

On the Impact of Digital Music Distribution

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Abstract

We present a framework to evaluate the impact of digital music distribution. We set up a representative model that enables the comparative static analysis. We then interpret two empirical observations about the music industry, the sales decline and the price constancy, and fit the model to these observations. We find that, while the impact of digitalization on the producers' profits is probably negative, it may not be as severe as the observed impact on the quantity. On the other hand, the impact of digitalization on the consumer surplus is unambiguously positive. The impact on the social welfare is rather ambiguous in general, but the social welfare may increase for plausible parameter values. (JEL codes: K11, L86, O34)

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1 Introduction

The music industry has experienced significant changes in recent years. In particular, the advent of broadband networks made it possible to freely download unauthorized copies of prerecorded music files via peer-to-peer (P2P) technologies: consumers can transmit the music in digital format among themselves using the online 'file-sharing' technology provided by Napster, Kazaa, Grokster, and others. These changes have generated heated debates regarding the possible impacts on the sound-recording industry. Some argue that the decline in the sales of recorded music endangers the viability of the industry, while others say that these changes may ultimately benefit the producers.

There exist some empirical works including Michel (2006), Oberholzer-Gee and Strumpf (2007), Peitz and Waelbroeck (2004), and Zentner (2006), as well as some theoretical discussion including Liebowitz (2005, 2006) and Peitz and Waelbroeck (2005, 2006b) on the impacts of file-sharing technology. Most of the works, however, are concerned with the

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causes for the sales decline of prerecorded music.¹ In particular, no previous work has studied the welfare consequences of these changes.

This article aims to provide a framework to evaluate the impact of digital music distribution on the social welfare as well as on the profit and the consumer surplus. To do so, we set up a representative model that enables the comparative static analysis before and after the advent of digital distribution technology.

The ‘digitalization’, i.e. the distribution of music files in digital format using online technology, affects several aspects of the industry. First, the unauthorized copies shared among end-users create competitive pressure on the legitimate products. That is, the copies are (inferior) substitutes for the original, and so possibly harm the producers of the music by decreasing their sales and profits. On the other hand, it is often argued that the ‘sampling’, i.e. consumers’ listening to the music before purchasing and finding the better fits for their tastes, afforded by the online technology may in effect boost the demand for the original, and help the producers. Finally, the digitalization may lower the producers’ costs of distribution, marketing, and promotion.

It is ultimately an empirical question to determine the net impacts of digitalization. Hence, after setting up a framework to evaluate the impacts, we start with interpreting two empirical observations of the music industry. The first and the most obvious observation is the sales decline. Liebowitz (2006, p. 14), for example, estimates that the actual sales in the United States have dropped up to 30% after digitalization. While various explanations are possible, it is most plausible that the file sharing activity exerted a strong substitution effect. Another interesting and rather puzzling observation is the virtual constancy of price. Liebowitz (2006, p. 21) again observes that ‘the list prices adjusted for inflation have been virtually constant for the last decade’. If the unauthorized copies are substitutes, then the price of the legitimate copies should have decreased due to the competitive pressure. That did not happen, however.

Several reasons may be proposed for this ‘constant price puzzle’. First, it may be argued that the producers were in a competitive environment to begin with and so could not afford to decrease the price. But this can be easily discarded, since the big four record labels (Universal, Sony BMG, EMI, Warner) essentially dominate the market and they are sometimes alleged to collude on price fixing.² Alternatively, it is possible that consumers are substantially differentiated with respect to their valuations and

¹ See Section 3 below for some of their results.

² See FTC Press Release on 10 May 2000, ‘Record Companies Settle FTC Charges of Restraining Competition in CD Music Market.’

attitudes toward the music so that the producers reacted by concentrating on the higher segment of the consumer population. In other words, the digitalization may have made it possible for the producers to provide more value to the high-valuation consumers so it was best to take a price strategy on them (while sacrificing the quantity on the low-valuation consumers). Our framework supports the latter interpretation. We find that the sampling effect substantially increased consumers' benefits and it worked better for the high-valuation consumers.

We then fit the model to these empirical observations. We first find that, while the impact of digitalization on the producers' profits is probably negative, it may not be as severe as the observed impact on the quantity. In particular, digitalization may lower the fixed costs of distribution as well as increasing the additional revenue from complementary products such as live performance. On the other hand, the impact of digitalization on the consumer surplus is unambiguously positive: consumers have benefited from all the possible effects of digitalization. We find that the impact on the social welfare is rather ambiguous in general. However, we show that the impact may be positive for plausible parameter values in our model. We also show that enhanced copyright protection to counteract the impacts of digitalization may have an unexpected effect on the social welfare.

The rest of the article is organized as follows. Section 2 sets up the model to evaluate the impacts of digitalization, and does some comparative statics before and after digitalization. Section 3 discusses the empirical observations and determines the possible impacts of digitalization. It also briefly discusses the possible effect of enhanced copyright protection on the social welfare. Section 4 concludes.

2 The model

Consider a music product that is produced by a monopolistic producer (record company, music label, or publisher). We first study the benchmark case of traditional distribution. We then see how the digitalization of music distribution affects the relevant variables. The model we employ is the one developed in Yoon (2002) for the study of copyright protection. Similar models are used in subsequent works including Belleflamme (2003) and Bae and Choi (2006).³

³ Peitz and Waelbroeck (2006a) is a comprehensive review of the relevant literature.

2.1 The benchmark

There are consumers who are interested in the product. Each consumer consumes at most one unit of the product. We denote the set of consumers by I and the valuation of consumer $i \in I$ by v_i . Consumers can consume the product either by purchasing from the original producer or by making unauthorized reproductions, i.e. by making copies. When $i \in I$ buys the product, her net utility is $v_i - p$, where p is the monopolist's price. When $i \in I$ copies the product, her net utility is $(1 - \alpha)v_i - z$. The parameter α measures the quality degradation of a copy, with $0 < \alpha < 1$.⁴ The parameter z captures the reproduction costs, including the physical costs as well as the inconveniences consumers have to bear in making the copies. If we let $w_i \equiv \alpha v_i + z$ be termed as the *gross reproduction cost*, the net utility from a copy is $v_i - w_i$. The utility when a consumer does not consume the product is normalized to zero.

Consumer i will make the following choices depending on the relative magnitudes of v_i , w_i , and p . When $p = \min\{v_i, w_i, p\}$, consumer i purchases from the producer. When $w_i = \min\{v_i, w_i, p\}$, consumer i makes an unauthorized copy. When $v_i = \min\{v_i, w_i, p\}$, consumer i does not consume the product.

For a concrete analysis, assume that consumers' valuations are uniformly distributed over the unit interval $[0, 1]$. Thus, we can identify the set I of consumers with the set of valuations, which is the unit interval. Then, consumers' choices given the price can be summarized as follows.

- (a) When $p < z/(1 - \alpha)$: this is the case when the monopolist's price is set low enough that no consumer makes an unauthorized copy. Consumers who belong to $[0, p)$ do not consume the product, while consumers who belong to $[p, 1]$ buy from the monopolist.
- (b) When $p \geq z/(1 - \alpha)$: this is the case when the unauthorized reproduction exists. Consumers who belong to $[0, z/(1 - \alpha))$ do not consume the product, consumers who belong to $[z/(1 - \alpha), (p - z)/\alpha)$ make unauthorized copies, and consumers who belong to $[(p - z)/\alpha, 1]$ buy from the monopolist.

This is a result in Yoon (2002, Proposition 2), and can be easily proved by using a diagram similar to Figure 1 below.⁵ By the way, we observe

⁴ The quality degradation may also come from the lack of accompanying lyrics, the lack of photographic illustrations of the singers, the lack of technical supports, and so on. See Yoon (2002) for a more detailed discussion of the model setup.

⁵ Note that Figure 1 deals with the case after digitalization. If we set $\alpha' = \alpha$, $s = t = 0$, and $z' = z$, this diagram can also be used for the benchmark case here.

both the legitimate product and its unauthorized copies in most real markets. As a matter of fact, copyright protection and related issues may not have attracted much academic attention if the original producer could profitably set the price low enough to deter unauthorized reproduction. Hence, we will be mainly interested in case (b) henceforth.

The monopolist incurs fixed costs of development, marketing, and promotion. In addition, he incurs the marginal reproduction cost of c for each additional unit of the product. We will assume $c = 0$ for the simplicity of analysis, as many previous papers on the copyright issues do.⁶ That is, we assume that the marginal reproduction costs of the legitimate products are negligible. Casual observation seems to support this normalization since the variable costs are quite low compared to the album price.

Given the consumers' choices, the monopolist chooses the optimal price and quantity by equating his marginal revenue with the marginal cost of $c = 0$. The equilibrium outcome for case (b) is characterized as follows. The equilibrium price, quantity, and profit are given by

$$\{p, q, \pi\} = \left\{ \frac{\alpha + z}{2}, \frac{\alpha + z}{2\alpha}, \frac{(\alpha + z)^2}{4\alpha} \right\}.$$

Consumers who belong to $[0, z/(1 - \alpha))$ do not consume the product, consumers who belong to $[z/(1 - \alpha), (\alpha - z)/2\alpha)$ make unauthorized copies, and consumers who belong to $[(\alpha - z)/2\alpha, 1]$ buy from the monopolist.⁷ Notice that the parameters need to satisfy $(\alpha - z)/2\alpha \geq z/(1 - \alpha)$, or to rearrange, $z \leq (1 - \alpha)\alpha/(1 + \alpha)$, in order to have the equilibrium outcome in which both the original and copies exist, i.e. of case (b). We assume $z \leq (1 - \alpha)\alpha/(1 + \alpha)$ throughout the article.

The consumer surplus CS and the social welfare SW are given by

$$\begin{aligned} CS &= \int_{z/(1-\alpha)}^{(\alpha-z)/2\alpha} (v - \alpha v - z)dv + \int_{(\alpha-z)/2\alpha}^1 \left(v - \frac{\alpha + z}{2}\right)dv \\ &= \frac{\alpha(1 - \alpha)(4 - 3\alpha) - 6\alpha(1 - \alpha)z + (1 + 3\alpha)z^2}{8\alpha(1 - \alpha)} \\ &= \frac{4 - 3\alpha}{8} - \frac{3}{4}z + \frac{1 + 3\alpha}{8\alpha(1 - \alpha)}z^2. \end{aligned}$$

⁶ See, for example, Belleflamme (2003) and Bae and Choi (2006).

⁷ This follows from a result in Yoon (2002, Proposition 3(i)). Alternatively, we can apply the analysis in the next subsection by setting $\alpha' = \alpha, s = t = 0, c' = c = 0$, and $z' = z$.

$$\begin{aligned}
SW = CS + \pi &= \int_{z/(1-\alpha)}^{(\alpha-z)/2\alpha} (v - \alpha v - z)dv + \int_{(\alpha-z)/2\alpha}^1 vdv \\
&= \frac{\alpha(1-\alpha)(4-\alpha) - 2\alpha(1-\alpha)z + (3+\alpha)z^2}{8\alpha(1-\alpha)} \\
&= \frac{4-\alpha}{8} - \frac{1}{4}z + \frac{3+\alpha}{8\alpha(1-\alpha)}z^2.
\end{aligned}$$

Note that the first and second term in CS (SW) corresponds, respectively, to the consumer surplus (the social welfare) for those who make unauthorized copies and who buy from the monopolist.

2.2 The digitalization

The digitalization of music products affects several aspects of the model. First of all, the parameters that pertain to unauthorized reproduction may be affected. For example, the reproduction costs might be lowered as the digital distribution channel made it easier for consumers to access and copy the music files. Digitalization may also affect the quality degradation of copies. Let α' and z' denote the new quality degradation parameter and the consumers' reproduction costs, respectively.

Second, the cost structure of music production changes. The move to online distribution channel seems to reduce the marginal costs of reproduction and distribution. In addition, the marketing and promotion costs would probably decline. It is thus fair to assume that the new marginal cost c' is not higher than the original marginal cost c . Thus, assume $c' = c = 0$.⁸

Finally, digitalization may enhance the valuation that consumers obtain from both legitimate music products and unauthorized copies. The reason is due to the 'sampling effect' among others: sampling allows users to experience the music and to find better fits for their tastes. In other words, as Liebowitz (2005) convincingly argues with a candy bar example, sampling in effect provides the users more utility. We want to note that we are not saying here that the actual sales may increase due to sampling,⁹ but only that consumers' valuations may increase because of enhanced satisfaction or reduced risks/uncertainty associated with the purchase. We introduce

⁸ It would not change the qualitative features of the main results, but would only complicate the analysis, if we instead adopt the more general specification of $0 \leq c' \leq c$, with c being strictly positive.

⁹ Peitz and Waelbroeck (2006b) show that the music industry may gain from sampling if there is sufficient taste heterogeneity and sufficient product diversity. Our main concern in this article, however, is different.

parameters s and t to capture this effect. Let s and t denote the sampling effect of legitimate products and unauthorized copies, respectively.¹⁰

We now assume that consumer i gets the net utility of $(1 + s)v_i - p$ when she buys from the monopolist. The net utility from a copy is $(1 + t - \alpha')v_i - z' \equiv (1 + t)v_i - w'_i$, and the net utility from no consumption is normalized again to zero. Consumer choice is determined by the relative magnitudes of $(1 + s)v_i - p$, $(1 + t - \alpha')v_i - z'$, and zero. Since

$$\max\{(1 + s)v - p, (1 + t)v - (\alpha'v + z'), 0\} \Leftrightarrow \min\{p - sv, (\alpha' - t)v + z', v\},$$

we can determine consumers' choices by using the diagram below (Figure 1).

Hence, given the monopolist's price p , consumers who belong to $[0, z'/(1 + t - \alpha'))$ do not consume the product, consumers who belong to $[z'/(1 + t - \alpha'), (p - z')/(\alpha' + s - t))$ make unauthorized copies, and consumers who belong to $[(p - z')/(\alpha' + s - t), 1]$ buy from the monopolist.

Note that the diagram is shown for the case when unauthorized copies co-exist with the original. Similar diagram can be drawn for the case when the monopolist charges the price low enough that no consumer makes an unauthorized copy.

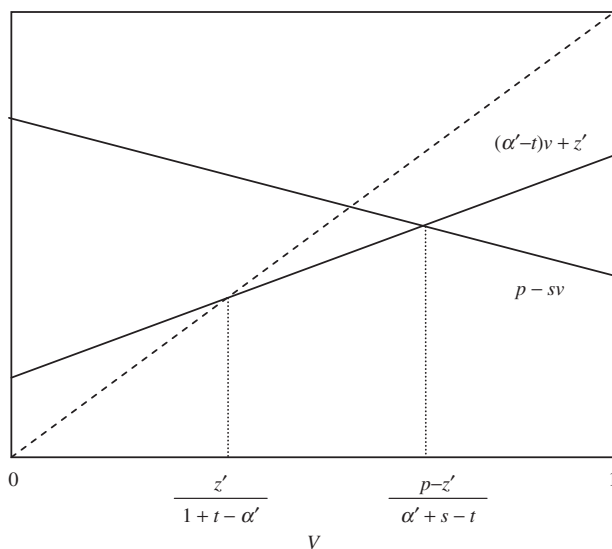


Figure 1 Consumer choice.

¹⁰ We want to note that this parametric representation of the sampling effect is used only to facilitate the comparative static analysis and to answer the question we have posed. It is obviously better to have a model with many products to analyze the sampling effect properly, but it may make the comparative statics intractable.

The demand function for the legitimate product is therefore

$$D(p) = \begin{cases} 1 - \frac{p-z'}{\alpha'+s-t} & \text{when } p \geq \frac{(1+s)z'}{1+t-\alpha'}, \\ 1 - \frac{p}{1+s} & \text{when } p < \frac{(1+s)z'}{1+t-\alpha'}. \end{cases}$$

The marginal revenue function is given as

$$MR(q) = \begin{cases} \alpha' + s - t + z' - 2(\alpha' + s - t)q & \text{when } q \leq 1 - \frac{z'}{1+t-\alpha'}, \\ 1 + s - 2(1 + s)q & \text{when } q > 1 - \frac{z'}{1+t-\alpha'}. \end{cases}$$

By equating this with the marginal cost of $c' = 0$ for the case when unauthorized copies co-exist with legitimate products, we get the equilibrium price, quantity, and profit after digitalization as

$$\{p', q', \pi'\} = \left\{ \frac{\alpha' + s - t + z'}{2}, \frac{\alpha' + s - t + z'}{2(\alpha' + s - t)}, \frac{(\alpha' + s - t + z')^2}{4(\alpha' + s - t)} \right\}.$$

The consumers' choices can be summarized as follows:

- (i) Consumers who belong to $[0, z'/(1+t-\alpha'))$ do not consume the product,
- (ii) Consumers who belong to $[z'/(1+t-\alpha'), (\alpha'+s-t-z')/2(\alpha'+s-t))$ make unauthorized copies, and
- (iii) Consumers who belong to $[(\alpha'+s-t-z')/2(\alpha'+s-t), 1]$ buy from the monopolist.

For unauthorized copies to co-exist with legitimate products in the equilibrium, the condition of $(\alpha'+s-t-z')/2(\alpha'+s-t) \geq z'/(1+t-\alpha)$, or to rearrange, $z' \leq (1+t-\alpha')(\alpha'+s-t)/(1+\alpha'+2s-t)$, needs to hold. We assume this condition to hold throughout the article, along with the previous condition of $z \leq (1-\alpha)\alpha/(1+\alpha)$.

The new consumer surplus CS' and the new social welfare SW' are

$$\begin{aligned} CS' &= \int_{z'/(1+t-\alpha')}^{(\alpha'+s-t-z')/2(\alpha'+s-t)} ((1+t)v - \alpha'v - z')dv \\ &+ \int_{(\alpha'+s-t-z')/2(\alpha'+s-t)}^1 \left((1+s)v - \frac{\alpha'+s-t+z'}{2} \right) dv \\ &= \frac{4 - 3\alpha' + s + 3t}{8} - \frac{3}{4}z' + \frac{1 + 3\alpha' + 4s - 3t}{8(\alpha' + s - t)(1 + t - \alpha')} (z')^2 \end{aligned}$$

$$\begin{aligned}
 SW' &= CS' + \pi' = \int_{z'/(1+t-\alpha')}^{(\alpha'+s-t-z')/2(\alpha'+s-t)} ((1+t)v - \alpha'v - z')dv \\
 &+ \int_{(\alpha'+s-t-z')/2(\alpha'+s-t)}^1 (1+s)v dv \\
 &= \frac{4 - \alpha' + 3s + t}{8} - \frac{1}{4}z' + \frac{3 + \alpha' + 4s - t}{8(\alpha' + s - t)(1 + t - \alpha')} (z')^2
 \end{aligned}$$

2.3 Comparative statics

We now turn to some comparative statics. To relate the benchmark to the digitalization, define the functions

$$\begin{aligned}
 p(\alpha, s, t, z) &= \frac{\alpha + s - t + z}{2}; \\
 q(\alpha, s, t, z) &= \frac{\alpha + s - t + z}{2(\alpha + s - t)}; \\
 \pi(\alpha, s, t, z) &= \frac{(\alpha + s - t + z)^2}{4(\alpha + s - t)}.
 \end{aligned}$$

Moreover, we have

$$\begin{aligned}
 CS(\alpha, s, t, z) &= \frac{4 - 3\alpha + s + 3t}{8} - \frac{3}{4}z + \frac{1 + 3\alpha + 4s - 3t}{8(\alpha + s - t)(1 + t - \alpha)} z^2, \\
 SW(\alpha, s, t, z) &= CS(\alpha, s, c, z) + \pi(\alpha, s, t, z) = \frac{4 - \alpha + 3s + t}{8} - \frac{1}{4}z \\
 &+ \frac{3 + \alpha + 4s - t}{8(\alpha + s - t)(1 + t - \alpha)} z^2.
 \end{aligned}$$

Then, the equilibrium prices of the benchmark and after digitalization are $p(\alpha, 0, 0, z)$ and $p(\alpha', s, t, z')$, respectively. We have similar expressions for other variables. We restate the relevant inequality constraint

$$z \leq \frac{(1 + t - \alpha)(\alpha + s - t)}{1 + \alpha + 2s - t} \tag{1}$$

that ensures the co-existence equilibrium outcomes in which both the legitimate purchase and the unauthorized reproduction prevail.

First, we have

$$\frac{\partial p}{\partial \alpha} = \frac{\partial p}{\partial s} = \frac{\partial p}{\partial z} = \frac{1}{2} > 0, \quad \frac{\partial p}{\partial t} = -\frac{1}{2} < 0.$$

Hence, the equilibrium price increases as a copy's quality degradation (α), the additional benefits of legitimate products (s), and the consumers' reproduction costs (z) increase, while it decreases as the additional benefits of copies (t) increase. Note that the positive effects of α and z are intuitive since the copies are (inferior) substitutes for the original. It is also obvious to see the positive effect of s and the negative effect of t .

Next, we have

$$\begin{aligned} \frac{\partial q}{\partial \alpha} = \frac{\partial q}{\partial s} &= -\frac{z}{2(\alpha + s - t)^2} < 0; \\ \frac{\partial q}{\partial t} &= \frac{z}{2(\alpha + s - t)^2} > 0; \\ \frac{\partial q}{\partial z} &= \frac{1}{2(\alpha + s - t)} > 0. \end{aligned}$$

Hence, an increase in z increases the equilibrium quantity of the originals. The effects of both α and s are negative while the effect of t is positive. The reason for the quantity decrease when either α or $s - t$ increases is because the marginal revenue curve $MR(q) = \alpha + s - t + z - 2(\alpha + s - t)q$ rotates clockwise with the center of $q = 1/2$ and $MR = z$, thus becoming steeper. This makes the monopolist to optimally concentrate on the higher segment of the market, by restricting the quantity and maintaining the high price, to maximize its profits.

Third, we have

$$\frac{\partial \pi}{\partial \alpha} = \frac{\partial \pi}{\partial s} = -\frac{\partial \pi}{\partial t} = \frac{(\alpha + s - t - z)(\alpha + s - t + z)}{4(\alpha + s - t)^2} \geq 0; \quad \frac{\partial \pi}{\partial z} = \frac{\alpha + s - t + z}{2(\alpha + s - t)} \geq 0.$$

Note that $\alpha + s - t - z \geq 0$ by the inequality constraint (1). All these effects seem quite intuitive.

Turning to the consumer surplus, we have

$$\begin{aligned} \frac{\partial CS}{\partial \alpha} &= -\frac{3}{8} - \frac{(1 + \alpha + 2s - t)(1 + 3t - 2s - 3\alpha)}{8(1 + \alpha - t)^2(\alpha + s - t)^2} z^2 \leq 0; \quad \frac{\partial CS}{\partial t} = -\frac{\partial CS}{\partial \alpha} \geq 0; \\ \frac{\partial CS}{\partial s} &= \frac{(\alpha + s - t - z)(\alpha + s - t + z)}{8(\alpha + s - t)^2} \geq 0; \\ \frac{\partial CS}{\partial z} &= -\frac{3}{4} + \frac{1 + 3\alpha + 4s - 3t}{4(\alpha + s - t)(1 + t - \alpha)} z \leq 0. \end{aligned}$$

These effects are also quite intuitive. Note that signs of $\partial CS/\partial\alpha$ and $\partial CS/\partial z$ are negative by the inequality constraint (1).

Finally, we can easily see that

$$\frac{\partial SW}{\partial s} = \frac{3(\alpha + s - t - z)(\alpha + s - t + z)}{8(\alpha + s - t)^2} \geq 0.$$

We also see that

$$\frac{\partial SW}{\partial \alpha} = -\frac{1}{8} + \frac{4s^2 - 3 - 2(t - \alpha)(4s + 3) + (t - \alpha)^2}{8(1 + t - \alpha)^2(\alpha + s - t)^2} z^2 \leq 0.$$

Although the sign appears ambiguous, we can easily verify that $\partial SW/\partial\alpha \leq 0$ for $z \leq (1 + t - \alpha)(\alpha + s - t)/(1 + \alpha + 2s - t)$. We also observe that $\partial SW/\partial t = -\partial SW/\partial\alpha \geq 0$. As for the effect of consumers' reproduction costs, observe that the function

$$\frac{\partial SW}{\partial z} = -\frac{1}{4} + \frac{3 + \alpha + 4s - t}{4(1 + t - \alpha)(\alpha + s - t)} z \tag{2}$$

is a strictly increasing function of z over the interval $[0, (1 + t - \alpha)(\alpha + s - t)/(1 + \alpha + 2s - t)]$. We also find that $\partial SW/\partial z = -1/4 < 0$ at $z = 0$, and $\partial SW/\partial z = (1 + s)/2(1 + \alpha + 2s - t) > 0$ at $z = (1 + t - \alpha)(\alpha + s - t)/(1 + \alpha + 2s - t)$. Therefore, the social welfare is a convex function which attains its minimum at

$$z^* = z^*(\alpha, s, t) = \frac{(1 + t - \alpha)(\alpha + s - t)}{3 + \alpha + 4s - t}.$$

The SW strictly decreases over the interval $[0, z^*]$ and strictly increases over the interval $[z^*, (1 + t - \alpha)(\alpha + s - t)/(1 + \alpha + 2s - t)]$. See Figure 2 below for representative curves. This behavior of the social welfare is due to two countervailing effects. First, an increase in z directly decreases the social welfare since it increases the reproduction costs of those consumers who choose to copy. Second, an increase in z induces some consumers to switch from making copies to buying from the original producer. This increases the social welfare because this switch decreases the social costs of production:

Table 1 Comparative statics

	∂p	∂q	$\partial \pi$	∂CS	∂SW
$\partial\alpha$	+	-	+	-	-
∂s	+	-	+	+	+
∂t	-	+	-	+	+
∂z	+	+	+	-	- then +

Note that the marginal consumers' reproduction costs who switch are higher than the producer's marginal cost due to the monopoly pricing.¹¹

Table 1 summarizes the discussion.

3 Main results

3.1 The impacts of digitalization

As discussed earlier, the digitalization of music products affects the equilibrium outcome through various routes: the quality of unauthorized copies may change (α to α'), consumers may get additional benefits from sampling effects ($s \geq 0$ and $t \geq 0$), and the consumers' reproduction costs may change (z to z'). Therefore, it is a difficult task to measure the net impacts of digitalization. Nevertheless, we will try to calibrate the model using some empirical observations about the price and the quantity, and determine the impacts of digitalization on the profit, the consumer surplus, and the social welfare. We are fully aware that this exercise is only heuristic at the best, and more empirical works need to be accumulated to accurately pin down the actual effects of digitalization.

One of the most obvious empirical facts after digitalization is the decline in the sales of recorded music. Liebowitz (2006), for example, estimates that the actual sales in the United States have dropped up to 30% after digitalization.¹² While various explanations may be possible to account for this decrease,¹³ most of the existing empirical works attribute the major cause to the file-sharing activities made possible by the digitalization. For example, Peitz and Waelbroeck (2004) find that music downloading could have caused a 20% reduction in music sales worldwide between 1998 and 2002. Michel (2006) finds that some music consumers could have decreased their CD purchases (prior to 2004) by about 13% due to Internet file sharing. Zentner (2006) finds that music downloading reduces the probability of buying music by 30%, and sales in 2002 would have been around 7.8% higher without downloads.¹⁴ This is plausible since the unauthorized copies easily obtainable through the Internet directly compete with the legitimate products.

¹¹ For a detailed discussion, see Yoon (2002).

¹² See Figure 3 of Liebowitz (2006). He uses the RIAA (Recording Industry Association of America) data on unit quantities of full-length albums.

¹³ Liebowitz (2005), for example, considers other factors such as income changes, changes in substitute/complement markets, changes in the quality of music, and changes in the supply of music for possible explanations.

¹⁴ On the other hand, Oberholzer-Gee and Strumpf (2007) find that file sharing has only had a limited effect on record sales.

Another interesting and rather puzzling empirical fact after digitalization is the virtual constancy of the album prices, especially in the United States. Liebowitz (2006) observes that ‘the list prices adjusted for inflation have been virtually constant for the last decade’, and Peitz and Waelbroeck (2005) provide similar observations.¹⁵ If we admit that the unauthorized copies work as substitutes for the legitimate products, we naturally expect that the original producer’s price should be lower after the file sharing activities. But, we observe otherwise. Why is this happening?

To see the reason, let us fit our model to these empirical observations. We make the following assumptions on the parameter changes. First, the quality degradation parameter may not increase due to digitalization, that is to say, digitalization may not deteriorate the quality of unauthorized copies. So, it is safe to assume $\alpha' \leq \alpha$. Second, the consumers’ reproduction costs may decrease due to easier access (say, via P2P networks) and copying technology. So, assume $z' \leq z$. Finally, we already set $s \geq 0$ and $t \geq 0$ to reflect the sampling effects for the legitimate products and unauthorized copies.

Given the comparative static analysis of the previous section, it is not hard to see that consumers get substantial additional benefits from the digitalization. The observed price has remained virtually constant while the changes in α , t , and z after digitalization should have lowered it. Hence, the increase in $s > 0$ must have counteracted against the price decrease. On the other hand, the cause for the observed decrease in quantity may have come from several directions: the decreased reproduction costs z have stolen significant parts of the legitimate demand, and the monopolist may have reacted to the additional benefit factor $s - t$ by focusing more on the high valuation consumers. It is noteworthy that the consumer surplus has increased undoubtedly after the digitalization, while the profit and the social welfare may have increased or decreased. Hence,

Result 1: The observed price constancy implies that the sampling effect is significant. The quantity decrease may be due to the substitution effect as well as the producer’s price strategy.

We now further specify the model to investigate the possible impacts of digitalization in depth. Let us assume $\alpha = \alpha'$, that is, the quality degradation parameter remains constant. Note that the sound quality of MP3 music files shared on the P2P networks is generally perceived to be

¹⁵ See p. 21 as well as footnote 30 of Liebowitz (2006), and Figures 4 and 5 of Peitz and Waelbroeck (2005).

inferior to the sound quality of the original soundtracks of CDs due to the compression rates. Observe also that the quality degradation may result from the lack of accompanying lyrics, the lack of photographic illustrations of the singers, and the lack of technical supports. It is therefore reasonable to assume that the quality degradation parameter pertaining to unauthorized copies did not change significantly even with the advent of online distribution. On the other hand, we capture the effects of digitalization on unauthorized copies with the parameter z . We assume $z' < z$, because the digital distribution channel made it easier for consumers to access and copy the music files.

With these additional assumptions, the price and quantity changes after digitalization are

$$p = \frac{\alpha + z}{2} \Rightarrow p' = \frac{\alpha + s - t + z'}{2}; \quad q = \frac{\alpha + z}{2\alpha} \Rightarrow q' = \frac{\alpha + s - t + z'}{2(\alpha + s - t)},$$

and we have

$$\frac{p'}{p} = \frac{\alpha + s - t + z'}{\alpha + z} \quad \text{and} \quad \frac{q'}{q} = \frac{\alpha}{\alpha + s - t} \cdot \frac{\alpha + s - t + z'}{\alpha + z} = \frac{\alpha}{\alpha + s - t} \cdot \frac{p'}{p}.$$

The empirical fact of constant price implies that $z - z' = s - t > 0$. Moreover, if the actual quantity decrease due to the digitalization is $100x\%$ so that $q'/q = 1 - x$, we get

$$s - t = \frac{x}{1 - x} \alpha.$$

Hence, regarding the impact on the price, the net additional benefits factor, $s - t$, has just offset the decrease in the consumers' reproduction costs, and that factor is about 43% (25%, 11%, respectively) of the quality degradation parameter when the quantity decreases by 30% (20%, 10%, respectively). Note that $s - t$ has a positive relationship with x .

The change in the profit after digitalization is given by

$$\frac{\pi'}{\pi} = \frac{(\alpha + s - t + z')^2}{\alpha + s - t} \cdot \frac{\alpha}{(\alpha + z)^2} = \frac{\alpha}{\alpha + s - t} \cdot \left(\frac{p'}{p}\right)^2 = 1 - x.$$

The change in the profit is equivalent to the change in the quantity, since the marginal cost is assumed to be zero and the actual price did not change. Hence, the profit has decreased by $100x\%$. As Liebowitz (2006, p. 18) argues, the net sampling effect (the increase in $s - t$) could not 'counterbalance the negative impacts of the substitution effect' (the decrease in z). We want to add, however, that the present model does not consider the possible changes in fixed costs. It is generally expected that the digitalization may substantially lower the distribution costs. In particular, sampling may replace costly marketing and promotion activities. Moreover, the file-

sharing activity may also increase the additional revenue from complementary products such as live performance by broadening the audiences. See Gayer and Shy (2006) for a related discussion. It is therefore possible that the profit has not decreased so much as predicted in this simple model. On the other hand, we have $\Delta CS > 0$, as discussed earlier, since $\partial CS/\partial s > 0$, $\partial CS/\partial t > 0$, and $\partial CS/\partial z < 0$. So, the consumer surplus has increased.

To see the impact on the social welfare, let us define

$r \equiv s - t = z - z'$. Then, the change in the social welfare is

$$\begin{aligned} \Delta SW &= SW(\alpha, s, t, z') - SW(\alpha, 0, 0, z) \\ &= SW(\alpha, t + r, t, z - r) - SW(\alpha, 0, 0, z) \\ &= \frac{k_0 + k_1 t + k_2 t^2}{8\alpha(1 - \alpha)(1 + t - \alpha)(\alpha + r)}, \end{aligned} \quad (3)$$

where

$$\begin{aligned} k_0 &= r(1 - \alpha)[\alpha(5\alpha - 5\alpha^2 + 8r - 4r\alpha + 4r^2) - 2(3 + \alpha + 4r)\alpha z - 3(1 - \alpha)z^2] \\ &= r(1 - \alpha)[4\alpha r^2 + 4(2 - 2z - \alpha)\alpha r + 5\alpha^2(1 - \alpha) - 2\alpha(3 + \alpha)z - 3(1 - \alpha)z^2], \\ k_1 &= \alpha(1 - \alpha)(4\alpha - 4\alpha^2 + \alpha r + 4r + 8r^2) - 6\alpha(1 - \alpha)r z - (3r + \alpha r + 4\alpha^2)z^2, \text{ and} \\ k_2 &= 4\alpha(1 - \alpha)(\alpha + r). \end{aligned}$$

Equation (3) shows that the numerator of ΔSW can be written as a quadratic function of t : k_0 is the constant term while k_1 and k_2 are the coefficients of t and t^2 , respectively. Observe first that both k_1 and k_2 are positive for $z \leq (1 - \alpha)\alpha/(1 + \alpha)$, so that ΔSW is positive if t is sufficiently large.¹⁶ Observe next that k_0 is positive if and only if z is small for an arbitrary r . Observe also that k_0 is positive if r is sufficiently large for an arbitrary $z \leq (1 - \alpha)\alpha/(1 + \alpha)$. Since $r = s - t = \alpha x/(1 - x)$ where $q'/q = 1 - x$, ΔSW will be positive for the case when there is a sufficiently large decline of the quantity even if t is small. However, ΔSW might be negative if both t and r are very small with z being sufficiently large.¹⁷

To understand these results, let us briefly review the sampling effects as well as the effect of the decrease in reproduction costs on the social welfare. As Table 1 shows, the sampling effects for legitimate products and unauthorized copies increase the social welfare. On the other hand, as Equation (2) shows, the decrease in reproduction costs may increase

¹⁶ Observe that k_1 is decreasing in z and the value of k_1 evaluated at $z = (1 - \alpha)\alpha/(1 + \alpha)$ is positive.

¹⁷ For example, if $t = 0$, $\alpha = 0.1$, $0.058 < z < 0.081$, and $0 < r = s < (19 - 20z + 10\sqrt{31}z^2 - 1.4z + 3.16)/20$, then ΔSW is negative.

or decrease the social welfare. In particular, if z is sufficiently large or $z \geq z^* = (1 - \alpha)\alpha/(3 + \alpha)$, a small decrease in z will decrease the social welfare. If we combine these two effects together, the logic is quite straightforward. When t is large, s is also large for a given $r = s - t$. That is, the sampling effects for both legitimate products and unauthorized copies are large, which clearly increases the social welfare more than enough to offset a possible decrease in the social welfare due to the decrease in z . Similarly, when r is large, the sampling effect for legitimate products on the social welfare is large enough to dominate the possible negative effect of the decrease in z , even when t is small. However, when both r and t are small, which means that the sampling effects are small, the effect of the decrease in z may dominate and the social welfare decreases as z decreases when z is sufficiently large.

As for the size of t , we believe that the sampling effects for legitimate products and unauthorized copies are not independently determined. The size of the sampling effect for unauthorized copies tends to be positively related to that for legitimate products. In particular, let us assume $t = (1 - \alpha)s$. Then the net utility of a consumer from a copy becomes $(1 + t - \alpha)v_i - z'_i \equiv (1 - \alpha)(1 + s)v_i - z'_i$ while the net utility from a legitimate product remains $(1 + s)v_i - p$. That is, we assume that the same quality degradation for copies applies to the sampling effect. The change in the social welfare becomes positive as follows:

$$\begin{aligned} \Delta SW &= SW(\alpha, s, t, z') - SW(\alpha, 0, 0, z) \\ &= SW\left(\alpha, \frac{r}{\alpha}, \frac{(1 - \alpha)r}{\alpha}, z - r\right) - SW(\alpha, 0, 0, z) \\ &= \frac{r[4r + \alpha(1 - \alpha)(4 + \alpha) - 2\alpha(3 + \alpha)z - (3 + \alpha)z^2]}{8\alpha(1 - \alpha)(\alpha + r)} \geq 0 \\ &\text{for } z \leq \frac{(1 - \alpha)\alpha}{1 + \alpha}. \end{aligned}$$

We have a clear-cut result here with the assumption of $t = (1 - \alpha)s$: the social welfare has increased for all parameter values of r , α , and z . From the previous discussion, the change in the social welfare is negative only if t tends to be 0. With the assumption of $t = (1 - \alpha)s$, the parameter r is also close to 0 when t is close to 0 since $r = s - t = \alpha s = \alpha t/(1 - \alpha)$. Moreover, the change in reproduction costs should also be close to 0, as $r = z - z'$ has to hold to ensure the price constancy. Therefore, the possible decrease in the social welfare due to the change in reproduction costs is also close to 0. It turns out that the sampling effects dominate the effect of the decrease in reproduction costs.

In summary,

Result 2: Empirical facts support the conclusion that (i) the profit decreases; (ii) the consumer surplus increases; and (iii) the social welfare either increases or decreases due to the digitalization. In our model, the social welfare may increase for plausible parameter values.

3.2 The effect of further protection

The empirical observations together with our model support the conclusion that firms' profits have declined due to digital music distribution. This is so even when the additional benefits factor s may have contributed positively to the profits. Hence, the firms' incentive to develop valuable new products may not be sufficiently provided since the profits may not cover the development and other costs. Addressing this problem, it is often argued that further protection of legitimate products is desirable. This protection is either legal protection such as strengthened copyright laws, and enforcement or technological protection such as use of digital rights management (DRM) technology.¹⁸

It is a very difficult task to discuss the trade-off between dynamic efficiency and static efficiency, that is, to meaningfully compare the development phase and the usage phase of the copyrightable works and obtain testable conclusions on the relevant economic variables. We do not attempt to do this in this article. Instead, while fully appreciating the importance of the dynamic incentive to create, we just want to point out the fact that 'reversing the substitution effect' by increasing z with legal and/or technological measures may have some unwanted effects on the social welfare. One may reason that this reversal will also reverse the impact of z on the social welfare. So, if the effect of z on the social welfare has been negative, then the stronger copyright or the DRM technology would increase the social welfare. This is not true.

Figure 2 depicts two social welfare curves as functions of z . The curve SW_1 corresponds to the benchmark before the digitalization, while the curve SW_2 corresponds to the situation after the digitalization. Since $s - t$ has increased, SW_2 lies above SW_1 . Observe also that z_1^* , the minimum point of SW_1 , lies to the left of z_2^* , the minimum point of SW_2 .

Suppose that the initial reproduction cost was relatively high, say somewhat bigger than z_1^* . Then, the digitalization that has lowered z would

¹⁸ The DRM technology can be defined generally as the 'secure packaging and delivery software designed to prevent purchasers and third parties from making unauthorized uses of digital works'. The DRM is a small piece of software that can detect, monitor, and block use of copyrighted material. The DRM for music generally includes: copy control, watermarking, fingerprinting, authentication, and access control.

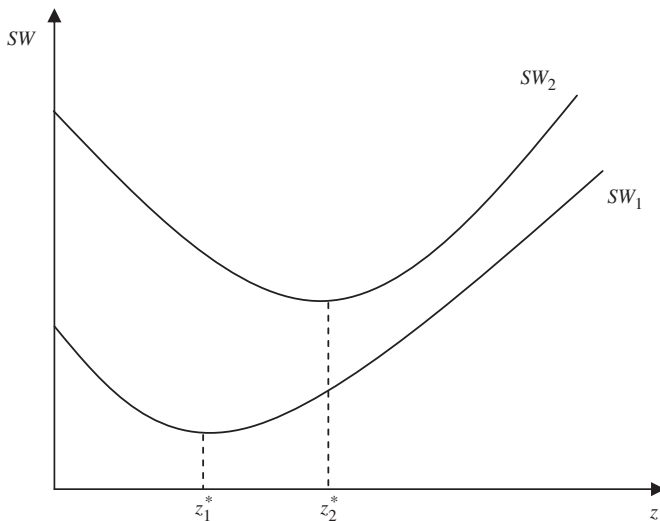


Figure 2 The social welfare.

have a negative impact on the social welfare along the curve SW_1 . An increase in z after digitalization, however, will change the social welfare along the curve SW_2 . As long as this increase does not go much beyond z_2^* , we see that the effect on the social welfare is negative again, further decreasing the social welfare. If, on the other hand, the effect of z on the social welfare has been positive, an increased protection would decrease the social welfare. But, this is not desirable at least from the static perspective.

Result 3: Legal or technological measures to reverse the substitution effect caused by digital music distribution may decrease the social welfare further.

4 Conclusion

There have been lively debates regarding the impact of the file sharing technology on the music industry. Most of the arguments, however, are concerned with the causes of the sales decline and its possible consequences on music producers. In this article, we took it one step further and studied the impacts on such important economic variables as the profit, the consumer surplus, and the social welfare.

We constructed a representative model that enabled the comparative static analysis. We then fitted the model to the empirical observations of substantial sales decline and price constancy. Main findings are as follows. First, though the producers' profits have probably shrunk,

the decrease may not be as severe as the observed sales decline. Second, the consumer surplus has unambiguously increased. Third, the social welfare may have increased for plausible parameter values. We are fully aware that these conclusions are only suggestive: as stated in the Section 1, it is ultimately an empirical question to determine the net impacts of digitalization. The present theoretical analysis does not attempt to settle this issue down, but only helps to highlight the trade-offs involved.

We end the discussion by listing some limitations of the present article that need to be addressed in later works. First, we assumed that consumers' valuations are distributed uniformly over the unit interval. We believe that this assumption can be relaxed in a rather straightforward fashion. Second, we captured the sampling effect with only two parameters s and t . It is desirable to develop a more detailed model that explicitly considers consumers' sampling process and at the same time that is easy to address the questions we pose here. Third, we did not consider the online sales of legitimate products. It is also desirable to see how the current results might change with the incorporation of authorized digital copies. Finally, we made several simplifying assumptions on the parameter values. It is worthwhile to calibrate these parameters using empirical data and models. We hope that this article provides a stepping stone for future empirical works.

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