Licensing Intellectual Property In the Presence of Non-Contractible Complements*

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Abstract

This paper provides a simple model of licensing intellectual property to licensees who sell complementary products, revenues from which are at least partially uncontractible. When the licensor cannot use fixed fees, he prefers output-based royalties over profit-sharing agreements if the licensee's revenues from complements are not too high and if the fraction thereof that can be brought under the incidence of a licensing agreement is sufficiently large. The public policy implication is that, in such licensing contexts, there is a compelling case for broadening the ability of licensors to share in revenues from sales of "adjacent" products in order to allow for the internalization of externalities due to product complementarities. We illustrate our arguments with two case studies: licensing of printer technology to Dell and licensing of music to Apple Computer.

Keywords: patents, technology transfer, cross-licensing.

1 Introduction

Technological progress has made cross-licensing and licensing from multiple sources a widespread business phenomenon. Most technology products and services today are made up of complementary components, which may be based on technology or intellectual property licensed from different firms. Consider for instance the mobile services offered by telecommunications network operators such as Sprint in the United States, Vodafone in Europe and NTT DoCoMo in Japan. They include chipsets from technology companies (such as Qualcomm), mobile handsets from hardware makers (Motorola, Nokia, Panasonic, Samsung), software applications and content from hundreds of independent vendors, and of course network capacity from the operator itself. Similarly, a music download service such as Real Networks' Rhapsody is composed from streaming and

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digital rights management software done by Real on the one hand, and music licensed from dozens of music labels on the other.

As the business practice of building services from complementary parts licensed from various sources has become more widespread, so have the difficulties associated with it. In particular, given the strong complementarities between components, it is oftentimes very hard if not impossible to associate revenue streams from the final service with the individual values of licenses for each component. In other words, even though a component of the final service may generate a relatively small share of revenues directly, it may in fact create much more value indirectly by enhancing the revenues from other components. When this is true for each component, it leads to the question: how does one place a dollar value on the license for an individual component?

A specific example (which we develop as a case study in section 2) is that of printer manufacturers, who are well-known for selling the printers at a price oftentimes below cost in order to lock customers in and then make profits from the sale of printer cartridges. Now imagine that a printer manufacturer licenses the technology underlying its printer hardware from another company, but produces its own cartridges: what should be the appropriate compensation to the licensor? Clearly, if one defined it based solely on the profits made from the sale of printers - which may be negative -, the value of the license would be likely underestimated.

While, at first glance, an obvious solution to such problems would be to allow the licensor to claim a share of total revenues (from both printers and cartridges), there are several obstacles that make it infeasible in practice. First, the manufacturer licensee may resist any attempt by the licensor to share in any of the revenues from the cartridges, on grounds that the licensor had no contribution in their production. Second, revenues from cartridges (or any complementary services to printers such as maintenance) may not be easily observable and hence not contractible. Third, the licensor may be limited by antitrust concerns from trying to extend the scope of claims for his license to complementary products. These obstacles may lead to a breakdown of licensing deals and therefore to economic inefficiency, which suggests that it is important to throw some light on the underlying economic issues arising in such licensing contexts. This is the objective of this paper.

To take a more extreme example, consider the problem of vendors of proprietary software attempting to license software pieces to companies selling open source software, such as IBM with its Websphere suite of services. The latter gives away the software for free and instead sells associated services (maintenance, upgrades, patches, etc.). In this case, there are no profits made from the product based on the license and it is exceedingly difficult for the licensor to claim a share of adjacent revenues, given that it is virtually impossible to isolate the part of those revenues which corresponds to services associated with the software licensed from the licensor. So how should the latter approach the licensing deal? Is such a deal feasible?

This paper provides a first pass at modelling the economic problem of licensors attempting to extract appropriate compenstion from licensees who sell com-

plementary products, revenues from which are at least partially uncontractible. We use a simple model to show that when the licensor cannot use fixed fees,[1] his choice between charging output-based royalties or pursuing a profit-sharing agreement with the licensee depends on the relative size of potential licensee revenues from complements and the fraction thereof that can be brought under the incidence of a licensing agreement. In general, when the licensee can make more profits from complements and a lower share of these are contractible under licensing, the licensor is more likely to choose output-based royalties over profit-sharing in order to make sure the product based on his license is not given away for free. Profit-sharing agreements become more attractive when revenues from complements are smaller and easier to contract upon.

The type of licensing problem we analyze here also has important implications for public policies regarding patent scope. Indeed, broadly speaking, the concern of antitrust lawmakers regarding licensing practices has generally been to ensure that licensors do not unduly leverage their power in the licensing relationship to restrict licensees' freedom to deal in products or services outside the scope of the patent. This is particularly problematic in contexts in which a licensee sells products complementary to those derived from a license, since he can choose to shift all of his revenues to the complements, in which case the licensor is effectively prevented by law from seeking appropriate compensation for his intellectual property. This suggests that in such contexts, there is a compelling case for broadening the ability of licensors to share in revenues from sales of "adjacent" products, or even broadening patent scope in certain cases. We use our model to support this view by showing that allowing a licensor to tax both sales of the product based on his license and of the complements enhances social welfare relative to a situation in which the licensor is prevented from charging fees based on complements sales.

This licensing issue has not been studied by the extensive economics literature on technology licensing to the best of our knowledge. Broadly speaking, the literature addresses two questions: when and how technology is licensed? The "how" question is the most relevant for our purposes: indeed, we start from the presumption that there are sufficient reasons compelling the licensor to seek a licensing agreement with the licensee. These reasons could be strategic (e.g. maintaining lead over a rival technology, such as in Gallini and Winter (1985)) or purely financial (obtaining licensing revenue) or a combination of both. One of the most robust findings in the literature is that flat fees determined through an auction yield the highest revenues for a licensee. Kamien's (1992) review includes a direct comparison of auction fees with royalties and concludes that "the patentee's licensing profits are higher if he auctions licenses than if he employs a royalty, except if the invention is drastic or the industry is perfectly competitive." Still, despite the emphasis on lump sum auction payments, Kamien (1992) admits that royalties are the "most commonly employed" terms in the

[1] This assumption is justified both because of uncertainty regarding the market potential of the licensed piece of intellectual property and because in the contexts we have in mind, the licensee endogenously determines through his choice of prices the profits he makes from the product based on the license relative to complements. See section 4 for more details.

"real world."

Several papers have proposed models to rationalize the use of royalties and thereby bridge the disconnect between theory and reality, usually by introducing asymmetric information between licensor and licensee. For instance, Gallini and Wright (1990) show that royalty payments can act as credible signals of an innovation's value when the licensee is not informed. Beggs (1992) also finds that asymmetric information justifies the use of incremental payments linked to sales, but in this model it is the licensor who lacks information about the licensee's intent and capabilities. Jensen and Thursby (2001) show that royalty payments also play the important role of providing the licensor with appropriate incentives to continue his involvement in developing the product based on the license.

None of these papers, however, explores licensing in the specific market setting which we study here, with the licensor facing a licensee that can also sell complementary products, revenues from which can be uncontractible. This may be viewed as an instance of asymmetric information with the licensor being the (partially) uninformed party. However, the focus here is not on the need for the licensor to signal the quality of the technology being licensed, but rather on the ways in which he should structure the licensing contract in order to prevent the licensee from using product complementarities to shift its profits to the products which do not fall under the incidence of the license.

The remainder of the paper is structured as follows. The next section provides two case studies - the first on licensing printer technology, the second on music licensing to Apple for use with IPod/ITunes, the goal of which is to illustrate the variety of contexts in which the licensing problem described above may arise. Section 3 presents a simple model for analyzing this licensing problem from the perspective of a licensor. In section 4 we discuss the public policy implications and use our analytical framework to support our argument. Section 5 concludes.

2 Case studies

2.1 Dell

Michael Dell started Dell Inc. when he was barely 19 years old. The company was founded under a new model of distribution and service that revolutionized the industry – the sell direct model.

The Dell model consists of selling directly to customers bypassing distributors and retailers. The company increases profit margins, manufactures on a build-to-order basis and reduces inventory to a minimum. In fiscal year 2006 Dell had net revenue amounting to $55.9 billion and 65,000 regular employees. Today, Dell sells one of every three PC's sold in the United States.

Dell traditionally does not to develop its own technology but instead licenses it as necessary. About 1.4% of Dell's revenues are invested in research and development compared to 4.5% for HP. Meanwhile, for the last three years Dell

has invested approximately $460 million in improving manufacturing and distribution processes. This allows Dell to quickly manufacture the best technology at the lowest price wherever and whenever it is available.

Originally, Dell strategy was to focus on selling computers. In 2001, Dell entered into an alliance and into original equipment manufacturer arrangements (OEMs) to sell Lexmark printers and other brands through its telephone and on-line system.

It was not until 2003, that Dell decided to develop its own brand of printers through a technology licensing with Lexmark. As Dell's entry into the printer business evolved, the company began licensing technologies from other companies such as Fuji and Canon selling new models under the Dell brand name.

Through the licensing technology tactic and its sell direct model, Dell quickly became an important client of traditional printing companies. By fiscal year 2005, Dell had turned into the biggest single client of Lexmark accounting for $782 million or 15.0% of the company's total revenue.

Dell's motivation to enter the printer business could have been to weaken Hewlett Packard's overall financial position. High margins in the ink-cartridges business had made HP's Printer Division the company's main profit center subsidizing other business units and price-cutting measures. Dell's move triggered a price war with competitors in the printer business which lowered the average selling price of printers to consumers.

Technology licensing, as opposed to the invention of technology, is at the core of Dell business strategy. Dell is on the licensee side of the negotiating table of a licensing agreement with Lexmark and sells printers as loss leader products in order to profit through ink cartridges.

Technology licensing allows Dell to have the flexibility of choosing the best technology to manufacture for their business and switch technologies whenever the market is looking for something new. In this sense, Dell avoids having the sunk costs of research and development, not only in terms of the cost of developing new products but also in terms of the time it takes to develop them. Unlike HP, Dell does not sell itself as an innovator. Instead, Dell is the best value for money supplier of computers and printers in the market today.

Dell continued success may depend on obtaining licenses to intellectual property developed by others on commercially reasonable and competitive terms.

Similar to cellular handsets, printers are often sold as loss leader products. Profits from the printer business are generated primarily by selling ink cartridges to consumers. Companies have even developed reminders for customers when their cartridge is running out of ink increase profits.

The marginal cost of producing an ink cartridge is very low. Once the cartridge box has been built, the only thing left is to fill it up with ink. Many companies have tried to recycle the cartridge boxes and fill them up with ink for resale, but companies such as Dell have fought against this by installing chips and other devices so that only a new cartridge will work. The marginal revenue of each cartridge sold by Dell is relatively high compared to the marginal cost of production. This increases profit margins of the cartridges when compared to other products.

Assuming the royalty fee of the licensing agreement is based on the average selling price of the printer we know that the company which licensed the printer technology will lose profits to the company that sold the cartridges. Dell and other companies such as HP appear to sell the printers below its average cost so that consumers will purchase the machine and later have an incentive to consume ink cartridges.

Since Dell simply sells the technology of another company, the marginal cost of the printer is simply the cost of manufacturing minus the percentage of royalty paid by to the licensor. In a business characterized by a short life cycle of products, it is cheaper to simply license. Otherwise you would have to take into account the costs of developing the technology into the marginal cost of production, or at least to the average cost of the product.

Furthermore, licensing agreements usually require an upfront cash investment as and the rest of the license is based on a royalty based on the value of the product sold. By licensing technology instead of developing its own, Dell incur in less upfront investments in technologies that may be risky. This strategy frees Dell's cash that can be used to improve the efficiency and time to market of the Dell operation.

This strategy leads to a conflict of incentives between Dell and the various technology owners. While Dell is comfortable with a low price that ensures considerable demand for replacement cartridges, the technology licensors—who apparently are unable to shape an arrangement which "shares the wealth" from these follow-on sales—are unlikely to be as comfortable with this strategy.

2.2 Apple Computer

In 1977, Steve Jobs and Steve Wozniak incorporated Apple "to change the world through technology" by selling more user friendly computing machines. Apple quickly became the industry leader and by 1980 went public. Soon IBM entered the market with a superior operating system, and Apple was unable to maintain market share.

In 1997, after years of lagging behind competitors in sales and innovation and plagued by two short CEO stints in a row, Apple brought back Steve Jobs. Soon Jobs envisioned a new digital "era" which Apple began by launching the digital music player iPod. Launching iPod revitalized Apple's finances.

A second element of success was that Apple devised a strategy to increase profits through the sale of complementary products. These items enhanced the iPod "ecosystem" and therefore the iPod experience. As part of this strategy Apple opened up more than 124 stores in the US and worldwide to sell iPods and its complementary products. But the Apple stores would also take advantage of the iPod's high traffic craze to reinvigorate hardware sales. Another goal of the Apple stores was to increase the number of hardware switchers from Dell and HP to Apple.

The financial results were truly impressive. In less than two years, Apple became a profitable company and its stock price rose to its highest level ever.

By early 2006, Apple's total value had surpassed Dell's based on equity market capitalization.

A third element of success was Apple's creation of iTunes - yet another revolution within the iPod frenzy. Launched in April 2003 , iTunes was the first successful attempt to sell digital music over the Internet through a legal method and adequate coordination with music labels By 2005, combined iPod and iTunes sales had accounted for 39% of total Apple revenue.

Licensing soon became an integral part of Apple's iPod growth strategy. Without adequate licenses, iPod would not be compatible with Microsoft's operating system. Apple eventually reached a licensing agreement with Microsoft so that the iPod operating system was Windows' compatible. Licensing arrangements with music industry labels helped iPod sales surge. Through iTunes, Apple had created a whole new music shopping experience on the Internet.

The iPod's success created pricing challenges. Apple priced music as a loss leader product in order to sell digital music at a reasonable price and offer a legal way of downloading it. By pricing songs at 99 cents per song, Apple created a price structure that encouraged more than a million downloads in three days of opening of iTunes.

The cost structure of the iTunes business was as follows: 65 cents went to the music labels, 25 cents went to distribution costs, and 10 cents went to Apple. This cost structure left Apple barely breaking even in the iTunes song business.

Though iTunes barely covered the marginal cost of songs, Apple had created a structure using songs as loss leader products to increase the sales of iPods. Profit margins on iPods were high. This created a winning formula for Apple that despite the entry of competitors has been kept so far.

Some competitors have entered the market pricing songs below marginal cost; for example, at 79 cents per song. But the price structures of many of these companies are not uniform and include monthly membership fees and price ranging in some cases from 79 cents to $1.49.

In addition, some of these new services did not allow one to own the music, only to rent it. By contrast, through the iTunes service one could own the songs, use them in an unlimited number of iPods and transfer them to up to 5 computers. On average, iTunes songs were a better deal than what the new competitors offered. It is fair to say that the price of songs at 99 cents is very close to the marginal cost of production. That is, the economic profit for Apple for selling songs at this price is close to zero. This is not the case, however, for the iPod itself. Indeed, iPod and iTunes are highly complementary and it is well-known that Apple's profits from this part of its business come largely from the sale of iPods. This has led to continued confrontations with music labels, which, not surprisingly, would like Apple to raise the price of songs above 99 cents and charge more for popular songs. On the contrary, Apple has every interest to keep the price of songs as low and uniform (simple) as possible; in fact, at the extreme, Apple does probably not mind much if the price of songs occasionally goes down to zero (because of piracy), since that increases its revenues from iPods, which it does not have to share with music labels.

The record companies' challenge of the iTunes uniform pricing policy has

been led by two major record labels: Sony BMG and Warner Music Group. In particular, when iTunes launched in Japan in 2005, both firms refused to license music to iTunes due to their pricing policy. At the time of the dispute, Sony pointed out at a technology conference that Apple got two revenue streams (music sales and iPod sales), while Sony only got one, which it claimed was extremely small. After an extended negotiation, Apple finally decided to introduce differential pricing, pricing songs in Japan at either ¥150 ($1.35) or ¥200 ($1.80) depending on the song. In part, this decision reflected Apple's relatively modest market share in Japan, and the perceived need to offer a comprehensive array of songs.

This policy pricing has also been controversial in the United States. The record labels have indicated that would like to charge a lot more for new singles, such as up to $1.49 each, while selling oldies for less than Apple's 99 cent pricing. But while Apple has made minor concessions (e.g., allowing small independent labels to charge slightly higher prices), they have been successful so far in resisting pressure from the record companies in the United States: when the major music licensing arrangements were renewed earlier in 2006, the pricing policy was retained.

In August 2006, Universal Studios announced that it would back a rival service to iTunes, which interestingly enough provides music essentially for free to users and makes money through advertising.[2] Put simply, Universal seems to have decided to overcome its inability to capture a share of the highly profitable sales of iPods by bypassing Apple entirely and monetizing its music by itself.

3 Model

In the remainder of the paper, we propose a formal model for throwing some light on the economic phenomena underlying the licensing issues illustrated by the case studies above. The licensing problem we consider has the following structure, depicted in figure 1. A licensor U (upstream firm) is considering licensing a piece of intellectual property to a licensee D (downstream firm), who can turn it into a product, but who in addition to the product based on the license (P1), may also sell complements or add-ons (P2, P3, ..., Pn), which may be based on other licensing agreements themselves.

[2] "Universal Backs Free Music Rival to iTunes," New York Times, August 29, 2006. http://www.nytimes.com/2006/08/29/business/29cnd-music.html?ex=1314504000&en=e839ce9c8b1fbabb&ei=5090&partner=rssuserland&emc=rss

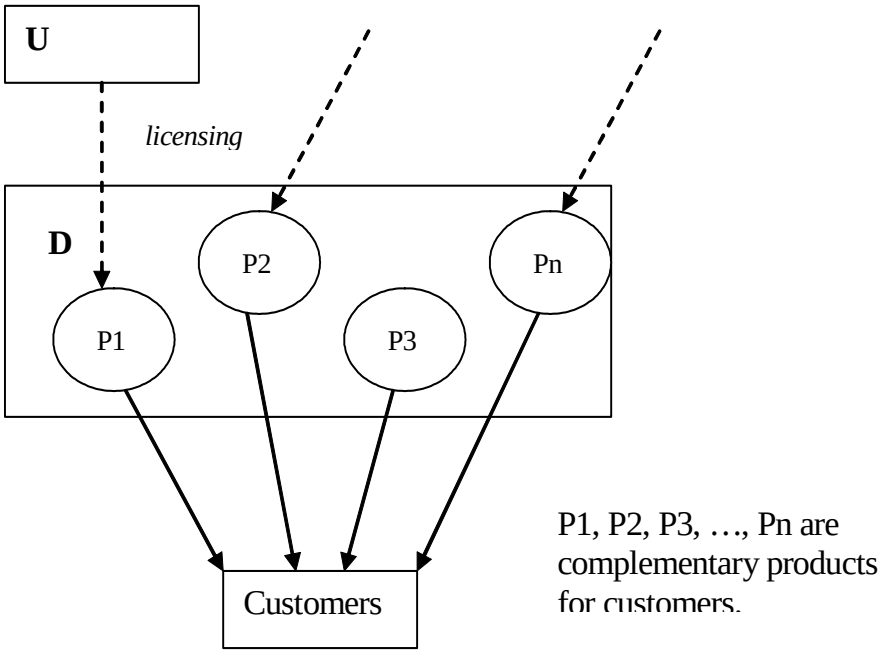

Figure 1

We denote by $d(p)$, $d' < 0$, the demand for the licensee's base product when it charges a price p (we assume D is a monopolist for this product).

The complements can be independently priced goods or add-ons to the base product that its consumers buy. In what follows, we choose the simplest possible formulation without loss of substance, i.e., we assume D derives additional benefits $B(d)$ when the demand for the base product is d, with $B' > 0$.

In general, the licensor U would like to charge both a fixed fee - that is, upfront fee, independent of whether the licensed intellectual property leads to realized profits for D- and variable fees - i.e., fees depending on the realization of output, or revenues or profits for D. In practice, however, fixed fees are seldom observed in this type of context, mainly because licensees are reluctant to pay upfront fees for uncertain or unproven technologies. The economics literature on technology licensing has formalized this argument by showing that the licensor will propose higher output-based payments (royalties) and lower fixed fees when it has more information relative to the licensee regarding the economic value of the intellectual property to be transferred. Jensen and Thursby (2001) for instance show that upfront frees should be smaller the more uncertain the technology is, either in technological terms or in commercial terms.

In addition, there exists another type of asymmetric information in the contexts we are interested in, which makes it difficult for U to demand a fixed

upfront payment from D. The licensee's (D) profits from sales of complementary products are usually unobservable to U and in fact may depend on the upfront fee asked by U. If this fee is too high, D can find it in his interest to forego any profits from the sale of the product based on the license by giving it away for free, and claim that it cannot (and should not) pay the upfront fee, which leads to a standoff. In order to avoid this, U may have to rely entirely on variable fees.

For all these reasons and also in order to simplify the formal analysis, we will assume in our model that U can only charge variable fees (no fixed fees).

Charging variable fees can also take several forms: output-based royalties, revenue or profit-sharing agreements, equity stakes, etc. The key aspect of variable fees however is whether or not they distort output (cf. Gallini and Wright (1990), Jensen and Thursby (2001)). In the frameworks developed in the previous economics literature on licensing, output-based royalties do, because they essentially modify the marginal cost of the licensee whereas profit-sharing agreements (including equity shares) typically do not. However, in the contexts we study in this paper, although levying a fixed portion of the licensee's profits does not change the latter's marginal cost, the option to sell complementary products creates an indirect mechanism through which profit sharing affects the pricing decision of the licensee and therefore distorts output. Indeed, as the profit share demanded by the licensor from the sale of the product based on the license increases, the licensee may find it optimal to decrease the share of profits he makes from the base product relative to the complements in order to decrease the amount he has to pay to the licensor. It is precisely this novel mechanism that we aim to illustrate with our framework.

It is therefore useful to examine two categories of variable fees: output-based royalties, which are charged on sales of the product based on the license and which distort output directly; and profit-sharing agreements (or equity stakes), which can potentially distort output only indirectly. Thus, we assume in our model that the licensor can therefore choose between two types of pricing for its technology: charge D royalties r per unit of the base product sold or ask for an equity stake (or profit share) ρ in D. Naturally, D may have other business activities aside from the sale of the good based on the technology licensed from U and its complements. We take the aggregate value of these other activities to be exogenously given, normalized at 0 without loss of generality.

In the case when U chooses to ask for royalties for the license, the respective profits of the two firms D and U are:

$$\pi^D(p, r) = (p - r)\, d(p) + B(d(p)) \tag{1}$$

$$\pi^U(r) = r d(p(r)) \tag{2}$$

where $p(r) = \arg\max_p \pi^D(p, r)$.

In the case when U chooses to ask for a share of profits or an equity stake (ρ) in D in exchange for its technology, we introduce an important parameter, α, which represents the fraction of D's profits from sales of complements which

falls under the incidence of the profit sharing agreement. The remaining fraction $(1-\alpha)$ accrues entirely to D. Thus, we have:

$$\pi^D(p,\rho) = (1-\rho)\left[pd(p) + \alpha B(d(p))\right] + (1-\alpha)B(d(p)) \tag{3}$$

$$\pi^U(\rho) = \rho\left[p(\rho)\, d(p(\rho)) + \alpha B(d(p(\rho)))\right] \tag{4}$$

where $p(\rho) = \arg\max_p \pi^D(p,\rho)$.

The parameter α measures the extent to which U can "tax" the sales of complements by D. One can think of the fraction $(1-\alpha)$ as representing private benefits which could accrue to the specific unit of D in charge of complements sales or as the part of revenues from complements that is unobservable to U and that can consequently be "hidden" by D, i.e., taken off the negotiations table. A more realistic view would be to assume $B(.)$ is in fact the sum of several types of complements: $B(.) = B_1(.) + B_2(.) + ... + B_n(.)$. In this case, if the sales of complements 1 through k, with $k < n$, are observable by U and can be therefore brought under the incidence of the profit-sharing agreement, then we would have:

$$\pi^D(p,\rho) = (1-\rho)\left[pd(p) + \sum_{i=1}^{k} B_i(d(p))\right] + \sum_{j=k+1}^{n} B_j(d(p))$$

$$\pi^U(\rho) = \rho\left[p(\rho)\, d(p(\rho)) + \sum_{i=1}^{k} B_i(d(p))\right]$$

In expressions (3) and (4) we have simplified the analysis by assuming $\alpha = \frac{\sum_{i=1}^{k} B_i(d(p))}{\sum_{i=1}^{n} B_i(d(p))}$ is a constant.

Again, one could allow for more complex variable pricing instruments (for instance a sliding scale of royalties combined with output milestone payments), but here we wish to focus on the contrast between the effects of the two categories of variable fees described above. We believe these are the most relevant for the licensing scenarios we are attempting to model: in the absence of upfront fees, the licensor's basic choices are to either focus on inducing higher prices for the product based on the license and extract a portion thereof through royalties or to attempt to reach a profit sharing agreement, covering as much of the revenue sales of complements as possible.

In what follows, we will assume for simplicity that both the demand function $d(.)$ and the private benefits function $B(.)$ are linear (the essence of the results presented below holds for more general functional forms):

$$d(p) = 1 - p$$

$$B(d) = bd, \textit{ with } b > 0$$

3.1 *Licensing by royalty*

With linear demand $d(.)$ and linear benefit function $B(.)$, expression (1) becomes:

$$\pi^D(p,r) = (p - r + b)(1 - p)$$

yielding:

$$p(r) = \begin{cases} 0 & \text{if} \quad b \geq 1 + r \\ \frac{1+r-b}{2} & \text{if} \quad -1 + r \leq b \leq 1 + r \\ 1 & \text{if} \quad b \leq -1 + r \end{cases}$$

and:

$$\pi^U(r) = \begin{cases} r & \text{if} \quad b \geq 1 + r \\ \frac{r(1-r+b)}{2} & \text{if} \quad -1 + r \leq b \leq 1 + r \\ 0 & \text{if} \quad b \leq -1 + r \end{cases}$$

Thus the profit maximizing royalty rate chosen by U is:

$$r^* = \begin{cases} b - 1 & \text{if} \quad b \geq 3 \\ \frac{1+b}{2} & \text{if} \quad b \leq 3 \end{cases}$$

and the licensor's profits are:

$$\pi_r^U = \begin{cases} b - 1 & \text{if} \quad b \geq 3 \\ \frac{(1+b)^2}{8} & \text{if} \quad b \leq 3 \end{cases} \tag{5}$$

3.2 *Licensing through profit-sharing*

Expression (3) contains the key issue the licensor is facing when licensing to a downstream firm that can derive benefits from selling complementary goods. When the share $(1 - \alpha)$ of benefits outside the scope of the licensing contract (private benefits) is high, if U is asking for too high an equity stake ρ, then D finds it optimal to price the good based on the license at a price of zero and make money from the complements, i.e. through $B(d(p))$. In this case, U's profits are low and decreasing in α.

Theorem 1 *The licensee D chooses to give away the product based on the license, i.e.* $p(\rho) = 0$*, if and only if:*

$$b\left[\alpha + \frac{(1-\alpha)}{1-\rho}\right] \geq 1 \tag{6}$$

If $b\left[\alpha+\frac{(1-\alpha)}{1-\rho}\right]<1$ *then the profit-maximizing price for D is:*

$$p(\rho)=\frac{1}{2}\left(1-b\left(\alpha+\frac{(1-\alpha)}{1-\rho}\right)\right)$$

Proof With linear demand $d(.)$ and linear benefit function $B(.)$, expression (3) becomes:

$$\begin{aligned}\pi^D &= (1-p)\left[(1-\rho)p+b(1-\alpha\rho)\right]\\ &= (1-\rho)(1-p)\left[p+\alpha b+\frac{(1-\alpha)b}{1-\rho}\right]\end{aligned}$$

This implies that the profit maximizing price $p(\rho)$ is 0 whenever (6) holds.■

Thus, the licensee D chooses to give away the good based on the license whenever: a) the private benefits b are large enough; or b) it has to give up a large enough share ρ of its equity; or c) when the share of private benefits α that falls under the licensing contract is small enough. All of these predictions are quite intuitive.

When (6) holds, $p(\rho)=0$ and we have:

$$\pi^D(\rho)=b(1-\alpha\rho)$$

$$\pi^U(\rho)=\rho\alpha b$$

If (6) does not hold, then $p(\rho)>0$ and we have:

$$\pi^U(\rho)=\frac{\rho}{4}\left[(1+\alpha b)^2-\frac{(1-\alpha)^2b^2}{(1-\rho)^2}\right]$$

Note that in the latter case, ρ has two effects on $\pi^U(\rho)$. One is a direct positive effect contained in the term in front of the square brackets: U gets a higher share of the profits it can claim from D. The second effect is indirect and negative: when U asks for a higher share of profits, D lowers the price of the good based on the license in order to shift profits to the complements, since part of the revenues from complements cannot be claimed by U. Overall, this decreases the revenues from which U claims a share ρ.

3.3 *Optimal licensing choice*

Note first that (6) holds for all $b\geq 1$. In this case, In this case, $\pi^U(\rho)=\rho\alpha b$, so that U will choose $\rho=1$, yielding:

$$\pi^D(\rho)=b(1-\alpha)$$

$$\pi^U(\rho)=\alpha b \tag{7}$$

For $b < 1$, (6) is equivalent to:

$$\rho \geq \frac{1-b}{1-\alpha b} = \overline{\rho}$$

If $\rho \geq \overline{\rho}$ then $\pi^U = \rho\alpha b$.
If $\rho < \overline{\rho}$, taking the derivative of $\pi^U(\rho)$ with respect to ρ we obtain:

$$\frac{\partial \pi^U}{\partial \rho} = \frac{1}{4}\left[(1+\alpha b)^2 - \frac{b^2(1-\alpha)^2(1+\rho)}{(1-\rho)^3}\right]$$

which is decreasing in ρ. Thus, if $\frac{\partial \pi^U}{\partial \rho}(\rho = \overline{\rho}) > 0$ then π^U is maximized by $\rho = 1$.

If $\frac{\partial \pi^U}{\partial \rho}(\rho = \overline{\rho}) < 0$ then π^U is maximized by either $\rho = 1$ or by $\rho = \widehat{\rho} \in [0, \overline{\rho}]$, where $\widehat{\rho}$ is uniquely defined by:

$$\frac{(1+\widehat{\rho})}{(1-\widehat{\rho})^3} = \frac{(1+\alpha b)^2}{b^2(1-\alpha)^2}$$

Figure 2 below illustrates the various cases that can arise with $\alpha = 0.5$ and $b = 0.2$ (blue line), $b = 0.3$ (red line), $b = 0.4$ (brown line), $b = 0.58$ (black line).

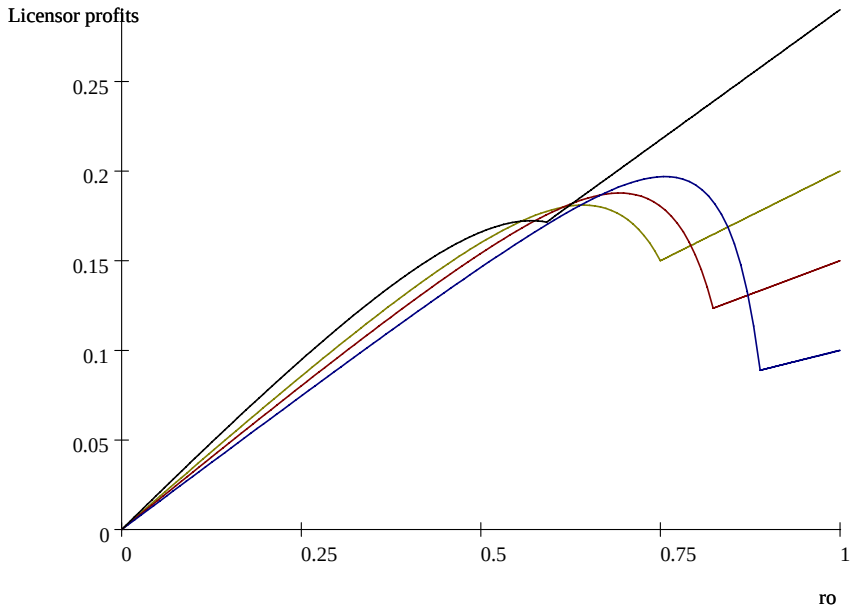

Figure 2

Since $\frac{\partial \pi^U}{\partial \rho}(\rho = \overline{\rho}) > 0$ is equivalent to $\left(\frac{1+\alpha b}{1-\alpha b}\right)^2 \geq \frac{2-(1+\alpha)b}{(1-\alpha)b}$ and the left hand side is increasing in b whereas the righthand side is decreasing b, we infer that

there exists $\overline{b} < 1$ such that for $b \geq \overline{b}$ the licensor U will choose $\rho = 1$ under a profit-sharing agreement. This is easily understood: if b is large enough, then the licensee will give away the product based on the license irrespective of ρ, so U might as well extract as much profit as possible.

As b decreases, D sets $p(\rho) = 0$ only if ρ is high enough, so in this case, U can either set again $\rho = 1$, inducing $p(\rho) = 0$, or settle for a lower share of contractible profits $\rho = \widehat{\rho} < 1$. The latter alternative ensures the licensee will create positive revenues from the sale of the product based on the license, not just the complements.

When b tends to 0, then $\pi^U(\rho = 1)$ also goes to 0, whereas $\widehat{\rho} \to 1$ and $\frac{(1-\alpha)^2 b^2}{(1-\widehat{\rho})^2} \to 0$ so that $\pi^U(\rho = \widehat{\rho}) \to \frac{1}{4}$.

Note also that π_r^U tends to $\frac{1}{8}$ when $b \to 0$,so that for b small enough, the licensor will strictly prefer to license through profit-sharing rather than use royalties and will ask for a profit share strictly lower than 1.

Let us now turn to the case of $b \geq 1$[3] so that (6) holds for any $\rho \geq 0$, meaning $p(\rho) = 0$. From (7) and (5), and noting that $\frac{(1+b)^2}{8} \geq b - 1$ for $b \geq 3$, we infer that there exists b such that licensing by equity is preferred to licensing by royalty if and only if the equation $\frac{(1+b)^2}{8} = \alpha b$ has a solution in b, which is equivalent to $\alpha \geq \frac{1}{2}$. In this case we have $\frac{(1+b)^2}{8} = \frac{1}{2} \leq \alpha = \alpha b$ for $b = 1$, therefore $\frac{(1+b)^2}{8} \leq \alpha b$ for $b \in \left[1, \tilde{b}\right]$ and $\frac{(1+b)^2}{8} \geq \alpha b$ for $b \geq \tilde{b}$, where $\tilde{b} = 4\alpha - 1 + 2\sqrt{4\alpha^2 - 2\alpha}$. Finally, $b - 1 \geq \alpha b$ if and only if $b \geq \frac{1}{1-\alpha}$. Therefore, if $\tilde{b} \leq 3$ then $\overline{b} = \tilde{b}$; if $\tilde{b} \geq 3$ then $\overline{b} = \frac{1}{1-\alpha}$. Figure 3 illustrates these results: the black line represents $\pi^U(b) = \begin{cases} b-1 & \text{if} \quad b \geq 3 \\ \frac{(1+b)^2}{8} & \text{if} \quad b \leq 3 \end{cases}$ (licensor maximum profits from using royaties); the other two lines represent $\pi^U(b) = \alpha b$ (licensor maximum profits from using profit sharing) for $\alpha = 0.4$ (red) and $\alpha = 0.7$ (green).

[3] We omit the analysis of the intermediate region for b, since the algebra turns out to be complicated and yields no additional insights. As can be expected, in this intermediate region, either of the two types of variable fee contracts can turn out to be optimal for the licensor.

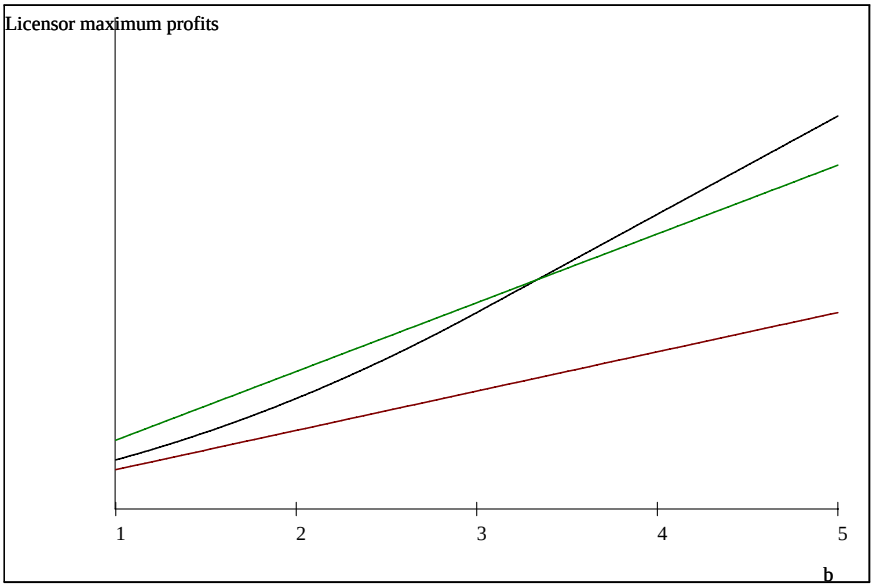

Figure 3

The results detailed above are summarized in the following theorem.

Theorem 2 *Assume $d(p) = 1 - p$ and $B(d) = bd$. For b sufficiently close to 0, the licensor U prefers licensing through a profit-sharing contract, in which the optimal profit share is strictly less than 1.*

For $b > 1$,if $\alpha \leq \frac{1}{2}$, then U always prefers licensing by royalty. If $\alpha \geq \frac{1}{2}$, then there exists $\bar{b}$ such that U prefers licensing by equity for $b \in \left[1, \bar{b}\right]$ and licensing by royalty for $b \geq \bar{b}$.■

The results contained in theorem 2 are quite intuitive and it should be clear that they do not depend on the specific functional forms assumed. If $b > 1$ then the licensee D always chooses to give away the product based on the license ($p(\rho) = 0$) under a profit-sharing contract and makes profits only from the sale of add-ons for all $b \geq 1$). In this case, when the share α of profits from add-ons that can be captured by U under a profit-sharing contract is small enough, U should always use a royalty contract. Indeed, royalties ensure that the product based on the license is sold at a positive price and although the royalty combined with monopoly pricing induce double marginalization and therefore a lower total quantity sold, U is better off from being able to extract positive revenues from the sale of the product derived from its license. If, however, U can extract a higher share α of revenues from the add-on sales, then if the magnitude of profits from add-ons is not to large ($b \leq \bar{b}$), an equity contract is better for U since it avoids double marginalization while still earning some positive revenues,

despite the base product being given away for free. When the profits from add-ons become too large, the royalty contract becomes again preferrable since it ensures higher revenues from the base product ($b - 1 > \alpha b$) even though the latter is given away for free under both type of contract.

4 Public policy

We now turn to the public policy issues raised by the type of licensing relationships we are studying. As hinted at in the introduction, the main concern of the relevant antitrust legislation has been to limit the scope of patents in order to prevent abusive extensions by licensors.

The classic case in defining broad licensing as problematic is *Morton Salt Co. v. G. S. Suppiger Co. Morton Salt*,[4] the owner of a patent for a machine used for depositing salt tablets into canned food, sued a competitor for infringement. As a condition for licensing its patent, Morton Salt required licensees to use its unpatented salt tablets. The Supreme Court found this condition to be an attempt "to secure an exclusive right or limited monopoly not granted by the Patent Office and which it is contrary to public policy to grant." The Court thus held that Morton Salt's patent was unenforceable until Morton Salt corrected its improper licensing practices.

While this was a case involving tying by the licensor rather than the attempt to derive licensing revenues from products other than those based directly on the license, it was arguably one of the foundations for the "Nine No-Nos," a list of licensing practices presumed to be *per se* violations of the antitrust laws and promulgated in the 1970s by the Department of Justice. A synthesized version of this list is[5]:

1) Requiring a licensee to purchase unpatented materials from the licensor (also known as tying).

2) Requiring a licensee to assign to the licensor patents issued to the licensee after the licensing arrangement is executed.

3) Restricting a purchaser of a patented product in the resale of that product.

4) Restricting a licensee's freedom to deal in products or services outside the scope of the patent.

5) Agreeing with a licensee that the licensor will not, without the licensee's consent, grant further licenses to any other person.

6) Requiring that the licensee accept a "package" license.

7) Requiring royalties not reasonably related to the licensee's sales of products covered by the patent.

8) Restricting the licensee's sales of (unpatented) goods made with the licensed patented process.

[4] MORTON SALT CO. v. G. S. SUPPIGER CO. No. 49; SUPREME COURT OF THE UNITED STATES; 314 U.S. 488; 62 S. Ct. 402; 86 L. Ed. 363; 1942 U.S.

[5] This version of the list is based on Bruce B. Wilson, Remarks to Michigan State Bar Antitrust Law Section and Patent, Trademark and Copyright Law Section (Sept. 21, 1972), reprinted in 7 Trade Reg. Rep. (CCH) ¶ 50,146.

9) Requiring a licensee to adhere to specified or minimum prices in the sale of the licensed products.

It should be noted however that the Court of Appeals for the Federal Circuit, the centralized appellate court for patent cases, has subsequently taken a much narrower view of patent misuse. A particularly notable case in which it addressed patent misuse in Windsurfing International, Inc. v. AMF, Inc. Windsurfing International (WSI) sought to enforce its patent, directed to a sailboard, against several alleged infringers, including AMF, Inc. In its defense, AMF claimed that WSI had misused its patent, basing its claim on a provision included in patent license agreements between WSI and eleven licensees. This provision required that each licensee acknowledge the validity of WSI's registered trademarks and refrain from using them. The court stated: "The doctrine of patent misuse is an affirmative defense to a suit for patent infringement, and requires that the alleged infringer show that the patentee has impermissibly broadened the 'physical or temporal scope' of the patent grant with anticompetitive effect." A key difference between the rule articulated in Windsurfing and the rule followed by earlier courts stems from three words strategically inserted into the Windsurfing rule: with anticompetitive effect. This requirement, that anticompetitive effect must be demonstrated, even in cases alleging "extension of the monopoly-type" patent misuse, was contrary to the approach followed by the courts in the two decades following Morton Salt.[6]

Still, the spirit contained in the above enumeration of problematic licensing practices has remained. In particular, note that items 4) and 7) refer directly to the licensing problems we are concerned with in this paper: they reflect the concern with awarding overly broad patents to licensors, which might stifle innovation downstream, i.e., by licensees. The most compelling argument that could be made for the context we have in mind is that when the downstream licensee is selling complements to a product based on a license from an upstream licensor, the licensor should not be allowed to make its license conditional on payments based on sales of complements in order to preserve the licensee's incentives for innovation in complements.

While this is a valid concern, the countervailing economic argument suggested by our analysis above is that whenever there exist complementarities or externalities, allowing a firm - even a monopolist - to use a richer set of pricing instruments may actually increase social welfare because the latter has an incentive to internalize the aforementioned complementarities/externalities. This is true in a wide variety of contexts: for instance, Hagiu (2006) shows that allowing a monopoly platform to charge both sides of a market in which each side exerts a positive externality on the other can result in higher welfare relative to the case when the platform is restricted to charging a single side or none of the two sides (open platform). In the remainder of this section, we provide a theoretical argument using a modified version of the model developed earlier.

[6] The discussion in the previous three paragraphs is based in part on Homiller (2006).

4.1 Formal analysis

For the purposes of the problem at hand, we will provide a simple illustration of the potential social benefits of allowing the upstream licensor to charge based on both sales of the base good and sales of complements.

We use the same model as above, assuming the demand for the base product is linear, $d(p) = 1 - p$. One modification we make is to introduce the possibility of downstream investment in improving the "quality" of the complements: when D invests $e > 0$[7], the benefit function is $B(d) = bed$. The cost of e is $C(e) = \frac{1}{2}ce^2$.

The other important change we make is to assume that there are in fact two downstream firms acting independently: D1, which sells the base product, and D2, which sells the complements and chooses how much to invest in the quality of the complements. The reason behind this assumption is to emphasize the effect of allowing U to derive revenues from both the sales of the base product as well as sales of complements: internalize complementarities which otherwise would remain uninternalized by the two downstream firms acting independently of each other. Our results below hold even when the two downstream firms are integrated, but the algebra turns out to be too intricate, which is why we have chosen to focus on this simpler case.

Theorem 3 *Under the assumptions above, for b high large enough, social welfare is higher when allowing the licensor to extract both royalties charged on the sales of the product covered by the license and a share of the revenues from the sales of complements, than when the licensor cannot appropriate any of the revenues from complements.*

Proof When the licensor U charges a royalty r on revenues from sales of the product based upon its license and extracts a share ρ of revenues from sales of complements:

$$\pi^{D1} = \max_p (p - r)(1 - p) \tag{8}$$

$$\pi^{D2} = \max_e \left\{ (1 - \rho) be (1 - p) - \frac{1}{2}ce^2 \right\} \tag{9}$$

The licensor's profits are:

$$\pi^U = r(1 - p) + \rho be(1 - p) \tag{10}$$

Suppose first that U is prevented by law from charging the sales of complements, i.e. ρ is forced to 0. Then we have $p(r) = \frac{1+r}{2}$ and $e(r) = \frac{b}{2c}(1 - r)$, leading to:

$$\pi^U = \frac{r(1 - r)}{2}$$

and therefore $r = \frac{1}{2}$. This implies:

$$p = \frac{3}{4}$$

[7] This can also be interpreted as an effort expenditure if D is an individual.

$$e = \frac{b}{4c}$$

Suppose now that U is allowed to derive revenues from the sales of both the base product and the complements. Then we have $p(r) = \frac{1+r}{2}$ and $e(r) = (1-\rho)\frac{b}{2c}(1-r)$, but now:

$$\begin{aligned} \pi^U(r,\rho) &= r(1-p) + \rho be(1-p) \\ &= \left(r + \frac{\rho b^2}{2c}(1-r)(1-\rho)\right)\frac{1-r}{2} \end{aligned}$$

which U maximizes with respect to both r and ρ. This leads to $\rho = \frac{1}{2}$ and:

$$\pi^U = \max_r \left(r + \frac{b^2}{8c}(1-r)\right)\frac{1-r}{2}$$

Assume now $\frac{b^2}{8c} > 1$. This implies that $\left(r + \frac{b^2}{8c}(1-r)\right)\frac{1-r}{2}$ is decreasing in r, so that U chooses $r = 0$, yielding:

$$p = \frac{1}{2}$$

$$e = \frac{b}{4c}$$

Since welfare is $W(p,e) = \int_p (1-q)\,dq + be(1-p) - \frac{1}{2}ce^2$ and the investment levels are the same in both cases, it follows that allowing U to charge royalties based on sales of complements results in higher social welfare because the resulting price for the base product is lower.■

The intuition behind the above result is straightforward: by charging royalties on sales of the base product, the licensor creates double marginalization, which reduce social welfare. Allowing U to also derive some revenues from sales of complements gives the licensor an incentive to reduce its royalties charged on the base good in order to create a higher installed base and therefore derive more revenues from complements. The effect on investment in quality by D2 is a priori ambiguous as, on the one hand, U creates a higher installed base but, on the other hand, it extracts a share of the D2's revenues. In our example, the two effects exactly cancel each other out so that the investment level stays the same, meaning that we are left with a net increase in social welfare due to a lower price for the base good.

4.2 Robustness

It is worth emphasizing that although the model used above is quite specific, the underlying mechanics are quite general. We have purposefully avoided more complex (and perhaps more realistic) formulations in order not to clutter the paper with algebra. For example, one alternative formulation is to assume that D is selling two complementary goods A and B and choosing prices p_A and p_B for both of them. Good A is based on the license acquired from L, in exchange for which the latter can charge a royalty or equity. The expressions of profits are then:

$$\pi^D = \max_{p_A, p_B} \left\{ (p_A - r)\, d_A\left(p_A, p_B\right) + p_B d_B\left(p_B, p_A\right) \right\}$$

$$\pi^L = \max_r r d_A\left(p_A\left(r\right), p_B\left(r\right)\right)$$

when L chooses royalties and:

$$\pi^D = \max_{p_A, p_B} \left\{ (1-\rho)\left[p_A d_A\left(p_A, p_B\right) + \alpha p_B d_B\left(p_B, p_A\right) \right] + (1-\alpha)\, p_B d_B\left(p_B, p_A\right) \right\}$$

$$\pi^L = \max_r \rho\left[p_A d_A\left(p_A\left(\rho\right), p_B\left(\rho\right)\right) + \alpha p_B d_B\left(p_A\left(\rho\right), p_B\left(\rho\right)\right) \right]$$

The resulting two-dimensional optimization problem is much more complex but yields the same qualitative results as the ones we have obtained above.

5 Conclusion

This paper has provided an initial exploration of the issues that arise in licensing contexts in which the licensee sells products complementary to that based on the license and at least some of the sales of complements cannot be brought under the coverage of the licensing contract (either because of observability issues or legal restrictions). The fundamental problem in such situations is that the licensee may use the complementarities to shift its profits to the sales of products falling outside the scope of the licensing deal, thereby limiting the licensor's ability to extract compensation for his license. We have provided two case studies (licensing of printer technology to Dell and of music to Apple's iTunes music service) illustrating this issue, as well as a simple theoretical model. The main prediction is that the licensor will find it profitable to use output-based royalties when the revenues the licensee derives from complements are more significant and the share of those revenues that falls outside the scope of the license is higher, whereas licensing in exchange for profit-sharing (equity stake) is preferrable in the opposite cases.

We have also argued that licensing situations when the licensee is also selling complements provide a setting in which antitrust legislation should allow a broader scope for patents and licensing agreements. In particular, while the usual concern that expanding patent scope may stifle complementary innovations remains justified, we have shown that social welfare can sometimes be

increased by permitting licensors to tax revenues from products complementary to those based directly on the license. Indeed, doing so puts licensors in a better position to reduce output distortions by internalizing complementary externalities which downstream licensees may leave uninternalized.

The motivation behind and primary inspiration for tackling the type of licensing issue we have studied in this paper came mainly from technology markets, where licensing of various complementary products or services form multiple sources has become a widespread practice in recent years.[8] However, the underlying economic issue can be recast in broader terms: who should be the residual claimant of the value created through complementarities between products or services which are produced by different economic agents? This formulation brings us closer to the economics literature on the theory of firms and organizations and therefore suggests that there is a wider range of contexts to which the issue we have studied here is relevant (aside from pure technology licensing).

One example of such a context is the problem faced by a professional with considerable expertise and clout in a field, considering a one-time engagement with an organization, which may benefit both directly by selling services based on the individual's work and indirectly by, for example, subsequent sales of services to customers acquired during the individual's tenure. Decisions regarding compensation and organization structure in professional service firms are driven in part by concerns about externalities[9]. We leave the exploration of this broader question for future research.

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[8] This may also explain why this problem has been heretofore ignored by the economics literature on patent licensing.

[9] See for instance Baker, Gibbons and Murphy (2002).

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