, a pool under Assumption 2, is least likely to arise when F1 has a monopoly in W but most likely to occur when both patentees share control of W.

If instead of limiting coordination, antitrust policy relaxed Assumption 2 to allow the pool to coordinate prices of *all* products under its members' control – that is "fully coordinate" – then forming a pool would be unambiguously profitable. The catch is that consumers may suffer under full coordination relative to no pool. In this section, conditions under which a more permissive policy benefits consumers as well as members of the pool are examined here for the regime $\omega=2$.

Figures 6 and 7 illustrate the welfare comparison for limited and full coordination policies with respect to the pooling and pricing decisions in the case of quadratic utility. Under Assumption 2, the private benefits from forming a pool over no pool is given by the lower curve in Figure 6; the corresponding curve for net consumer utility is shown by the higher curve in Figure 7. While the net benefits from pooling turn negative for sufficiently close products (γ beyond point C), net consumer surplus continues to rise in γ. But no pool will form for $\gamma \geq 0.55$ and so the realized net utility over the no-pooling outcome falls to zero at C.

If instead the pool is given broader scope to set prices on all products owned by members of the pool, then the net private and consumer benefits from a pool are described by the higher curve in Figures 6 and the lower one in Figure 7. Since the alternative is no pool (or zero net benefits), both consumers and firms would gain from the relaxation of Assumption 2, allowing the outcome to follow DE in Figure 6 and IJ in Figure 7. Figures 6 and 7 also reveal that both firms and consumers are better off when the pool coordinates both inside and outside prices when W and Z are complements ($\gamma < 0$). And so, if coordination is complete for both complements and strong substitutes but limited for $\gamma \in (0, \overline{\gamma})$, then profits and consumer surplus will be given, respectively, by ABCDE in Figure 6 and FGHIJ in Figure 7.

At the other end of the policy spectrum, firms are sometimes required to divest assets on competing products as a condition of merging or entering into cooperative agreements. Such a policy can be socially efficient when prospective pool members own assets on W. The impact of this condition for pooling in the range $\gamma < \overline{\gamma}$ in which pooling is profitable is next considered.

If patentees must divest their assets in order to pool, then the organizational environment changes from ω>0 to ω=0. As compensation, suppose the divesting firm(s) receive the market value of the assets, $d(\gamma; \omega)$ equal to the actual profits from sales of W that would accrue to the outside firm under pooling, $\pi_w^P(\gamma; 0)$, less its opportunity profit in the current ω environment if neither the transaction nor pooling takes place, denoted by $\tilde{\pi}_o^{NP}(\gamma; \omega)$.[41] Divestiture could dampen incentives to enter an efficient patent pool in the first place, in which case consumers would be worse off. So, an efficient policy will be constrained by the patentees' incentive compatibility constraint to form a pool. Adopting the framework in Shapiro (2003), I assume that consumers must be at least as well off under a policy of divestiture than under no divestiture. Therefore, an efficient policy must satisfy:

(23) $\pi_z^P(\gamma, 0) + d(\gamma; \omega) - \sum_i \pi_i^{NP}(\gamma; \omega) \geq 0$, for i = 1, 2 where

(24) $d(\gamma; \omega) = \pi_w^P(\gamma; 0) - \tilde{\pi}_o^{NP}(\gamma; \omega)$.

The constraints in (23) and (24) imply that the optimal policy requires total industry profits under divestiture ($\Pi^P(\gamma; 0)$) to exceed total industry profits under an environment with neither pooling nor divestiture ($\Pi^{NP}(\gamma; \omega)$). Therefore, the policy in (23) and (24) can be described by:

(25) $\Pi^P(\gamma; 0) - \Pi^{NP}(\gamma; \omega) \geq 0$.

The above framework yields the following result:

Result 2 (Quadratic Utility): If W and Z are strategic complements and if divestiture does not discourage firms from pooling their patents, then requiring firms to divest their outside assets as a condition of pooling increases consumer utility; however, industry profits may fall under divestiture. If the requirement to divest changes the decision to pool then both consumers and firms will be worse off under a divestiture policy than under the status quo.

Result 2 for quadratic utilities follow directly from Proposition 2. Since equilibrium prices have the relationship $p_i^P(\gamma; 0) \leq p_i^P(\gamma; \omega) \leq p_i^{NP}(\gamma; \omega)$, for i = W,Z, consumer utility is higher under pooling and outside ownership than under overlapping ownership and pooling, and lowest when divesture discourages the firms from pooling.

The results on full coordination and divestiture are combined to illustrate in Figure 8 an antitrust policy that maximizes consumer utility in terms of γ and ω. Since the latter is not continuous, the partitions are denoted by dotted curves. First, note that if W and Z are strong

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[41] Note that the acquiring firms would earn zero in all environments except for ω=1 in which both inside and outside firms own W. See Tan and Yuan (2003) for a related problem involving divestiture of conglomerate firms.

substitutes, F1 and F2 will not have the incentive to pool under Assumption 2 when $\omega = 2$ but if allowed to fully coordinate, both consumers and firms could benefit.[42]

As also shown, if W and Z are sufficiently weak substitutes given a particular ownership regime ω, both consumer utility and total surplus are higher when prospective pool members are required to divest their assets. For the quadratic utility case, divestiture is more likely the higher is ω, as indicated by the dashed curve. However, as the degree of substitutability increases for a given ω, a pool of Z inputs with divestiture eventually reduces industry profits below the status quo in which case firms choose to retain their assets and operate separately. In this middle region, divestiture is no longer welfare improving and the policy of limited coordination is optimal. Divestiture is never optimal and full coordination is always desirable for $\gamma < 0$. For sufficiently strong substitutes (large γ) and weak ownership overlap (low ω), pooling will not be profitable. [43]

As noted earlier, since antitrust authorities generally proscribe agreements that coordinate prices of substitute products, the concern here is that a patent pool could soften competition between horizontal competitors. Result 2 for quadratic utility suggests that, in fact, it is precisely when substitutes are strong that antitrust rules might be more permissive, broadening the scope of the pool so it can coordinate prices on its members' outside as well as inside goods. Moreover, it recommends that for relatively weak substitutes the firms might be required to divest its assets in the outside good as a condition of joining the pool.

The above recommendation that antitrust policy be relatively permissive for strong substitutes and tough for weak substitutes may appear to contradict a basic premise of antitrust policy. Yet, it follows directly from the endogenous reorganization of IP rights: Since a patent pool increases competition in the relevant market, the private incentive to form a pool is less for strong substitutes. But that is precisely when a pool is socially desirable.[44]

Before such a result can transform into a policy recommendation, however, several caveats merit careful consideration. First, if a pool forms when members are engaged in the production of outside substitutes, then it may signal that the members are in fact extending their reach beyond the pool's prescribed mandate; that is, it may be using the pool to *explicitly* coordinate prices of their outside substitutes as well as of their complementary patents. The concern arises when the

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[42] Relaxing Assumption 2 will have no impact on ownership regimes $\omega=0$ and $\omega=3$ since Z firms do not own W in the former case and are able to achieve full coordination in the latter case. Simulations reveal that consumers are not better off under full coordination for $\omega=1$ in which F1 shares W with an outside firm.

[43] Algebraic derivations of the results for quadratic utility are available from the author.

[44] This result parallels a result on mergers derived by FaulÍ-Oller and Sandonis (2002), where licensing and mergers are two options for transferring a superior technology. If only fixed fees are available, licensing of large inventions and close substitutes may not be profitable, potentially justifying a more lenient merger policy in this case.

pool expands its reach for weak substitutes in which case an efficient pool would have formed without the added incentive. In the latter case, expanding the scope of the pool will have negative consequences for consumers. Consequently, antitrust authorities will want to be scrupulous in assessing the competitive relationship between downstream substitutes when there is overlap, even for pools comprising complementary and essential patents.

Second, if incentives to form a pool increase in the complexity of the patent thicket, then a more permissive antitrust regime may not be necessary to encourage efficient pools: Although the social benefits from a pool increase as the thicket becomes more dense, so too do the private benefits. Finally, a more lax antitrust policy can also influence the development of new products, potentially with negative consequences, at the earlier standard-setting stage. The effect of antitrust rules on the direction of technological change is examined in the next section.

7.2 Antitrust and Product Choice

In this section, the impact of the *limited coordination* and *full coordination* antitrust rules on product choice is determined. As before, consider the net profits and consumer utility in Figures 6 and 7 for ownership regime $\omega = 2$ and quadratic utilities. Let γ_2^P and γ_2^{NP} be the respective profit-maximizing product type if a pool under Assumption 2 is anticipated and when it is not, and $\gamma_{LC}*$ the most profitable product choice under limited coordination. As before, $\overline{\gamma}$ is the critical product choice above which no pooling would take place in the next stage. Then, there are three outcomes in the substitute range of products $\gamma > 0$: (1) if development costs of differentiating are relatively low such that $\gamma_2^P \leq \overline{\gamma}$, then $\gamma_{LC}* = \gamma_2^P$; (2) if costs of differentiating are moderate/high such that $\gamma_2^P > \overline{\gamma}$ but pooling at $\overline{\gamma}$ is more profitable than not pooling at γ_2^{NP}, then $\gamma_{LC}* = \overline{\gamma}$; and (3) if costs of differentiating are moderate/high such that $\gamma_2^P > \overline{\gamma}$ but pooling at $\overline{\gamma}$ is less profitable than not pooling at γ_2^{NP}, then $\gamma_{LC}* = \gamma_2^{NP}$, where profitability is defined by (22) evaluated at the relevant values.

Now suppose that the antitrust authorities allow members of the pool to *fully coordinate* prices of all the products owned by its members when $\gamma < 0$ and $\gamma \geq \overline{\gamma}$ (that is when welfare would increase from greater coordination). To consider the impact of this policy change on product choice, let γ_3^P be the product choice when both firms share ownership of W ($\omega = 3$) and pool their patents, and $\gamma_{FC}*$ the profit-maximizing product choice when only F1 owns W but the patentees can coordinate prices on both their inputs and W. Furthermore, define $\overline{\overline{\gamma}}$ as the product type such

that profits in (22) under pooling are equal to industry profits under full coordination at $\bar{\gamma}$. The critical values $\bar{\bar{\gamma}}$ and $\bar{\gamma}$ are illustrated in Figure 9.

Next consider whether the firms, under a more permissive regime will choose a more or less differentiated substitute. [45] Three cases follow from the limited coordination outcomes:

(a) If $\gamma_{LC}* \in [0, \bar{\bar{\gamma}}]$, then $\gamma_{FC}* = \gamma_{LC}*$.

(b) If $\gamma_{LC}* \in (\bar{\bar{\gamma}}, \bar{\gamma}]$, then $\gamma* = \max(\bar{\gamma}, \gamma_3^P)$

Note that (a) and (b) correspond to case (1) for limited coordination since the product choice lies in the region in which pooling is profitable. Cases (2) and (3) for limited coordination is captured in (c) below:

(c) If $\gamma_{LC}* > \bar{\gamma}$, then $\gamma_{FC}* = \gamma_3^P$.

The full coordination outcomes in (a)-(c) are compared with those for limited coordination in (1)-(3) above. First consider the case of relative low development costs in which $\gamma_{LC}*$ lies in the pooling region. Under a more permissive antitrust policy, the choice of standards will either not be affected (as in (a)) or a closer substitute will be chosen (as in (b)). That is, for products in the $(\bar{\bar{\gamma}}, \bar{\gamma}]$ pool range under limited coordination, it is more profitable to chose a closer product, thus making the pool eligible for full coordination.

For moderate to high development costs, either the product chosen under limited coordination will be at the boundary of the pooling-no pooling divide (as in (2)) or in the no-pooling zone (as in (3)). If the former, then under full coordination, the firms will again choose a closer substitute γ_3^P. However, in the latter case, a more permissive policy will induce the firms to pool and, in doing so, increases the profitability of a more differentiated standard. It is case (c) that reflects the intention behind a more permissive policy: to encourage efficient pools that otherwise would not take place, but with the added bonus of encouraging more efficient product selection. These results follow directly from Result 1.

Therefore, a permissive antitrust policy can induce firms to develop either a closer or a weaker substitute than under limited coordination. Cases (b) and (c) are illustrated in Figure 9. For the former case, the profit-maximizing selection under limited coordination lies in region $(\bar{\bar{\gamma}}, \bar{\gamma})$ and so relaxing Assumption 2 biases firms' product choice toward the full coordination

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[45] Suppose instead that the profit-maximizing product choice is a complement of W; that is, $\gamma < 0$. If allowed to coordinate prices of both W and Z inputs, then F1 and F2 will choose $\gamma_{FC}* = \gamma_3^P$, where $\gamma_3^P < \gamma_2^P$; that is, under full coordination, the firms will have the incentive to choose a more compatible complement, thereby increasing consumers' and producers' welfare.

region, as indicated by the arrow pointing right. Since the policy does not alter the decision to pool but increases γ and prices, consumers are worse off. Also shown is case (c) in which full coordination encourages pooling and a more distant substitute, indicated by the arrow pointing left, thereby making both consumers and firms better off.

And so, while a more permissive policy categorically makes patentees better off, consumers may be worse off if the innovating firms would have formed an efficient pool without the extra motivation. However, when the policy is effective in encouraging firms that otherwise would not have pooled to coordinate their patents, it has the added benefit of redirecting technological change toward higher valued products and lower prices.

8. Predictions and Conclusions

While litigating each other in the courtroom over patent rights, competing innovators have also been engaged in forming productive alliances for combining IP in support of new standards or products. The DVD patent pool and the 3G Platform, for example, comprise patents from technology giants such as Toshiba, Panasonic and Samsung in the former, and Fujitsu, Mitsubishi and Sony (among others) in the latter. As noted in Section 2, strategic alliances extend beyond the IP arena into manufacturing and transportation markets. Although participants are often horizontal competitors, the current antitrust approach is not to challenge the agreements as long as they combine complementary and essential components.

This paper offers insights into the effectiveness of that simple but elegant antitrust rule for evaluating IP agreements when the cooperating patentees own products that compete with downstream substitutes arising from the agreement. In particular, the following question is posed: Is it sufficient to examine the nature of the relationship between the *patents inside the pool* as is currently the practice, or is this inadequate, requiring a more complete evaluation of the relationship between *patentees in the relevant market*? The analysis here lends support for the current antitrust practice – even when members are rivals at the time of pool formation – although situations in which a firm with overlap also contributes a dominant share of essential patents to the pool merit closer scrutiny. In fact, the analysis suggests that efficient collaborations may need to be encouraged (rather than simply not challenged), consistent with Merges (1999) who suggests a role for government in facilitating the formation of patent pools in overcoming "the collective action problem inherent in group bargaining." Expanding the scope of the pool can improve

consumer welfare when firms are asymmetric in their outside options and the downstream products inside and outside the pool are strong substitutes. Moreover, when that rule is successful in identifying efficient pools, it will have the added benefit of encouraging better product choices at the standard-setting stage.

A message to take away from the paper is that collaborations of complementary assets are generally pro-competitive for a given degree of overlap in competing products, but that increases in overlap for a given collaboration can decrease welfare. When the degree of overlap by pool members increases, not only do prices rise, but new products are either likely to be less differentiated or not offered at all if the firm with overlap chooses to hold-up the new standard by exercising its outside option. And so, if a strategic alliance is approved, antitrust should be circumspect in its evaluation of changes in the ownership structure by pool members into downstream competing products. It is in this sense that divestiture of assets as a condition of entering a pool with competitors, as analyzed in this paper, can improve welfare.

In addition to these normative implications, the paper also offers several positive testable predictions. The first set of predictions describe equilibrium pricing outcomes: (1) When patentees of complementary inputs have a financial stake in competing goods, then prices of downstream products that are substitutes and strategic complements will be lower under coordinated pricing relative to no pool for any degree of ownership overlap. (2) However, both upstream and downstream prices under a pool increase as the degree of overlapping ownership by the cooperating patentees increases. (3) If a pool is formed, one or more prices may be higher relative to uncoordinated prices if the input firm with the majority of patents, compensated by the patent-based rule, also has ownership in an outside competing good.

A second set of results involves the likelihood of pool formation. If firms are constrained to set prices only on patents in the pool and new products that emerge are close substitutes to those owned by the patentees, a pool will be less likely to form. And so: (3) Patents that are pooled are more likely to support downstream products that are distant substitutes of competing products owned by the cooperating patentees, compared to those not pooled. (4) Also, patentees participating in pools are more likely to be symmetric in both their shares of the pooled profits as well as in their outside ownership; or are more likely to be asymmetric in both their outside ownership and their shares of the pooled profits, relative to patentees not participating in a pool.

The third set of testable hypotheses applies to the type of standards that are introduced when complementary patents can be coordinated: (5) The products implementing a new standard are

likely to be more distant substitutes to current products when the relevant complementary components are pooled than when they are not for any degree of ownership overlap. (6) However, for a greater degree of ownership overlap, the new product (or standard) chosen will be closer to the current products owned by the cooperating patentees.

The framework could be extended in several directions. First, it could be broadened to incorporate the two related but distinct industrial structures of vertical integration and multi-market contact, explored in the literature, especially given that all three multi-product relationships are observed in many standard-related patent pools. As note in the DVD case, for example, pool members are vertically related into the manufacturing of DVD players; they are involved in related products in the relevant market; and they confront each other in unrelated markets for consumer electronics.

A second extension would permit the suppliers of the current good in the market (W in this framework) to engage in a pooling decision. In the paper it is assumed that for multiple owners of essential inputs, the prices of W are jointly coordinated. Preliminary results on this extension reveal that strategic complementarity in W and Z reveal that equilibrium prices are lower under a pool in Z if the W inputs are also pooled.[46] A corollary is that producers of the current standard (W) may have muted incentives to pool if in response patentees of the follow-on standard will also pool: Although the W input firms prefer to coordinate prices if the other firms do not, they are better off when neither pools than when both do.[47]

Third, the framework could be extended to analyze a situation in which the patents support an improvement over the current standard (rather than a differentiated but not necessarily superior product). Imperfect competition in the current product might be introduced in order to explore whether patentees form pools for the purpose of strategically displacing a current standard upon which their competitors rely. This situation allegedly arose in Princo Corp. v. International Trade Commission, a patent abuse case in which Phillips and Sony entered an arrangement for CD-RW technologies.[48] They chose a particular method Raamaker to be the standard and then suppressed another standard Lagadec, which was covered by patents held by both companies. Princo asserted that the creation of the patent pool on Raamaker and suppression of Lagadec constituted patent

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[46] Proof available from author.

[47] For quadratic utilities, it can be shown that a pool of the Z inputs is profitable when W inputs are not pooled for $\gamma < .66$ and the incentive to pool the Z inputs given a pool in W if $\gamma < .77$. It is straightforward to show that it would pay W not to pool for $\gamma \in (.66, .77)$. For any value less than .66 or greater than .77, W firms will pool their inputs since they cannot stop the Z input firms from doing the same (for $\gamma \in (0, .66)$), or the high degree of substitutability makes the pool in Z unprofitable (for $\gamma \in (.77,1)$).

[48] *Princo Corp. v. International Trade Commission*, No. 2007-1386 (Fed. Cir. Aug. 30, 2010).

misuse. The Federal Circuit disagreed, that an agreement not to practice one's own technology does not constitute patent misuse if an alternative technology is being promoted, although it did not rule out potential liability of an antitrust violation.

Related to the last observation, a natural question to ask is: What impact do patent pools have on the incentives to innovate by pool members and by outside firms? In particular, will the Z pool members have the incentive to coordinate their research efforts toward developing the next generation by investing in complementary inputs to support it or will they compete in parallel standards (as in the HD-DVD and Blu-Ray technologies case) and how do these decisions depend on the prospect of future pooling? Will pool members be more aggressive, relative to independent patentees, toward outside research firms threatening to develop a competing standard or will licensing to deter competitive innovation be more profitable than litigation?[49] In analyzing the "next generation" research incentives, this extension would endogenize the ownership structure ω for new standards and products.

Finally, this paper has implications for the larger debate on the efficacy of the IP system. In recognition that incentives to cooperate, as well as to innovate and litigate, impact on the benefits and costs of a system of IP, private agreements should play a more prominent role in the patent debate. To the extent that IP encourages innovators to engage in patent pools and other sharing arrangements, the economic benefits from enhanced utilization and coordinated pricing may counter (at least partially) the social costs identified in the literature from an overreaching IP regime.[50]   In a discussion of genetic pools, van Overwalle (2010) suggests that, in turning exclusive rights into commonly shared patents, IP collaborative mechanisms have the potential to "safeguard the social contract...(and) restore trust in the patent system." Even if that view is overly optimistic and the benefits are only second-order, developing a sharper understanding of incentives for engaging in cooperative agreements is valuable for identifying when those agreements are "a beneficial way of cutting through the patent thicket" (Shapiro 2001) or merely attempts to suppress competition. Antitrust policy can be an effective instrument, complementary to IP policy, for ensuring that IP rights do not extend beyond the protection intended by the grant.

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[49] In addition to the literature on patent pools noted above, the literature on research joint ventures (RJV) can also shed light on this problem. For example, Kamien, Muller and Zang (1992) show that a "competitive RJV" in which the firms independently choose research levels but share efforts, R&D is lower than under full competition for which firms compete in R&D. Lampe and Moser (2010a,b) also show a decline in innovative activity after pool formation in their study of the sewing machine pool.

[50] The diffusion of innovations may be greater under IP protection since first, more technologies may be disclosed when patents are strong, and second, for those innovations that are patented, licensing and other sharing agreements can facilitate more effective use of the innovation (Arora, 1995). For empirical studies on the relationship between the propensity to license and patent strength see Yang and Maskus(2001), Arora et. al.(2002), Gallini(2002) Park and Lippoldt(2005), Branstetter et. al.(2006) and Kanwar(2010).

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Figures and Tables

TABLE 1
Membership in DVD Patent Pool

Rank in Semiconductor Industry	Member of DVD6C Patent Pool
2	Toshiba
4	Samsung
11	Mitsubishi
12	Hitachi
17	Panasonic
19	Sharp
--	JVC
--	Sanyo
--	Time Warner

Source: iSuppli Corporation Rankings for 2000

TABLE 2
Potential Substitutes Controlled by DVD Pool Members

Potential Substitutes	Pool Member
VHS (1976 - 2006)	JVC, Panasonic
Second-Run Movie Theatres	Time Warner
Netflix (1999 -)	Samsung
HD-DVD (2003-2008)	Toshiba
Blu-Ray (2003 -)	Hitachi, Mitsubishi, Panasonic, Samsung, Sharp, Warner Brothers
Future: Holographic Versatile Disc	HVD Forum: Hitachi, Mistubishi
Future: USB-compatible televisions	Hitachi, Samsung, Toshiba, Sharp

TABLE 3
Equilibrium Prices for Quadratic Utilities

Θ	Z inputs	Price of Z	Price of W
(0, 0)	Not Pooled	$(2-\gamma^2-\gamma)/(3-\gamma^2)$	$(3-\gamma-2\gamma^2)/(6-2\gamma^2)$
	Pooled	$(1-\gamma)/(2-\gamma)$	$(1-\gamma)/(2-\gamma)$
(½, 0)	Not Pooled	$(8-3\gamma-6\gamma^2+\gamma^3)/(12-9\gamma^2)$	$(2-2\gamma^2)/(4-3\gamma^2)$
	Pooled	$(2-2\gamma)/(4-3\gamma)$	$(2-2\gamma)/(4-3\gamma)$
(1, 0)	Not Pooled	$(4-\gamma)/6$	½
	Pooled	$2(1-\gamma^2)/(4-3\gamma^2)$	$(4-\gamma-3\gamma^2)/2(4-3\gamma^2)$
(½, ½)	Not Pooled	$(4+3\gamma)/(6+6\gamma)$	$(3+4\gamma)/(6+6\gamma)$
	Pooled	½	½

Figure 1
Overlapping Ownership of Firm 1
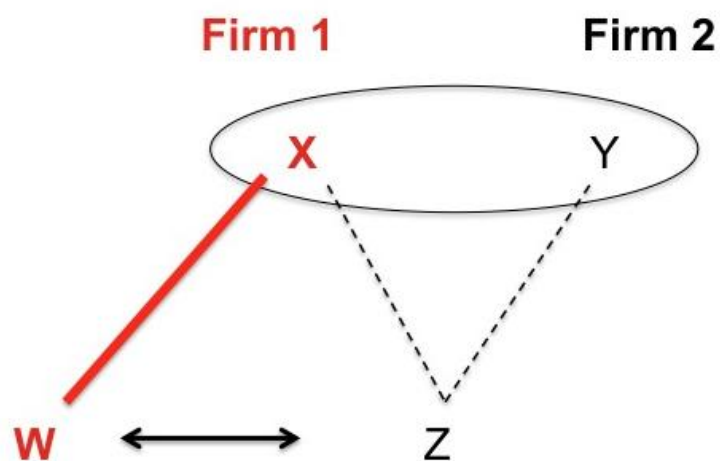
Figure 2
Private Benefits from Pool in Z

Figure 3
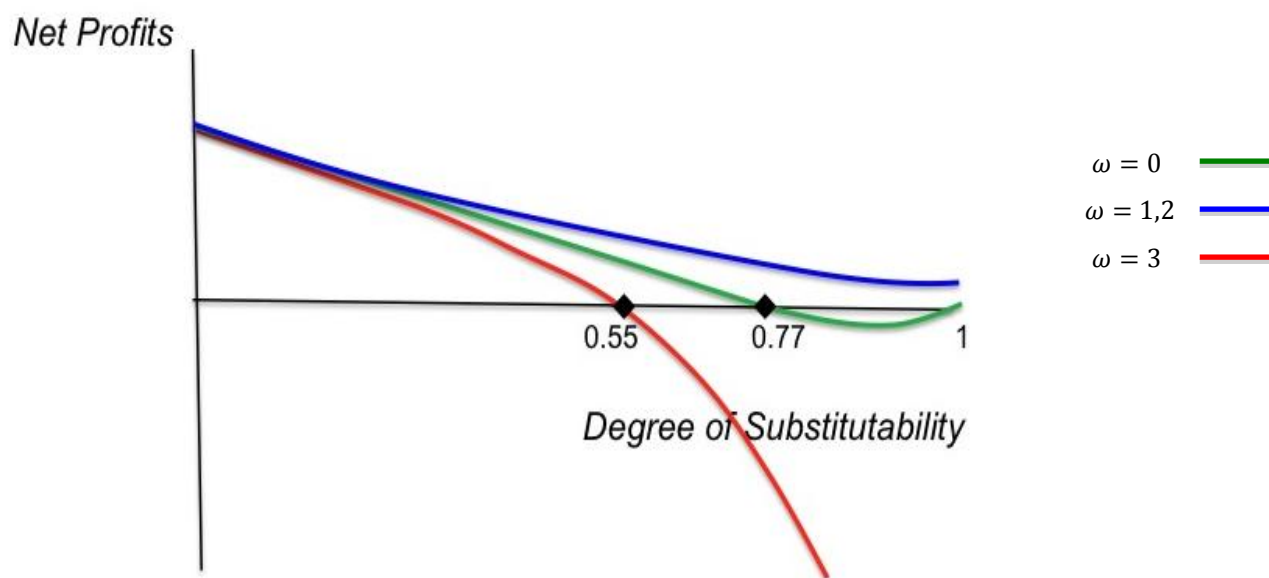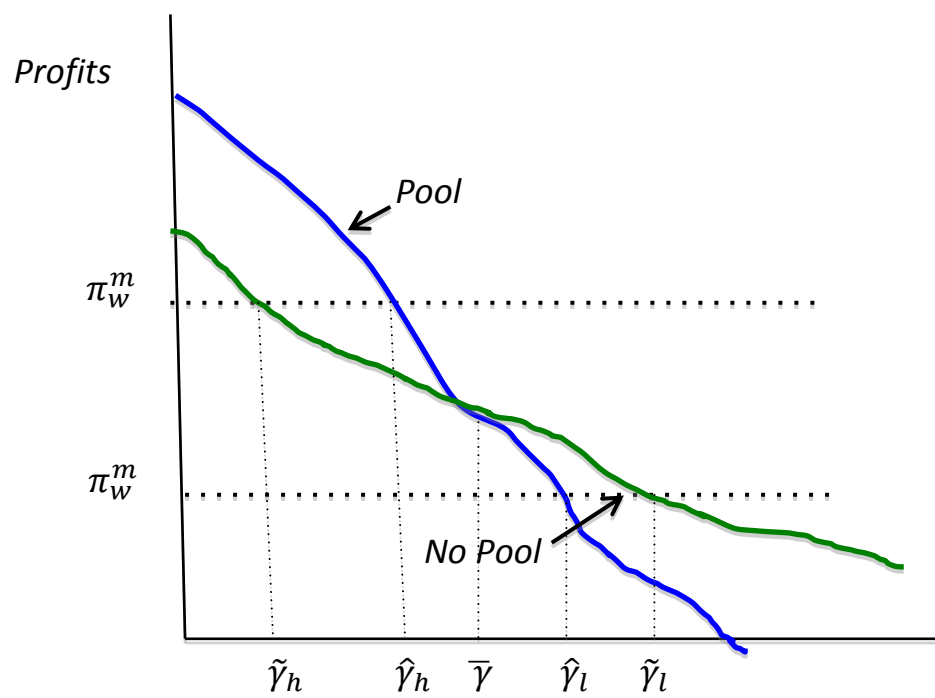## Outside Option at Pooling Stage

π_w^m

π_w^m

Profits

Pool

No Pool

$\tilde{\gamma}_h$ $\hat{\gamma}_h$ $\overline{\gamma}$ $\hat{\gamma}_l$ $\tilde{\gamma}_l$

Figure 4
Exercising Outside Option for Moderately Profitable W

Net Profits from Pool

Pooling:
Both W and Z
available

No Pooling:
Both W and Z
available

No Pooling:
Z foreclosed;
only W available

$\bar{\gamma}$ $\hat{\gamma}_l$ $\tilde{\gamma}_l$
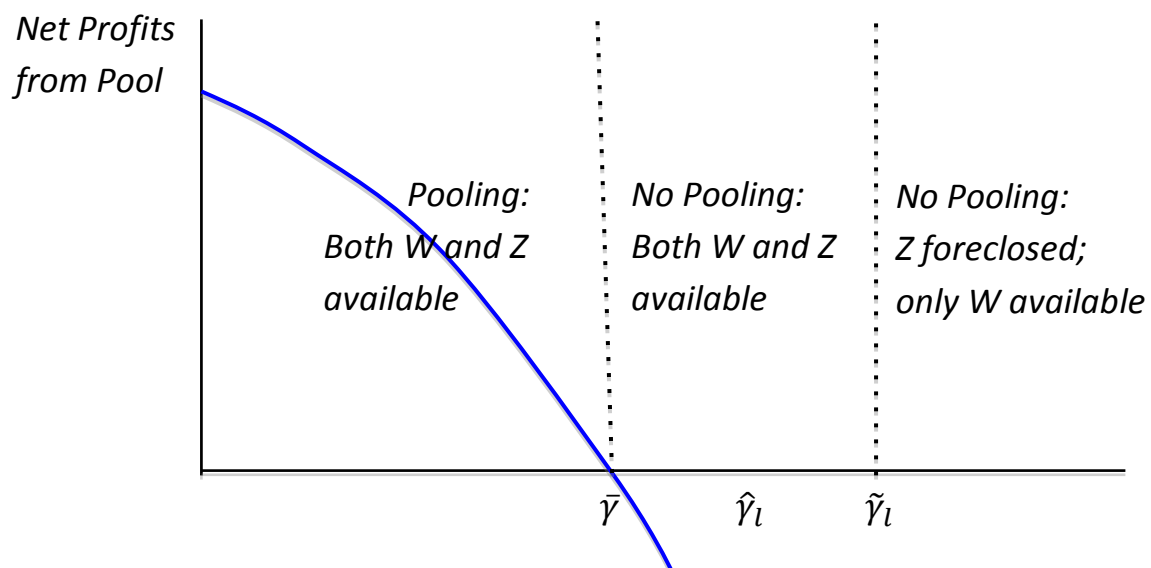
Figure 5
Foreclosure for Profitable W

Net Profits from Pool

Pooling:
W and Z
available

No Pooling:

Z foreclosed; Only W available

$\tilde{\gamma}_h$ $\hat{\gamma}_h$ $\bar{\gamma}$
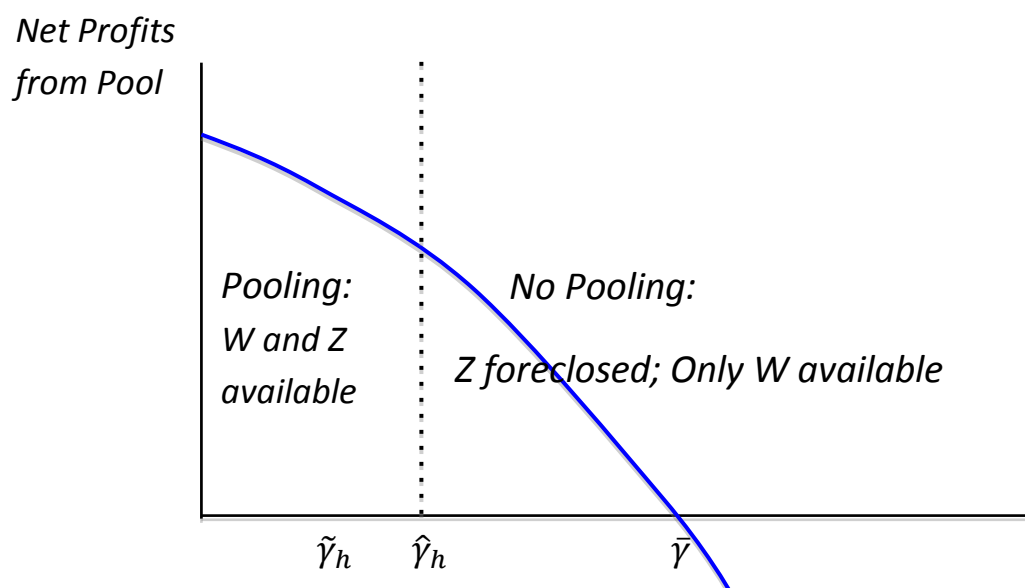
Figure 6
Net Profits under Full Coordination
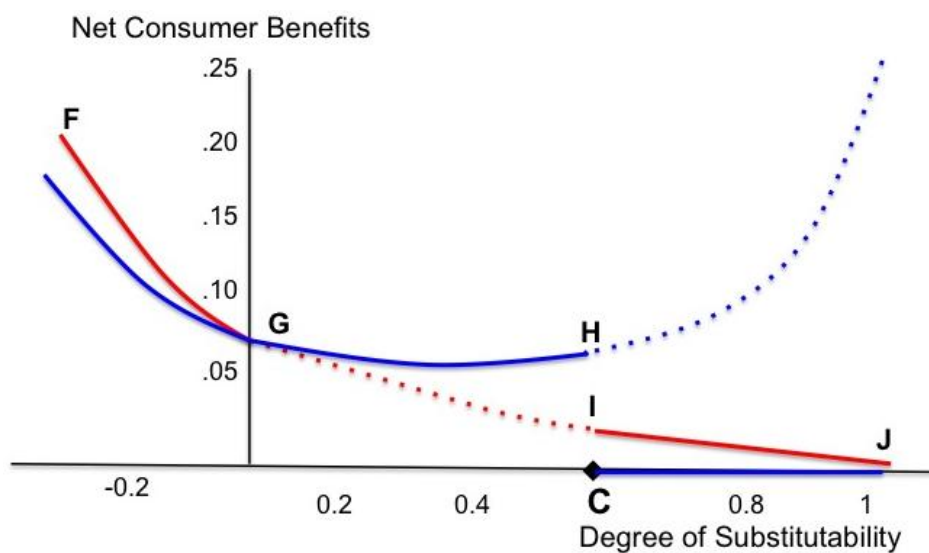
Figure 7
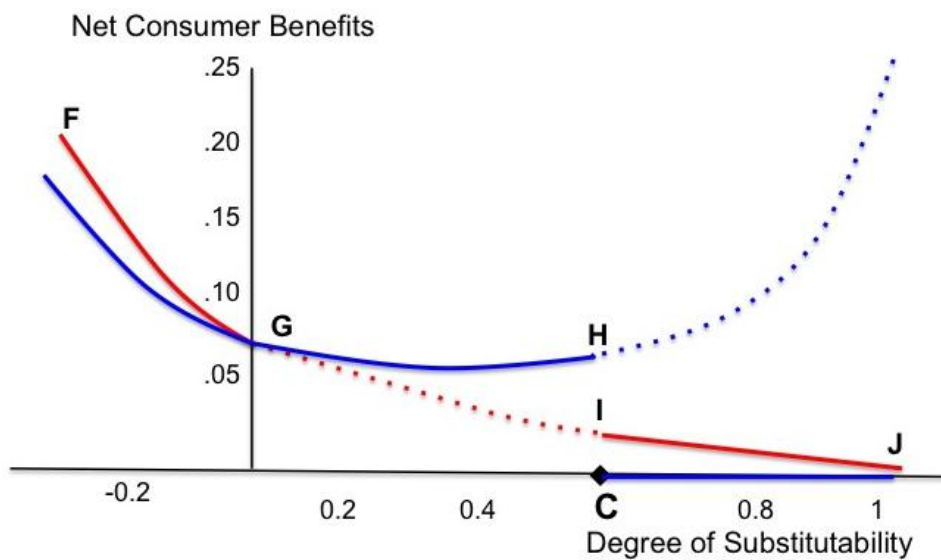Net Consumer Benefits under Full Coordination

Figure 8

Antitrust Rules for Patent Pools

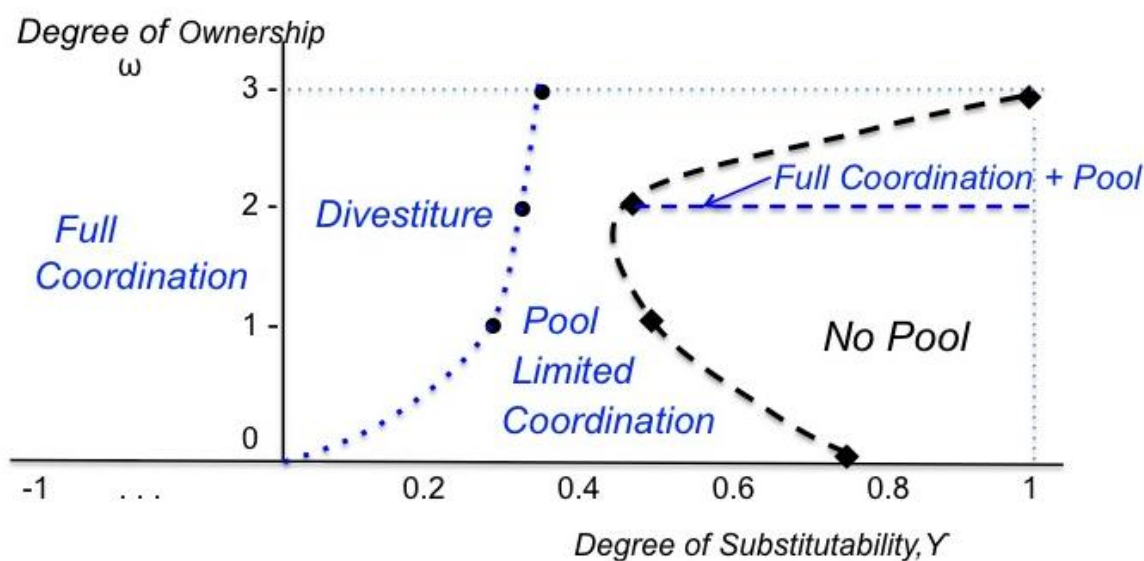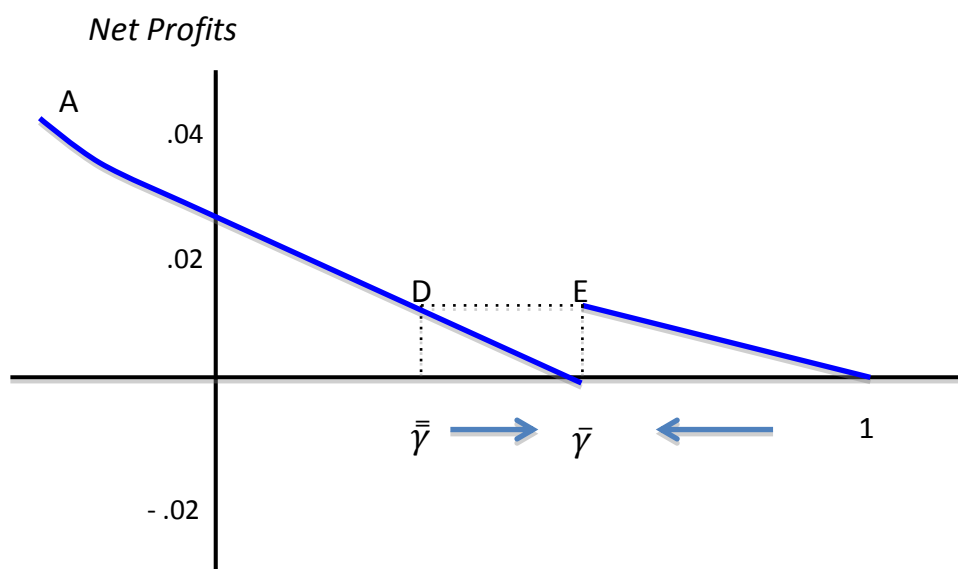(given product choice and ownership structure)

Figure 9

Product Choice and Permissive Antitrust Rules

Appendix

A. Proof of Proposition 5 on Pool Size

To show that Propositions 1 and 2 are preserved for pools of size N, the equilibrium conditions for the no pool case are given from (16) to be:

(A1) $\qquad \dfrac{\partial \tilde{\pi}_i}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z} = 0 \qquad\qquad$ *for i = 1,...,N_1*

(A2) $\qquad \dfrac{\partial \tilde{\pi}_j}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z}(\dfrac{1}{M+N_2}) = 0 \qquad$ *for j = 1,...,N_2*

(A3) $\qquad \sum_j p_j \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} = 0.$

And for the pool in (17), equilibrium prices are:

(A4) $\qquad \dfrac{\partial \pi_z}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z}\left(\dfrac{N_2}{M+N_2}\right) = 0$

(A5) $\qquad N_2 \alpha p_z \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} = 0.$

Adding (A1) and (A2) and substituting into (A4) yields the marginal profit of Z under pooling, evaluated at the no pool prices. That expression is:

(A6) $\qquad -(N-1)f(p_z^{NP}, p_w^{NP}; \gamma) < 0.$

Therefore, $p_z^P \le p_z^{NP}$ when the price of W is held constant at p_w^{NP}.

Next, compare the marginal conditions for W by substituting (A3) into (A5), which gives the marginal profit of W under pooling, evaluated at the no pool prices. That expression is:

(A7) $\qquad N_2\big(\alpha p_z - p_j\big)\dfrac{\partial f}{\partial p_w}$

Under the value-based allocation rule, the expression in (A7) is zero; as before, if W and Z are strategic complements, then both prices of W and Z will fall. Under the patent-based rule, $\alpha = \dfrac{1}{N}$. Therefore, the expression in (A7) is negative if $\dfrac{p_z}{N} - p_j < 0$. Since the j firms internalize the impact of raising p_j on the demand for W, $p_j > p_i$ and therefore $\dfrac{p_z}{N} < p_j$, preserving part (i) of Proposition 2.

To show part (ii) – that pool prices increase in the degree of overlap – let N_2 increase, holding constant N. First evaluate (A4) at N_2^0 and N_2', where $N_2' > N_2^0$; refer to the respective marginal conditions as (A4)' and (A4)''. Substitute prices from (A4)' into (A4)'' gives: $\Big(\dfrac{N_2'}{M+N_2'} -$

$\dfrac{N_2^0}{M+N_2^0}\Big) p_w \dfrac{\partial g}{\partial p_z} > 0$ since $N_2' > N_2^0$. Therefore, price of Z is higher under the pool with greater

overlap, holding constant the price of W at $p_w^{N^0}$. Similarly, a parallel exercise on (A5) yields a marginal profit of W under the larger pool gives: $(N_2' - N_2^0)\alpha p_z \frac{\partial f}{\partial p_w} > 0$ since $N_2' > N_2^0$.

Therefore, the price of W is higher under the pool with greater overlap, holding constant the prize of Z at p_z^0. Note that if W and Z are strategic complements, such that an increase in the price of W (Z) results in an increase in the marginal profits of Z (W), then the price increase of one good is reinforced by the price increase in the other good.

B: Sequential Pricing

When Pricing Decisions are Sequential

<u>*Proposition B1:*</u> *Under a sequential framework in which the upstream input prices are chosen in period 1 and the downstream prices in period 2, the prices of the downstream product Z will be higher than in the simultaneous framework. If W and Z are strategic complements and a value-based rule is used, their prices will be lower under a pool than under uncoordinated pricing. Under a patent-based rule, a sufficient condition for downstream prices to be lower under a pool than uncoordinated pricing is:* $\frac{1}{1-\alpha} > (\frac{p_z}{p_w})^{NP} \epsilon^{NP}$, *where* $\epsilon^{NP} = (\frac{p_w}{f} \frac{\partial f}{\partial p_w})^{NP}$.

There are two effects from a pool: pressure to reduce prices from coordinating complements and pressure to increase prices from coordinating substitutes. In the simultaneous game, the former dominates the latter for strategic complements. In the sequential game, pool members recognizes that by increasing the price of the bundled Z inputs, the owner of W will respond with an increase in its price. However, it is less likely to do so if F1 does not need the inducement (α is high) or it the incentive to respond is low (the cross-price elasticity of demand for Z is low). For quadratic utilities and symmetric goods, the results in Propositions 1 and 2 are preserved.

Proof. Suppose that the pool members, in choosing the prices of the Z inputs, maximize total profits of its members (including profits from its members' outside goods) subject to the incentive-compatibility constraint for the W firms. For illustration purposes, consider the environment (1,0) in which F1 has a monopoly in W. The profit-maximizing problem facing the pool will be:

(B1) $Maximize \; \{\pi_z(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)\}$
$\qquad\;\; p_z$

s.t. $p_w = argmax \; \{\alpha\pi_z(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)\}$

In the uncoordinated case, F1 and F2 choose their input prices prior to the W firm setting its. For example, it may be that the upstream input firms can commit to license contracts before the W firm sets its price. For the no pool case, again for $\Theta=(1,0)$ (or $\omega = 2$), the problem becomes:

(B2) $Maximize \; [\pi_z(p_z, p_w; \gamma) - N(1-s)p_2 f(p_z, p_w; \gamma) + \pi_w(p_z, p_w; \gamma)]$
$\qquad\; p_1$

$$\underset{p_2}{Maximize}\ [\pi_z(p_z,p_w;\gamma) - Nsp_1 f(p_z,p_w;\gamma)]$$

s.t. $\quad p_w = argmax\ \{\pi_z(p_z,p_w;\gamma) - N(1-s)p_2 f(p_z,p_w;\gamma) + \pi_w + \pi_w(p_z,p_w;\gamma)\}$

From (B1), the profit-maximizing conditions for the equilibrium prices of W and Z are respectively

(B3) $\quad \alpha p_z \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} \qquad\qquad\qquad = 0$

(B4) $\quad (\dfrac{\partial \pi_z}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z}) + (\dfrac{\partial \pi_z}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w}) \dfrac{dp_w^P}{dp_z} \qquad = \ 0.$

Substituting the first-order condition for the second stage choice of the price of W in (B3) into the first stage choice of the price of Z in (B4) gives:

(B5) $\quad (\dfrac{\partial \pi_z}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z}) + (1- \alpha) \dfrac{\partial \pi_z}{\partial p_w} \dfrac{dp_w^P}{dp_z} \qquad = \ 0.$

Next consider the first order conditions for the second stage price of W and the first stage choice of the Z inputs when the latters' prices are uncoordinated. From (B2) they are:

(B6) $\quad Nsp_1 \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w} \qquad\qquad\qquad = 0$

(B7) $\quad (\dfrac{\partial \pi_z}{\partial p_z} - N(1-s)p_2 \dfrac{\partial f}{\partial p_z} + \dfrac{\partial \pi_w}{\partial p_z}) + (Nsp_1 \dfrac{\partial f}{\partial p_w} + \dfrac{\partial \pi_w}{\partial p_w}) \dfrac{dp_w^{NP}}{dp_1} \qquad\qquad = \ 0$

(B8) $\quad (\dfrac{\partial \pi_z}{\partial p_z} - Nsp_1 \dfrac{\partial f}{\partial p_z}) + (N(1-s)p_2 \dfrac{\partial f}{\partial p_w}) \dfrac{dp_w^{NP}}{dp_2} \qquad\qquad = \ 0$

Consider the first-order conditions for the price of W in (B3) and (B6). Substitution of (B6) into (B3) yields the same expression as in the proof of Proposition 2. So, as before, the price of W under no pooling will be optimal under coordinated pricing if prices are allocated according to the value-based rule, holding the price of Z at the no pool level. However, for the patent-based rule the relationship between the pool and no pooling prices (given p_z^{NP}) is ambiguous.

To determine the impact of the pool on the price of Z, note first that substituting (B6) into (B7) makes the second term in (B7) vanish. Also, note that p_z and p_2 enter the maximization problem for p_w in the same way so that $(\dfrac{dp_w}{dp_z})^{NP} = (\dfrac{dp_w}{dp_2})^{NP}$. Given these observations, substituting the sum of (B7) and (B8) (no pooling conditions for p₁ and p₂) into (B5) (the pooling condition for p₂), and rearranging gives the marginal profit of Z under pooling when evaluated at the no pooling equilibrium values to be:

(B9) $\quad -f(p_w^{NP},p_z^{NP}) + [(1-\alpha)p_z^{NP}\ (\dfrac{dp_w}{dp_z})^P - N(1-s)p_2^{NP}\left(\dfrac{dp_w}{dp_z}\right)^{NP}](\dfrac{\partial f}{\partial p_w})^{NP}\ .$

Finally note that $1 > (\frac{dp_w}{dp_z})^\vartheta > 0$, for $\vartheta = \text{NP}$ and P, found by totally differentiating the marginal profit of W under no pooling and pooling and invoking second-order conditions. Then, a sufficient condition for the expression in (B9) to be negative is:

(B10) $\qquad -f(p_w^{NP}, p_z^{NP}) + (1 - \alpha)p_z{}^{NP}(\frac{\partial f}{\partial p_w})^{NP} < 0,$

which yields the condition in the Proposition: $\quad \frac{1}{1-\alpha} > \frac{p_z{}^{NP}}{p_w} \epsilon^{NP}$, where $\epsilon^{NP} = (\frac{p_w}{f} \frac{\partial f}{\partial p_w})^{NP}$.

If the price of Z is lower, then so too will be the price of W if Z and W are strategic complements. To show that prices are higher in the sequential than the simultaneous game, compare (14) and (15) with (B3)-(B5) for the pooling case and (9)-(11) with (B6)-(B8) for the no pooling case and noting that $\frac{dp_w^\vartheta}{dp_z} \geq 0$, where $\vartheta = \text{NP}$ and P environments.

C: Proof of Result 1 on Product Choice

To prove (i) of the proposition note that the first-order conditions of (22) before substituting in the incentive compatibility constraints is given by:

(C1) $\qquad \frac{\partial \pi_z}{\partial \gamma} + \frac{\partial \pi_w}{\partial \gamma} + \frac{dp_z}{d\gamma}\left[\frac{\partial \pi_z}{\partial p_z} + \frac{\partial \pi_w}{\partial p_z}\right] + \frac{dp_w}{d\gamma}\left[\frac{\partial \pi_z}{\partial p_w} + \frac{\partial \pi_w}{\partial p_w}\right] - K'(\gamma) = 0$

Substituting the IC constraints on prices from (14)-(15) under a pool for ownership regime ω=3 renders the 3rd and 4th terms zero and the profit-maximizing product choice γ_3^P is given by:

(C2) $\qquad \frac{\partial \pi_z}{\partial \gamma} + \frac{\partial \pi_w}{\partial \gamma} - K'(\gamma) = 0$

Next consider the IC constraints in anticipation of a pool for ownership regime ω=2, given by:

(C3) $\frac{\partial \pi_z}{\partial p_z} + \frac{\partial \pi_w}{\partial p_z} = 0$

$\qquad\qquad \alpha \frac{\partial \pi_z}{\partial p_w} + \frac{\partial \pi_w}{\partial p_w} = 0.$

Substituting (C3) into (C1) gives the marginal profit condition for γ_2^P:

(C4) $\qquad \frac{\partial \pi_2^P}{\partial \gamma} = \frac{\partial \pi_z}{\partial \gamma} + \frac{\partial \pi_w}{\partial \gamma} + \frac{dp_w}{d\gamma}(1-\alpha)\frac{\partial \pi_z}{\partial p_w} - K'(\gamma)$

Evaluating (C4) at γ_3^P from (C2) gives:

(C5) $\frac{\partial \pi_2^P}{\partial \gamma} = \frac{dp_w}{d\gamma}\left[(1-\alpha)\frac{\partial \pi_z}{\partial p_w}\right].$

Table 3 reveals that for quadratic utility, $\frac{dp_w}{d\gamma} < 0$ for all γ under pooling in the regime. Moreover, the bracketed term in (C5) is positive for substitutes and negative for complements. Therefore, the marginal profit for an increase in γ is negative for substitutes, implying that $\gamma_2^P < \gamma_3^P$ for $\gamma > 0$, and positive for complements and therefore $\gamma_2^P > \gamma_3^P$ for $\gamma < 0$. A similar exercise, but where π_w does not enter the pool's objective function, proves part (ii) of the propositions.

To prove (iii), conduct the same exercise substituting into (C1) the IC constraints on prices for the ω=2 regime with no pooling from (9)-(11). It is straightforward to show that this yields:

$$(C6) \qquad \frac{\partial \pi_z}{\partial \gamma} + \frac{\partial \pi_w}{\partial \gamma} + N(1-s)p_2 \left[\frac{dp_z}{d\gamma} \frac{\partial f}{\partial p_z} + \frac{dp_w}{d\gamma} \frac{\partial f}{\partial p_w} \right] - K'(\gamma)$$

And substituting (C2) into (C6) reveals:

$$(C7) \qquad \frac{\partial \pi_2^{NP}}{\partial \gamma} = N(1-s)p_2 \left[\frac{dp_z}{d\gamma} \frac{\partial f}{\partial p_z} + \frac{dp_w}{d\gamma} \frac{\partial f}{\partial p_w} \right],$$

which is positive for quadratic utility, implying that $\gamma_3^P \leq \gamma_2^{NP}$.