Cooperating with the Competition:
Efficient Patent Pooling and the Choice of a New Standard

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Abstract

I examine the private and social efficiency of patent pools in a setting in which owners of intellectual property (IP), are both vertically and horizontally related. The relationship is vertical through the ownership of complementary IP and horizontal in that at least one member owns a competing product. For this hybrid structure – referred to as *overlapping ownership* – I analyze the interplay between two organizational decisions: the standard-setting process in which participants choose a product type (indexed by its differentiation from the current standard), and the subsequent patent pooling decision. Consumers can be better off with patent pooling as a result of lower prices (the complements effect) and greater product variety (the differentiation effect), even when a pool member is also a competitor of the new standard. However, in comparing new product collaborations across ownership regimes, consumers prefer those that admit no overlapping ownership. These results yield insights for antitrust rules promoting efficient IP agreements.

Key words: Intellectual Property, Industrial Organization, Patent Pools, Standards, Antitrust
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1. Introduction

Since the mid-19th century, patent pools have been widely used in almost every sector of the economy for the purpose of overcoming blocking patents and facilitating collaboration of essential inputs for a new standard. But they can also be used to extend market power, thereby making them a subject of antitrust scrutiny. In the United States, for example, antitrust oscillated from viewing patent pools as effectively *per se* legal (in 1902 "the general principle [was] absolute freedom in the use and sale of rights under the patent laws") [1] to *per se* illegal (in 1948 a pool of complementary patents was deemed to illegally "fix prices of…commercially successful devices embodying ...patents") [2]. More recently, antitrust authorities have adopted a balanced approach, in recognizing the pro-competitive effects of pools of complementary and, typically standard-essential patents[3], while remaining cautious of those that admit substitute patents. This has allowed patent pools to reemerge as a dominant mechanism for sharing intellectual property (IP).[4]

The above approach, inspired by Cournot's well-known result on the efficiency of price coordination of complements (1838), ignores two striking features of modern collaborations: Prospective members of newly formed pools often are incumbent firms that produce or supply inputs to products that are substitutes for the pool-supported downstream product. The DVD patent pool, for example (see section 2), comprises patents from technology competitors such as Toshiba and Samsung, with a stake in products that compete with the DVD technology. So, even if the IP included in the pool are not in competition with each other, their owners may be, thereby raising potential antitrust concerns. Second, virtually all modern patent pools follow from standard-setting processes;[5] therefore, anticipation of price coordination through pooling can influence the choice of the standard, as well as its prices.

In this article, I examine the efficiency of patent pooling in an environment that allows for the interplay between the standards process and patent pooling, in which at least one participant has a stake in competing products. Under the latter feature – referred to as *overlapping ownership* – an IP owner of essential patents both supports and competes with a new standard. Therefore, the

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[1] *Bement v. National Harrow Co.,* 186 U.S. 70 (1902).
[2] *United States v. Line Material,* 333 U.S. 287 (1948).
[3] Patents are essential to a standard or product if there are no economic substitutes; that is, anyone implementing the standard would naturally infringe the patents.
[4] According to Clarkson (2003), over $100 billion of sales are generated each year in the United States from products or devices that are based wholly or in part on technologies in patent pools.
[5] However, the reverse is not true. 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 pools of software or related patents and copyrights. See Lin (2002) for a discussion of the relationship between standardization and patent pools in the software industry.

collaborating IP owners are horizontally related in their involvement in competing downstream products, as well as vertically related by nature of their complementary upstream IP. This hybrid structure gives rise to a tension: Coordination of complements promotes efficient pricing, but it can also soften competition between the pooled and non-pooled competing downstream products. The analysis also allows for the interplay between standard-setting and patent pooling in which participants of the standard-setting process choose product type (or degree of differentiation from the current standard), and subsequently, decide whether to set input prices separately or cooperatively through a patent pool. In a simple framework with two IP owners and an incumbent, I ask whether the conventional result regarding the social efficiency of price coordination over separate pricing continues to hold when standard/product choice is endogenous and ownership overlaps.[6]

Two effects of patent pooling are identified: the *complements effect* that typically inspires greater price competition in the downstream market, and the *differentiation effect* or incentive to develop a more distant standard. The former relates to the conventional result: if the competing products are strategic complements then, for a given product type, coordinated pricing of complementary inputs (through patent pools) results in lower downstream prices than would separate pricing of those inputs. While beneficial to consumers, this effect can render pools privately unprofitable, in which case socially efficient pools may not form. This is especially true when one of the members with ownership in competing goods cannot be adequately compensated for its outside losses, due to technological constraints or antitrust restrictions faced by the pool.

In addition to the latter constraints faced by IP owners, the decision to pool depends on the product type they selected at the standard-setting stage. Anticipating greater competition from pooling (complements effect), the IP owners will attempt to soften price competition by selecting a more distant standard from the one currently available (differentiation effect). This ability to choose the standard type makes pooling more likely if the costs of developing a distinct standard are not too high. If costly development renders such a strategy unprofitable, the IP owners will moderate competition by committing not to coordinate input prices through a pool. And, if development costs are so high that only a near substitute to the current standard can be developed, then the incumbent may foreclose new product entry by refusing to license its essential IP. That is, when pooling is an option, the firms can combine standard setting and price coordination to soften price competition by either pooling a relatively distant substitute or committing to separate pricing

[6] In this paper, a standard is defined by a bundle of inputs that gives rise to a particular product; therefore "standard" and "product" are used interchangeably.

of a closer substitute. Although pooling may not always be chosen, the firms are clearly no worse off having the option.

The impact on consumer welfare, in general, depends on consumers' tradeoff between product variety and price competition. For the case of quadratic preferences, for example, consumers are better off when pooling is an option. When a pool member has a stake in an outside competing good, the net effect of the complements effect (that lowers prices for a given standard) and the differentiation effect (that softens price competition), is to lower both prices of the standard and the incumbent's competing product; that is the former effect dominates the latter. Pooling in this extended framework has the effect of redirecting product choice toward greater variety, as well as facilitating efficient coordination of complements. These findings have implications for antitrust policy; in particular, a more permissive policy that encourages efficient collaborations that otherwise might not take place can be socially beneficial when the cost of developing a new standard is sufficient high.

Although price coordination can generate positive social benefits (in both product choices and pricing) given overlapping ownership, the converse is not true: Consumers will be worse off under overlapping ownership relative to independent ownership, given pooling is chosen under both industrial structures. That is, while they are better off from pooling under overlapping ownership, they could be even better off if the pool members were divested of their assets in competing products or, less dramatically, prevented from further integration. Moreover, a pool of complements may not be efficient under overlapping ownership if it is used to facilitate price coordination between competing products, as well among essential IP admitted to the pool.

Section 2 reviews the related literature and offers examples of IP sharing agreements with overlapping ownership. In Section 3, a simple product – pooling – pricing framework is presented. Three organizational decisions are outlined: First the standard-setting process for developing a new product; second the decision to combine the patentees' complementary inputs through a patent pool; and third the pricing game in which the new standard competes with the current product. In Section 4, the benchmark case of an independent incumbent (no overlap) is explored. Section 5 derives the equilibrium under overlapping ownership for the standard-setting, pooling and pricing decisions. The results are then used to inform antitrust policy. Section 6 concludes with a discussion of the predictions and normative implications of the paper and places it in context of the larger debate on the effectiveness of the IP system.

2. Related Literature and Policy Relevance

2.1 Related Literature

The analysis in this paper builds upon the industrial organization literature regarding the efficiency of cooperative agreements, namely patent pools, standards and related strategic alliances. In particular, Kim (2004) and Lerner and Tirole (2004) examine patent pooling by vertically integrated firms. Overlapping ownership is similar in involving integration of an upstream input; however, under vertical integration, the firm's downstream product requires that input; whereas the product owned by the firm with overlap relies on a technology distinct from one that its IP supports. In the former case, the IP owner also produces the downstream pooled product; in the latter, she effectively competes with it.

To get a better sense of this distinction, consider Figure 1. In both panels, an incumbent produces Z_0 that implements standard-essential patent bundle X_0 (provided by competitive suppliers), whereas Firms 1 and 2 own respective patent bundles X_{11} and X_{12}, required for production of the competing downstream product Z_1. The right oval, encompassing X_{11} and X_{12}, in both panels reflect that the IP owners' standard-essential patents are coordinated within a patent pool. Solid lines indicate production relationships along a vertical chain, and the dotted ovals in both panels indicated integrated relationships within a firm. So, for example in panel (a), the incumbent firm is independent from the IP owners of Z_1 and Firm 1 is shown to be integrated along the vertical chain of production from downstream product Z_1 to its input X_{11}. In contrast, in panel (b), Firm 1 is *diagonally* integrated from its exclusive rights to downstream product Z_0 to its upstream input bundle X_{11}, required by a different but competing downstream product.[7,8]

These differences imply distinct effects on prices, pooling incentives and the standard-setting process. In Kim (2004) and Lerner and Tirole (2007) two inefficiencies are identified in the absence of pooling: the complements problem (Cournot (1838), Shapiro (2001)) and raising rivals' costs to non-member selling differentiated versions of the product (Salop and Scheffman (1983)). Kim (2004) shows that a patent pool of essential inputs is efficient in that it internalizes the two externalities, and results in lower downstream prices and reduced incentives to foreclose non-

[7] Alternatively, the incumbent could be the IP owner of the essential input X_0 and Z_0 (produced by competitive firms for symmetry). In that case, the overlap can be interpreted as "horizontal" integration of inputs since Firm 1 owns IP rights on essential patents for two competing standards. In a previous version, Firms 1 and 2 were incumbents of the current standard in that each owned a subset of the X_0 patents in panel(b). In that case, the incentive to pool their patents for the new product is greater when the firms coordinate prices for the current standard than when they do not. This is related to Bernheim and Whinston (1990) in that cooperation in one market can sustain collusive gains in another market, however where the markets are unrelated and the coordination mechanism is very different.

[8] Firm 1 can be reinterpreted as selling its input bundle X_{11} to Firm 2, which then combines it with its IP to produce Z_1 in competition with Firm 1's Z_0, which highlights the horizontal nature of the firms' relationship in Figure 1(b).

integrated downstream firms. In contrast, overlapping ownership puts the entire new standard at risk, rather than versions of the same product offered by firms outside of the pool.[9] Consistent with Kim's findings for vertical integration, the opportunity to pool can reduce the likelihood of foreclosure; however, the mechanism by which pooling becomes more profitable (thereby reducing incentives to foreclose the new standard) is through more efficient pricing and a redirection of standard design toward a weaker substitute for the incumbent's product.[10]

Anticompetitive effects of collaborations between horizontal competitors have also been analyzed in the licensing literature. In particular, Tepperman (2000) examines a situation in which the licensor of a new product and its licensee also produce competing products. He shows that the firms will have an incentive to impose a price restriction (namely, resale price maintenance) in the licensing contract. There, the agreement acts as a price-coordinating device between competitors, particularly when they compete in close substitutes. In contrast, patent pools have efficiency benefits, and so a permissive antitrust policy may be required for close substitutes in order to encourage cooperation among firms with overlap in competing products.

While the standards literature is also relevant, the standard-setting process, as modeled here, is very simple, abstracting from many of the interesting and complex realities of bargaining and coordination explored in the literature. For example, Farrell and Saloner (1988) model delays in standard setting as a war of attrition; Simcoe (2012) empirically analyzes coordination delays in the standard development process; and Farrell and Simcoe (2011) examine consensus rules. Moreover, with perfect information, the concern over nondisclosure of essential patents to the standard-setting organization does not arise here (Rysman and Simcoe (2008)).[11]

Although abstracting from internal and bargaining issues of cooperative agreements, I allow for firm heterogeneity and its role in affecting incentives to join them. In this sense, the paper is more related to Aoki and Nagaoka (2004) who consider stability of pools with heterogeneous members (researchers and vertically integrated firms); in my analysis, the players are heterogeneous in terms of their outside options. Since the outside option is modeled as ownership in a competing product, the framework is also related to Schiff and Aoki (2007), who analyze incentives for pool formation with competing standards. Moreover, standard setting, as modeled here, can be

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[9] See Reisinger and Tarantino (2011), which explores incentives to vertically integrate for suppliers of complementary inputs.

[10] The vertical merger literature is also relevant in that the pool considered here comprises complementary patents. See, for example, Gaudet and Salant (1992) for an analysis of vertical mergers and Church (2002) for a review of the vertical merger literature.

[11] Similarly, there are no opportunities for unanticipated hold-up by IP owners that set high prices after investments are committed, thereby necessitating FRAND (fair and reasonable non-discriminatory licensing) and other pricing rules. For a discussion and analysis of pricing rules in standard-setting organizations, see for example, Swanson and Baumol (2005), Lemley and Shapiro (2013), and Lerner and Tirole (2013).

interpreted as a strategic alliance, such as a research joint venture, in which firms combine their complementary expertise to develop a new product.[12] A related paper by Chen and Ross (2003) shows that two firms, competing in differentiated products, can soften price competition by forming a joint venture around an essential input rather than developing the input separately. It contrasts with the framework here in that neither IP owner can independently develop the standard; therefore the joint venture of a standard-setting organization is necessary for entry of new products. Moreover, the joint venture of pooling can affect decisions at the earlier (standard-setting) and later (pricing) stages.

Finally, the paper builds on analysis of efficient antitrust rules toward patent pools and other IP collaborations (Gilbert (2004, 2011), Shapiro (2003)). In providing a comprehensive review of the history of patent pool cases, Gilbert (2004) identifies those that are socially efficient or anti-competitive according to their vertical or horizontal nature, and the complexities that arise when the collaborations do not fall squarely into either category. Patent pools under overlapping ownership are of that variety, representing a hybrid of vertical and horizontal attributes.[13] I now turn to an example of overlapping innovation in a modern patent pool.

2.3 Policy Relevance and the DVD Patent Pool

Overlapping ownership has been largely dismissed or overlooked in antitrust reviews of recently approved patent pools. In his business review letter to members of the DVD pool, the Assistant Attorney General for the Department of Justice noted that, even with complementary patents, a pool could overextend its reach and "collude on prices outside the scope of the Portfolio license" and restrict competition.[14] That is, he recognized that even if patents in the pool are not in competition with each other, their owners may indeed be active competitors in related products. Nevertheless, the Assistant Attorney General concluded that the pooling agreement is "not likely to

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[12] For analysis of research joint ventures (RJVs), see for example, D'Aspremont and Jacquemin (1988), Kamien, Muller and Zang (1992), Motta (1992), and Scotchmer (1998). The focus of these papers tends to be on the impact of RJVs on R&D activity under various competition environments in the innovation and product markets. In this article, the standard-setting agreement is similar to an RJV, where attention is more on the direction than the level of R&D conducted. Other collaborations such as licensing and cross-licensing are alternative forms of strategic alliances not considered in this paper (e.g., Gallini (1984, 2002), Fershtman and Kamien (1992), Arora et.al. (1995, 2001), Park and Lippoldt (2005), Green and Scotchmer (1995), Branstetter et. al.(2006)).

[13] This article does not address issues of litigation as in Choi (2010) or incentives to patent either before or after entering the patent pool as in Dequiedt and Versaevel (2006), Baron and Pohlmann (2011) and Delcamp (2011). See also Gallini (2011) and Flamm (2012) for a general discussion and case studies. Also related are Merges (1996,1999) and Aoki and Schiff (2008) in their analysis of institutions for coordinating intellectual property rights and related market mechanisms.

[14] Although it was acknowledged that "each of the Licensors is a leading manufacturer of consumer electronics equipment…" the potential anticompetitive effects were not explored. See the business review letter from Joel Klein to Carey R. Ramos (June 10, 1999) regarding the formation of pools for the DVD-Rom and DVD-video formats. See also the *Antitrust Guidelines for Collaborations among Competitors,* issued by the Federal Trade Commission and the U.S. Department of Justice, April 2000.

impede competition… for other products that conform to alternative formats, or in the markets in which DVDs, players and decoders compete."[15]

More generally, antitrust authorities have tolerated, even encouraged, pools among competing firms as long as the they comprise only patents that are deemed to be complementary and essential.[16] The rationale is based on the fact that complements are not in competition with each other and so, in antitrust parlance, combining them in a pool would not harm competition that would have occurred in the absence of the agreement. However, even if the *patents* are not in competition, the *patentees* may be. That is, overlapping ownership effectively turns a patent pool of complementary inputs into a vertical merger between two horizontally related firms, which would typically merit antitrust scrutiny.

An example of overlapping ownership between competing products inside and outside the pool is the DVD-ROM and DVD-video patent pool (DVD6C) formed in 1999. 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. At the time of forming the pool, several members were engaged in vigorous competition as well as alleged anti-competitive behavior. For example, Toshiba and Samsung were strong competitors in the flash drive memory market among others, while being investigated along with Sharp, Hitachi and others by the U.S. Department of Justice and European Commission for price-fixing in the liquid crystal display market from 1999 (when the DVD6C pool formed) to 2006.

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 and related markets. It is the latter variety which 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 pool members previously were or currently are involved: 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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[15] This concern is also noted in Layne-Farrar and Lerner (2011): "firms contributing complementary patents to the standard may be rivals, offering competing products in downstream markets…".

[16] The *U.S. Department of Justice-Federal Trade Commission Guidelines on the Licensing of Patents* (1995, 2007) note that pools of complementary patents "may provide competitive benefits by integrating complementary technologies, reducing transaction costs, clearing blocking positions and avoiding costly infringement litigation."

The 3G Patent Platform Partnership is another example of a collaboration with potential overlapping ownership.[17] In that Partnership, five different radio interface technology standards, approved by the International Telecommunication Union, were designated for use in the 3G systems. While each of the separate and independent Platform Companies were responsible for licensing functions with its own board of directors, an overarching Management Company and Common Administrator were allowed to coordinate shared functions to a limited extent. The responsibilities of the Management Company were administrative in nature (e.g., providing industry-wide market research and analysis and information to third parties), but was "precluded from suggesting royalty rates or other competitively sensitive license terms, or otherwise becoming involved in competitively sensitive functions."[18] Recognizing the potential antitrust implications of this arrangement especially since some participants may have held patents in more than one standard, the Assistant Attorney General cautioned that the licensors and Platform Companies "should establish appropriate firewalls to safeguard against sharing of competitively sensitive information."[19] This is a curious expectation since it would be challenging for a company with overlap to safeguard against using its own proprietary information within its enterprise. Even if one disregards coordination at the mega-pool level, the question of whether overlapping ownership across the five platforms can soften competition nevertheless remains.

Other information-communication technology pools are characterized by some degree of overlap. For example, some members of the Radio Frequency Identification (RFID) 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 DVD3C pool formed in 1998 that supplies products arguably in related markets. 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 several licensors in the DVD pool and Microsoft, which owns Windows Media Audio, a competing audio compression technology.

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[17] The Partnership differed from a patent pool in that the patents were not bundled and the licensors collected the royalties rather than the licensing administrator. (See Balto, 2004, for a discussion of the 3G Patent Platform Partnership.) The five interface technologies were W-CDMA, CDMA2000, TD-CDMA, TDMA-EDGE and DECT under the International Mobil Telecommunications-2000 umbrella standard.

[18] Charles A. James, Assistant Attorney General, Letter to Ky P. Ewing regarding the 3G Patent Platform Partnership, Nov. 12, 2002, Section II. C, p. 5.

[19] *Ibid.* footnote 13.

Although patent pools are less common in biotechnology markets, they are beginning to emerge as a promising mechanism for sharing patents.[20] In addition to pools formed in recent years to facilitate developing countries' access to drugs, MPEG LA has recently announced a for-profit diagnostic genetics patent licensing facility or clearinghouse. This "licensing supermarket" intends to aggregate patent rights; negotiate non-exclusive licenses to diagnostic firms, researchers and labs; allocate royalties to its members; and monitor use for potential infringement. In contrast to technology pools, the diagnostic pool is not developed around a particular standard but appears to be primarily for the purpose of reducing transactions costs to users. An interesting development to watch is whether this alliance will be permitted to include substitutes or be constrained to admit only patents essential to particular diagnostic tests or related products.

Finally, the analysis in this paper extends beyond the IP arena to strategic alliances across a wide range of industries including telecommunications, airlines, automobiles and general manufacturing. There, collaborations between companies that currently compete in the market often develop around new competing products. For example, Star Alliance that comprises United, Air Canada, Lufthansa and other major airlines coordinate reservations and share planes, lounges and other facilities on routes that they also serve separately; the Toyota-Subaru partnership developed a new sports car under respective model names Scion FR-S (Toyota) and BRZ (Subaru) that compete with their current models; and the partnership between Nokia and Microsoft combines complementary phone technology and software to create a global smartphone ecosystem, which competes with their current brand-name products.

Given the prevalence of overlapping ownership in new technology markets, I turn now to the formal analysis. The next section introduces the product-pooling-pricing framework to examine collaborations between patentees for developing and pricing new standards, and antitrust rules encouraging the formation of efficient alliances.

3. The Framework

The analysis begins in a market for a downstream product Z_0 that implements a particular standard. An incumbent firm is a monopolist producer of Z_0 or, equivalently, the exclusive owner of a bundle of essential inputs X_0 that it sells at a royalty r_0 to perfectly competitive producers of Z_0. The costs of producing X_0 are assumed to be 0. Furthermore, it is assumed that there are no additional costs of producing Z_0 so the competitive market price is $p_0 = r_0$.

[20] See Heller and Eisenberg (1998) and van Overwalle (2010) for insightful discussions on pools for biotechnology patents.

An alternative standard that supports a competing product Z_1 can be developed exclusively by two firms, Firms 1 and 2. Implementation of the new standard requires the combination in fixed proportions of *N* essential and identical patents, which Firms 1 and 2 own or are capable of developing. Firm 1 has rights to *sN* of the Z_1 patents, denoted as bundle X_{11}, Firm 2 controls the remaining *1-s* components, denoted by bundle X_{12}. There are no outside uses of the inputs. [21]

3.1 Ownership Regimes

Two ownership regimes, denoted by $k \in \{0, 1\}$ are considered. In the benchmark case ($k = 0$), illustrated in Figure 1(a), the incumbent is unrelated to the two Z_1 input firms. In the second regime ($k = 1$), illustrated in Figure 1(b), Firm 1 is both the incumbent monopolist of Z_0 and patentee of a subset of the standard-essential patents for Z_1. The latter is referred to as *overlapping ownership*.

3.2 Sequence of Organizational Decisions

In the first stage of standard setting, the firms choose product type, indexed by γ: a measure of product differentiation of Z_1 is from the current standard Z_0. The role that γ plays in the demands for the products is described in more detail below; for now, assume lower (higher) values of γ denote more (less) differentiation. Moreover, the cost of developing a standard or product of type $\gamma, K(\gamma)$, is assumed to be continuous in γ with $K'(\gamma) \leq 0$; that is, development costs increase in the "distance" from the current product Z_0. For $k = 0$, the firms are symmetric in their outside option; however, for $k = 1$, they are asymmetric: Firm 1 can choose to simply produce Z_0 as a monopolist by refusing to offer its essential patents for the new standard, whereas Firm 2's outside option at the standard-setting stage is valued at 0.

When outside options are asymmetric as when $k = 1$, Firms 1 and 2 generally will differ in their preferred technologies at the product-development stage. To settle disagreements and achieve consensus, standards organizations may implement concessions or side-payments (Simcoe (2012)). I make the simplifying assumption that side-payments are feasible, both economically and legally, at this stage and at the subsequent pooling stage: [22]

Assumption 1. Lump sum transfers are allowed between Firms 1 and 2 participating in a standards and/or pooling arrangement.

[21] This contrasts with Fershtman and Kamien (1992) where firms can choose between producing one or both complementary components required in production, when cross-licensing is anticipated.
[22] This contrasts with Simcoe (2012), whose analysis of the bargaining process in standard-setting organizations is based on the assumption that side-payments between participants are costly to make (e.g., due to antitrust or transactions costs constraints).

Moreover, the firms are assumed to fully disclose their respective patents and expertise and there are no failures in coordination or bargaining (Rysman and Simcoe (2008)). Therefore, if a new standard or pooling agreement does not emerge, it is due to the collaboration being relatively unprofitable.[23]

If the new standard γ is developed, Firms 1 and 2 then engage in a second organizational decision: whether or not to coordinate input prices through a patent pool. In particular, they can offer separate licenses of their inputs to downstream producers of Z_1 at respective royalties, r_{11} and r_{12}, or license them jointly at the bundled royalty r_b. The decision to pool or price separately is denoted by $\vartheta = P, S$, and depends on the pooling agreement for a given γ, characterized by two parameters: (i) the profit allocation rule, $(\alpha, 1-\alpha)$, where $\alpha \in [0,1]$, is the share of profits to Firm 1 and (ii) the weight $t \in [0,1]$ on the incumbent's outside Z_0 profits in the pool's objective function. Under Assumption 1, the pool design (α, t) will be chosen to maximize joint profits given product type γ, subject to individual participation, technological, and antitrust constraints described below. If it yields greater profits than would be earned under separate pricing, the pooling agreement will be implemented. The tasks of managing the pool, collecting royalties and distributing them back to members are delegated to a central administrator.[24] Therefore, the pooling agreement (α, t) for a given γ, can be thought of as instructions to the patent administrator on managing the pool.

After the pooling decision is made, the Z_0 incumbent and the Z_1 input firms compete in a differentiated Bertrand pricing game. If the latter firms price their inputs separately, then r_0, r_{11} and r_{12} are chosen simultaneously to maximize respective profits; if they pool their inputs, then the incumbent firm and pooling administrator, respectively, choose r_0 and r_b. Firms 1 and 2 sell their inputs at their respective royalties to downstream competitive firms that face no other costs.[25] So, in the case of independently supplied inputs $p_1 = r_{11} + r_{12}$, and $p_1 = r_b$ under a patent pool. Figure 2 illustrates the sequence of the standards, pooling and pricing decisions.

3.3 Consumer Preferences

Consumers are assumed to have identical quasi-linear and concave preferences over quantities of the two goods given by $U(q_0, q_1; \gamma) + m$, where q_i is the quantity of the i^{th} good, i = 0, 1;

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[23] As noted in Section 2, the process by which the firms choose γ abstracts from coordination problems studied in the literature.
[24] Patent pools are managed by a member (as in the DVD pool in which Toshiba manages the pool) or by an independent entity (as in the MPEG pool in which MPEG-LA is the pool administrator). Five of the six patent pools that followed a numeric proportional allocation rule, examined in Layne-Farrar and Lerner (2011), were managed by an independent administrator MPEG-LA.
[25] This assumption, which is equivalent to vertical integration by Firms 1 and 2 for a homogeneous Z_1, abstracts from product differentiation within the new standard in order to focus on product differentiation between the two standards Z_0 and Z_1.

$\gamma \in [0,1]$ is the degree of differentiation between Z_0 and Z_1; and m is expenditure on the numeraire good. The indirect utility function over the prices of the two goods is $V(p_0, p_1; \gamma)$. The following assumption is made:

Assumption 2. The two goods Z_0 and Z_1 are economic substitutes or independent goods (i.e, $\frac{\partial q_i(p_0,p_1;\gamma)}{\partial p_j} \geq 0, i \neq j$)[26] with demands $q_i(p_0, p_1; \gamma) = -\frac{\partial V_i}{\partial p_i}$ that are twice-continuously differentiable in their arguments. Moreover, the absolute value of the own price effect exceeds the cross-price effect on demand: $|\frac{\partial q_i(p_0,p_1;\gamma)}{\partial p_i}| \geq \frac{\partial q_i(p_0,p_1;\gamma)}{\partial p_j}, i \neq j$.

As noted earlier, γ is the index of differentiation or substitutability between the downstream products, and so is related to cross-price effects in demand. A candidate measure for symmetric demands is $\gamma = \left|\frac{\partial q_i}{\partial p_j} / \frac{\partial q_i}{\partial p_i}\right|, i \neq j$. When demands are linear (which arise from quadratic preferences assumed in simulations of the model): $q_1 = a - bp_1 + cp_2$, then $\gamma = c/b$.[27] For this definition of product differentiation, $\gamma \in [0,1]$: the index represents at its minimum and maximum values, respectively, independent and perfectly homogeneous goods.

3.4 Profits under Independent and Overlapping Ownership

In this section, the basic profit relationships at the final pricing stage, conditional on the standards choice γ and pooling decision ϑ, are presented. First note that since the downstream market for products Z_0 and Z_1 are perfectly competitive, the derived demands for the inputs X_0 and X_{1j} in both ownership regimes can be written respectively $q_0 = q_0(p_0, p_1; \gamma)$ and $q_{1j} = q_1(p_0, p_1; \gamma), j = 1,2$, where $p_0 = r_0$ and $p_1 = r_{11} + r_{12}$.

To characterize the profits of Firms 1 and 2 and of the incumbent firm, consider the case in which pooling is not permitted (or it is but the firms have elected not to pool), and so Firms 1 and 2 price their inputs separately. Let $\pi_i(p_1, p_0; \gamma)$ denote industry profits from the sales of Z_i, $i = 0,1$ for product type γ. Then for ownership regime k, profits earned by Firms 1 and 2, $\tilde{\pi}_{1j}$, $j = 1,2$ and the incumbent, $\tilde{\pi}_I$, for $\vartheta = S$ are as follows:

(1) $\tilde{\pi}_{11} = r_{11} q_1(p_1, p_0; \gamma) + k\pi_0(p_1, p_0; \gamma)$

[26] Pooling upstream inputs when downstream products are *complementary* would be socially desirable since coordination would lead to more efficient pricing of both upstream inputs and downstream products. Only the case of substitutes is considered here since it suggests a potential tradeoff between efficient input pricing and potentially anti-competitive downstream pricing.

[27] See Singh and Vives(1984) for analysis of quadratic preferences in differentiated oligopoly games.

(2) $\tilde{\pi}_{12} = r_{12} q_1(p_1, p_0; \gamma)$

(3) $\tilde{\pi}_I = k r_{11} q_1(p_1, p_0; \gamma) + \pi_0(p_1, p_0; \gamma)$.

where $p_0 = r_0$ and $p_1 = r_{11} + r_{12}$.

Alternatively, if pooling is an option and chosen by the firms ($\vartheta = P$), then the pool administrator chooses one price: the price of the bundle of Z_1 inputs (or equivalently the price of the product Z_1). The following antitrust restriction is imposed:

Assumption 3: The pool is allowed to set only prices of the standard-essential patents approved for the pool.

Assumption 3 reflects the current antitrust approach toward patent pools in making illegal the coordination of prices of goods outside of the pool. As the Assistant Attorney General wrote in the business review letter for the MPEG pool: Patent pools must not "collude on prices outside the scope of the Portfolio license".[28] It effectively rules out horizontal mergers and contracts that would allow the firms to set prices of both goods, as in Assumption 3. Later, that assumption is relaxed in order to analyze an alternative, more permissive antitrust rule to contrast with current policy.

Then, given product choice γ and pool design (α, t), the pool administrator will choose p_1 to maximize the joint objective, $\hat{\pi}_J$; moreover, the incumbent (*"I"* or Firm 1 for $k = 1$) will choose p_0 to maximize $\hat{\pi}_I$. These profit relationships for $k \in \{0,1\}$ are:

(4) $\hat{\pi}_J = \pi_1(p_1, p_0; \gamma) + k t \pi_0(p_1, p_0; \gamma)$

(5) $\hat{\pi}_I = k \alpha \pi_1(p_1, p_0; \gamma) + \pi_0(p_1, p_0; \gamma)$.

Expressions for the profit-maximizing pricing decisions are presented below. First, consider the no pooling regime. From (1)-(3), the first-order conditions for equilibrium prices $r_{1j}^S(\gamma)$ firms $j = 1,2$ and downstream price of Z_0, $p_0^S(\gamma)$, given ownership regime, k, product choice γ and pooling agreement (α, t) satisfy:

(6) $q_1(p_0, p_1; \gamma) + r_{11} \frac{\partial q_1(p_0,p_1;\gamma)}{\partial p_1} + k \frac{\partial \pi_0(p_0,p_1;\gamma)}{\partial p_1} = 0$

(7) $q_1(p_0, p_1; \gamma) + r_{12} \frac{\partial q_1(p_0,p_1;\gamma)}{\partial p_1} = 0$

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

(8) $k\, r_{11} \frac{\partial q_1(p_0,p_1;\gamma)}{\partial p_0} + \frac{\partial \pi_0(p_0,p_1;\gamma)}{\partial p_0} = 0.$

Note that (6) and (7) together imply the following condition for the equilibrium price of Z1, $p_1^S(\gamma)$:

(9) $q_1(p_0, p_1; \gamma) + \frac{\partial \pi_1(p_1,p_0;\gamma)}{\partial p_1} + k \frac{\partial \pi_0(p_0,p_1;\gamma)}{\partial p_1} = 0$

Next consider the equilibrium conditions under pooling. From (4)-(5), the equilibrium prices under pooling $p_i^P(\alpha, t, \gamma)$ for products $i = 0,1$ satisfy:

(10) $\frac{\partial \pi_1(p_1,p_0;\gamma)}{\partial p_1} + kt \frac{\partial \pi_0(p_1,p_0;\gamma)}{\partial p_1} = 0$

(11) $k\alpha p_1 \frac{\partial q_1(p_1,p_0;\gamma)}{\partial p_0} + \frac{\partial \pi_0(p_1,p_0;\gamma)}{\partial p_0} = 0.$

The following assumption ensures that the reaction functions under separate pricing in (8)-(9) and under pooling in (10)-(11) yield a unique equilibrium:

Assumption 4. The profit functions from sales of product i, $\pi_i(p_1, p_0; \gamma), i = 0,1$ *are concave in their respective prices* p_i *and the firms' profit functions in (1)-(5) satisfy the following conditions:*

(a) $\frac{\partial^2 \hat{\pi}_J}{\partial p_1^2} \frac{\partial^2 \hat{\pi}_I}{\partial p_0^2} - \frac{\partial^2 \hat{\pi}_I}{\partial p_0 \partial p_1} \frac{\partial^2 \hat{\pi}_J}{\partial p_1 \partial p_0} > 0$ *if the firms coordinate their prices through a pool or*

(b) $\frac{\partial \tilde{y}}{\partial p_1} \frac{\partial^2 \tilde{\pi}_I}{\partial p_0^2} - \frac{\partial^2 \tilde{\pi}_I}{\partial p_0 \partial p_1} \frac{\partial \tilde{y}}{\partial p_0} > 0$*, if they price their inputs separately,*

where $\tilde{y} = q_1(p_0, p_1; \gamma) + \frac{\partial \pi_1(p_1,p_0;\gamma)}{\partial p_1} + k \frac{\partial \pi_0(p_0,p_1;\gamma)}{\partial p_1}$. [29]

Given the above framework, the equilibrium for a particular ownership regime is characterized by the choices at each of the three stages: (i) product choice γ, (ii) pool agreement (α, t) and decision $\vartheta = P, S$ for a given γ, and (iii) prices (p_1, p_0) for a given (α, t), ϑ, and γ. They are derived and analyzed in the following sections for the two ownership regimes. I turn first to the case of independent ownership ($k = 0$); overlapping ownership ($k = 1$) follows in Section 5.

[29] The conditions in Assumption 4(a)-(b) are more complex for $k = 1$ than $k = 0$ because the profits in (4)-(5) reflect more than one product. Concavity of the profits, $\pi_0(p_1, p_0; \gamma)$ and $\pi_1(p_1, p_0; \gamma)$ does not guarantee concavity of the multi-product profits of the incumbent when ownership is overlapping.

4. No Overlap in Ownership between Competing Standards/Products

In this section, the standards-pooling-pricing equilibrium is analyzed for the case in which the incumbent monopolist of Z_0 is independent from the patentees of the Z_1 inputs. All the analysis in this section applies to this ownership regimes so the notation $k = 0$ is suppressed.

4.1 The Pricing Game for k = 0

Beginning with the last stage – the pricing game – the equilibrium prices (p_1, p_0) are derived, given the product choice γ and the pooling decision (α, t) and pooling decision ϑ from the previous stages. For $\vartheta = P$, (4) and (5) indicate that neither α nor t enters the profit objectives of the incumbent and pooling firms and, therefore, do not affect equilibrium prices. In particular, the value of pool members' outside options at the pricing stage is 0 so the IP owners will be willing to contribute their inputs to the pool for any $\alpha \in [0,1]$. Moreover, the incumbent is indifferent among allocation rules since it does not receive a share of the pool profits, nor do Firms 1 and 2 receive profits from sales of Z_0. Therefore, the pooling administrator and the incumbent choose respective prices of Z_1 and Z_0 to maximize profits generated from that good.

Equilibrium prices for the downstream products when inputs are priced separately are given by conditions (8)-(9) for $k = 0$. Under pooling, the equilibrium prices are given by (10)-(11). Let $p_i^{\vartheta}(\gamma)$ be the equilibrium price of good Z_i, $i = 0,1$, product type γ and pooling decision ϑ. Then:

<u>Proposition 1:</u> *Given Assumptions 2-4 and k =0, if* $\frac{\partial^2 \pi_i}{\partial p_i \partial p_j} \geq 0, i \neq j,$ *then* $p_i^S(\gamma) \geq p_i^P(\gamma)$.
Proof in the Appendix.

Proposition 1 states that for strategic complements, equilibrium prices of Z_0 and Z_1 will necessarily be lower under pooling than under separate pricing, for a given product type γ. This result is consistent with Schiff and Aoki (2007), as well as with the well-known efficiency result on price coordination of complements, reinforced by increased competition from an outside substitute.

4.2 Pooling Decision

In this section, the decision by Firms 1 and 2 to form a pool is analyzed. Let $v_j^S(\gamma) = \tilde{\pi}_j(p_0^S(\gamma), p_1^S(\gamma); \gamma)$ be the equilibrium profits of Firm *j* under separate pricing *j*=1,2 and $v_1^P(\alpha, \gamma) = \alpha\pi_1(p_0^P(\gamma), p_1^P(\gamma); \gamma)$ and $v_2^P(\alpha, \gamma) = \pi_1(p_0^P(\gamma), p_1^P(\gamma); \gamma) - v_1^P(\alpha, \gamma)$ under pooling.

Furthermore, denote $\mathcal{V}^{\vartheta}(\gamma) = \sum_j v_j^{\vartheta}(\gamma), j = 1,2$. The alternative to pooling is to price the inputs separately, and so the participation constraints for the IP owners are given by:

$$(12) \qquad v_j^P(\alpha, \gamma) - v_j^S(\gamma) \geq 0 \qquad for\ j = 1,2.$$

Then, a necessary condition for the firms to agree to pool their patents is:

$$(13) \qquad \mathcal{V}^P(\gamma) - \mathcal{V}^S(\gamma) \geq 0.$$

The inequality in (13) is also sufficient for pooling to privately dominate separate pricing under Assumption 1, since transfers can be made to satisfy the individual constraints in (12) for any allocation rule α. More generally, the pool design decision (α, t) is not relevant for ownership regime $k = 0$: α for reasons given above and t because pooling firms care only about profits earned in the pool.[30]

It is possible that (13) may not be satisfied for some γ, especially for high values in which Z_0 and Z_1 are close substitutes. In particular, there may exist a critical value $\bar{\gamma} < 1$ such that

$$(14) \qquad \mathcal{V}^S(\gamma) \geq \mathcal{V}^P(\gamma) \text{ for } \gamma \in [\bar{\gamma}, 1].$$

That is, if $\bar{\gamma}$ exists, then for $\gamma \geq \bar{\gamma}$, pooling will be unprofitable for strong substitutes. This situation is illustrated in Figure 3. The intuition follows from Proposition 1, which states that for strategic complements, equilibrium downstream prices will be no higher under a pool than under uncoordinated pricing. While pooling facilitates the efficient pricing of complementary components, it also induces a price reaction from Z_0, thereby offsetting at least some of the gains from a pool (Schiff and Aoki, 2007). The latter effect will be more acute, the less differentiated are the downstream products. In that case, the IP owners may be discouraged from engaging in price coordination that could benefit consumers.

To see this more formally, first note that for $\gamma = 0$ (i.e., Z_0 and Z_1 are independent), profits under a pool exceed those under no pooling since it solves the complements problem; therefore, $\mathcal{V}^P(0) > \mathcal{V}^S(0)$. At the other extreme in which the two products are perfect substitutes ($\gamma = 1$), then $\mathcal{V}^P(1) = \mathcal{V}^S(1)$ for Bertrand firms. Although this information is not sufficient to ensure that the curves will cross in order to yield a critical value $\bar{\gamma}$ in general, $\bar{\gamma}$ is shown to exist for quadratic

[30] The latter assumption may seem natural to make but, in fact, the pooling firms may wish to set a positive weight on the incumbent's profits ($t > 0$) in their objective function in (4) if unconstrained to do so. However, this strategy is ruled out by the assumption that the incumbent cannot observe the pool agreement, or alternatively, by antitrust policy that would view such a strategy as anticompetitive. Therefore, equilibrium prices do not depend on either t or α.

preferences in section 4.4. Before reviewing that example, the initial stage of the framework – the standards process – is considered.

4.3 Standards Decision: Product Choice

In this section, Firms 1 and 2 coordinate on product selection of Z_1 through a simple standard-setting process. Product type, designated by γ, is chosen jointly by Firms 1 and 2 with exclusive rights to their respective essential inputs, in anticipation of future pooling and pricing decisions. As noted earlier, the joint cost of developing a new product or standard is given by K(γ), which is continuous and twice-differential with K'(γ) < 0, implying that the cost increases in the degree of differentiation from the current product Z_0.

To identify the profit-maximizing product choice, initially assume that if pooling is an option, it is always chosen; otherwise the firms price their inputs separately for all γ. Then, the profit-maximizing γ for $\vartheta = P, S$ satisfies:

(15) $\gamma^{\vartheta} = argmax\left[\mathcal{V}^{\vartheta}(\gamma) - K(\gamma)\right],\ \vartheta = P, S.$

Without placing further restrictions on $\left[\mathcal{V}^{\vartheta}(\gamma) - K(\gamma)\right]$, an interior maximum cannot be guaranteed.[31] So, the problem is solved for quadratic preferences in the next section. To better motivate that example, consider the solutions to (15) arising from quadratic preferences in which $\gamma^P < \gamma^S$. That is, the most profitable standard when firms are assumed to pool for all γ, is more differentiated than the product type chosen when pooling is not an available option. However, pooling may not always be profitable when it is available, in particular, when $\gamma^P \geq \bar{\gamma}$, where $\bar{\gamma}$ is defined in (14) above. Therefore, in order to derive the optimal product choice, γ^*, under endogenous pooling requires a second step. Let $\tilde{\mathcal{V}}(\gamma)$ be defined as $\mathcal{V}^P(\gamma)$ for $\gamma \leq \bar{\gamma}$ and $\mathcal{V}^S(\gamma)$ for $\gamma > \bar{\gamma}$, and $\gamma^* = argmax[\tilde{\mathcal{V}}(\gamma) - K(\gamma)]$. Since he derivative of $\tilde{\mathcal{V}}(\gamma)$ generally will be discontinuous at $\gamma = \bar{\gamma}$, the optimal product choice γ^* can be characterized as follows:

(16)
$$\gamma^* = \begin{cases} \gamma^P \text{ if } \text{(a) } \gamma^S \leq \bar{\gamma} \text{ or} \\ \qquad \text{(b) } \gamma^P < \bar{\gamma} < \gamma^S \text{ and } \tilde{\mathcal{V}}(\gamma^P) - K(\gamma^P) \geq \tilde{\mathcal{V}}(\gamma^S) - K(\gamma^S) \\ \\ \gamma^S \text{ if } \text{(c) } \gamma^P \geq \bar{\gamma} \text{ or} \\ \qquad \text{(d) } \gamma^P < \bar{\gamma} < \gamma^S \text{ and } \tilde{\mathcal{V}}(\gamma^P) - K(\gamma^P) < \tilde{\mathcal{V}}(\gamma^S) - K(\gamma^S) \end{cases}$$

where γ^P and γ^S solve (15).

[31] If $V^{\vartheta}(\gamma)$ is convex in γ, then convexity of K(γ) will be necessary for an interior maximum.

Before turning to an illustration of the framework, it is useful to identify the primary tradeoff between two effects – *complements* and *differentiation* – that impact on the prices, pooling and product equilibrium choices. Under the *complements effect,* price coordination results in lower prices of both downstream products relative to separate pricing, conditional on a given product type γ (Proposition 1). If the new product type is too close to the incumbent's product, however, the patentees will set their prices separately since, by committing not to pool, they can maintain higher prices in the market. Then, when standard-setting is endogenous and cooperating firms anticipate pooling, they will attempt to soften the expected price competition by choosing a more distant substitute from the current standard; hence, the *differentiation effect.* As will be seen in the example below, the latter effect can overwhelm the former, for sufficiently low development costs, such that the equilibrium price of the competing product can be higher under pooling.

4.4 Application of Quadratic Preferences

In this section consumer preferences are represented by the quadratic utility below, where $\gamma \in [0,1]$ is a parameter that measures the degree of differentiation between the products Z_0 and Z_1:

$$(17) \qquad U = q_0 + q_1 - ½\,(q_0^2 + q_1^2) - \gamma q_0 q_1 .$$

Maximizing the expression in (17), net of expenditures, with respect to q_0 and q_1 yields the following symmetric demand system:

$$(18) \qquad q_i = \frac{1-\gamma-p_i+\gamma p_j}{1-\gamma^2} \quad for\ i,j = 0,1.$$ [32]

For illustration purposes, symmetry is imposed on the demands and the pool allocation rule is given by α = ½ . The equilibrium prices of the downstream goods for $k = 0$ that solve (8)-(11) are presented in the first row of Table 3. Note that for economic substitutes ($\gamma > 0$), the downstream prices are also strategic complements,[33] implying lower prices under pooling relative to uncoordinated pricing, for a given γ (Proposition 1).

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[32] Note that the range of products represented by this utility function extends from perfect substitutes γ = 1 to perfect complements at γ = -1). Not represented is the case of an improvement that replaces Z_0, which would require a second dimension in product space. See for example, Eswaran and Gallini (1996) where patent policy is analyzed for both product differentiation and improvements.
[33] For quadratic utility, $\partial^2 q_1/\partial p_1 \partial p_0 = \partial^2 q_0/\partial p_0 \partial p_1 = 0$, which implies $\partial^2 \pi_1/\partial p_1 \partial p_0 = \partial q_1/\partial p_0$ and $\partial^2 \pi_0/\partial p_1 \partial p_0 = \partial q_0/\partial p_1$; that is, economic substitutes imply strategic complements.

Next consider the pooling decision. Derivation of the relationship in (15) for symmetric demands in (18) reveals that pool profits decline in γ more rapidly than non-pool profits, resulting in $\bar{\gamma} = .77$. The profit gains from pooling relative to no pooling are illustrated by the higher curve in Figure 4, which intersects the γ axis at $\bar{\gamma} = .77$. For strong substitutes, the downward pressure on the price of Z_0 overwhelms the efficiency gain from pooling so the firms choose to price separately.

Finally, to compare the standard/product choice decision under pooling and no pooling, the following specification of development costs, declining and convex in γ, is adopted:

(19) $K(\gamma) = a(1-\gamma)^2$,

where a indexes the research costs of differentiation.

Table 4(a) presents the simulation results for $a \in \{.2,.4,.6,.8,1\}$. First note that $\gamma^P \leq \gamma^S$ in all cases, consistent with the general discussion above. For relatively low costs of developing a differentiated standard ($a \leq .4$), $\gamma^S < \bar{\gamma}$ and so from (16), $\gamma^* = \gamma^P$; that is, the firms choose a product type that is subsequently supported by pooling. For high costs of differentiation ($a \geq .8$), $\gamma^P \geq \bar{\gamma}$ and a closer substitute is chosen; that is, the inputs are priced separately and so $\gamma^* = \gamma^S$. For the intermediate case of $a = .6$, $\gamma^P < \bar{\gamma} < \gamma^S$ and $\gamma^* = \gamma^S$ since the cost of developing a differentiated substitute overwhelms the benefits from coordinated pricing.

This example illustrates the full equilibrium of the standards-pooling-pricing game when the incumbent does not have a stake in the new standard. Note that if pooling is possible and the firms agree to collaborate, then the new standard will be at least as differentiated from the current product than if pooling were not an option. The reason for this *differentiation effect*, as noted earlier is to offset the expected increase in price competition from pooling for a given γ (*complements effect* under Proposition 1). In trading off the two effects, the patentees choose pooling of a distant substitute in equilibrium for relative low development costs ($a \leq .4$); otherwise, they opt out of pooling in order to maintain higher prices on a relatively close substitute. The case of $a = .2$ merits further consideration. There, the differentiation effect entirely offsets the complements effect for the incumbent good, resulting in a (slight) increase in its price under pooling relative to separate pricing. That is, when standard-setting is endogenous, the price of the competing good can be higher under patent pooling in equilibrium.[34]

[34] Nevertheless, consumers are better off under pooling because the new standard's price is lower and they value product differentiation. In fact, consumer utility can be shown to increase for all a in this example, but this may not be true in general if, for example, consumers value price competition more highly than product differentiation.

In the next section the ownership structure is altered to allow the incumbent firm to be a co-developer of the new standard: the case of $k = 1$.

5. Overlapping Ownership between Competing Standards

When a patentee of the new standard is also the incumbent of the current competing product ($k = 1$), the incentives to collaborate, both on the standard and on prices, are altered. Prices will differ from the case of $k = 0$ since the incumbent (also Firm 1) will internalize the impact of its price decision on the profits it earns from the new standard, whether it pools its inputs with Firm 2 or not. Moreover, overlapping ownership reinforces the disincentive to pool relative to the case of independent ownership of Z_0 since, in making the market more competitive, pooling compromises the profits earned on Firm 1's outside competing good. This is illustrated in Figure 4 for quadratic preferences by the net profits from pooling when $k = 1$ (lower curve),[35] which includes the loss in Z_0 profits from increased competition and are, therefore, lower than for $k = 0$. In this case, the critical value $\bar{\gamma}$ above which pooling is not profitable, is lower under overlapping than independent ownership. This in turn leads to a different standard choice from the $k = 0$ case, with the possibility that the firm with overlap will choose not to contribute to the new standard and, therefore, block its entry. To show these effects more formally, I turn now to the standards-pooling-pricing game under overlapping ownership.

5.1 Pricing Game

As in the benchmark case, the equilibrium prices of the differentiated Bertrand game, following the product choice γ and the pooling decisions ϑ and (α, t), are derived. As noted above, when Firm 1 is also the incumbent, it will internalize the impact of increasing the price of its current product on the profits from sales of the new standard. However, in contrast to the S regime where it values the latter effect at its input price r_{11}, under a pool it is valued at the profits share αp_1. Moreover, the pool may wish to take into account the impact of the collective pricing decision on profits generated from sales of its members' competing goods.

From (8)-(9) and (10)-(11), the equilibrium prices for $k = 1$ can be derived. Denote the equilibrium downstream prices under coordinated (pooling) and uncoordinated (separate) pricing, respectively, by $p_i^P(\alpha, t, \gamma)$ and $p_i^S(\gamma)$, for $i = 0,1$, product type γ and pool agreement (α, t). Note

[35] For direct comparison with $k = 0$, the profits for $k = 1$ in Figure 4 are derived under a pool agreement $(\alpha, t) = (0,0)$, similar to the situation in $k = 0$ in which both the incumbent's share of pool profits and the weight on the its outside profits in the pool objective equal 0.

that, in contrast to $k = 0$, equilibrium downstream prices under pooling depend on the allocation rule α and the weight given on the incumbent's outside competing good t. Then, the following result obtains:

Proposition 2: *Under Assumptions 2-4, if the downstream products are economic substitutes and their prices strategic complements then for $k = 1$, $\alpha \leq ½$ is a sufficient condition for pooling to result in lower prices of both products.*[36]
Proof in the Appendix.

The proof of Proposition 2 reveals that for strategic complements, pooling of the Z_1 inputs necessarily reduces prices of both downstream products, for new product type γ, if Firm 1's share of the Z_1 profits under pooling is no greater than under separate pricing. In the latter case that share is at least ½, so a share no greater than ½ under the pool ensures lower prices for both the new and current standards.[37]

To relate Proposition 2 to common practice by pools, suppose the allocation scheme is a numeric proportional allocation rule in which a firm's profit share is based on its proportion of total patents contributed to the pool. In particular, if $\alpha = s$, the incumbent with a majority patent contribution may have the incentive to increase the price of its competing product in order to soften competition. But this cross-price effect would be present even if the patents were not pooled because Firm 1 would control prices of Z_0 and its essential inputs for Z_1. As the Proposition implies, if $s \leq ½$, then the value of each additional unit of Z_1 will be lower under pooling than separate pricing; therefore, the incumbent will have less incentive to increase the price of Z_0 in order to enhance the demand for Z_1. Reinforcing this effect is the reduction in the marginal profits on Z_0 when the price of Z_1 falls under a pool, thereby reducing the price of Z_0 further.

While pooling can lead to lower prices compared to separate pricing, those prices will increase in both α and t – the terms of the pooling agreement – as stated below.

[36] It should be noted that the prices are derived under the assumption that the participation constraints are satisfied. Although Firm 2 has no outside option at this stage, Firm 1 does: it could raise the price of its essential input sufficiently high under separate pricing to make Z_1 undesirable. As will be shown later, if Firm 1 has the incentive to hold-up the new standard at the pricing stage, it will have had the incentive to do so earlier at the standards or product development stage. Foreclosure is discussed further in Section 5.4.

[37] Note that $\alpha \leq ½$ is a sufficient condition so prices can fall even when Firm 1 is the incumbent and dominant in the pool.

<u>*Proposition 3:*</u> *Let Assumptions 2-4 hold and equilibrium pool prices* $p_i^P(\alpha, t, \gamma), i = 0,1$ *satisfying (10)-(11) be continuous in* α *and t. If the prices of* Z_0 *and* Z_1 *are strategic complements, then* $\frac{dp_i^P}{d\alpha} \geq 0$ *and* $\frac{dp_i^P}{dt} \geq 0$. Proof in the Appendix.

The comparative statics result in the proposition is intuitive. With an increase in α and *t*, the incumbent and pool administrator internalize the positive externality from increasing their respective prices on profits earned on the pooled and competing product. Finally, the following proposition compares equilibrium prices for overlapping and independent ownership.

<u>*Proposition 4:*</u> *Under Assumptions 2-4, if the prices of the downstream substitute products are strategic complements then for k = 1,* $p_i^P(\gamma)|_{k=0} \leq p_i^P(\alpha, t, \gamma)|_{k=1}$ *and* $p_i^S(\gamma)|_{k=0} \leq p_i^S(\gamma)|_{k=1}$ *for i=0, 1.* Proof in the Appendix.

Proposition 4 states that prices of downstream products, for a given γ, are lower when Z_0 is owned by an outside firm than by a member of the pool. Hence, while consumers may prefer a pool to uncoordinated pricing for a given ownership regime, as revealed by Propositions 1 and 2, they are better off when patentees do not have a stake in competing goods.

5.2 When does it pay to join a patent pool?

Section 4 indicates that for $k = 0$, a pool of complementary patents may not be profitable if the product it supports is a close substitute to the current standard. Price competition from efficient pricing of the complementary inputs elicits a price response from the incumbent that can offset, at least partially, the benefits from collaboration. Consequently efficient pools may not form. This disincentive effect on pool formation is reinforced when $k = 1$ since Firm 1, also as the incumbent, must be compensated for its loss in Z_0 profits, and that loss will be more acute for closer substitutes.

There is another important difference between $k = 0$ and $k = 1$. In the former case, neither *t* nor α enters the equilibrium pricing, pooling or product choices. In contrast, the terms of the pooling agreement matter when ownership overlaps. In setting the price of the outside good, the incumbent (also Firm 1) takes into account the impact of its choice on its share of profits from the new standard. Therefore, α will have efficiency implications for equilibrium prices, in its effect on incentives to pool, and on the firms' choice of the standard/product type. Moreover, pool members may take into account profits earned by its members on competing products with a weight of $t > 0$, even when it is prohibited from directly setting p_0 by Assumption 3. That is, Firms 1 and 2 will want to choose a pooling agreement (α, t) that maximizes their collective profits (under Assumption 1), subject to antitrust or transactions cost constraints. The latter constraints are identified below.

Constraints on the Pooling Agreement under Overlapping Ownership

Assumption 3 prohibits the pool from setting prices of both Z_0 and Z_1. For $k = 0$, this effectively rules out horizontal collusion between the incumbent and Z_1 input firms. However, if one of the pool members is also the incumbent, then complete separation between the pricing of Z_0 and Z_1 is more difficult to enforce. That is, even if the pool administrator and the incumbent (also Firm 1) independently set their respective prices of the Z_0 and Z_1 inputs, Firm 1 will want to internalize the impact of its choice of p_0 on its profits earned from the pool. Similarly, the pool may wish to take into account the effect of p_1 on its members' total profits, including those earned outside the pool. Recall that Proposition 3 states that, in doing so, equilibrium prices will be higher the greater is the incumbent's weight on pool profits (that is, the larger is α), and the greater the pool's weight on profits of the outside competing good (that is, the larger is t).

Antitrust authorities generally will want to restrict patent pools from adopting strategies that reduce competition, relative to a no-pooling environment. Recall that the Assistant Attorney General expected participants with overlap in the 3G Patent Platform agreement to "establish appropriate firewalls to safeguard against sharing of competitively sensitive information". Notwithstanding the difficulty in enforcing such a restriction, it nevertheless indicates a concern that arises when pool members are involved in competing products. To reflect this concern, the following antitrust constraint is introduced:

<u>Firewall Restriction (FR):</u> *The pool is restricted from incorporating information on profits of competing products when setting the royalty for the new standard (or equivalently the price of the new product implementing the standard). That is, $t = 0$.*[38]

In addition to *FR*, a constraint may be imposed on the allocation share α, but for technological rather than antitrust reasons. Indeed, the most common rule observed in modern pools is the numeric proportional rule in which profits are allocated according to the share of patents

[38] The *FR* constraint may seem at odds with Assumption 1 but, even if the *FR* constraint were strengthened to rule out lump sum transfers (and set $t = 0$), then this would reinforce the above results in that the range of γ for profitable pooling would be narrowed.

contributed to the pool (s and 1-s) (Layne-Farrar and Lerner (2011)).[39] The proportional rule does not arise naturally in this model. Rather, it would be best for the pool to make the firm with overlap the residual claimant, while allocating to the other member a payment that reflects its patent contributions. However, the latter rule may not be so attractive if transactions costs of verifying relative patent values are prohibitively high. Even with its shortcomings, a rule based on patent shares is among the easiest to administer, as reflected by its common implementation.

Alternatively, if both pools members had a stake in outside competing products, then $\alpha < 1$ may very well characterize the best allocation rule. Finally, introduction of moral hazard into the framework could generate an allocation rule in which both firms received a positive share of profits if, for example, effort by both firms required to enhance the value of the pool's bundled output increased in a firm's patent contributions. If effort levels were not verifiable, and therefore not contractible, then both firms would need a share of the profits to incur positive levels of effort.[40] These technological constraints on the problem are captured in the restriction below.

Transactions Costs Restriction (TR): The pool is exogenously constrained to set an allocation rule $\alpha < 1$ *for all* γ.

Let *FR* and *TR* take on the values 1 or 0, indicating whether they are binding or not. Then, it is intuitive that under Assumption 1, if *FR* = 0 then $t = 1$ will maximize the firms' joint profits; otherwise, it is constrained at $t = 0$ for all γ.[41] Similarly, if *TR* = 0, then Firm 1 will be made the residual claimant ($\alpha = 1$) for all γ; otherwise it is constrained at some exogenously determined value for all γ. In this set-up, the pooling agreement (α, t) is assumed to be independent of γ, in which case it can be treated conveniently as a parameter that indexes the constraint environment (*FR*, *TR*).

[39] Layne-Farrar and Lerner (2008) report that the numeric proportional rule has been used in six of the nine pools examined.

[40] To see that α =1 would not be jointly optimal in this case, suppose that $t = 1$ and the *ex post* effort would add to the value of the pools by some amount $F(e_1, e_2)$ and effort costs were given by se_1 and (1-s)e_2, where s is the share of patents by firm 1. So joint profits for a product type and allocation rule (α, γ) are given by $\pi_0(p_1(\alpha,\gamma), p_2(\alpha,\gamma); \gamma) + \pi_1(p_1(\alpha,\gamma), p_2(\alpha,\gamma); \gamma) + F\big(e_1(\alpha,\gamma), e_2(\alpha,\gamma)\big)$ $-se_1(\alpha,\gamma) - (1-s)e_2(\alpha,\gamma)$. Now suppose the pool members chose the allocation rule α upfront, accounting for the impact it will have on prices and effort levels. Prices would be given by (10)-(11), and individually optimal effort levels by: $\alpha \frac{\partial F}{\partial e_1} = s$ and $(1-\alpha)\frac{\partial F}{\partial e_2} = (1-s)$. Then, the first-order condition of joint profits with respect to α after invoking the envelope theorem and evaluating it at $\alpha = 1$, reduces to $\frac{\partial F}{\partial e_2}\frac{de_2}{d\alpha} < 0$. This establishes that joint profits could be improved by reducing α; that is, not making either firm a residual claimant of the pool. See Neary and Winter (1995) for related analysis.

[41] The see this, maximize $\pi_0(p_1^P(\alpha,t,\gamma), p_0^P(\alpha,t,\gamma),\gamma) + \pi_1(p_1^P(\alpha,t,\gamma), p_0^P(\alpha,t,\gamma),\gamma)$ with respect to t (follow a similar approach for α). Then, employing the envelope theorem yields $(1-t)\frac{\partial \pi_0}{\partial p_1}\frac{dp_1^P}{dt} + (1-\alpha)\frac{\partial \pi_1}{\partial p_0}\frac{dp_0^P}{dt} \geq 0$ for all t and α since $\frac{dp_i^P}{dt} \geq 0$ by Proposition 3 and the fact that Z_0 and Z_1 are economic substitutes.

An important special case is *FR* = *TR* = 0 in which Firm 1 is made the residual claimant and the pool maximizes *total* profits of its members. That is, (α, t) = (1,1). In this case, the firms can achieve first-best monopoly profits even if Firm 1 is constrained to set only p_0 and the pool only p_1 as dictated by Assumption 3. That is, when the incumbent and pool administrator internalize the impact of their respective prices on profits of the other downstream product, Assumption 3 is rendered ineffective. This unconstrained outcome is referred to as *full coordination,* in contrast to *limited coordination* which arises when either *FR* or *TR* binds.

Given the pooling agreement that arises from the (*FR, TR*) constraints, the next problem is to determine whether Firms 1 and 2, in fact, will want to participate in the collaboration. Let $v_j^S(\gamma)$ and $v_j^P(\alpha, t, \gamma)$ denote firm *j*'s total profits from sales of all its goods under uncoordinated and coordinated pricing, respectively. The notation *k* = 1 is suppressed, but it is important to keep in mind that the expressions below differ from the parallel expressions for *k* = 0 in (12) and (13). Then, the participation constraints for Firms 1 and 2 to join the pool are given by:

(20) $$v_j^P(\alpha, t, \gamma) - v_j^S(\gamma) \geq 0 \qquad for\ j = 1,2.$$

Given appropriate transfers allowed by Assumption 1, a pool will be collectively and individually profitable if:

(21) $$\mathcal{V}^P(\alpha, t, \gamma) \ - \ \mathcal{V}^S(\gamma) \ \geq \ 0,$$

where $\mathcal{V}^P(\alpha, t, \gamma)$and $\mathcal{V}^S(\gamma)$, are, respectively, the sum of the firms' total equilibrium profits in (20) under pooling and separate pricing.

Under full coordination, pooling is a mechanism for achieving maximum profits in the industry, so it will always be chosen when (*FR*, *TR*) = (0,0). However, for (*FR, TR*) ≠ (0,0), an incumbent firm with ownership in both the current product and new standard may not have the incentive to participate in the pool if the resulting downstream product Z_1 is sufficiently close to Z_0. That is, a critical value $\bar{\gamma}$ such that $\mathcal{V}^S(\alpha, t, \gamma) \geq \mathcal{V}^P(\gamma)$ for $\gamma \in [\bar{\gamma}, 1]$ may exist, rendering pooling unprofitable for strong substitutes.

As before, $\bar{\gamma}$ is not derived in general, but a unique critical value is shown to exist for quadratic preferences in (17). Toward motivating that example, it is assumed for the remainder of this section that a unique $\bar{\gamma}$ exists. The intuition for the existence of $\bar{\gamma}$, as noted earlier, is even more persuasive than for *k* = 0: By increasing competition in the market, pooling compromises Firm 1's outside profits beyond the benefits received from efficient pricing. Under separate pricing, Firm 1 is able to control both prices of Z_0 and its share of the standard-essential patents for Z_1. As γ increases (i.e., the products become more homogeneous), the incumbent is able to set the price of its inputs sufficiently high to foreclose Z_1 and guarantee profits no less than those under a monopoly in Z_0. In contrast, when it joins a pool, it delegates pricing authority to the collective (pool administrator); that is, under pooling, the incumbent has both ownership and control of Z_0 but only ownership of its essential input for Z_1. Since price competition will be more aggressive under pooling, relative to no pooling, the incumbent's profits can fall below those under separate pricing.

These conjectures (supported for quadratic preferences below) parallel those found in Aoki and Nagaoka (2004) and Layne-Farrar and Lerner (2011) for heterogeneous pool members. There, heterogeneity is defined by productive activity *inside* the pool (e.g., research-only or vertically integrated firms), or by the value of their patent contributions. They predict that, due to this potential instability from heterogeneity, pools will tend to attract patentees that are symmetric in their activities or patent contributions *inside* the pool. In contrast, firms here differ according to their ownership in *outside*, competing products but with similar effects: Pooling is more likely to occur when neither firm has a stake in *outside* goods, as when $k = 0$, than when firms are asymmetric in their outside ownership, as for $k = 1$.[42]

In the latter case – when an IP owner is also a competitor of the new standard – pools may not form even if members are symmetric inside the pool. Indeed, the firm with overlap is asymmetric in its contributions to the pool: in internalizing its outside price effect on the demand for the new standard, it generates higher profits for the pool. But, as long as *ex ante* transfers are allowed, as in Assumption 1, the firm can be awarded for its value added. The problem arises when the increase in pool profits is not sufficient to compensate Firm 1 for its *asymmetric losses* in Z_0. For example, if *TR* binds and Firm 1 cannot be made the residual claimant of the pool, then the price effect will be only partially internalized. And so, the total profit generated in the market (for Z_0 and Z_1) under pooling can fall short of what could be earned collectively under separate pricing, especially for strong substitutes. By Proposition 3, as the profit share of Firm 1 increases, the joint profits generated from pooling increases and the pooling outcome approaches full monopoly. This suggests

[42] Another case of symmetry is where firms have joint (and pooled) ownership in the current competing standard. In a previous version, this case is shown to be equivalent to full coordination, in which pooling is always profitable. An example of this is the DVD-6C pool and One-Blue consortium, in which Samsung, Hitachi and Panasonic are common members. However, the case of both firms being symmetric in outside ownership, but in *distinct* competing products has not been explored. When the incumbent market is a duopoly and the firms can develop a new (third) standard, it may be even more difficult to compensate both firms for lost profits than when k =1.

that a pool will be collectively more attractive if the firm that is asymmetric outside of the pool is also asymmetric within the pool in terms of its profit share.

Aoki and Nagaoka (2004) and Gilbert (2011) analyze pool failure for reasons owing to incentives to defect from and free-ride on the pool as independent patentees, particularly for heterogeneous members. In contrast, under overlapping ownership, pools may fail when the private cost to outside profits overwhelms the efficiency benefits from a pool. If sufficiently severe, the firm with overlap may not agree to engage in the standard process in the first place. I turn now to this initial stage of the game.

5.3 Standard-Setting

In this section, Firms 1 and 2 coordinate on product selection of Z_1 through a simple standard-setting process. Product type, designated by γ, is chosen jointly in anticipation of future pooling and pricing decisions. As before, the joint cost of developing a new product or standard is given by K(γ), where K'(γ) < 0; $\mathcal{V}^P(\alpha, t, \gamma)$ is the equilibrium joint profits when ownership overlaps if pooling is chosen for all γ; and $\mathcal{V}^S(\gamma)$ is the equilibrium profits if the inputs are priced separately for all γ. Equilibrium profits under *full coordination* are given by $\mathcal{V}^P(1,1,\gamma)$; *limited coordination* applies for all other values of (α, t).

When pooling is an option, the firms switch strategies from pooling to no pooling at $\bar{\gamma}$. As before, the analysis is conducted in two parts: First, the profit-maximizing γ is derived for environments in which pooling is always or never chosen for all γ. The analysis then is refined to allow for the endogenous decision to pool (or not) when pooling is an option. The first step toward choosing the most profitable standard is to solve the following problem:

(22) $$\gamma^P(\alpha, t) = argmax[\mathcal{V}^P(\alpha, t, \gamma) - K(\gamma)]$$

$$\gamma^P(1,1) = argmax[\mathcal{V}^P(1,1, \gamma) - K(\gamma)]$$

$$\gamma^S = argmax[\mathcal{V}^S(\gamma) - K(\gamma)]$$

The relationship among the profit-maximizing product choices under limited and full coordination, and separate pricing can be characterized as follows:

<u>*Proposition 5:*</u> *Let k =1 and Assumptions 1-4 hold. Furthermore, assume the net profit functions in (22) are concave in* γ. *Then, (i) firms anticipating a pool will choose a more distant substitute under limited coordination than under full coordination if* $\frac{dp_i^P}{d\gamma} \leq 0$, *i = 0, 1; that is,* $\gamma^P(\alpha, t) \leq$

$\gamma^P(1,1)$. *Moreover, (ii) the firms will choose a closer substitute under separate pricing than under full coordination if* $\left[\frac{dp_1^S}{d\gamma}\frac{\partial q_1}{\partial p_1}+\frac{dp_0^S}{d\gamma}\frac{\partial q_1}{\partial p_0}\right]\geq 0$*; that is,* $\gamma^S \geq \gamma^P(1,1)$. Proof in the Appendix.

The first condition ($\frac{dp_i^P}{d\gamma}\leq 0$) requires that equilibrium prices under pooling decline as competing products become more homogeneous. The second condition ($\frac{dp_1^S}{d\gamma}\frac{\partial q_1}{\partial p_1}+\frac{dp_0^S}{d\gamma}\frac{\partial q_1}{\partial p_0}\geq 0$) requires that under no pooling, the increase in the new standard's price on its quantity demanded when γ changes is greater (in absolute value) than the cross-price effect. Together, conditions (i) and (ii) imply that the new standard will tend to be a stronger substitute to the current product if pooling is not an option than if it is; that is $\gamma^S \geq \gamma^P(1,1) \geq \gamma^P(\alpha,t)$. If pooling is anticipated, the firms will attempt to soften competition in the downstream market by choosing a more distant substitute; otherwise, with less intensive competition, the firms will want to choose a closer substitute that is less costly to develop. The reason for firms distancing themselves in product space here contrasts with an explanation in the literature that firms acquire differentiated patents as valuable bargaining chips for future legal settlements (Hall and Ziedonis, 2001). Here, they distance themselves, not for fear of reprisal, but in order to soften competition in the market intensified by the anticipated pool.

According to Proposition 5, if pooling is anticipated, then the product chosen by the IP owners under limited coordination (i.e., either *FR* or *TR* binds) will be more differentiated than if the pool could control both downstream prices. This may seem counterintuitive but it is attributed to the fact that firms are better positioned to dampen the competitive effect of the pool under full coordination and so choose a closer (and less costly-to-develop) substitute. Under limited coordination, Firm 1 does not fully internalize the negative effect that a reduction in the price of Z_0 has on the demand for Z_1 since Firm 1 receives only α of the profits generated by the pool. Therefore, it sets a price too low relative to full coordination. Anticipating this price-setting behavior, the firms develop a substitute that is more differentiated than if the pool were allowed to coordinate both prices of Z_0 and Z_1. So, in developing a new standard, the firm with overlap creates competition for its outside product, similar to Arrow's replacement effect (1962), but the cost of doing so is less when it can coordinate both prices than when it cannot.

In comparing no pooling with full coordination, Firm 1 in the former case does not take into account the full benefit of a demand increase in Z_1. Therefore, it will set its price of Z_0 too low relative to a pool that is fully coordinated. But it also does not internalize the full impact of an increase in its input price on the reduction in demand for Firm 2's inputs, thereby setting an inefficiently high input price. For quadratic utility (examined in Section 5.5 below), the latter dominates the former effect, in which case the firms choose a closer (less costly) substitute relative to the fully coordinated outcome.

The above analysis is based on pooling either being anticipated or not, for all γ. However, when pooling is available but coordination is limited, it may not be chosen in equilibrium for γ sufficiently large. As before, assume a unique $\bar{\gamma} < 1$ exists and let $\tilde{\mathcal{V}}(\alpha, t, \gamma)$ denote the function $\mathcal{V}^P(\alpha, t, \gamma)$ for $\gamma < \bar{\gamma}$ and $\mathcal{V}^S(\gamma)$ for $\gamma \geq \bar{\gamma}$. For reasons given in Section 4.3, the derivative of $\tilde{\mathcal{V}}(\alpha, t, \gamma)$ generally will be discontinuous at $\gamma = \bar{\gamma}$ and so $\gamma^P(\alpha, t) \geq \bar{\gamma}$ in (22) will not be the privately optimal standard if it is not less than $\bar{\gamma}$. Therefore, turning to the second step of the problem, let $\gamma^*(\alpha, t)$ be the privately optimal product type when pooling is endogenous and $(\alpha, t) \neq (1,1)$. Proposition 5 reveals that, for the conditions presented, $\gamma^*(\alpha, t)$ will be no greater than γ^S: that is, the choice of γ under limited coordination when pooling is an option supports a standard that is at least as differentiated as the one chosen when prices cannot be coordinated through a pool. The relationships in Proposition 5, which hold for quadratic utility (examined in Section 5.5), imply that $\gamma^*(\alpha, t)$ can be characterized by (16) where γ^P is replaced by $\gamma^P(\alpha, t)$. The intermediate case $\gamma^P(\alpha, t) < \bar{\gamma} < \gamma^S(\alpha, t)$ is illustrated in Figure 6. For a given (α, t), $\mathcal{V}^P(\alpha, t, \gamma) - K(\gamma)$ and $\mathcal{V}^S(\gamma) - K(\gamma)$ are denoted by the dotted curves, and $\tilde{\mathcal{V}}(\alpha, t, \gamma) - K(\gamma)$ by the solid curve. Note that for the case illustrated, $\gamma^*(\alpha, t) = \gamma^P(\alpha, t)$.

5.4 Foreclosing the Standard: When Pool Members have Competing Outside Options

Thus far it has been assumed that in equilibrium, both Z_1 and Z_0 are available, regardless of the ownership regime. However, when a pool member is also an incumbent firm, it may have the incentive to exercise its outside option and refuse to supply its essential expertise or patents to the new standard. The following assumption is made:

Assumption 5. If a single firm owned the essential inputs for both Z_0 and Z_1 then developing both products Z_0 and Z_1 would be at least as profitable as closing down production of one good and producing the other as a monopolist.

Assumption 5 ensures that foreclosure is attributed to the inability of firms to achieve full coordination rather than to the intrinsic value of the new product. However, it does not rule out the possibility that a patentee with a monopoly in Z_0 but only a *subset* of the Z_1 inputs ($s < 1$) may wish to withhold its patents in order to prevent the introduction of the competing standard. In contrast, Firm 2 does not have a profitable outside option at this stage. To see when foreclosure may occur, suppose pooling is allowed but only under limited coordination. Let π_O^m be monopoly profits earned when only Z_0 is offered in the market: the value of Firm 1's outside option. Then, under Assumption 1, foreclosure will occur if:

$$\pi_O^m \geq \tilde{V}\big(\alpha, t, \gamma^*(\alpha, t)\big) - K(\gamma^*(\alpha, t)), \tag{23}$$

where $\gamma^*(\alpha, t)$ is defined in (16) with the adjustment for the $k = 1$ ownership structure.

Suppose $\gamma^*(\alpha, t)$ satisfies $\pi_O^m \geq \tilde{V}(\alpha, t, \gamma^*(\alpha, t))$ at the pooling stage. In that case, Firm 1 will refuse to pool in order to raise its input price sufficiently high to foreclose Z_1. However, under perfect certainty, $\pi_O^m \geq \tilde{V}(\alpha, t, \gamma^*(\alpha, t))$ implies (23) and so foreclosure will occur earlier at the standard-setting stage, before development costs are committed. Therefore, only product types that are collectively profitable will be chosen or, alternatively, the new standard will be abandoned.

Finally, note that since the option to pool can increase the profitability of a new standard, then it also can moderate the incentive to deter entry. That is, pooling affects the profitability of a new standard through efficient pricing (*complements effect*) and by redirecting the choice of the standard (*differentiation effect*) toward a weaker substitute for the incumbent's product.[43]

5.5 Application of Quadratic Preferences to Overlapping Ownership

In this section, the results in Propositions 2-5 and informal discussions are illustrated for the case of quadratic preferences in (17) and the corresponding symmetric demand system in (18). Beginning with the third stage, the equilibrium prices for $k = 1$ that solve (8)-(11) are given in the second row of Table 3; the special case of *full coordination* when $(\alpha, t) = (1,1)$ is in the third row. As predicted by Proposition 2, both prices under limited coordination pooling are lower than for separate pricing for $k = 1$. Also by Proposition 3, note that prices increase in both the allocation rule α and in the weight t on Z_0 profits in the pooling agreement. Moreover, for a given $\vartheta(= P, S)$ decision, equilibrium prices are higher when a member of the pool has a stake in Z_0 than when the

[43] Foreclosure of the current standard (in contrast to a new standard as discussed above) was the focus of the complaint in Princo Corp. v. International Trade Commission, a patent abuse case, *Princo Corp. v. International Trade Commission,* No. 2007-1386 (Fed. Cir. Aug. 30, 2010). Phillips and Sony entered into an arrangement for CD-RW technologies. In choosing the method Raamaker to be the standard, they foreclosed the current standard Lagadec, which they also owned. Princo asserted that the creation of the patent pool on Raamaker and suppression of Lagadec constituted patent 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 the possibility of an antitrust violation.

latter product is controlled by an independent firm (in top row), consistent with Proposition 4. Finally, if pooling maximizes total profits of its members (t = 1) while making the firm with overlap residual claimant of the pool profits (α = 1), the equilibrium prices (in bottom row) achieve full monopoly profits.

Next consider the ϑ pooling decision. Figure 5 illustrates the joint profits from pooling net of profits from separate pricing in (21) for: (i) *full coordination*, and two situations under *limited coordination:* (ii) α = ½ and t = 1; (iii) α = ½ and t = 0. Note that under case (ii) only one of the *FR* or *TR* constraints is imposed, whereas (iii) represents the most constrained environment in which both constraints bind. In (i), a pool becomes a mechanism for achieving full monopoly profits and therefore is profitable for all γ, but in the latter two cases, $\bar{\gamma}$ will be less than 1. That is, for strong substitutes, the downward pressure on prices is too great for the increase in pool profits to compensate Firm 1 for its loss in Z_0 profits.

Note that the range of γ for forming a profitable pool under limited coordination is smaller than that for independent ownership of Z_0 illustrated in Figure 4. To understand the relationship between k (the ownership parameter) and $\bar{\gamma}$, consider the marginal effects when ownership of Z_0 switches from an outside to an inside firm. At γ = .77, Firms 1 and 2 are indifferent between forming a pool and separate pricing when k = 0: a pool raises profits on the Z_1 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 effect occur when Firm 1 owns Z_0 but, in that case, the collective cost of forming a pool includes the loss in profits from reduced sales of Z_0. If the firms are indifferent between forming a pool and not when k = 0, then when Firm 1 has a stake in Z_0, the status quo will be strictly preferred to a pool, hence, the reason for a decline in $\bar{\gamma}$.

Proposition 5 can be applied to quadratic preferences to reveal the effect that the patent pooling option has on product type selected during the standards process. Both conditions (i) and (ii) in Proposition 5 are satisfied under quadratic preferences. Columns 1-3 of Table 4(b) show the product choices for limited coordination with pooling agreement $(\alpha, t) =$ (½, 1), full coordination $(\alpha, t) =$ (1, 1), and separate pricing (no pooling). The cost function parameter a in (19) takes on the same values as in the independent ownership case, as well as .23 and .25 to illustrate the intermediate situation in Figure 6, relevant for later antitrust analysis.

Consistent with Proposition 5, $\gamma^P(½ ,1) \leq \gamma^P(1,1) \leq \gamma^S$ for the all the values of a. Next consider the privately optimal $\gamma^*(\alpha, t)$ under limited coordination when $(\alpha, t) =$ (½, 1). In that case, $\gamma^*(\alpha, t)$ in column 4 depends on the relationship among $\gamma^P(\alpha, t), \bar{\gamma}$, and γ^S. For a = .2, $\gamma^S \leq$

$\bar{\gamma}$ and so $\gamma^*(½,1) = \gamma^P(½,1)$. For $a \in \{.23, .25\}$, $\gamma^P(½,1) < \bar{\gamma} < \gamma^S$ as in Figure 6, in which case $\gamma^*(½,1)$ equals either $\gamma^P(½,1)$ or γ^S, depending on which one yields the higher net profits; for *a* = .23, pooling is more profitable but separate pricing dominates pooling for *a* = .25. Finally, for $a \geq .4$, 1, $\gamma^P(½,1) \geq \bar{\gamma}$; therefore, $\gamma^*(½,1) = \gamma^S$.

In equilibrium, the option to pool under either limited or full coordination inspires a standard that is at least as differentiated than if pooling were not an option. Although this *differentiation effect* of pooling runs counter to the price reduction from the *complements effect*, Table 3 indicates that equilibrium prices of the downstream products under limited or full coordination are never higher than under separate pricing. The ability of Firm 1 (or incumbent) to manipulate its two prices, when not in a pool, has the effect of maintaining equilibrium prices significantly above the pooled prices for all γ. This differs from the case of no overlap in which the equilibrium price of the competing product was shown to be higher under pooling for sufficiently low costs of developing a differentiated standard.

Further comparisons between ownership regimes can be made. Together, Tables 4(a) and 4(b) reveal that the equilibrium product choice $\gamma^*(½,1)$ under limited coordination for *k* = 1 may be more or less differentiated than under independent ownership. For $a \leq .25$, for example, pooling is chosen under both ownership regimes, in which case the standard is *more differentiated* under pooling. Although consumers value the additional product differentiation under the *k* = 1 regime, they prefer independent ownership since prices are significantly lower in equilibrium. But for higher development costs, $a \geq .6$, no pooling is chosen under both regimes, in which case, the product is *less differentiated* under overlapping ownership. Moreover, the increase in competition under the latter regime is not sufficient to overwhelm the inefficient input prices from separate pricing and so consumer prices are higher, as well as product variety lower. Finally for the case of *a* = .4, pooling is chosen when ownership is independent but not when it overlaps. As in the last case, consumers lose from both higher prices and lower product variety when *k* = 1 relative to independent ownership.

Finally, it can be shown that Firm 1 will never want to foreclose the new standard for the values of the cost parameter *a* given in Table 4(b). However, if a fixed cost, f, were added to development costs, then a range of f could be found for each *a* for which (23) would be satisfied.[44] I turn now to an evaluation of the current antitrust rules with reference to the above results.

[44] As noted above, if exercising the outside option is not profitable at the product development stage, it will also not be attractive after development costs are sunk. So, Firm 1 will not have the incentive to later hold-up the new standard by refusing to pool and demanding a prohibitive price for its input.

5.6 Antitrust Rules, Patent Pools and Overlapping Ownership

As shown in the previous section, for the case of symmetric quadratic utility and $k = 1$, equilibrium prices are lower and the new standard more differentiated under pooling than in its absence. However, because pooling increases price competition, it is less likely to occur for close substitutes, especially if antitrust or technological constraints on the pooling arrangement are restrictive. A pool of complementary inputs that is not profitable can nevertheless be beneficial to consumers. Merges (1999) suggests a role for government in “the collective action problem inherent in group bargaining” and Gilbert (2011) makes a case for allowing pool members “the same latitude to determine royalties and licensing terms as a single licensor, provided that the pool does not harm lawful competition that would have occurred in the absence of the pool’s licenses” when economic forces “prevent beneficial pools from forming.”[45] These ideas are explored in this section for the case of overlapping ownership and endogenous standard-setting.

Note that if Assumption 3 were relaxed, effectively allowing the pool to coordinate prices of *all* products under its members’ control, the IP owners would be unambiguously better off.[46] However, for product choices in which pooling would have been chosen under limited coordination, such a policy would increase prices to consumers (Proposition 3). Therefore, a more moderate policy that allows pool members to fully coordinate *only* when their choice of product exceeds $\bar{\gamma}$ (those products for which a pool would otherwise be unprofitable) is considered in the remainder of this section.

The net profit and consumer utility relationships for $k = 1$ under limited and full coordination, relative to no pooling for demand specification in (18) and pooling agreement (α, t)= (½,1), are illustrated in Figures 7 and 8, respectively. In particular, the private benefits from pooling under limited coordination, net of uncoordinated profits is given by the lower curve in Figure 7; the corresponding curve for consumer utility gains is shown by the higher curve in Figure 8. While the gains from pooling over separate pricing turn negative for sufficiently close products (at $\gamma = .55$ or point B), net consumer surplus continues to rise in γ. But no pool will form for $\gamma \geq .55$ and so the actual utility gains over the no-pooling outcome fall to zero at B.

If instead the pool is given broader scope to set prices on all products owned by members, then firm and consumer benefits from a pool are given, respectively, by the higher curve in Figure 7

[45] See Gilbert (2011) for a comprehensive discussion on the role of antitrust in affecting private incentives to pool.
[46] In particular, if *TR* does not bind, then it suffices to relax *FR* to achieve first-best monopoly profits. But if *TR* also binds, Assumption 3 will also need to be relaxed for full coordination.

and the lower one in Figure 8. Note that relative to the alternative of separate pricing, therefore, both consumers and firms gain from the relaxation of Assumption 3 for $\gamma \geq .55$, with the benefits following CD in Figure 7 and HI in Figure 8. So under a policy in which full coordination is allowed for strong substitutes but is limited when $\gamma \in [0, \bar{\gamma})$,[47] the firm and consumer benefits from pooling over separate pricing are, respectively, ABCD in Figure 7 and FGHI in Figure 8. That is, a more permissive policy can be welfare improving, relative to limited coordination, for sufficiently high costs of developing a differentiated standard.[48]

As noted earlier, since antitrust authorities generally proscribe agreements that coordinate prices of substitute products, the concern here is that a patent pool with full coordination will soften competition between horizontal competitors. This example illustrates that, in fact, it is precisely when substitutes are strong that antitrust rules might be more permissive, allowing a merger or a broadening of the pool's scope so it can coordinate prices on its members' outside competing products as well as those inside the pool.[49]

However, the analysis is not complete without considering the effect of the more permissive antitrust climate on standard selection. Proposition 5 gives some insight into that problem. Consider first the case in which Assumption 3 binds and only limited coordination is permitted. Recall the results obtained for a range of research cost parameters in Table 4(b): when research costs are moderately high ($a \geq .4$), $\gamma^*(½, 1) = \gamma^S$. For flatter research costs ($a = .2$), $\gamma^*(\alpha, t) = \gamma^P(½, 1)$. In the intermediate cases, $a \in \{.23, .25\}$, $\gamma^P(½, 1) < \bar{\gamma} < \gamma^S$ and the privately best product choices, respectively, are γ^P and γ^S.

Now suppose members of the pool are allowed to fully coordinate prices of all the products owned by its members *only* when $\gamma \geq \bar{\gamma}$. Denote the profit-maximizing product choice under the latter policy by $\gamma^{**}(½, 1)$. As before, let $\gamma^P(1,1)$ be the profit-maximizing product choice when Firms 1 and 2 can fully coordinate for *all* γ. As implied by Proposition 5 for quadratic preferences, if research costs are steep such that $\gamma^*(½, 1) = \gamma^S$, then the standard chosen under the permissive policy will be at least as differentiated; that is, $\gamma^{**}(½, 1) = \gamma^P(1,1) \leq \gamma^S = \gamma^*(½, 1)$. Consumer utility is higher from lower prices at every γ (complements effect in Proposition 2), enhanced

[47] For illustration purposes, full coordination is assumed to take effect at $\bar{\gamma}$.

[48] For the same reasons that coordination of complementary inputs is socially efficient, a permissive policy would be socially preferred to limited coordination if Z_0 and Z_1 were complements ($\gamma < 0$).

[49] In fact, for low values of γ, divestiture could be appropriate. If Firm 1 were required to sell its assets outside of the pool, then consumers could gain for sufficiently weak substitutes. For higher γ, Firm 1 might wish to retain its Z_0 assets and not pool rather than pool and face divestiture, in which case, consumers would be worse off. This conjecture, supported for quadratic utility, suggests that requiring pool members to divest assets in the incumbent product may be beneficial only if that product is a sufficiently *weak substitute* for the new standard. See also Tan (2003) for a related discussion on divestiture.

further by a more distant standard (differentiation effect in Proposition 5), indicated by the negative slope of HI in Figure 8.[50] That is, in encouraging firms to pool, full coordination increases both firm profits and consumer benefits. This case, shown in Table 4(b) for $a \geq .25$, in which $\gamma^{**}(½\,,1) < \gamma^{*}(½\,,1)$, reflects the intention behind a more permissive policy: to encourage efficient pools that otherwise would not take place.

Next consider the case of relatively low development costs (a = .2) such that $\gamma^S \epsilon\ [0, \bar{\gamma})$. Then, applying Proposition 5 to quadratic preferences in which $\gamma^P(½\,,1) \leq \gamma^P(1,1) \leq \gamma^S$, the profit-maximizing product type will remain at the limited coordination outcome; that is, the firms will not move from $\gamma^P(½\,,1)$ to $\gamma^P(1,1)$ since the restrictive policy (Assumption 3) is in force for this interval of γ. However, for slightly higher development costs, a = .23, the patentees will want to "jump" to a standard at least as differentiated as $\bar{\gamma}$, where they will be allowed to coordinate both prices. That is, a permissive policy would give the firms the incentive to choose $\gamma^{**}(½\,,1)$ = .55 rather than $\gamma^{*}(½\,,1)$ = .4 under limited coordination. Consumers lose in that case both from higher prices and less product variety. [51]

The impact of a permissive antitrust policy on product choice, therefore, depends on the equilibrium pooling decision under the more restrictive policy (limited coordination). Notably, relaxing Assumption 3 can inefficiently bias the firms' product choice toward the full coordination region ($\gamma \geq \bar{\gamma}$). Alternatively, a more permissive policy that succeeds in encouraging efficient pooling that otherwise would not have occurred can lead to lower prices and a greater product variety, thereby making consumers as well as firms better off.

5.7 Discussion of Antitrust Policy toward Patent Pools

The above analysis indicates that when the policy is effective in encouraging firms that otherwise would not have pooled to coordinate their patents, it has the added potential benefit of redirecting technological change toward greater product variety as well as lower prices. The latter observation that a permissive approach for strong substitutes can be efficient appears to contradict a basic premise of antitrust policy. Yet, it follows directly from the endogenous reorganization of IP

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[50] Note that consumers' tradeoff between product variety and prices depends on the antitrust regime. In particular, consumer welfare is show to decline in γ under full coordination; however, for limited coordination, the relationship is U-shaped: initially consumers are worse off for a decline in differentiation but, beyond a moderate level, they benefit from closer substitutes. Intuitively, fully coordinated firms are able to adjust prices of both downstream products to soften competition as γ increases. It should be noted that issues of interoperability (e.g., if closer substitutes facilitate compatibility between standards) are not considered here.

[51] Note that the lowest product type for taking advantage of the permissive policy is γ=.55, which is greater than the privately optimal $\gamma^P(1,1)$=.54. Operating under the permissive policy is still more profitable. However, equilibrium prices are higher under the permissive policy, as revealed by Table 3, even though the new standard chosen is a closer substitute.

rights: Patent pools that increase competition in the market – that is, those benefitting consumers – may not be profitable for firms with competing interests to join. [52]

The above discussion lends some support for the recommendations of Merges and Gilbert noted earlier. In particular, when the costs of developing a distant substitute are high, a more permissive policy that encourages efficient price coordination may benefit both consumers and producers. However, implementing such a policy would be challenging, especially in requiring an accurate estimate of $\bar{\gamma}$. If $\bar{\gamma}$ were underestimated then firms that already had the incentive to pool, would be able to set higher prices; if overestimated, then benefits of the policy would be limited. Even if $\bar{\gamma}$ were estimated with precision, the pooling firms could have the incentive to inefficiently choose a higher γ simply to qualify for full coordination, as noted above. Alternatively, a policy that simply relaxed Assumption 3 for *all* γ, while easier to implement and enforce, would be less preferable from a social point of view since the range of γ for which consumers lose would expand to $[0, \bar{\gamma}]$; in that range, a pool with lower prices on more differentiated products would have formed without the added incentive.

Even under the current antitrust approach (Assumption 3), efforts should be made to ensure that pools admitting members with overlap do not broaden their mandate of efficiently coordinating upstream complements to inefficiently coordinating prices of downstream substitutes. This concern applies particularly to low or moderate costs of developing a standard, since for high development costs extended price coordination can facilitate an efficient pool (or standard). Finally, even if price coordination through pooling were socially beneficial, it could become less so if members were to make further acquisitions in related products or participate in competing standards. As suggested by the comparison of independent and overlapping ownership regimes (Proposition 4), a deepening of the horizontal nature of the pool through further acquisitions can overwhelm the initial benefits of price coordination of complements. Therefore, restrictions on further acquisitions, divestiture of assets in related products, or dissolution of the pool may be appropriate to consider when approving collaborations between IP owners that both compete with and support a new standard.

6. Predictions and Conclusions

The current antitrust approach toward patent pools focuses on the nature of the relationship between the patents admitted into the pool. This paper asks if that approach is adequate for

[52] This result is in the spirit of Faulí-Oller and Sandonis (2003), 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.

screening welfare-decreasing pools. This question is analyzed in a framework that allows for the interplay between standard-setting and patent pooling, in which a prospective member has exclusive rights to essential inputs for a new standard as well to a competing product. This overlapping ownership structure transforms the relationship between participants into a hybrid one that is both vertical and horizontal. The analysis reveals that patent pooling, the prices of both the new and incumbent products can fall, *for a given standard* (complements effect). However, if the standard-setting process is also endogenous, the IP owners will choose a more distant substitute (differentiation effect) to soften price competition anticipated from patent pooling. Although the latter effect can partially offset the benefits from price coordination, the impact on consumer welfare depends on consumers' trade off between product variety and price competition. [53]

Even if pooling raises consumer welfare when ownership overlaps, it is nevertheless incumbent on antitrust authorities to be scrupulous in ensuring that the participants are not broadening the pool's price-coordination scope to include competing products of its members. For high development costs, the costs of such behavior can be less harmful in encouraging the incumbent to participate in rather than foreclose the new standard. Even for pools deemed socially beneficial, however, antitrust should scrutinize further acquisitions of competing products by pool members, especially those firms that receive a significant share of the pool profits: While pools with complementary patents can be pro-competitive, consumers prefer when members have less of a stake in outside, competing goods. These cautionary considerations imply that attention should be given on the competitive relationship between members of the pool, and not simply between the products admitted to the pool.

This analysis has implications for the interplay between patent and antitrust policy. A permissive antitrust approach toward patents can increase welfare for relatively weak patent protection. If the latter is defined by low costs of imitation, then the IP owners will be more likely to choose a standard close to the current product and be less inclined to pool. Therefore a more permissive antitrust approach may be required to encourage efficient pooling. However, if strong patents increase the cost of developing a close substitute, then a more distant standard likely will be chosen, in which case efficient pooling will occur even in a more restrictive antitrust environment. Note that this complementarity between antitrust and IP policies arises from their common objective to facilitate efficient IP collaborations.

[53] When confronted with a pool *ex post* product development, Proposition 2 suggests that a pool of complements should be approved since it will yield lower prices. However, a more or less favorable antitrust approach might be committed *ex ante* in order to influence product choice. For analysis and discussion of the role of antitrust in encouraging innovation, see Segal and Whinston (2007) and the *U.S. Department of Justice-Federal Trade Commission Guidelines on the Licensing of Patents* (1995, 2007).

In addition to these normative implications, the paper also offers several testable predictions (at least in theory). The first set describes equilibrium pricing outcomes:

- *Prices of competing products that are strategic complements will be lower under a pool of standard-essential patents than under separate pricing for a given standard, especially if the firm with overlap does not hold a majority of the patents in the pool.*
- *However, both upstream and downstream prices under a pool will be higher under overlapping than independent ownership, for a given standard.*

A second set of results involves the likelihood of pool formation and the direction of technological change:

- *If pool members are asymmetric in their outside ownership, then they will likely be asymmetric in their share of the pool profits.*
- *For a given ownership structure, downstream products supported by pools are likely to be more differentiated compared to those not pooled.*
- *For a given pooling arrangement, downstream products supported by pools are likely to be more differentiated when pool members overlap in their ownership of competing products than when they do not.*

The framework could be extended in several directions. First, it could be broadened to incorporate two related but distinct industrial structures of vertical integration and multi-market contact explored in the literature, especially given that all three are observed in many standard-related patent pools. For example, in the DVD case, 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.

The framework could also be extended to allow for multiple incumbents producing different products that compete with a new standard. In that extension, the horizontal nature of the standard/pool process would be more explicit and allow for explorations into the impact of pool size and degree of overlap on the equilibrium product-pooling-pricing decisions. Moreover, a dynamic model including both standard-setting and subsequent product development would incorporate both incentives for new product development, *ex ante* to pool formation as examined here, as well as *ex post* incentives for future product development by members in a pool.[54]

[54] For example, see Jeitschko and Zhang (2012) show that, when further product development is required to bring a drug or standard to market, then pooling can reduce incentives to research; also related is Lampe and Moser (2011).

Finally, demand uncertainty could be introduced. Then, a new standard that is jointly profitable *ex ante*, may not be profitable to the incumbent firm for low demand realizations, in which case it may have the incentive to part ways and price the new standard out of the market. Such a hold-up strategy by a firm with IP rights, could be at odds with licensing obligations typically invoked by standard-setting organizations, for example, FRAND rules that require patentees to license other members and users at "fair, reasonable and non-discriminatory" terms. Even if difficult to enforce, these rules are intended to prevent members from exploiting their IP rights to improve their position or jeopardize the standard's competitiveness. However, constraining a firm with overlap from foreclosing the new product in unprofitable states could reduce its incentive to contribute its essential patents in the standards process in the first place. This suggests that, consistent with Aoki and Nagaoka (2004), current analyses of FRAND and other agreements surrounding standards should consider firm heterogeneity, particularly with respect to economic activity both within and outside the standard/pool in related products.

This article has implications for the larger debate on the efficacy of the IP system. Collaborative – as well as innovative and litigious activity – are influenced by and contribute to the benefits and costs of an IP system. To the extent that stronger protection encourages innovators to reorder their IP rights (Heller and Eisenberg 1998), the benefits from efficient coordination or costs of anticompetitive behavior can counter or magnify the social costs identified in the literature from an overreaching IP regime. Moreover, a sharper understanding of technology sharing agreements – the ways in which IP rights are reordered and by whom – can inform antitrust policy at identifying when agreements suppress competition or when they effectively "cut through the patent thicket" (Shapiro 2001).

Appendix

Proof of Proposition 1. Evaluating the left hand-side of (10), for $k = 0$, at the no-pool prices $p_i^S(\gamma)$, i=0,1 from (8)-(9) yields $-q_1(p_1^S, p_0^S; \gamma) < 0$. This implies that the profit-maximizing price of Z_1 under pooling, when the price of Z_0 is held constant at $p_0^S(\gamma)$, is lower than $p_1^S(\gamma)$. Similarly, evaluating (11) at the no-pool prices in (8)-(9) reveals that $p_0^S(\gamma)$ maximizes profits under a pool, when the price of Z_1 is held constant at $p_1^S(\gamma)$. If there were no change in the price of Z_0, then the equilibrium price of Z_1 under a pool would fall. However, a decline in the latter price would render the left-hand side in (11) non-positive if $\frac{\partial^2 \pi_0}{\partial p_0 \partial p_1} \geq 0$. Therefore, the price of Z_0 under pooling will be no higher than the no-pool equilibrium value. This decrease in the pooled price of Z_0, in turn, reinforces the negative value of the marginal profit of $p_1^S(\gamma)$ (left-hand side of (10)) if $\frac{\partial^2 \pi_0}{\partial p_0 \partial p_1} \geq 0$, thereby yielding the result in the proposition. ■

Proof of Proposition 2. As in the proof of Proposition 1 when $k = 1$, evaluating the pooling condition in (10) at the no-pool prices $p_i^S(\gamma)$ from (8)-(9) yields:
$-q_1(p_1^S, p_0^S; 1) - (1-t)\frac{\partial \pi_0(p_1, p_0, \gamma)}{\partial p_1} < 0$, implying that the profit-maximizing price of Z_1 under pooling, when the price of Z_0 is held constant at $p_0^S(\gamma)$, is lower than $p_1^S(\gamma)$. (The arguments in the equilibrium prices are suppressed for the remainder of the proof.) However, analysis of the price of Z_0 is not as straightforward. In particular, substitution of the no-pool equilibrium prices in (8)-(9) into (11) for $k = 1$ yields the expression:

$$\left(\alpha - \frac{r_{11}}{p_1^S}\right) p_1^S \frac{\partial q_1(p_1^S, p_0^S, \gamma)}{\partial p_0}.$$

From (6)-(7), $\frac{r_{11}}{p_1^S} \geq \frac{1}{2}$; therefore a sufficient condition for the above expression to be negative (and therefore for prices to be no higher under pooling than separate pricing) is for $\alpha \leq \frac{1}{2}$. In that case, the price of Z_0 will be lower under pooling, holding the price of Z_1 at p_1^S. But if the price of Z_1 is actually lower, then this will reinforce the negative marginal condition in (11) if $\frac{\partial^2 \pi_0}{\partial p_0 \partial p_1} + \alpha \frac{\partial^2 \pi_1}{\partial p_0 \partial p_1} \geq 0$. This implies that for strategic complements, the price of Z_0 under pooling will be no higher than under separate pricing. Furthermore, note that a lower price of Z_0 also reinforces the downward pressure on the price of Z_1 since the change in the left-hand side of (10) with respect to

p_0 is $\frac{\partial^2 \pi_1}{\partial p_1 \partial p_0} + t \frac{\partial^2 \pi_0}{\partial p_1 \partial p_0}$, which is positive for strategic complements. So, the price of Z_1 will be at least as high under uncoordinated pricing as under pooling. ■

Proof of Proposition 3. The demand curves and, therefore, the profit functions in (4) and (5) are twice continuously differentiable in (p_0, p_1). Moreover, the profit function of the pool in (4) has increasing differences in (p_1, t) since $\frac{\partial^2 \hat{\pi}_J}{\partial p_1 \partial t} = \frac{\partial \pi_0(p_1, p_0; \gamma)}{\partial p_1} \geq 0$ and the incumbent's profit function in (5) has increasing differences in (p_0, α) since $\frac{\partial^2 \hat{\pi}_I}{\partial p_0 \partial \alpha} = \frac{\partial \pi_1(p_1, p_0; \gamma)}{\partial p_0} \geq 0$. Finally, the profit functions have increasing differences in $((p_1, t), (p_0, \alpha))$ if $\frac{\partial^2 \pi_i}{\partial p_i \partial p_j} \geq 0, j \neq i$ since differentiation of (4) and (5) reveals:

(3a) $\frac{\partial^2 \hat{\pi}_J}{\partial p_1 \partial p_0} = \frac{\partial^2 \pi_1}{\partial p_1 \partial p_0} + t \frac{\partial^2 \pi_0}{\partial p_1 \partial p_0} \geq 0$ and $\frac{\partial^2 \hat{\pi}_I}{\partial p_0 \partial p_1} = \alpha \frac{\partial^2 \pi_1}{\partial p_0 \partial p_1} + \frac{\partial^2 \pi_0}{\partial p_0 \partial p_1} \geq 0$;

(3b) $\frac{\partial^2 \hat{\pi}_J}{\partial p_1 \partial \alpha} = \frac{\partial^2 \hat{\pi}_I}{\partial p_0 \partial t} = 0$.

Therefore, equilibrium prices $p_0(\alpha, t, \gamma)$ and $p_1(\alpha, t, \gamma)$ increase in *t* and α, for a given γ (Vives (2005 a,b)).

Proof of Proposition 4. Pairwise comparisons of (10)-(11) for *k* = 0 and *k* = 1 yield the result in the proposition. In particular, the equilibrium prices for *k* = 0 satisfy $\frac{\partial \pi_1(p_1, p_0; \gamma)}{\partial p_1} = 0$ and $\frac{\partial \pi_0(p_1, p_0; \gamma)}{\partial p_0} = 0$. At these prices, the marginal profits for *k* = 1 are:

(4a) $t \frac{\partial \pi_0(p_1, p_0, \gamma)}{\partial p_1} \geq 0$

(4b) $\alpha \frac{\partial \pi_1(p_1, p_0, \gamma)}{\partial p_0} \geq 0$

for $\alpha, t \in [0,1]$, since Z_1 and Z_2 are economic substitutes. But the expressions in (4a) and (4b) indicate that the profit-maximizing prices of Z_1 and Z_0, respectively, will be higher under *k* = 1 than for *k* = 0, holding constant the other price at the *k* = 0 value. Differentiating the left-hand side of the marginal conditions in (10) and (11) with respect to the other price, indicates that an increase in the latter price will reinforce the positive marginal profit if $\frac{\partial^2 \pi_0}{\partial p_1 \partial p_0} \geq 0$. ■

<u>*Proof of Proposition 5.*</u> From (22), the firms choose γ to maximize joint profits, anticipating equilibrium values $p_i^P(\alpha,t,\gamma), i = 0,1$ under pooling given γ, and $p_i^S(\gamma), i = 0,1$ for separate pricing given γ. For notational convenience, the arguments in the equilibrium prices are suppressed. Then, the first-order condition is:

$$\text{(5a)} \quad \frac{\partial \pi_1}{\partial \gamma} + \frac{\partial \pi_0}{\partial \gamma} + \frac{dp_1^\vartheta}{d\gamma}\left[\frac{\partial \pi_1}{\partial p_1} + \frac{\partial \pi_0}{\partial p_1}\right] + \frac{dp_0^\vartheta}{d\gamma}\left[\frac{\partial \pi_1}{\partial p_0} + \frac{\partial \pi_0}{\partial p_0}\right] - K'(\gamma) = 0$$

where $\vartheta = S,P$. To prove part (i) of the proposition, first note that under full coordination, $\gamma^P(1,1)$ satisfies the following condition, after applying the envelope theorem to (5a):

$$\text{(5b)} \qquad \frac{\partial \pi_N}{\partial \gamma} + \frac{\partial \pi_O}{\partial \gamma} - K'(\gamma) = 0.$$

Under limited coordination, equilibrium prices for Z_0 and Z_1 from (10)-(11) satisfy $\alpha\frac{\partial \pi_1}{\partial p_0} + \frac{\partial \pi_0}{\partial p_0} = 0$ and $\frac{\partial \pi_1}{\partial p_1} + t\frac{\partial \pi_0}{\partial p_1} = 0$. Substituting these expressions into (5a) yields the condition for $\gamma^P(\alpha,t)$:

$$\text{(5c)} \qquad \frac{\partial \pi_1}{\partial \gamma} + \frac{\partial \pi_0}{\partial \gamma} + \frac{dp_1^P}{d\gamma}(1\text{-}t)\frac{\partial \pi_0}{\partial p_1} + \frac{dp_0^P}{d\gamma}(1\text{-}\alpha)\frac{\partial \pi_1}{\partial p_0} - K'(\gamma) = 0.$$

Comparison of (5b) and (5c) reveals that if $\frac{dp_i^P}{d\gamma} \le 0, i = 0,1$, then $\gamma^P(\alpha,t) \le \gamma^P(1,1)$ (since $\frac{\partial \pi_i}{\partial p_j} \ge 0, i \ne j$). To show part (ii) of the proposition, the profit-maximizing prices for Z_0 and Z_1 in the no pooling and k =1 regime are found in (8)-(9): $\frac{\partial \pi_1}{\partial p_0} + \frac{\partial \pi_0}{\partial p_0} = r_{12}\frac{\partial q_1}{\partial p_0}$ and $\frac{\partial \pi_1}{\partial p_1} + \frac{\partial \pi_0}{\partial p_1} = r_{12}\frac{\partial q_1}{\partial p_1}$. Substituting these expressions into (5a) gives the first-order condition for γ^S:

$$\text{(5d)} \qquad \frac{\partial \pi_1}{\partial \gamma} + \frac{\partial \pi_0}{\partial \gamma} + r_{12}\left[\frac{dp_1^S}{d\gamma}\frac{\partial q_1}{\partial p_1} + \frac{dp_0^S}{d\gamma}\frac{\partial q_1}{\partial p_0}\right] - K'(\gamma) = 0.$$

Evaluating (5d) at $\gamma^P(1,1)$ from (5b) reveals that $\gamma^S \ge \gamma^P(1,1)$ if $\left[\frac{dp_1^S}{d\gamma}\frac{\partial q_1}{\partial p_1} + \frac{dp_0^S}{d\gamma}\frac{\partial q_1}{\partial p_0}\right] \ge 0$. ■

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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 Utility

Ownership	**Pooling Decision**	**Price of Z_1**	**Price of Z_0**
Independent	Separate Pricing	$\frac{2-\gamma^2-\gamma}{3-\gamma^2}$	$\frac{3-2\gamma^2-\gamma}{6-2\gamma^2}$
	Pooling	$\frac{1-\gamma}{2-\gamma}$	$\frac{1-\gamma}{2-\gamma}$
Overlapping: Limited Coordination	Separate Pricing	$\frac{4-\gamma}{6}$	½
	Pooling	$\frac{(1-\gamma)(2+\gamma(1+t)))}{4-\gamma^2(1+\alpha)(1+t)}$	$\frac{(1-\gamma)(2+\gamma(1+\alpha))}{4-\gamma^2(1+\alpha)(1+t)}$
Overlapping: Full coordination	Pooling	½	½

TABLE 4
Profit-Maximizing Standard γ for Different Development Costs *a*

(a) Independent Ownership: $\bar{\gamma} = .77$

	γ^P	γ^S	γ^*
a = .20	.51	.58	.51
a = .40	.69	.72	.69
a =.60	.77	.78	.78
a = .80	.81	.82	.82
a = 1.0	.84	.84	.84

(b) Overlapping Ownership: $\bar{\gamma} = .55$

	γ^P(½ ,1)	$\gamma^P(1,1)$	γ^S	γ^*(½, 1) *restrictive*	γ^{**}(½, 1) *permissive*
a = .20	0	0	.52	0	0
a = .23	.40	.54	.64	.40	.55
a = .25	.48	.62	.69	.69	.62
a = .40	.66	.81	.84	.84	.81
a = .60	.73	.88	.90	.90	.88
a = .80	.77	.92	.93	.93	.92
a = 1.0	.80	.93	.94	.94	.93

Figure 1

(a) Pooling under Independent Ownership

(b) Pooling under Overlapping Ownership

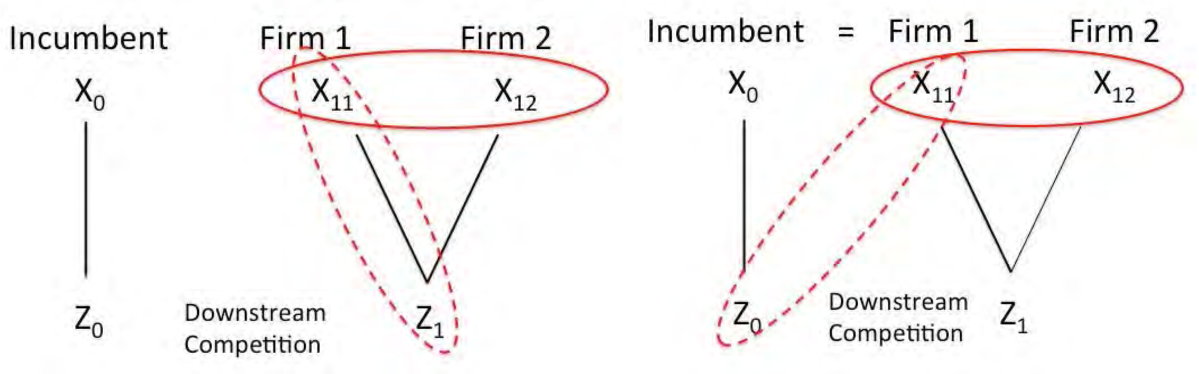

Figure 2

Time Line

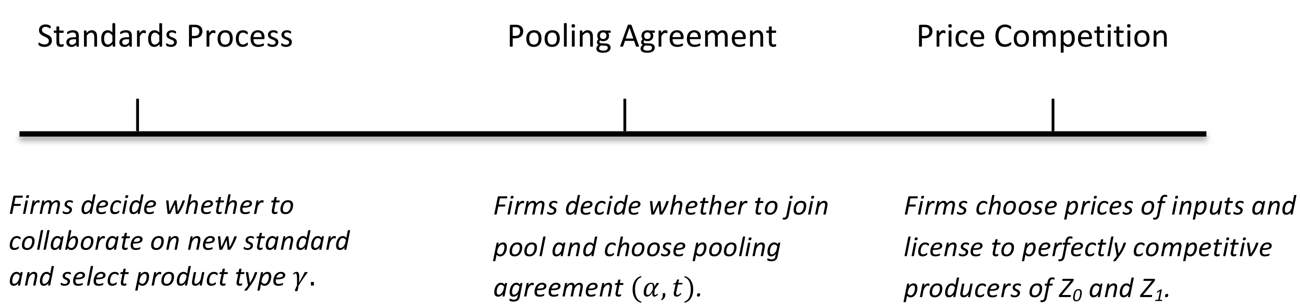

Figure 3
Critical Value of $\bar{\gamma}$

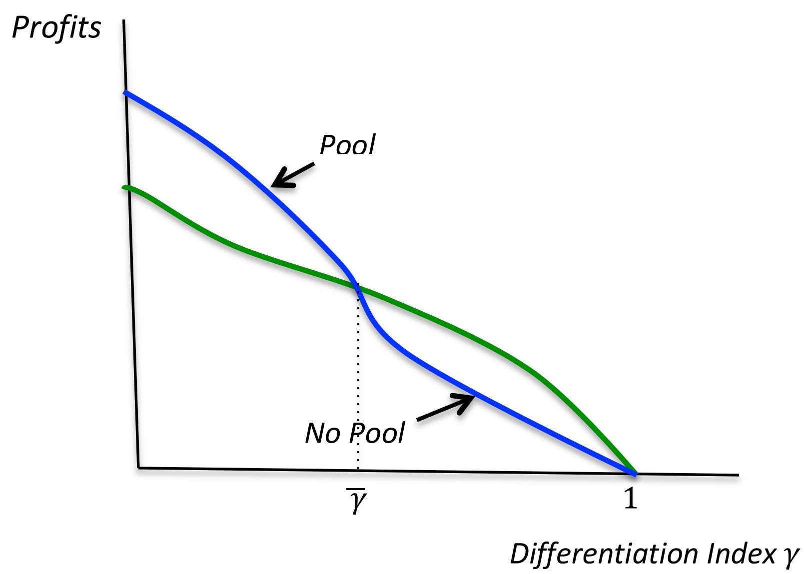

Figure 4

Private Benefits from Pooling over Separate Pricing
Independent Ownership v. Overlapping Ownership

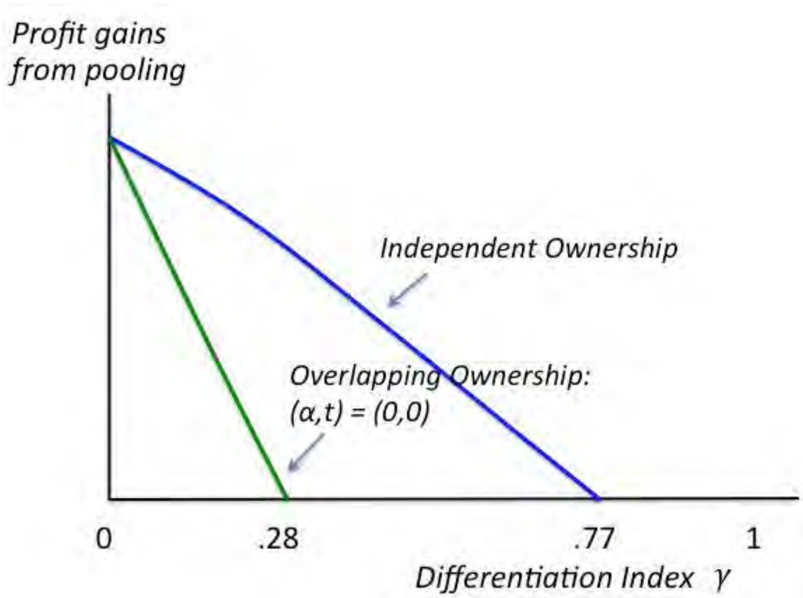

Figure 5

Private Benefits from Pooling over Separate Pricing
Overlapping Ownership for Different (α, t)

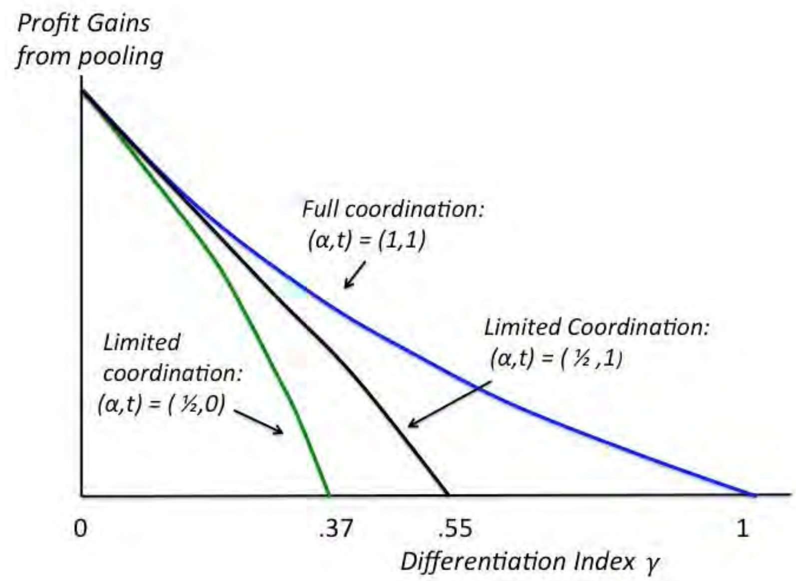

Figure 6

Equilibrium Product Selection
under Limited Coordination

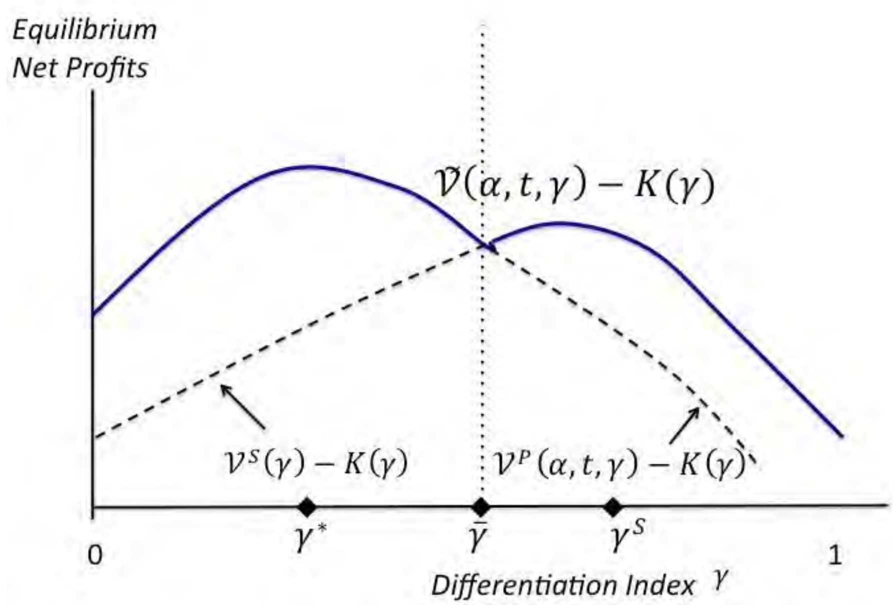

Figure 7

Private Benefits from Pooling:
Restrictive and Permissive Antitrust Policy

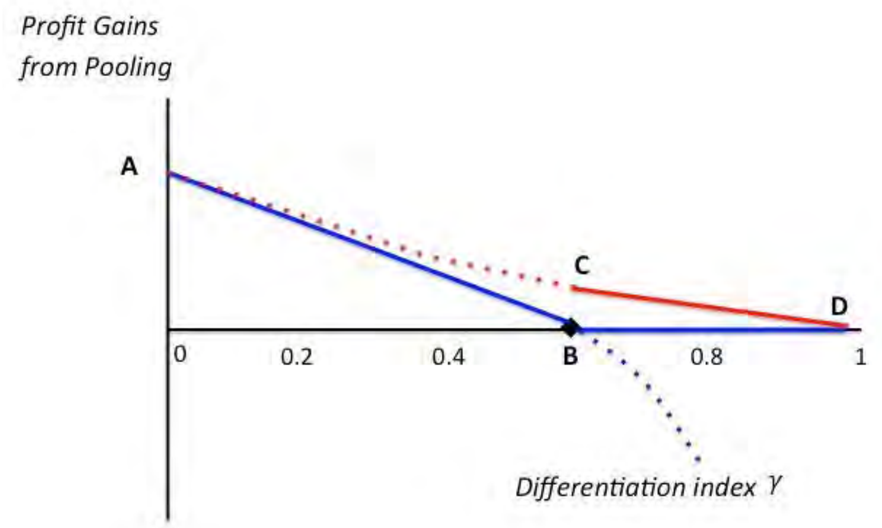

Figure 8

Consumer Gains from Pooling:
Restrictive and Permissive Antitrust Policies