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COPYRIGHT PROTECTION AND HARDWARE TAXATION*

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Abstract

This paper investigates the recently-practiced method of taxing hardware and transferring the proceeds to software makers, or artists in general. We demonstrate that this policy of compensating copyright owners for infringements on their intellectual property using hardware taxation is inefficient.

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1. Introduction

1.1 Major observations and legal issues

Violation of copyrighted material in general and software in particular is known as *piracy*. Piracy is conducted via copying for personal usage, or for commercial purposes. Copying could be utilizing analog formats, for example, dubbing audio and video cassettes, or could be digital, for example, copying computer software, DVD, or MP3 artistic works.

There are many different estimates concerning the level of piracy in the various entertainment and software industries. Some argue that software piracy in the West could be between 25% to 50%, whereas it could reach 90% in the developing countries in the Far East. Clearly, the degree of piracy heavily depends on the enforcement of copyright laws to eliminate markets for pirated entertainment media and for computer software. Music and software publishers often quote their “losses” resulting from piracy in the billions of dollars, however, one should bear in mind that these quotes tend to be exaggerated since they are based on the *false* assumption that if copyright laws were strictly enforced, those who pirate would necessarily become buyers.

The fast penetration of the Internet into the home and business communities further intensified the piracy of artistic titles. In addition to public and commercial mainframe computers that store computer software as freeware and shareware packages for the public to download, Napster developed software in which users can exchange music titles over the Internet.¹ The innovation was that music titles can be downloaded not only from a particular mainframe computer, but also from hard drives of other participating users.

Theoretically, the second-best solution to the piracy problem (assuming that copyright enforcement is infeasible) would be to tax those consumers who purchase pirated copies. However, taxing this consumers is equivalent to selling the software, and is therefore infeasible. This raises the question whether there exist economic methods for compensating

¹See, www.napster.com. Napster was recently ordered to block all copyprotected music titles. Germany’s publishing powerhouse Bertelsmann is planning for introduction of a subscription service of Napster music downloads over the Internet since an internal survey of 25,000 Napster users conducted by the group showed that 70 percent would be willing to pay for a subscription service.

music and software publishers (software producers in what follows) for the partial loss of their intellectual property rents.

The present paper investigates the effects of the imposition of tax on hardware and using the proceeds to recover the loss of profits claimed by software producers. Some countries have already implemented hardware taxes and some are planning to introduce this tax. For example, France imposes a surcharge of 59¢ to 69¢ on each recordable medium such as on blank CDs, minidisks, and cassettes, with the intention of levying a surcharge on personal computer's hard drives as well.² The proceeds of the already imposed surcharge go to royalty funds for artists. The "thinking" behind this mechanism is that blank disks (the hardware in this case) would be used for storing pirated copies.

1.2 The literature and our investigation

Several papers have already analyzed the effects of piracy on the demand for the legally-supplied software. See, a pioneering paper by Conner and Rumelt (1991), and extensions in Shy and Thisse (1999), Shy (2000) and Shy (2001, Ch.3). An empirical investigating showing how the increase in software piracy can boost the demand for the legal software is conducted in Givon, Mahajan, and Muller (1995). Earlier papers discussing the effects of photocopying include Besen and Kirby (1989), Johnson (1985), Liebowitz (1985), and Novos and Waldman (1984).

Our investigation differs from the above literature in that it investigates the effects of hardware taxation on the profit of a software publisher whose software is pirated by some users. We develop a model in which the user population gain utility from software to be used on a piece of hardware. Thus, users must purchase hardware and software from different manufacturers. We calculate equilibrium prices under which the user population is divided into three groups: Those who buy hardware and software, those who buy the hardware and pirate the software, and those who do not buy anything so they become nonusers. We then investigate how a tax on hardware affects the profit of the software producer under the extreme assumption that the proceeds from this tax are transferred to the software publisher,

²*Business Week*, February 5, 2001, p.19.

as a compensation for the partial violation of the publisher's intellectual property right. We also investigate the effects of hardware taxation on social welfare.

1.3 Organization

The paper is organized as follows. Section 2 sets up a model of hardware and software producers, where consumers can either buy the software or use it illegally without paying for it. Section 3 investigates the effects of hardware taxation and the welfare consequences of the hardware tax. Section 4 analyzes an extreme case of an economy with no copyright infringement. Section 5 concludes.

2. The market for hardware, software, and piracy

Consider a market composed of users who wish to utilize a certain piece of software (e.g., computer software, a music performance, a digitally-stored book, or a movie). For the sake of brevity we call this title by the name *software*, and assume that this software is copyrighted.

The software analyzed in this paper can be obtained in two ways. It can be purchased on conventional media such as diskettes or compact disks. Alternatively, it can be illegally copied. There are many ways in which copyrighted media can be copied, for example, it could be downloaded via the Internet, sent by e-mail, copied on diskettes, CD, DVD, or audio cassettes.

2.1 Users

There is a continuum of types of potential software users indexed by x on the interval $[0, 1]$, with density of $\eta \geq 1$ users per type. Thus, the total number of consumers in this market is η . Each user consumes at most one unit of this software, either by purchasing it from the store for a price p^s , or by pirating it without paying p^s . In addition, each user who wishes to use the software must purchase one unit of hardware (e.g., a computer, CD/DVD player, or a cassette player) for a price of p^h . The utility of each user indexed by x ($0 \leq x \leq 1$) is

defined by

$$U_x \stackrel{\text{def}}{=} \begin{cases} \alpha x + \gamma N - p^h - p^s & \text{if buys hardware and software} \\ \beta x + \gamma N - p^h & \text{if buys the hardware and pirates the software} \\ 0 & \text{if does not use software and hardware.} \end{cases} \quad (1)$$

The parameters $\alpha > 0$ and $\beta > 0$ measure a user's basic utility from the services provided by this software title of a type- x user. Thus, user-types indexed by x close to 0 are interpreted as those who gain very little from using computers, whereas users indexed by an x close to 1 gain the most out of using computers and software. We make the following assumption.

ASSUMPTION 1

For every user x , legally-purchased software yields more services than pirated software. Formally, purchased software and pirated software are vertically differentiated, i.e., $\alpha > \beta$.

The interpretation of Assumption 1 is as follows. Legally-purchased software is bundled with manuals, installation software, service, as well as discount on upgrades. In contrast, users who pirate the software may not be able to copy the manuals, may be forced to utilize complicated installation techniques, and are not entitled to service and upgrades. In addition, users who do not buy the software may have hard time in finding the software, and then copying or downloading it for installation purposes. Finally, some illegal users may be uncomfortable in using copyrighted software without paying for it.

The variable N is the endogenously-determined total number of *users*, which is the sum of those who buy the software and those who illegally copy the software. The parameter $\gamma \geq 0$ is the *network externality* parameter reflecting the degree of importance of the total number of users. Therefore, if $\gamma > 0$, the utility of each user increases with the total number of all people who also use this software. There are two interpretations for this assumption. In one interpretation, users gain from having more people using the same software since they can work together, say by exchanging files. A second interpretation refers to popularity or fashions where people “feel better” by using products that are similar to what others consume. It is important to observe that all users, regardless of whether they are buyers or illegal users, gain from the network size. Thus, buyers benefit with an increase in the

number of buyers as well as in the number of illegal users, and illegal users also benefit from an increase in the number of buyers as well as in the number of illegal users.

We confine our analysis to the following parameter range.

ASSUMPTION 2

The network effect parameter is bounded by the basic valuation for the software. Formally,

$$\frac{\beta}{2\eta} < \gamma < \max \left\{ \frac{\beta}{\eta}; \frac{2\alpha}{3\eta} \right\}.$$

Assumption 2 constrains the network externality effect. Higher values of γ would make the software highly valuable by all consumers (type $x = 0$ in particular) thereby generating an equilibrium where all potential users become actual users even with the imposition of a revenue-maximizing hardware tax. Lower values of γ would complicate the analysis as it would make those who most value the software pirate the software, whereas buyers would consist of those who less value the software.

2.2 Users' choice problem

Let x^p denote the type of consumers who are indifferent between pirating the software and not using the software at all. In view of the utility function (1), this consumer type is solved from

$$\beta x^p + \gamma N - p^h = 0, \quad \text{hence} \quad x^p = \frac{p^h - \gamma N}{\beta}. \quad (2)$$

Thus, all users indexed on $[0, x^p]$ do not use (and do not purchase) any hardware and software.

Similarly, let x^b denote the type of consumers who are indifferent between buying the software and pirating the software. In view of the utility function (1), this consumer type is solved from

$$\alpha x^b + \gamma N - p^h - p^s = \beta x^b + \gamma N - p^h \quad \text{hence} \quad x^b = \frac{p^s}{\alpha - \beta}. \quad (3)$$

Thus, all users indexed on $[x^p, x^b]$ pirate the software, and all users index on $[x^b, 1]$ buy the software, Therefore, the number of software buyers is $\eta(1 - x^b)$.

Figure 1 illustrates how the market is divided among buyers, illegal users and nonusers. Therefore, the aggregate number of users (i.e., the sum of buyers and illegal users) is given

Figure 1: Pirates, nonusers, and buyers.

by

$$N = \eta(1 - x^p) = \eta \left(1 - \frac{p^h - \gamma N}{\beta} \right), \quad \text{hence} \quad N = \frac{\eta(\beta - p^h)}{\beta - \gamma\eta}. \quad (4)$$

2.3 The government

Clearly, the government is unable to directly tax those who illegally copy the software since pirated copies are not purchased in any formal way. Also, it is clear that piracy cannot be reduced if the government taxes software buyers. In fact, taxing software buyers would only reduce the number of buyers. Thus, the only tax mechanism available to the government is to tax each unit of hardware purchased by each legal and an illegal software user. Let t denote the per-unit (specific) tax on hardware, and by T the total revenue collected from this tax. Then,

$$T = t \cdot N. \quad (5)$$

Finally, to make our investigation complete, we assume that the purpose of this tax is to “compensate” the software producer for the copyright infringement associated with piracy. Thus, we assume that the government’s sole objective is to compensate the software producer by transferring the entire revenue collected by the tax on hardware.

2.4 The hardware producer

We assume that hardware is produced and sold by a single monopoly firm with zero production cost. Therefore, the hardware producer chooses a price, p^h , that solves

$$\max_{p^h} \pi^h = (p^h - t)N = (p^h - t) \frac{\eta(\beta - p^h)}{\beta - \gamma\eta}. \quad (6)$$

Therefore, the hardware producer's profit-maximizing price is

$$p^h = \frac{\beta + t}{2}. \quad (7)$$

Notice that the hardware producer's price increases with the tax on hardware and with β which is the software-valuation parameter of a pirating user.

2.5 The software producer

The seller of the software chooses p^s that solves

$$\max_{p^s} \pi^s = \eta(1 - x^b)p^s + T = \eta \left(1 - \frac{p^s}{\alpha - \beta} \right) p^s + T. \quad (8)$$

There are two ways to interpret the software maker's profit function (8). The first interpretation involves a non-strategic software developer who treats the government's subsidy, T , as given. Such an interpretation is commonly used in the public finance literature. The second interpretation involves a strategic software developer who can indirectly "manipulate" the subsidy via the price of software. However, inspecting (4) reveals that the aggregate number of users is influenced only by p^h and not by p^s , which means that these two interpretations yield the same results. Thus, maximizing (8), the software firm's profit-maximizing price is then given by

$$p^s = \frac{\alpha - \beta}{2}. \quad (9)$$

3. The Consequences of Hardware Taxation

Substituting (7) and (9) into (4), and then also into (2) and (3), we obtain the aggregate number of users (buyers and illegal users), as well as the user types indifferent between not using and pirating, and pirating and buying the software. Therefore,

$$N = \frac{\eta(\beta - t)}{2(\beta - \gamma\eta)}, \quad x^p = \max \left\{ 0, \frac{\beta - 2\gamma\eta + t}{2(\beta - \gamma\eta)} \right\}, \quad \text{and} \quad x^b = \frac{1}{2}. \quad (10)$$

Notice that (10) and Assumption 2 imply that when hardware is not taxed ($t = 0$) all the market is served ($x^p = 0$). Next, (10) implies that the tax revenue collected by the

government is

$$T = tN = t \frac{\eta(\beta - t)}{2(\beta - \gamma\eta)}. \quad (11)$$

Substituting (7) into (6), and (9) and (11) into (8) yields the equilibrium profit levels as functions of the tax rate on hardware. Thus,

$$\pi^h = \frac{\eta(\beta - t)^2}{4(\beta - \gamma\eta)}, \quad \text{and} \quad \pi^s = \frac{\eta(\alpha - \beta)}{4} + T = \frac{\eta(\alpha - \beta)}{4} + t \frac{\eta(\beta - t)}{2(\beta - \gamma\eta)} \quad (12)$$

We now ask what would be the hardware tax rate that would maximize the government revenue, and what would be the rate which would maximize the profit of the software developer. However, inspecting (11) and (12) reveals that these two tax rates are identical. Therefore, maximizing (11) with respect to t yields

$$t = \frac{\beta}{2}. \quad (13)$$

Altogether, we can state the following proposition.

Proposition 1

- (a) *By setting the hardware tax rate $t = \gamma\eta$, the government can eliminate piracy. However,*
- (b) *The hardware tax rate that maximizes the (tax inclusive) profit of the software developer is below the tax rate that eliminates piracy.*

Proof. (a) From (10) we see that $x^p \rightarrow x^b$ as $t \rightarrow \gamma\eta$. (b) $t = \beta/2 < \gamma\eta$ by Assumption 2. □

The tax on hardware clearly reduces the profit of the hardware firm, but increases the profit of the software firm up to a certain level. However, the main concern of the regulator should be how the tax on hardware affects aggregate social welfare. We define aggregate consumer surplus by the sum of the utilities of all users. Formally,

$$\begin{aligned} \text{CS} &\stackrel{\text{def}}{=} \eta \int_{x^p}^{x^b} (\beta x + \gamma N - p^h) \, dx + \eta \int_{x^b}^1 [\alpha x + \gamma N - p^h - p^s] \, dx \\ &= \frac{\eta [3\alpha(\beta - \gamma\eta)^2 + 2\beta^2(2\gamma\eta - t) - \beta(3\gamma^2\eta^2 + t^2) + 2\gamma\eta t^2]}{8(\beta - \gamma\eta)^2} - \eta p^h(1 - x^p) - \eta p^s(1 - x^b). \end{aligned} \quad (14)$$

Note that (1) implies that all potential users indexed on $[0, x^p)$ gain a utility of zero since they neither buy the software nor they pirate it.

The sum of profits of the hardware and software producers is given by

$$\pi^h + \pi^s = (p^h - t)(1 - x^p)\eta + p^s(1 - x^b)\eta + t\eta(1 - x^p) = p^h(1 - x^p)\eta + p^s\eta(1 - x^b). \quad (15)$$

Clearly, aggregate profit (15) enters as a negative sum in aggregate consumer surplus (14) since it reflects a transfer from users to firms. Altogether, we define the social welfare function by the sum of users' utilities and the profits of the hardware and software firms. Formally,

$$W(t) \stackrel{\text{def}}{=} \text{CS} + \pi^h + \pi^s = \frac{\eta[3\alpha(\beta - \gamma\eta)^2 + 2\beta^2(2\gamma\eta - t) - \beta(3\gamma^2\eta^2 + t^2) + 2\gamma\eta t^2]}{8(\beta - \gamma\eta)^2}. \quad (16)$$

Differentiating (16) with respect to t yields

$$\frac{d^2W}{dt^2} = \frac{\eta(2\gamma\eta - \beta)}{4(\beta - \gamma\eta)^2} > 0, \quad \text{and} \quad \left. \frac{dW}{dt} \right|_{t=0} = \frac{-\eta\beta^2}{4(\beta - \gamma\eta)^2} < 0.$$

We are now ready to state the following proposition.

Proposition 2

The tax on hardware reduces aggregate social welfare.

Proposition 2 implies that the distortion created by taxing hardware for the purpose of reimbursing software producers for the piracy they experience causes a severe distortion to resource allocation, leading to a reduction in social welfare.

4. Strong enforcement

In this section we consider an hypothetical economy where all users always buy the software. We use the term “hypothetical” since we believe that a strict enforcement of copyrights is prohibitly costly to government, since it requires a police inspection of every house. However, it is instructive to analyze such an economy since it highlights the consequences of piracy in this type of markets. Because an absolute enforcement is prohibitly costly, we do not perform any welfare analysis in this section.

4.1 Equilibrium in the absence of piracy

When there is no piracy, the number of users equals the number of software (and hardware) buyers. Hence, $N = (1 - x^b)\eta$. The utility function (1) implies that the user-type who is indifferent between not using and buying is determined by $\alpha x^b + \gamma(1 - x^b)\eta - p^h - p^s = 0$. Therefore,

$$x^b = \frac{p^h + p^s - \gamma\eta}{\alpha - \gamma\eta} \quad \text{hence} \quad N = \frac{\eta(\alpha - p^h - p^s)}{\alpha - \gamma\eta}. \quad (17)$$

The hardware producer chooses p^h , and the software chooses p^s to solve³

$$pi^h = p^h N = p^h \frac{\eta(\alpha - p^h - p^s)}{\alpha - \gamma\eta} \quad \text{and} \quad pi^s = p^s N = p^s \frac{\eta(\alpha - p^h - p^s)}{\alpha - \gamma\eta}. \quad (18)$$

The best response functions are given by

$$p^h = \frac{\alpha - p^s}{2} \quad \text{and} \quad p^s = \frac{\alpha - p^h}{2}. \quad (19)$$

Therefore, the equilibrium prices and profit levels are

$$p^h = p^s = \frac{\alpha}{3} \quad \text{and} \quad \pi^h = \pi^s = \frac{\alpha^2\eta}{9(\alpha - \gamma\eta)}. \quad (20)$$

The equilibrium buyer who is indifferent between buying and not using, and the number of users/buyers are then given by

$$x^b = \frac{2\alpha - 3\gamma\eta}{3(\alpha - \gamma\eta)} \quad \text{and} \quad N = \frac{\alpha\eta}{3(\alpha - \gamma\eta)}. \quad (21)$$

Notice that $0 < x^b < 1$ by Assumption 2.

4.2 A comparison with the case of piracy

This subsection demonstrates that our simple model is sufficiently robust to demonstrate how piracy in the presence of network effects (under $t = 0$) influences the number of software buyers and the profit of the software firm.

Comparing the equilibrium number of buyers, $(1 - x^b)\eta$ given in (10) to (21) yields the following proposition.

³This type of problem of price competition between firms producing perfect-complements was first analyzed by Cournot, see Economides and Salop (1992). In this type of industries, a merger between the two firms may yield a Pareto-superior outcome due to an increase in market participation.

Proposition 3

If network effects are insignificant (formally, if $\gamma\eta < \alpha/3$), piracy reduces the number of software buyers.

Reversing the condition of Proposition 3 we can obtain the Conner and Rumelt (1991) effect where in the presence of strong network effects piracy increases the total number of users thereby making the software more valuable, hence generating a higher demand for purchasing the software.

Comparing the equilibrium number of users, N given in (10) to (21), piracy leads to a higher number of users if $\gamma\eta(2\alpha - 3\beta) > -\alpha\beta$. Finally, comparing the profit levels given in (12) and (20) yields that piracy increases the profit of the software firm if $\gamma\eta(\alpha - \beta) < \alpha(5\alpha - 9\beta)/9$. The last two conditions are interpreted in Figure 2. Recall that the

Figure 2: Users and profit of the software firm. *Note:* Superscript “ p ” denotes variables when piracy is feasible, “ n ” when piracy is not feasible.

parameters α and β measure the basic utility derived from a purchased software and pirated software, respectively. Therefore, as β increases (the range closer to the 45°-line in Figure 2) purchased and pirated software yield similar services. In this case, piracy reduces the profit of the software firm. In this parameter range, piracy reduces the total number of users when network effects are significant. However, the profit of the software firm can be higher under

piracy when β is small relative to α and network effects are insignificant (the range far from the 45°-line in Figure 2).

5. Discussions

A tax on hardware indeed reduces the illegal use of software. But, it also reduces the entire demand for using software in general and the demand for buying software in particular, since this tax raises the consumer price of buying a system combining hardware and software. Even in the extreme case analyzed in this paper where all the proceeds from the hardware tax are transferred to the software producer, Proposition 2 then shows that this tax is harmful from a social welfare point of view (at all levels of implementation).

5.1 Network externality effects

In this simple model, piracy is enhanced by the network externality effect. When the network parameter, γ increases (within the permissible range of Assumption 2), (10) reveals that x^p decreases and N increases, meaning that the piracy level is intensified. Proposition 1(a) reveals that a higher hardware tax would be needed to eliminate piracy. As it turns out, despite the fact that piracy increases when the network factor becomes more important (γ increases), (12) shows that the profit of the software developer also increases. This demonstrates that in the presence of network effects an increase in the level of piracy need *not* reflect a decline in the profit of software developers, since the software becomes more valuable to buyers. Consequently the profit of software maker may increase with the level of piracy.

5.2 A look towards the future

Finally, we believe that the solution for the violation of intellectual property rights will eventually come from the private sector and not from the public sector. More precisely, since surcharges and even an aggressive enforcement can achieve only a very limited success (if any), it is the technology advance which will make intellectual property rights self enforced. For the case of computer software, with an increased speed of the Internet, it is possible that

most software will be installed on commercial servers and not on individuals' hard drives. This means that file servers will be able to track down who owes and how much for the use of a particular piece of software and other type of information and entertainment products, see Varian (1995). Thus, software publishers will be able to rent software for the time it is actually used.

As for digitally-stored music, books, and movies, technology will soon enable publishers to rent them as well by encrypting the digital bits using self-destroying software which could be activated by counters allowing the specific medium to be played the number of times they are rented for. Such a mechanism was tried out on the DIVX standard which was competing with the DVD standard during the 1990s. To sum up, we believe that copyrights are more efficiently protected by the technology itself rather than by hardware taxes.

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