

LICENSING COMPLEMENTARY PATENTS: “PATENT TROLLS,” MARKET STRUCTURE, AND “EXCESSIVE” ROYALTIES

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I. INTRODUCTION

This Article challenges a common definition of “patent troll” as any non-practicing patent holder. The association between non-practicing patent holder and troll was made in the infamous *NTP, Inc. v. Research in Motion, Ltd.* decision (the *BlackBerry* case).¹ In early 2006, the e-mail correspondence of millions of BlackBerry users nearly came to a halt when NTP, Inc. accused Research in Motion, Ltd. (“RIM”), the maker of the popular communication device, of infringing several of its patents.² The Federal Circuit found that BlackBerry’s e-mail retrieval system was indeed infringing on some of NTP’s

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1. 397 F. Supp. 2d 785 (E.D. Va. 2006).

2. *Id.*

patents and awarded damages and a permanent injunction against RIM.³ Armed with the injunction, NTP threatened to shut down BlackBerry's e-mail services if RIM did not pay royalties for the future use of NTP's patents.⁴ In March 2006, in order to avert the injunction, RIM agreed to pay 612.5 million dollars in a last minute settlement, an amount significantly greater than the past damages of 33.5 million dollars awarded by the trial court.⁵

The plaintiff in this highly visible case is often quoted as an example of a so called "patent troll."⁶ This term is used to describe a company that uses a patent to "hold-up" manufacturing companies and to extort "excessive" royalties that are higher than the "fair share" dictated by the contribution of its patent. Unfortunately, it is notoriously difficult to determine whether royalties are "excessive," and to distinguish between a hold-up and aggressive, but legitimate, bargaining. Because a workable definition is lacking, patent trolls are sometimes associated with entities that do not develop innovations of their own and even more frequently with "non-practicing" or "non-manufacturing" patent holders (often referred to as "NPEs," for non-practicing entities).⁷ In the Blackberry example, NTP is an NPE. It does not produce cell phones or any other goods but owns a portfolio of patents that it licenses to manufacturing companies. In contrast to a vertically integrated firm (which both holds a patent and uses it to produce a good in a downstream market), an NPE does not require cross-licenses from competitors in the downstream market. Therefore, it is claimed

3. NTP, Inc. v. Research in Motion, Ltd., 418 F.3d 1282 (Fed. Cir. 2005).

4. Stephen Lawson, *BlackBerry Users Face Shutdown*, PC WORLD, Dec. 1, 2005, available at http://www.pcworld.com/article/123761/blackberry_users_face_shutdown.html.

5. For a more detailed discussion of this case, see Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991, 2009 n.36 (2007); James F. McDonough III, Comment, *The Myth of the Patent Troll: An Alternative View of the Function of Patent Dealers in an Idea Economy*, 56 EMORY L.J. 189, 194-95 (2006).

6. Peter Detkin, former assistant general counsel for Intel, coined the term "patent troll" after Intel was sued for libel for its use of the term "patent extortionist." Detkin explains that "[a] patent troll is somebody who tries to make a lot of money off a patent that they are not practicing and have no intention of practicing and in most cases never practiced." McDonough III, *supra* note 5, at 192; see also Ian Austen & Lisa Guernsey, *A Payday for Patents 'R' Us; Huge Blackberry Settlement Is Grist for Holding Company*, N.Y. TIMES, May 2, 2005, at C1.

7. See, e.g., John M. Golden, "Patent Trolls" and Patent Remedies, 85 TEX. L. REV. 2111, 2112 (2007); McDonough III, *supra* note 5, at 189; Carl Shapiro, Injunctions, Hold-Up, and Patent Royalties 3 (Aug. 2006) (unpublished manuscript, on file with the Haas School of Business, University of California). As Lemley & Shapiro put it: "Defining a patent troll has proven a tricky business, but that does not mean the problem does not exist. Nonpracticing entities file 30-40% of all patent suits in the computing and electronics industries, for example." Lemley & Shapiro, *supra* note 5, at 2009.

that an NPE is not constrained in its behavior and may choose unjustifiably high royalty rates that are not in proper relation to the contribution of its patents.

The identification of NPEs and patent trolls has important legal consequences. In *eBay Inc. v. MercExchange, L.L.C.*,⁸ Justice Kennedy stated in his concurring opinion that there are firms that “use patents not as a basis for producing and selling goods but, instead, primarily for obtaining licensing fees For these firms, an injunction . . . can be employed as a bargaining tool to charge exorbitant fees”⁹ Kennedy’s statement implied that the lower courts should be careful in granting injunctive relief to non-practicing patent holders. In fact, since *eBay*, many district courts have denied injunctive relief to non-manufacturing and non-competing firms.¹⁰

This Article analyzes how patent holders choose their royalties depending on their business model (vertically integrated or not), the structure of the upstream and downstream markets, and the type of licensing agreements feasible: linear and non-linear royalties, cross-licensing, and patent pools. This Article shows that an NPE has different incentives regarding royalty rates than a vertically integrated company. However, there is no reason to presume that a non-integrated patent holder will charge *higher* rates than vertically integrated companies. To the contrary, the vertically integrated firm has an incentive to raise its royalties in order to raise its rivals’ costs and to restrict entry in the downstream market, which does not hold true for non-integrated patent holders. Thus, an integrated firm may charge higher royalties than an NPE.

8. *eBay Inc. v. MercExchange, L.L.C.*, 547 U.S. 388 (2006).

9. *Id.* at 396 (Kennedy, J., concurring) (joining in concurrence Stevens, Souter, and Breyer, JJ.) (citation omitted).

10. See John L. Dauer Jr. & Sarah Elizabeth Cleffi, *Trends in Injunctive Relief in Patent Cases Post-eBay*, THE METRO. CORP. COUNSEL, Feb. 2007, at 16. Drauer and Cleffi state:

[A] survey of the cases decided since *eBay* proves useful in identifying one trend in the decisions. What has become apparent thus far is the district courts’ attention to the considerations expressed in Justice Kennedy’s concurrence and whether the parties are in direct competition. . . .

. . . .
 . . . When the parties are not in direct competition, the courts . . . would likely find monetary damages are adequate To date, district courts appear to have thus far heeded Justice Kennedy’s warnings in his *eBay* concurrence and not issued injunctions to such parties.

Id.; see also Bernard H. Chao, *After eBay, Inc. v. MercExchange: The Changing Landscape for Patent Remedies*, 9 MINN. J. L. SCI. & TECH. 543, 553 (2008) (“[T]he existence of direct competition generally results in a permanent injunction. The converse is also true. Lack of direct competition generally results in the denial of a permanent injunction.”).

There are a few recent papers in the law and economics literature dealing with the problem of patent trolls and NPEs.¹¹ Several authors have pointed out that NPEs, such as universities, government-sponsored research labs, and some high technology companies, can and do perform important and valuable functions in a market economy.¹² For example, many NPEs concentrate on their comparative advantage of conducting research and development while leaving the manufacturing of final products to other companies.¹³ NPEs can also foster the dissemination of new technologies and encourage entry in the downstream market because their primary, if not only, source of revenue relies on making their innovations tradable by patenting and licensing.¹⁴ Other NPEs can act as intermediaries, buying and selling patents to provide liquidity and increased efficiency to technology markets.¹⁵ This literature establishes that a general condemnation of non-practicing patent holders as “trolls” is clearly not warranted. However, none of these papers addresses the question of whether NPEs may have an incentive to charge higher royalties than vertically integrated firms.

In a seminal paper, Carl Shapiro identifies two sets of conditions under which a hold-up problem may give rise to patent troll behavior.¹⁶ First, the manufacturing firm is unaware of the patent when it invests in the production of its product.¹⁷ In this case, after the investment is sunk, the patent holder can extort supra-normal royalties by threatening to obtain an

11. See, e.g., Mark Lemley, *Are Universities Patent Trolls?*, 18 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 611 (2008).

12. For instance, universities are arguably NPEs, but are productive elements of the economy. See *id.* at 629–30. Likewise, research firms with no manufacturing arms, such as Qualcomm and Palo Alto Research Center (PARC) specialize in R&D and can contribute valuable technologies to society, albeit for others to make and commercialize. Finally, patent aggregators such as RPX Corporation, Intellectual Ventures, and OPTI INC can play an important market-making function. See McDonough III, *supra* note 5, at 211.

13. Motivated by the example of universities, Lemley refines the definition of a patent troll. He argues that universities are not patent trolls because they are actively engaged in technology transfer, while patent trolls are non-manufacturing entities that do not engage in technology transfer but instead license only the right not to be sued. However, Lemley concedes that this definition is too abstract and could easily be gamed if applied by the courts. See Lemley, *supra* note 11, at 629–30.

14. See Damien Gerardin, Anne Layne-Farrar, & Jorge Padilla, *Elves or Trolls? The Role of Non-Practicing Patent Owners in the Innovation Economy* (TILEC Discussion Paper No. 2008-018, 2008), available at <http://ssrn.com/abstract=1136086>; Sannu K. Shrestha, Note, *Trolls or Market-Makers? An Empirical Analysis of Nonpracticing Entities*, 110 COLUM. L. REV. 114, 126–31 (2010) (reviewing the various arguments put forth in support of NPEs).

15. See McDonough III, *supra* note 5, at 213–15.

16. Shapiro, *supra* note 7, at 10–11. See generally Lemley & Shapiro, *supra* note 5, for a more detailed discussion of the implications of this model.

17. Shapiro, *supra* note 7, at 11.

injunction and shut down production of the entire product. Second, the manufacturing firm is aware of the patent before it invests in the production of its product, but the patent is “weak,” i.e., the probability that it will be declared valid by a court is considerably smaller than one.¹⁸

In the weak patent scenario, Shapiro’s model assumes two possible outcomes. First, the manufacturing firm can start production without a license and wait for a decision of the court, facing the same sunk cost hold-up problem as described above. Alternatively, the manufacturer can threaten to invent around the patent, such that negotiations with the patent holder are based on the assumption that the patent is valid with certainty. In both cases the patent holder will get supra-normal royalties.

The scenarios, *supra*, considered by Shapiro are illustrations of the hold-up problem and fit the stylized facts of the *BlackBerry* case, but they have nothing to do with the distinction between non-practicing and vertically integrated patent holders. If one of Shapiro’s model hold-up problems arises, both an NPE and a vertically integrated patent holder would have the exact same incentive to exploit it.

This Article considers a set-up that allows for different market structures and different types of licensing contracts. In the upstream market, there are one or more patent holders, each of whom has at least one patent that is essential for the production of the downstream good.¹⁹ All parties are aware of all patents and their validity is not in dispute. Thus there is no hold-up problem stemming from weak patents,²⁰ but each patent holder has considerable market power because he can threaten to interrupt downstream production if the downstream firms are unwilling to accept his royalties.

In Part II this Article analyzes how patent holders choose their royalties depending on their business model (vertically integrated or not) and the structure of the upstream and downstream markets (in situations where all firms act non-cooperatively and set individual linear and non-discriminatory royalties). It is well known in economics that vertical integration eliminates

18. *Id.* at 21.

19. This Article restricts its attention to the case in which the patents at issue are essential for downstream production, so there are no feasible substitutes. This is the most suitable case for its purposes since the presence of viable substitutes prevents hold-up. If there are imperfect but viable substitutes for the patent upstream, the analysis is more complicated. See Daniel Quint, *Economics of Patent Pools When Some (But Not All) Patents Are Essential* (SIEPR Discussion Paper 06-028, 2009), available at <http://www.ssc.wisc.edu/~dqunt/papers/patent-pools-quint.pdf>.

20. This Article finds this form of hold-up far less plausible since licensees can and do challenge the validity of a patent and need not negotiate as if the patent were valid and infringed.

the vertical double mark-up problem within the vertically integrated firm (but not across firm boundaries), which leads to lower royalties.²¹

Part III evaluates the situation of coordinated royalty setting in the upstream market, i.e., cross-licensing agreements or patent pools. Part IV extends the analysis to the case where patent holders can charge non-linear royalties, such as those that combine an upfront fee with a running royalty rate.

These results will show that non-integrated companies are constrained by the impact their behavior has on the downstream market and, in some cases, may charge *lower* royalties than their vertically integrated counterparts. Ultimately, whether a company charges excessive royalties depends on whether there is scope for hold-up, because of either sunk investments or weak patents (coupled with high litigation costs). These factors are orthogonal to whether patent holders are vertically integrated or not. The results suggest that two commonly applied definitions of patent troll—either all non-practicing patent holders or all non-innovating patent collectors—are misleading. The business model of the patent holder is not the key factor for identifying a patent troll. Instead, the crucial factor is the weakness of the patents at issue or the presence of factors that facilitate hold-up in the circumstances at hand.

II. COMPLEMENTS, DOUBLE MARK-UPS, AND RAISING ONE'S RIVALS' COSTS

To clarify the assumptions and the logic behind this Article's conclusions, this Part develops a simple economic model. Consider a high technology good, such as a cell phone or a DVD player, that is based on a technological standard requiring the use of a number of different patented technologies to be operational. Each of the patents is essential in the sense that no firm can legally produce the good without access to each patent. The essential patents are often owned by different companies and each firm that produces the good requires a license from each of the patent holders. The market for licenses will be referred to as the "technology" or "upstream market" and the market for the good (for example, the cell phone or the DVD player) will be the "product" or "downstream market." Some firms may be vertically integrated in that they hold an essential patent and produce the final good. Other companies may be non-vertically integrated: either they hold a patent but do not use it to produce the final good themselves, or they produce the

21. *See, e.g.*, DENNIS CARLTON & JEFFREY PERLOFF, MODERN INDUSTRIAL ORGANIZATION 417 (4th ed. 2005).

final good but do not hold any essential patents. These will be referred to as non-integrated companies—upstream and downstream firms, respectively. To simplify the model, this Article assumes that each company in the upstream market owns exactly one essential patent and that all firms in the downstream market have the same cost functions and produce end goods that are substitutes.

The focus of this analysis is on the royalties that will be charged by vertically integrated and non-integrated patent holders. In this Part, it will be assumed that all patent holders are restricted to using linear, non-discriminatory royalties.²² The prevalence of linear royalty rates in real world licensing contracts can be explained by asymmetries of information between the licensee and the licensor and their risk-sharing properties.²³ Non-discriminatory royalties are often explicitly noted in contracts and are a common commitment made during standard setting (known as Reasonable and Non-Discriminatory licensing (RAND)). Part IV extends this analysis to the case where firms can use two-part tariffs and can discriminate between different downstream producers.

What royalties will be charged by a vertically integrated as opposed to a non-integrated patent holder? The answer depends on the market structure. There are several effects that have opposing impacts on vertically integrated patent holders when compared with non-integrated patent holders.²⁴ In general, it is ambiguous whether a non-integrated patent holder or a vertically integrated firm charges higher or lower royalties. Nevertheless, it is highly instructive to understand the different effects in order to evaluate their relative importance.

22. In other words, for now it can be assumed that the straightforward royalty rates comprise the license payment; non-linear royalty schedules and lump sum fees are not used.

23. If there are asymmetries of information, linear royalties can be used as optimal screening or signaling devices. See, e.g., A.W. Beggs, *The Licensing of Patents Under Asymmetric Information*, 10 INT'L J. INDUS. ORG. 171 (1992) (discussing optimal screening); Alain Bousquet et al., *Risk Sharing in Licensing*, 16 INT'L J. INDUS. ORG. 535 (1998) (characterizing licensing agreements with optimal risk sharing properties); Jay P. Choi, *Technology Transfer with Moral Hazard*, 19 INT'L J. INDUS. ORG. 249 (2001) (showing that linear royalties are optimal when there is moral hazard); Nancy T. Gallini & Brian D. Wright, *Technology Transfer Under Asymmetric Information*, 21 RAND J. ECON. 147 (1990) (discussing signaling devices).

24. As explained in Part II.B, vertical integration reduces double marginalization by combining the entities seeking a profit margin, which tends to lower the royalty rate. But vertical integration also creates incentives to raise downstream rivals' costs, which tends to increase the royalty rate.

A. NON-INTEGRATED PATENT HOLDERS

A non-integrated upstream firm owning a single patent required for downstream production will exercise its monopoly over the patent and charge a royalty that maximizes profits. If the patent holder increases its royalty rate, it will increase the marginal cost that each downstream firm incurs. Downstream firms will, at least partially,²⁵ pass this cost increase through to their customers. Thus, downstream prices will increase and the quantities of the final good sold in the downstream market will decrease. When the monopolistic patent holder chooses its royalty rate, it considers that a higher royalty rate raises its profit on each unit but lowers the number of units sold. Because marginal costs are essentially zero for patent licensing, the patent holder will raise its royalties to the point that a one percent increase in the royalty rate yields a one percent decrease in the quantity sold. This is just the standard monopoly profit maximization problem as applied to patent licensing.

However, in contrast to the standard monopoly problem, there are several additional externalities that the monopolistic patent holder imposes on other active producers in these markets. First, when upstream patent holders choose their royalties they do consider that higher royalties might reduce the profits of the downstream firms. Specifically, if downstream firms cannot pass the increase in the royalty rate through to end prices, then higher royalties reduce the margins of downstream firms. Furthermore, any increase in end prices reduces the quantities that they can sell downstream. Since both the upstream and downstream producers require a profit margin—whereas for an integrated firm a single profit margin suffices—the result is known as a “double mark-up problem.” This problem typically arises when two vertically related firms both have market power.

Second, an upstream patent holder does not take into account that if he raises the royalty rate for his patent, he reduces the profits of the other patent holders, because the patents are perfect complements. This is called the “complements effect.”²⁶ Within a technical standard, patents are perfect complements: each is essential for producing the final good, so each unit sold in the downstream market requires exactly one license of each of the patents. If one patent holder raises its royalty and thereby reduces the total quantity

25. The pass-through rate may be larger than one, for example, in the case of a constant elasticity demand function.

26. *See generally* AUGUSTIN A. COURNOT, RESEARCHES INTO THE MATHEMATICAL PRINCIPLES OF THE THEORY OF WEALTH (A. M. Kelley 1971) (N.T. Bacon trans., 1838) (describing the effects for the first time).

of the final good sold downstream, this increase reduces the revenues of all the other patent holders.

In recent IP literature, the complements problem has acquired the moniker of “royalty stacking” because many firms’ royalty rates stack up to form a large cumulative burden for manufacturers.²⁷ Both the complements and the double mark-up effects may result in an aggregate royalty rate that is higher than the royalty rate a fully integrated monopolist (i.e., a monopolist who owns all essential patents and all downstream firms) would choose.

Both the complements effect and the double mark-up effect tend to raise royalties above their optimal level.²⁸ In fact, if all patent holders set their royalty rates independently and non-cooperatively, then the sum of all royalties would be higher than the total royalties a fully integrated monopolist charges. In this case, upstream and downstream firms, as well as consumers, would benefit if total royalties were lower. The effect occurs because as royalties fall, quantities sold rise, meaning higher royalty revenues for the patent holder.²⁹

B. VERTICALLY INTEGRATED PATENT HOLDERS

A well-known remedy to mitigate the double mark-up problem is vertical integration. In a simple chain of monopolies, vertical integration eliminates the double mark-up problem. However, in a more complicated world with several upstream and downstream firms, vertical integration does not necessarily improve social welfare. For example, suppose one upstream and one downstream firm vertically integrate. When the upstream division of this integrated firm increases its royalty rate, it fully internalizes the effect on the profits of its downstream division. Note that the total firm profits remain unaffected because the royalty rate of its own downstream division is just an internal transfer payment that shifts profits from the downstream to the upstream division. The internalization mitigates the double mark-up problem within the integrated firm. However, with vertical integration there is a new strategic effect pointing in the opposite direction. By raising its royalty rate, the vertically integrated firm raises the costs of its downstream competitors without raising its own cost. Thus, by raising the marginal costs of its rivals, the integrated firm gains a competitive advantage, pushes its rivals’ prices

27. See Lemley & Shapiro, *supra* note 5, at 1993.

28. See *id.* at 2014.

29. In the region where prices exceed the monopoly level, the effect of increasing quantities outweighs the effect of falling royalty rates. See CARLTON & PERLOFF, *supra* note 21, at 91.

higher, and as a result, gains a higher market share downstream for the sale of its own good.³⁰

The source of this “raising one’s rivals’ costs effect” is vertical integration.³¹ A non-integrated patent holder does not participate in downstream profits. Thus an upstream patent holder benefits if the downstream market becomes more competitive, if there is market entry, and if more units of the final good are sold as a result. In contrast, a vertically integrated firm makes part, or most, of its profits in the downstream market. Therefore, since the vertically integrated firm wants this market to be less competitive, it will oppose market entry, and it will use the royalty rate for the patent of its upstream division to achieve an advantage over rival downstream firms that do not hold patents for cross-licensing.

To illustrate this point, suppose that there is just one upstream patent holder and a large number N of potential downstream firms with identical cost functions that compete in quantities in the downstream market. Suppose that a Cournot equilibrium³² exists in the downstream market for any royalty rate $r > 0$ charged by the upstream monopolist.³³ No other assumptions need to be imposed on the cost and demand functions.

30. The “raising one’s rivals’ costs” effect was first described by Salop and Scheffman. See Steven C. Salop & David T. Scheffman, *Raising Rivals’ Costs*, 73 AM. ECON. REV. 267 (1983); see also Steven C. Salop & David T. Scheffman, *Cost-Raising Strategies*, 36 J. INDUS. ECON. 19 (1987) (generalizing and extending the results from *Raising Rivals’ Costs*, as well as developing a theory of raising rivals’ costs through vertical integration showing that vertical integration can be anticompetitive). However, they restrict attention to a dominant firm that can affect marginal and average costs of a competitive fringe. They show that the dominant firm will raise its rivals’ cost in order to either foreclose the market or to induce competitors to raise their prices and to relax competition. The situation this Article is interested in is closer to the models examined by Ordober et al. and Kim, and considers a two-stage duopoly model with price competition and differentiated products. Their model looks at the more conventional case where the goods produced upstream are perfect substitutes while this Article looks at the opposite case of perfect complements. See Janusz A. Ordober, Garth Saloner & Steven C. Salop, *Equilibrium Vertical Foreclosure*, 80 AM. ECON. REV. 127, 138–40 (1990) (finding that a vertically integrated firm must be able to commit ex ante to a price for the input good, even though there is an incentive to reduce this price ex post). No such commitment is necessary in this Article’s analysis. Kim analyzes a similar model, but he restricts attention to the case of a linear demand curve. See Sung H. Kim, *Vertical Structure and Patent Pools*, 25 REV. INDUS. ORG. 231, 236–38 (2004).

31. See Klaus M. Schmidt, *Licensing Complementary Patents and Vertical Integration* (CEPR Discussion Paper No. 5987, 2006), available at <http://www.cepr.org/pubs/new-dps/dplist.asp?dpno=7005>.

32. See COURNOT, *supra* note 26, and accompanying text.

33. That is, an equilibrium where firms compete on quantities supplied and the equilibrium price is determined by the sum of these quantities. Novshek offers a set of fairly weak sufficient conditions that guarantee existence and uniqueness of an equilibrium in the Cournot model. He requires that there exists a \bar{q} (where the upper bar indicates an upper

Suppose that the patent holder is non-integrated and not active in the downstream market. In this case it will charge the monopolistic royalty rate $r^M > 0$ that maximizes profits given the Cournot equilibrium in the downstream market. The larger the N , the more competitive the downstream market, the smaller the mark-up charged by the downstream firms, the greater the volume of goods sold, and the higher the patent holder's profits.

If the upstream patent holder vertically integrates with one of the downstream firms, one possible strategy of the integrated firm is to charge a royalty rate that is so high that no other downstream firm can make a profit which forces them to exit the market. The rate increase does not affect the downstream division of the integrated firm because within the integrated firm the royalty rate is a mere transfer price that has no effect on overall firm profits: each dollar spent on higher royalties by the downstream division is a dollar of revenue for the upstream division. Thus, by raising its royalty rate to a prohibitively high level, the integrated firm can foreclose all other downstream firms and monopolize the downstream market. Because a fully integrated monopolist (who controls both the upstream and the downstream market) maximizes profits, this strategy is indeed optimal.³⁴

This extreme example shows that a vertically integrated firm has a natural inclination to use its royalty rate to raise the costs of its rivals in order to increase its profits in the downstream market. If the downstream firms are not all identical, but instead sell sufficiently differentiated products or have lower marginal costs than the downstream division of the integrated firm, then the integrated firm will not want to completely shut out all of its downstream rivals from the market.³⁵ The presence of other differentiated downstream firms extends the market, and increases the royalty income of the upstream division. However, the integrated firm still charges a royalty rate that discriminates against its downstream rivals. Thus the integrated firm's royalty rate may be higher than the royalty rate chosen by a non-integrated upstream firm under identical circumstances and patented technology.

bound for Q) such that $P(Q) > 0$ for all $Q < \bar{Q}$ and that $P(Q) = 0$ for all $Q > \bar{Q}$, and that $P(Q)$ is twice continuously differentiable with the first derivative $P'(Q) < 0$ for all $Q < \bar{Q}$ (note that a single apostrophe is the typical mathematical symbol for a first derivative). Furthermore, $P'(Q) + q \cdot P''(Q) < 0$ for all $0 \leq q \leq \bar{Q}$. William Novshek, *On the Existence of Cournot Equilibrium*, 52 REV. ECON. STUD. 85, 90–94 (1985).

34. And has thus been a real world problem. See, e.g., *United States v. Aluminum Co. of America*, 148 F.2d 416, 427 (2d Cir. 1945); *Case T-5/97, Industrie des Poudres Sphériques SA v. Comm'n*, 2000 E.R.C. II-3755.

35. See also X.H. Wang & B.Z. Yang, *On Licensing Under Bertrand Competition*, AUSTL. ECON. PAPERS, June 1999, at 106, for a similar result with Bertrand competition.

In conclusion, vertical integration has two effects on the market outcome. First, vertically integrated firms internalize the double mark-up effect between upstream and downstream divisions, which tends to improve efficiency. Second, the “raising one’s rivals’ costs effect” tends to raise royalties and to reduce efficiency. The specific structure of the cost and demand functions determines which of the two effects dominates. Klaus Schmidt shows in a much more general model, with arbitrarily many firms in the upstream and downstream markets and a general model of downstream competition, that a market in which all firms are vertically integrated may give rise to higher *or* lower total royalties than a market in which all firms are non-integrated.³⁶ For the special, but natural example of Cournot competition with linear demand and cost functions and identical firms, Sung H. Kim shows that if the number of vertically integrated firms is not too large, then vertical integration induces an equilibrium price in the downstream market that is strictly higher than the equilibrium price obtained under non-integration.³⁷ Thus, vertical integration may well reduce total output, total industry profit, and social welfare.

If there are several vertically integrated upstream firms, each of them has an incentive to raise the costs of the other vertically integrated firms by raising its royalties. This gives rise to the prisoners’ dilemma. All vertically integrated upstream firms would be better off if they would all charge lower royalties, but for each firm, it is optimal to charge high royalties. Part III shows that cross-licensing agreements or patent pools can solve this prisoners’ dilemma, although they do not necessarily solve the problem of raising rivals’ costs.

III. POOLING AGREEMENTS AND CROSS-LICENSING

One assumes thus far that all firms active in the upstream market choose their royalty rates independently and non-cooperatively. However, it is quite common that firms coordinate their behavior through bilateral cross-licensing agreements.³⁸ Moreover, within standard setting contexts, it is becoming more common for at least some patent holders among a group of firms with complementary patents to coordinate their licensing through patent pools.³⁹ Such cross-licensing and pooling agreements are often

36. See Schmidt, *supra* note 31, at 13–14.

37. See Kim, *supra* note 30, at 245 (Theorem 3).

38. See Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, in 1 INNOVATION POLICY AND THE ECONOMY 119, 127 (Adam B. Jaffe, Josh Lerner & Scott Stern eds., 2000).

39. See, e.g., Sabra Chartrand, *The Federal Government Will Allow a Group of Companies to*

reciprocal.⁴⁰ Each firm agrees to a low royalty rate for its own patents as long as the other firms involved in the agreement also charge a low royalty rate.

This Part shows that if all firms are vertically integrated—as was largely the case within standards setting in past decades—it is possible to solve both the complements and the double mark-up problem as well as sustain the fully integrated monopoly outcome with a set of cross-licensing agreements. If the firms are symmetric, they will charge symmetric royalty rates.⁴¹ Because everything is symmetric, the royalty payments cancel out and there are no net payments in equilibrium for other vertically integrated firms. However, if non-integrated downstream firms are present in the market (e.g., semiconductor chip fabricators that are not active in chip design), the problem of raising rivals' costs returns.

Some have argued that because the need to get cross-licenses from fellow patent holders does not restrict a non-integrated patent holder's behavior, it will turn such a patent holder into a patent troll charging unjustifiably high royalties.⁴² Without the constraints that reciprocal cross-licensing imposes, it is claimed that non-integrated patent holders will hold-up vertically integrated firms and charge excessively high royalties.⁴³ However, this argument misses the mark. Pooling agreements may solve the complements and the double

Unify Administration of 27 Patents, N.Y. TIMES, June 30, 1997, at D8 (discussing the pool that is under development for radio frequency identification (RFID) standards); Philip Goldstein, *SISVEL Launches CDMA2000 Patent Pool*, FIERCEWIRELESS, June 11, 2009, <http://www.fiercewireless.com/press-releases/sisvel-launches-cdma2000-patent-pool>; Olga Kharif, *The RFID Patent Pool: Will It Make Waves?*, BUSINESSWEEK, Sept. 11, 2006, (The Tech Beat Blog), http://www.businessweek.com/the_thread/techbeat/archives/2006/09/the_rfid_patent.html; Lynette Luna, *Patent Pool Can Work in the 4G World*, FIERCEWIRELESS, June 22, 2009, <http://www.fiercewireless.com/story/patent-pool-can-work-4g-world/2009-06-22>; Press Release, Via Licensing Corp., *Via Licensing Announces Progress Toward Establishing AVC License Terms* (Oct. 15, 2003), available at http://www.vialicensing.com/news/details.cfm?VIANEWS_ID=309 (discussing many of the video and audio MPEG standards already involving patent pools).

40. See Shapiro, *supra* note 38.

41. In other words, if the firms hold similar patent portfolios (in terms of estimated value and composition), serve the same markets and similar customers, and generate roughly the same size in terms of revenues, then they will charge each other roughly similar licensing fees, so that a royalty free swap is likely.

42. See, e.g., Carl Shapiro, *Technology Cross-Licensing Practices: FTC v. Intel (1999)*, in THE ANTI-TRUST REVOLUTION: ECONOMICS, COMPETITION, AND POLICY 350, 357 (4th ed. 2004). On the other hand, some authors recognize that cross-licensing represents just one possible constraint, with other constraints remaining in place. See, e.g., Anne Layne-Farrar, Gerard Llobet & A. Jorge Padilla, *Preventing Patent Hold Up: An Economic Assessment of Ex Ante Licensing Negotiations in Standard Setting*, 37 AIPLA Q.J. 445 (2009).

43. See Shapiro, *supra* note 42.

mark-up problem even if some upstream firms are non-integrated.⁴⁴ In this case, firms are no longer symmetric. The non-integrated patent holders make their profits in the upstream market only and must insist on charging relatively higher royalties, while the integrated firms make their profits both upstream and downstream and tend to prefer lower royalties that shift profits downstream. This follows because with imperfect competition in the downstream market, vertically integrated firms earn additional margins downstream. For equally allocated profits amongst all integrated and non-integrated patent holders, the non-integrated patent holders must charge higher royalties than the integrated firms.

To make these arguments more precise, consider the case where there are $N \geq 2$ symmetric and vertically integrated companies. Suppose that these firms negotiate a set of cross-licensing agreements according to which each firm charges each other firm the royalty $r \geq 0$ for using its patent. Thus, the total royalty that each firm has to pay for each unit of the final good it sells in the downstream market is equal to the sum of rival upstream firm's royalty rates, which, given the assumed symmetry, amounts to multiplying the royalty rate, r , by the number of rivals: $R = (N-1)r$. Let R^* denote the total royalty payment that induces each firm to produce $1/N$ of the output in the downstream market. If the firms choose $r = r^* = R^* / (N-1)$, then, given the set of cross-licensing agreements, each firm will produce $1/N$ of the quantity downstream and each firm will earn $1/N$ of the fully integrated profit. Thus, if all vertically integrated firms agree to charge the same royalty, r^* , the complements and the double mark-up problems disappear, just as if the firms had literally merged into a single monopoly firm. Furthermore, the cross-licensing agreements prevent the firms from raising their vertically integrated rivals' costs.

The above example mimics the outcome of a patent pool where a single licensing authority handles licensing of the full bundle of patents. Note that N vertically integrated firms forming such a pool is an agreement that fixes input prices. Antitrust authorities could regard this as an illegal cartel. In fact, the vertically integrated firms charge each other royalties that pass through to consumers and induce downstream divisions to charge the monopoly price. But, as previously discussed, this price is lower than if firms did not coordinate their behavior. The reason is the complements problem. If the N upstream monopolists do not coordinate their behavior, each will try to

44. Keeping with the chip example, these firms would be the design-only shops, having no manufacturing plants.

exploit their monopoly power. Total royalties will be even higher than the royalty a fully integrated monopolist charges.

To be sure, the outcome of a patent pool is a monopoly outcome. But, the monopoly is based on the IP rights of the patent holders, which are the rewards for their innovations. The patent pool ensures that none of the patent holders monopolizes their invention, which would impose negative externalities on the other monopolists; instead, patent holders coordinate their behavior to make benefit everyone.

Nevertheless, antitrust authorities tend to view patent pools that fix input prices with great suspicion, while they are generally much less skeptical about bilateral, reciprocal cross-licensing agreements.⁴⁵ However, in terms of economic effects, there is little difference between a patent pool and a bilateral cross-licensing agreement. For example, with a linear Cournot game, the same outcome can be sustained in equilibrium if only bilateral cross-licensing agreements are feasible, rather than a full-fledged pool.⁴⁶ To see this, consider two firms, i and j , who agree to a reciprocal royalty rate amongst themselves. This royalty rate has to be optimal given the royalty rates that all other pairs of firms have already agreed to. If all firms bilaterally agree to charge each other r^* , then firms jointly produce the monopoly quantity and earn the monopoly profit. Suppose now that firms i and j reduce the royalty rate that they charge each other. This reduces their marginal costs, so they gain an advantage in the downstream market. However, all the other firms now produce less downstream which implies less licensing income for firms i and j upstream. It turns out that these two effects just cancel out.⁴⁷ Thus, the patent pool outcome is also an equilibrium outcome if bilateral cross-licensing agreements are the only contract choice for firms.

If, in addition to the N vertically integrated firms, there are some non-integrated downstream firms, the double mark-up and the raising one's rivals' costs effects reappear. This scenario, where the more traditional large

45. U.S. DEP'T JUSTICE & FED. TRADE COMM'N, ANTITRUST ENFORCEMENT AND INTELLECTUAL PROPERTY RIGHTS: PROMOTING INNOVATION AND COMPETITION 8, 66 (2007), available at <http://www.ftc.gov/reports/innovation/P040101PromotingInnovationandCompetitionrpt0704.pdf>; Commission Notice, Guidelines on the Application of Article 81 of the EC Treaty to Technology Transfer Agreements, 2004 O.J. (C 101/2); see also Richard Schmalensee, *Standard-Setting, Innovation Specialists and Competition Policy*, 57 J. INDUS. ECON. 526, 542–47 (2009) (arguing that antitrust policy should not allow or encourage collective negotiation of patent royalty rates).

46. See *infra* Appendix.

47. This equilibrium need not be unique. However, even if there are multiple equilibria, the equilibrium that implements the monopoly outcome maximizes total surplus of all firms and is a natural focal point.

vertically integrated firms compete with both upstream and downstream specialists, is the best description of the composition of firms participating in most cooperative standard-setting bodies today. In this common case, under this Article's model, the vertically integrated firms will charge the low reciprocal royalty rate, r^* , only among themselves but a higher royalty rate, $r > r^*$, to their non-integrated downstream competitors. Part of the increased royalty rate is due to the downstream specialists' lack of patents to cross-license,⁴⁸ which eliminates a payment in kind. Some portion of the increase, however, is set in order to discriminate against the non-integrated downstream rivals.

What happens if, in addition to the N vertically integrated firms, there is also some number $M > 0$ of non-integrated patent holders? Is it still possible to solve the complements and the double mark-up problem with a multi-lateral cross-licensing agreement? If the total royalty rate that each downstream division has to pay equals the sum set before, R^* , then each firm will again produce $1/N$ of the monopoly output, just as before. However, the non-integrated patent holders have no interest in cross-licensing agreements because they do not require a license for the other patents. Furthermore, note that the integrated firms make part of their profits upstream and part of them downstream, while the non-integrated patent holders rely entirely on their royalty income. Finally, vertically integrated firms can also accept a portion of their upstream payment in the form of a cross-license, which tends to reduce the explicit royalty rate sought. For these reasons, non-integrated patent holders tend to ask for higher royalties than vertically integrated firms. In particular, if all firms have the same bargaining power and agree to share profits equally, the non-integrated patent holders must get a higher royalty rate than the vertically integrated firms.

If constraints forced firms to charge equal royalties independent of whether they are active in the downstream market or not, a conflict of interest would arise. Vertically integrated firms prefer a royalty rate, r , that is somewhat smaller than the monopoly royalty rate, $r^* = R^*/(M+N-1)$. This rate corresponds to the monopoly outcome and lowers total industry profits, but it does so at the expense of the non-integrated upstream firms, while the vertically integrated firms benefit from the lower downstream costs. In comparison, the non-integrated upstream firms prefer a royalty rate that is somewhat higher than the monopoly rate, $r^* = R^*/(M+N-1)$, because they want to shift profits from the downstream to the upstream market.

48. For an introduction to the interaction between contract terms, see generally THE ECONOMICS OF CONTRACTS: THEORIES AND APPLICATIONS (Eric Brousseau & Jean-Michel Glachant eds., 2002).

IV. NON-LINEAR AND DISCRIMINATORY ROYALTIES

Firms may also use non-linear royalty schemes, such as two-part tariffs, which are licenses with an upfront lump sum fee paid in conjunction with a linear running royalty rate based on sales spread over a specified time period. Such licenses are common in practice. The upfront fee reflects the agreed upon value of the patented technology, while the running royalty shares the risk over any remaining uncertainty regarding the commercial success of the product employing the patented technology. If written cross-licensing agreements are an option, the ability to employ similar non-linear payment schedules does not change the analysis.⁴⁹ The parties can set the linear portion of the royalties to implement the monopoly outcome and then use the fixed fees to redistribute profits.

Non-linear royalties are more interesting if firms have to set their rates independently and non-cooperatively, as is often the case in standard-setting bodies. The following analysis shows that the monopoly outcome can still be achieved if all firms are non-integrated. Suppose that each non-integrated upstream patent holder u , $u=1, \dots, N$, makes a take-it-or-leave-it offer of a two-part tariff consisting of a fixed fee, R_u , and a linear royalty rate, r_u .⁵⁰ The first step of the argument is to show that all of the non-integrated downstream firms must make zero economic profits in equilibrium.⁵¹ Suppose, to the contrary, that downstream firms make an economic profit that is strictly positive. Then an upstream patent holder could raise its fixed fee, R_u , in order to capture this profit for itself, without affecting the downstream firm's decision to continue participating in the market. As long as economic profits are non-negative, the downstream firm will stay in the market. In fact, if the sum of the fixed fees of the other upstream firms leaves any profit for the downstream firms, then each upstream firm has an incentive to further raise its fixed fee until all downstream firms make zero

49. Note that cross-licensing agreements are not always possible. For instance, if patented technology has many applications across multiple industries, it is possible that a particular licensee has no patents of interest to offer the licensor. Alternatively, if the licensee is a patent aggregator or an upstream R&D specialist, it may have no interest in any cross-licenses.

50. The combination of take-it-or-leave-it offers and two-part tariffs implies that upstream patent holders have all the bargaining power and that downstream firms do not get any rents. In a more complex bargaining procedure that gives some bargaining power to downstream firms, this extreme result disappears. However, all the qualitative results, described *infra*, still hold true.

51. Recall that accounting profits are very different from economic profits, which consider opportunity costs in addition to costs of production. Zero economic profits simply indicate a competitive market, where downstream firms do not earn anything above the competitive return for their production investments.

economic profits. Thus, in equilibrium, upstream firms will extract the entire surplus from downstream firms.⁵² If a downstream firm controls an input factor that increases the value of the downstream good, such as a brand name, its bargaining power would be stronger and the allocation of profits would surely differ.

The second step of the argument is to show that linear royalties will be set efficiently so as to maximize the downstream profits that can then be captured by the upstream firms. To illustrate, suppose that the sum of the linear royalties is higher than the royalty rate that implements the monopoly price. This circumstance has been described as “royalty stacking” in the literature.⁵³ If rates were to stack to a level higher than the monopolistic rate, the upstream patent holder, u , could reduce its royalty rate, r_u , which would increase total profits because rates higher than a monopolist’s yield strictly smaller profits for the patent holder. The patent holder can simultaneously increase its fixed fee, R_u , as a means of capturing the entire increase in total profits for itself, leaving the downstream firms with zero economic profits, described *supra*. Thus, if the sum of the linear royalties does not lead to the monopoly outcome, each upstream firm has an incentive to change its royalty structure in order to obtain the resulting increase in profits through an increase of the fixed fee. There is a symmetric pure strategy equilibrium in which all patent holders charge the same linear royalties and fixed fees such that the sum of the linear royalties implements the monopoly outcome and the sum of the fixed fees captures all the downstream profits. Thus, with the flexibility of two-part tariffs, both the double mark-up and the complements problem, including royalty stacking, disappear. To summarize, if all firms are non-integrated and two-part tariffs can be used, the same outcome will manifest with a patent pool even if no written cross-licenses are utilized.

However, this result holds only if all patent holders are non-integrated—an unlikely scenario. Today, most complex industries, where the complements and double mark-up problems are likely to emerge, are characterized by a mixture of vertically integrated and non-integrated firms. In fact, under this Article’s model, if there are at least two vertically integrated firms along with the other non-integrated firms, then there is no symmetric, pure strategy equilibrium where all patent holder royalty rates are the same—some asymmetry must persist. For example, suppose that there is an equilibrium in which all firms charge symmetric fees, r , and royalties, R .

52. This extreme outcome is due to the assumption that the upstream firms have all the bargaining power and can make take-it-or-leave-it offers. See Schmidt, *supra* note 31, at 10.

53. See Lemley & Shapiro, *supra* note 5, at 1993.

First of all, it must be the case that the fixed fees extract all the profits from the downstream market, otherwise each firm would have an incentive to further raise its fixed fee. But if fees and royalties extract all of the downstream economic profits, then all vertically integrated firms are indifferent as to whether or not to produce downstream. Suppose that vertically integrated firm, i , further increases its linear royalty rate or its fixed fee. The increase does not affect i 's own costs, but it does raise the costs of its downstream rivals. As a result, some other firms will now decide not to buy the licenses at all and to produce a quantity of zero—all to the benefit of firm i . Therefore, firm i has an incentive to deviate from the proposed equilibrium candidate. Thus, the “raising rivals’ costs” effect implies that a symmetric, pure strategy equilibrium does not exist when both integrated and non-integrated firms are present.

As seen *supra*, when all downstream firms are vertically integrated, firms can deal with the “raising rivals’ costs” effect by writing a cross-licensing agreement. However, they nonetheless have an incentive to discriminate downstream against non-integrated firms in order to jointly monopolize the market. Non-integrated upstream firms do not have this incentive. To the contrary, they benefit from more downstream competition because it increases downstream quantities sold and therefore increases their royalty income. This result leads us to reject the prevalent definition of a patent troll as any non-practicing or non-innovating entity. Indeed, NPEs are the least likely to exhibit troll behaviors. Instead, a better gauge is the presence of special conditions for a patent hold-up and the exploitation of irreversible investments, regardless of the business model of the patent holder.

V. CONCLUSIONS

This analysis shows that the presumption that NPEs always charge higher royalties than vertically integrated companies is not warranted. It is true that if firms set linear royalties non-cooperatively, a vertically integrated firm will internalize the vertical double mark-up problem which tends to reduce royalties. However, a vertically integrated firm also has an incentive to raise its royalties in order to raise its rivals’ costs and to restrict entry in the downstream market, especially among non-integrated downstream firms. The overall effect on rates is ambiguous. In fact, under some circumstances, a vertically integrated firm may charge *higher* royalties than its non-integrated counterpart.⁵⁴

54. In particular, when the downstream market is comprised of both vertically integrated firms and downstream manufacturing specialists, the integrated firms have strong

If firms can coordinate their royalties through patent pools or cross-licensing agreements, they can solve the complements and the double-mark-up problem independently of whether or not they are vertically integrated. However, if there are non-integrated downstream firms, vertically integrated firms will nonetheless want to increase royalties in order to discriminate against them, while non-integrated patent holders will want to decrease royalties to benefit from increased competition and entry downstream.

When both non-integrated and integrated firms hold patents and are able to coordinate their royalties, a conflict of interests arises. Non-integrated firms have to make their profits upstream, while the vertically integrated firms make some part, or even the bulk of their profits in the downstream market. Furthermore, vertically integrated firms may reduce their royalty rates in exchange for a cross-license payment in kind—an option not available to upstream firms. Therefore, if firms want to split *profits* equally, or if they want to achieve the same aggregate licensing payments, then non-integrated firms must receive higher explicit *royalties* than the integrated firms.

This Article's analysis suggests that there is no justification for the presumption that non-integrated patent holders always charge higher royalties than vertically integrated companies. Moreover, even when non-integrated patent holders charge "higher" royalties than their vertically integrated counterparts, it does not imply that the rates are "excessive" or that the firm is exhibiting troll-like behavior. Rather, non-integrated patent holders naturally require higher royalty earnings because they earn no profits downstream and receive no payments in kind in the form of cross-licenses.

The findings presented in this Article are consistent with the larger patent literature. In a recent empirical paper, Allison, Lemley, and Walker analyzed a data set of litigated patents.⁵⁵ Almost by definition, litigated patents are patents that are highly valuable. A large fraction of these patents are owned by NPEs, held mainly by invention specialists and by patent holding companies. This shows that NPEs play a major role in the modern patent system. Allison et al. compare the characteristics of the most litigated patents, specifically patents that have been litigated at least eight times, to patents that have been litigated only once. They find that the most litigated patents are much more likely to be owned by NPEs.⁵⁶ This is consistent with this

incentives to raise their non-integrated rivals' costs through high royalty rates. This strategy softens downstream competition and enables the integrated firms to earn higher profits.

55. John R. Allison, Mark A. Lemley & Joshua Walker, *Extreme Value or Trolls on Top? The Characteristics of the Most-Litigated Patents*, 158 U. PA. L. REV. 1 (2009); see also Shrestha, *supra* note 14 (similar findings).

56. *Id.* at 23–26.

Article's analysis that suggests that there is more potential for conflict if NPEs are involved.⁵⁷ Furthermore, in the overwhelming majority of cases studied by Allison et al., the patent holders were invention specialists.⁵⁸ Only seven percent of all lawsuits involved patent holders that did not invent the patent themselves, but rather, acquired it.⁵⁹ This suggests that court-based discrimination against all NPEs could have severe adverse effects on the investment incentives of innovation specialists who play an important role in advanced market economies.

In conclusion, remedy rules, such as entitlement to injunctive relief, should not depend on the plaintiff's business model status. Whether a company charges "excessive" royalties depends on the potential scope for a hold-up, either because of sunk investments or weak patents. These factors are orthogonal to whether patent holders are vertically integrated or not.

57. *See supra* Part II.

58. Allison et al., *supra* note 55, at 23–26.

59. *Id.* at 32.

APPENDIX: BILATERAL CROSS-LICENSING

Consider N vertically integrated firms producing with identical constant marginal production cost k . Each firm owns one essential patent. Firms compete in quantities in the downstream market and face a linear inverse demand function, $P(Q)=a-bQ$. Each pair (i,j) , $i, j \in \{1, \dots, N\}$, of firms agrees to symmetric cross-licensing at rate $r_{ij}=r_{ji}$, where r_{ij} is the linear royalty charged by firm i to firm j . Thus, the total licensing costs of firm i are given by $R_i \sum_{j \neq i} r_{ji}$.

We look for a subgame perfect equilibrium with the two following properties:

- Given the licensing cost R_i the firms play a Cournot-Nash equilibrium at the second stage of the linear Cournot game.
- There does not exist a pair (i, j) of firms that could increase its joint profits by agreeing to a different cross-licensing rate.

CLAIM

There is a symmetric subgame perfect equilibrium in the cross-licensing game in which all firms agree to charge the same cross-licensing royalty rate $r_{ij} = r = \frac{a-k}{2N}$. This licensing rate implements the monopoly outcome.

PROOF:

Suppose that each pair of firms agreed to the cross-licensing rate $r = \frac{a-k}{2N}$. Then each firm has marginal cost $c = k + \frac{(N-1)(a-k)}{2N}$. It is straightforward to compute the symmetric Cournot-Nash equilibrium at the second stage of the game. In equilibrium, each firm produces $q = \frac{a-k}{2bN}$, so the total quantity supplied is $Q = \frac{a-k}{2b}$ which is equal to the monopoly quantity. The resulting price is the monopoly price $p = \frac{a+k}{2}$, and each firm makes $\Pi_i = \frac{(a-k)^2}{4bN}$ which is $1/N$ of the monopoly profit.

Suppose now that two firms 1 and 2 consider a deviation and charge each other $r_{12} = r_{21} = r - d$, (where d may be positive or negative). This deviation changes the marginal costs of these two firms to $\underline{c} = k + (N-2)r + r - d = (N-1)r - d$, while the marginal costs of all other firms remain unchanged. We now have to solve for the Cournot-Nash

equilibrium in the downstream market with asymmetric cost functions. Note that downstream profit functions are given by

$$\Pi_i = \left(a - b \sum_{j=1}^N q_j - k - (N-1)r + d \right) \cdot q_i \text{ if } i \in \{1,2\}$$

$$\Pi_i = \left(a - b \sum_{j=1}^N q_j - k - (N-1)r \right) \cdot q_i \text{ if } i \in \{3, \dots, N\}$$

The first order conditions for profit maximization are given by

$$\frac{\partial \Pi_i}{\partial q_i} = a - 2bq_i - b \sum_{j \neq i} q_j - k - (N-1)r + d = 0 \text{ if } i \in \{1,2\}$$

$$\frac{\partial \Pi_i}{\partial q_i} = a - 2bq_i - b \sum_{j \neq i} q_j - k - (N-1)r = 0 \text{ if } i \in \{3, \dots, N\}$$

Symmetry of firms 1 and 2 and firms 3, ..., N requires $q_1 = q_2 = \bar{q}$ and $q_3 = \dots = q_N = \underline{q}$. Solving for \bar{q} , \underline{q} , and P and plugging in $r = \frac{a-k}{2N}$ yields:

$$\bar{q} = \frac{a - k - (N-1)(r - d)}{b(N+1)} = \frac{a - k}{2Nb} + \frac{N-1}{N+1} d$$

$$\underline{q} = \frac{a - k - (N-1)r - 2d}{b(N+1)} = \frac{a - k}{2Nb} - \frac{2d}{N+1}$$

$$P = \frac{a + Nk + rN(N-1)}{N+1} = \frac{a + k}{2} - \frac{2d}{N+1}$$

Thus, the profit of firm $i \in \{1,2\}$ is given by

$$\Pi_i = \underbrace{(P - k - (N-1)r + d) \cdot \bar{q}}_{\text{downstream profit}} + \underbrace{(r - d)\bar{q} + (N-2)r\underline{q}}_{\text{upstream profit}}$$

Substituting P , r , \bar{q} , and \underline{q} yields

$$\Pi_i = \frac{-4akN + a^2N^2 + k^2N^2 + 2a^2N + k^2 - 2ak - 2aN^2k - 8d^2N(N-1)}{4bN(N+1)^2}$$

Differentiating with respect to d we get:

$$\frac{\partial \Pi_i}{\partial d} = \frac{-16dN(N-1)}{4bN(N-1)} = -\frac{4d}{b}$$

Note that this profit function is globally concave and maximized at $d = 0$. Thus, no pair of firms has an incentive to deviate and to change its bilateral royalty rate. *Q.E.D.*

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