Contributions to Economic Analysis & Policy

Volume 2, *Issue* 1 | 2003 | *Article* 11

Piracy and the Legitimate Demand for Recorded Music

Kai-Lung Hui* Ivan Png†

*National University of Singapore, lung@comp.nus.edu.sg

†National University of Singapore, ipng@comp.nus.edu.sg

Piracy and the Legitimate Demand for Recorded Music*

Kai-Lung Hui and Ivan Png

Abstract

Publishers of computer software and music claimed losses of over $17.6 billion to piracy in 2002. Theoretically, however, piracy may raise legitimate demand through positive demand-side externalities, sampling, and sharing. Accordingly, the actual impact of piracy on the legitimate demand is an empirical issue. Addressing this issue in the context of recorded music, we develop and test hypotheses from theoretical models of piracy on international data for music CDs over the period 1994-98. Empirically, we find that the demand for music CDs decreased with piracy, suggesting that "theft" outweighed the "positive" effects of piracy. However, the impact of piracy on CD sales was considerably less than estimated by industry. We estimated that, in 1998, actual losses amounted to about 6.6% of sales, or 42% of industry estimates. But, we found evidence that publishers would have raised prices in the absence of piracy, suggesting that the actual revenue loss would have been higher.

KEYWORDS: piracy, copyright, music

*We gratefully acknowledge contributions to a previous version of this paper by Yan Cui, discussions with Yehning Chen, Keith Jopling (IFPI), Tom S. Y. Lee, and Poonam Ramchand (Euromonitor), and advice from the editor, anonymous reviewers, and seminar participants at the 2002 American Economic Association Annual Meeting, Ohio State University, Stanford University, UCLA, Washington University, St Louis, National University of Singapore, and Nanyang Technological University.

1. Introduction

Publishers of computer software and recorded music claim to have suffered staggering losses to piracy. Software publishers claimed that, in 2002, the worldwide piracy rate for PC business software was 39%, which translated into a $13.08 billion loss in revenue (International Planning and Research Corporation 2003). For the same year, the recorded music industry estimated that a total of 1.8 billion units were pirated worldwide, representing a loss of $4.6 billion to recording studios (International Federation of the Phonographic Industry 2003). All these figures indicate significant losses to the relevant copyright owners.

Such huge losses dilute the incentive for development of information product.[1] However, the losses claimed by the computer software and recorded music industries may be excessive. If piracy could be prevented, many of those who used pirated products might not switch to buying the legitimate item. Instead, they might simply not use the product. With no reduction in price, it is not likely for all the illegal users to switch to the legitimate item.

The harm caused by piracy also depends on publishers' pricing strategies. When private copying raises the benefit to the buyer of a legitimate product, publishers could raise the price of the legitimate item to extract the increased consumer surplus. If this happens, directly treating all pirated copies as lost sales would overstate the harm caused by piracy. However, if publishers deliberately set low prices to discourage copying, then the number of copies would understate the lost revenue (see Besen 1986, 1987).

Theoretically, there are several additional reasons why publishers' losses to piracy might not be as large as claimed. Piracy may actually boost the demand for legitimate information products through positive demand-side externalities. Some people just like to conform (Festinger 1953) owing to informational influence, normative influence, or internalization (Burnkrant and Cousineau 1975; Deutsch and Gerard 1955). Others benefit from direct and indirect network externalities (Conner and Rumelt 1991; Nascimento and Vanhonacker 1988; Shy and Thisse 1999; Takeyama 1994). Music CDs provide a good example of indirect externalities: By increasing the provision of recorded music, higher piracy might increase the ownership of CD players, which in turn stimulates the demand for legitimate music CDs.[2]

Even in settings without demand-side externalities, piracy may benefit the legitimate producer of an information product. The legitimate demand may derive from the buyers' supply of copies to others (Besen 1986; Besen and Kirby 1989; Liebowitz 1985; Varian 2000) and sharing among peer users (Bakos et. al. 1999). Pirated items may facilitate sampling of the information product (Fader 2000; Hall 2000). For all these reasons, piracy may raise buyers' willingness to pay and hence the demand for the legitimate item.

---

[1] Shapiro and Varian (1998) define information products to be goods, such as software, music, videos and books, that can be distributed in digital form.

[2] Empirical evidence for hardware-software complementarity in demand has been found for CD players and music CDs (Gandal et al. 2000), as well as DVD players and digital video disks (Karaca-Mandic 2003).

Further, piracy may raise the legitimate demand for information products by enabling producers to credibly commit to not reduce their price in the future (Takeyama 1997). When consumers anticipate a producer to reduce price, they may delay purchasing in the current period. The presence of cheap pirated copies, however, dissuades the producer from price skimming. Hence there is no incentive for future price reduction, which in turn leads high-value consumers to buy the legitimate item. Finally, piracy may serve as an instrument of price discrimination for the legitimate producer to drive out potential competitors (Jacob and Ben-Shahar 2002).

Therefore, on the one hand, piracy steals from the legitimate demand as potential buyers switch to pirated products. On the other hand, piracy raises the legitimate demand by inducing more people to buy and raising their willingness to pay. The balance of these effects is an empirical question.[3]

A related issue is how the legitimate producer should adjust price in response to the encroachment of pirated products. As Shapiro (1988) noted, this is not a trivial question. For instance, if piracy is severe, the producer might maximize profit by selling a small quantity at a high price and conceding the rest of the market to pirated copies.

In this paper, we present a simple model of piracy that accounts for the producer's price and other market factors. We apply the theory to international panel data for music CDs. Owing to data limitations, instead of separately identifying the demands for legitimate and pirated music CDs, we estimate an integrated equation that reflects the net impact of piracy on the legitimate demand.

According to our estimates, on a per-capita basis, a one-unit increase in music CD piracy was associated with a *reduction* in legitimate music CD sales by 0.42 (±0.25) unit.[4] The overall effect of piracy on the legitimate demand for music CDs was negative. Apparently, the positive influences of piracy, if any existed, did not outweigh the direct substitution of pirated for legitimate CDs.[5] However, our results do contradict the industry claim that every pirated unit would reduce legitimate sales by one unit. We find that the losses of music CD sales caused by piracy were *58% lower* than the industry estimates. Assuming that the industry did not adjust CD prices, it lost about 6.6 (−3.8 or +3.5) % of sales to piracy in 1998.

---

[3] Using an analytical model, Gopal and Sanders (1997) show that, in the computer software industry, no more than 50% of revenue would be lost to piracy. However, they did not provide empirical validation of this assertion. Empirically, national software piracy rates have been shown to be related to income and culture, among other factors (Gopal and Sanders 1998 and 2000; Holm 2003; Husted 2000; Marron and Steel 2000; Rodrigues-Andres 2002).

[4] We report all point estimates with a range of minus/plus one standard error. In the case of the loss due to piracy as a percentage of sales, the end-points of the range are calculated as the point estimate minus/plus the standard error of loss divided by the actual sales plus the point estimate and minus or plus the standard error respectively. Accordingly, the range is not symmetric about the point estimate.

[5] For brevity, we use "positive influences" to include all the possible ways by which piracy may raise the legitimate demand for information products, including positive demand-side externalities, supply to others and product sharing, sampling, and providing a price commitment mechanism.

Realistically, music publishers would have reduced their prices to mitigate the impact of piracy. The prices that we observed were the outcomes of such adjustments. Accordingly, the actual revenue loss to publishers would have been larger than 6.6%.

The rest of our paper is organized as follows: Section 2 presents our theoretical model and the resulting hypotheses; Section 3 describes the econometric model and the data; Section 4 presents the estimation results; Section 5 discusses the implications of our research findings. Finally, Section 6 concludes the paper.

2. Theory

We first present a model that addresses the piracy of information products. Because the model considers copying as an alternative to buying the legitimate item, it explicitly captures the "theft" aspect of piracy. We then expand the model by incorporating the positive influences, and formulate our research hypotheses based on the comparative statics derived from the model.[6]

2.1 "Theft"

Consider the market for an information product that has been developed and produced by a single profit-maximizing publisher.[7] For potential users, there are three possible actions: Buy the product, copy the item, or not use. Since the publisher is aware of the possibility of illegal copying, it may choose to invest effort to detect piracy and take enforcement action against pirates. Let the resultant detection rate be μ. If a user is detected with a pirated item, she will be subject to a legal penalty, which is denoted by f. The publisher sets price p to maximize profit.

We assume a distribution $\Phi(v)$ of potential users, who differ in their value, v, for the item. All potential users are risk neutral, and they make independent decisions regarding buying, copying or not using the item. If a user does not use the item, she will enjoy reservation utility, r. For simplicity we assume zero cost of copying.

If a user with value v buys the legitimate product, she receives a net benefit of

$$U_L = v - p. \quad (1)$$

We suppose that, if she copies the item, she enjoys a proportionately lower benefit, $(1-\delta)v$, instead of v. The parameter $\delta \in (0,1)$ captures the quality differential between the legitimate and pirated items. For instance, the pirated item may lack features such as the user manual, printed literature, and attractive packaging.

[6] For brevity, we only present a model that addresses copying by individual end-users. The model can readily be adapted to encompass re-seller piracy by letting the re-seller bear the legal consequence of copying and selling the pirated item. All the comparative statics results remain unchanged in the re-seller model. According to the Business Software Alliance, re-seller piracy occurs in the United States and Europe as well as in Asian countries like China and Malaysia.

[7] Chen and Png (1999; 2003) develop a model in which the end-user, if caught copying, would be deprived of using the software.

Further, if the user copies the item, she will be caught with probability μ and must pay a fine f. Let X represent the expected fine, or $X = \mu f$. Hence her net expected benefit will be

$$U_C = [1-\delta]v - X\ . \tag{2}$$

For a potential user to buy the item, it is necessary that $U_L \geq U_C$, which, by (1) and (2), implies

$$v \geq v_1 \equiv \frac{p-X}{\delta}\ . \tag{3}$$

Therefore v_1 defines a cut-off value: those with values $v \geq v_1$ buy the legitimate product, while those with $v < v_1$ choose to copy or not use the product. The demand for the legitimate product is then

$$Q_L = \int_{v_1}^{\infty} d\Phi(v) = 1 - \Phi(v_1)\ . \tag{4}$$

For a potential user to copy the item, it is necessary that the net expected benefit be less than that from buying the legitimate item, $U_L < U_C$, and no less than that from not using the item, $U_C \geq r$. The latter condition defines a cut-off value,

$$v \geq v_2 \equiv \frac{r+X}{1-\delta}\ . \tag{5}$$

Those with values v satisfying $v_2 \leq v < v_1$ copy the product, while those with $v < v_2$ choose not to use the item. The demand for copying (choosing the pirated product) is

$$Q_C = \int_{v_2}^{v_1} d\Phi(v) = \Phi(v_1) - \Phi(v_2)\ . \tag{6}$$

From equations (3) to (6), we can easily derive the following set of comparative statics relationships:

$$\frac{\partial v_1}{\partial p} > 0,\quad \frac{\partial v_2}{\partial p} = 0 \quad \Rightarrow \quad \frac{\partial Q_L}{\partial p} < 0 \quad \text{and} \quad \frac{\partial Q_C}{\partial p} > 0\,, \tag{7}$$

$$\frac{\partial v_1}{\partial X} < 0,\quad \frac{\partial v_2}{\partial X} > 0 \quad \Rightarrow \quad \frac{\partial Q_L}{\partial X} > 0 \quad \text{and} \quad \frac{\partial Q_C}{\partial X} < 0\,. \tag{8}$$

2.2 Positive influences

Piracy may raise the demand for a legitimate information product by increasing the overall user base in several ways. Some people just like to conform (Burnkrant and Cousineau 1975; Deutsch and Gerard 1955; Festinger 1953), while others benefit from direct and indirect network externalities (Conner and Rumelt 1991; Nascimento and Vanhonacker 1988; Shy and Thisse 1999; Takeyama 1994). Following Conner and Rumelt (1991) and Shy and Thisse (1999), we model these "positive influences" through an additive term $e(Q_L, Q_C)$, where the function e is increasing in each of its arguments, Q_L and Q_C. Recall from (4) and (6) that Q_L and Q_C denote the demands for the legitimate and pirated items respectively.[8]

If an end-user buys the product, she enjoys a net benefit of $v + e(Q_L, Q_C) - p$. If she copies, her net benefit is $[1 - \delta]v + [1 - \lambda]e(Q_L, Q_C) - X$, where λ denotes the proportionate reduction in the positive influences for the user of a pirated item.[9]

Then, similar to (3), in the case of end-user piracy, the individual just indifferent between buying and copying would be that with

$$v_1 = \frac{p - X}{\delta} - \frac{\lambda}{\delta} e(Q_L, Q_C) . \quad (9)$$

Further, as in (5), the individual just indifferent between copying and not using would be that with

$$v_2 \equiv \frac{r + X}{1 - \delta} - \frac{1 - \lambda}{1 - \delta} e(Q_L, Q_C) . \quad (10)$$

Then, the demands for the legitimate and pirated items would follow (4) and (6) respectively. Now, the positive influences imply that $\partial e/\partial Q_L > 0$ and $\partial e/\partial Q_C > 0$, and hence by (9), $\partial v_1 / \partial Q_C < 0$. Using this and implicitly differentiating (4) with respect to Q_C, we have,

$$\frac{\partial Q_L}{\partial Q_C} > 0 . \quad (11)$$

By contrast, our theory does not predict the sign of $\partial Q_C / \partial Q_L$. This function depends on the distribution Φ and the relative magnitude of δ and λ, and may be positive or negative.[10]

2.3 Hypotheses

We used a very simple model of piracy and positive influences to derive the comparative statics relations (7), (8), and (11). However, it should be noted that the results are robust to alternative modeling assumptions, such as assuming that pirated items are confiscated. Further, other than expected penalty, the variable X could represent copying costs or any other factor that has opposite effects on the demands for the legitimate and pirated items.

Based on the above analysis, our first hypothesis focuses on the impact of the expected penalty as derived in (8):

---

[8] The general formulation $e(Q_L, Q_C)$ encompasses both situations where the legitimate demand increases with the absolute *extent* of piracy Q_C and those where the legitimate demand increases with the piracy *rate*, $Q_C / [Q_L + Q_C]$. Note that the extent of the positive influences depends on the scale of e; if the scale of e is very small, having a high (legitimate and pirated) demand does not add much value to the item.

[9] Users of pirated items derive relatively less benefit from the positive influences as they may be inhibited in "openly" showing or sharing with others.

[10] Supposing that Φ is linear (i.e., v is uniformly distributed), it can be shown that, if $\delta > \lambda$, then $\partial Q_C / \partial Q_L > 0$; if $\delta = \lambda$, then $\partial Q_C / \partial Q_L = 0$; and if $\delta < \lambda$, then $\partial Q_C / \partial Q_L < 0$.

H1 (Theft): The demand for the legitimate (pirated) information product is *increasing* (*decreasing*) in the expected penalty.

Note that the substitution between the legitimate and pirated items depends on the magnitude of the expected penalty, which is exogenously determined. If the expected penalty is low, *ceteris paribus*, piracy would prevail. Therefore, H1 indirectly implies the "stealing" of legitimate demand by private copying.

The next hypothesis is based on the comparative statics relation (11):

H2 (Positive Influences): The demand for the legitimate information product is *increasing* in the extent of piracy.

Because H1 and H2 hypothesize opposite effects, the *net* impact of piracy on the legitimate demand is unclear. It could be positive or negative.

3. Empirical Investigation

3.1 Econometric Model

Previous theoretical research has emphasized that piracy could potentially increase the legitimate demand. As we showed in the analysis leading to (7) and (8), the extent of piracy is endogenous – it depends on the price of the legitimate item and the expected penalty. Accordingly, to study the real impact of piracy, it is important to begin from the underlying variables that shape the demands for the legitimate and pirated items. It would be wrong to treat piracy as an exogenous factor and directly relate the legitimate demand to the extent of piracy.

Before introducing the empirical model, we first explain why we chose the music CD market as the context for testing. The only available sources of data on piracy were studies by the IFPI (International Federation of the Phonographic Industry), and the BSA (Business Software Alliance) and SIIA (Software and Information Industry Association). These report piracy on a national basis, which led us to specify the unit of empirical analysis as a country. We were only able to collect sufficient longitudinal data on volume of sales and price of the product at the national level for music CDs.

Further, recorded music products are quite closely priced across different artists and labels. By contrast, there is wide price dispersion within the categories of computer software and books. This price dispersion would add noise to the effect of price on demand, and might possibly obscure the estimated effect of piracy.

Apart from the variables considered in our theory, we incorporated three exogenous demand-side factors – personal disposable income, ownership of music CD players, and the worldwide number of MTV subscribers. Generally, we expect the demands for both legitimate and pirated music CDs to increase with income, CD player ownership (Gandal et al. 2000), and the MTV subscriber base.

Accordingly, based on (7), (8), and (11), we set up the following structural demand equations:

$$Q_{L,it} = \alpha_0 - \alpha_1 p_{it} + \alpha_2 X_{it} + \alpha_3 Y_{it} + \alpha_4 N_{it} + \alpha_5 M_t + \alpha_6 Q_{C,it} + \varepsilon_{it}, \quad (12)$$

$$Q_{C,it} = \beta_0 + \beta_1 p_{it} - \beta_2 X_{it} + \beta_3 Y_{it} + \beta_4 N_{it} + \beta_5 M_t + \beta_6 Q_{L,it} + u_{it}, \quad (13)$$

where i indexes the countries and t indexes the years of observation, the independent variables are price (p), expected penalty (X), income (Y), CD player ownership (N), and worldwide MTV subscriptions (M), and ε and u denote random errors with zero means.

By (7) and (8), the coefficients α_1, α_2, β_1, and β_2 are predicted to be positive. By the general theory regarding the impact of income, CD player ownership, and MTV subscriptions, the coefficients α_3, α_4, α_5, β_3, β_4, and β_5 are predicted to be positive. By (11), the coefficient α_6 is predicted to be positive. Finally, we do not predict the sign of β_6 for the reasons stated in Section 2.2.

We could not observe the expected penalty X_{it} on a country-year basis. Indeed, even if we had information on enforcement rates and penalties, it would be difficult to transform the data into a common operational scale. How would a $1,000 fine on an end-user compare with a one-year jail term for a re-seller? Absent the data on the expected penalty, we substituted for the X_{it} in (12) from (13) to arrive at the following equation,

$$Q_{L,it} = \gamma_0 + \gamma_1 p_{it} + \gamma_3 Y_{it} + \gamma_4 N_{it} + \gamma_5 M_t + \gamma_6 Q_{C,it} + \psi_{it}, \quad (14)$$

where

$$\gamma_0 \equiv \frac{1}{\eta}\left[\alpha_0 + \frac{\alpha_2 \beta_0}{\beta_2}\right], \quad (15)$$

$$\gamma_1 \equiv \frac{1}{\eta}\left[-\alpha_1 + \frac{\alpha_2 \beta_1}{\beta_2}\right], \quad (16)$$

$$\gamma_3 \equiv \frac{1}{\eta}\left[\alpha_3 + \frac{\alpha_2 \beta_3}{\beta_2}\right], \quad (17)$$

$$\gamma_4 \equiv \frac{1}{\eta}\left[\alpha_4 + \frac{\alpha_2 \beta_4}{\beta_2}\right], \quad (18)$$

$$\gamma_5 \equiv \frac{1}{\eta}\left[\alpha_5 + \frac{\alpha_2 \beta_5}{\beta_2}\right], \quad (19)$$

$$\gamma_6 \equiv \frac{1}{\eta}\left[\alpha_6 - \frac{\alpha_2}{\beta_2}\right], \quad (20)$$

and

$$\psi_{it} \equiv \frac{1}{\eta}\left[\varepsilon_{it} + \frac{\alpha_2}{\beta_2} u_{it}\right] \quad (21)$$

is a mean-zero random error term;

$$\eta \equiv 1 - \frac{\alpha_2 \beta_6}{\beta_2} \quad (22)$$

denotes a constant, which we find below to be positive.

The equation (14) contains parameters from the demands for both legitimate and pirated music CDs. The coefficient of piracy in (14),

$$\gamma_6 \equiv \frac{1}{\eta}\left[\alpha_6 - \frac{\alpha_2}{\beta_2}\right], \qquad (20)$$

consists of two parts: $\alpha_6 > 0$ represents the positive aspect of piracy (H2), while $-\alpha_2/\beta_2 < 0$ represents the substitution between the legitimate and pirated items due to the expected penalty (H1). Absent the data on expected penalty X_{it}, we could not identify the structural demand equations (12) and (13) and so, we could not separately test H1 and H2. However, by estimating the integrated equation (14), we can gauge the *net* impact of piracy on the legitimate music CD demand.

To eliminate country-specific factors that might affect music CD demand, we specify equation (14) with country fixed effects. This would effectively control for persistent, country-specific factors, such as national culture, that were stable over the period of study. With the fixed-effect specification, γ_0 in (14) represents a vector of national constants rather than a single intercept.

3.2 Data

We compiled a set of music CD data for 28 countries.[11] Generally, our dataset includes countries from all the major continents, and it also samples representative countries in every band of piracy level defined by the IFPI.[12]

To estimate (14), we need national data on music CD price (p), music CD demand (Q_L), piracy level (Q_C), CD player ownership (N), MTV subscriptions (M), and personal disposable income (Y). We collected these data from multiple sources. First, data on national music CD sales revenue and volume, CD player ownership, and personal disposable income for 1994-98 were acquired from *Global Market Information Database* (*GMID*), which is a comprehensive statistical archive compiled from various trade sources by Euromonitor International.[13]

From sales revenue and volume data, we calculated the average price of music CDs across the various countries and years. As a check, we compared the *GMID* with IFPI music CD data for 1998, the year for which the IFPI began publishing music CD sales and volume information. The two data sets were highly consistent: the correlation coefficients were 0.993 ($p < 0.01$) for CD sales volume and 0.996 ($p < 0.01$) for CD sales revenue.

---

[11] The specific countries are listed in Table 2 below.

[12] The IFPI (http://www.ifpi.org/), with a membership of 1,500 record producers and distributors in 76 countries, represents the international recorded music industry. It publishes a wide range of industry statistics. Currently, the IFPI classifies countries into four piracy bands: less than 10%, 10-25%, 25-50%, and above 50%.

[13] http://www.euromonitor.com/.

For data on national piracy, we used the IFPI's music CD piracy rates (pirated quantity as percentage of legitimate and pirated quantities). The IFPI estimated piracy by combining estimates from specialist market researchers for the difference between CD production capacity and legitimate sales by country, and direct estimates of piracy by the respective national recorded music organizations. These estimates were then moderated and combined by the IFPI management to produce the official numbers for each country.[14] Applying the IFPI piracy rates to the yearly sales of legitimate music CDs, we could calculate the pirated quantity $Q_{C,it}$.

Finally, we compiled the worldwide number of MTV subscribers from various issues of the annual report of VIACOM, the parent company of MTV Networks, and converted the subscriber base into per capita terms using the world population, obtained from the U.S. Census Bureau. All the other independent variables, except music CD price, were converted into per capita terms using the respective country's population as reported by the *GMID*.

Note that we could not extend our dataset beyond 1998 because in the following years, Euromonitor International included estimates of pirated quantities in its calculations of music CD sales volume and revenue. Therefore, accurate data for $Q_{L,it}$ and p_{it} were not available after 1998. Because we could not locate systematic piracy information before 1994 (the year that the IFPI piracy data started), the scope of our investigation was limited to 1994-98, a period in which music CDs were gaining popularity and replacing music cassettes.

Table 1 reports descriptive statistics of the sample. Per capita consumption of music CDs was slightly more than one unit per year, while only around 12% of people owned CD players. The standard deviations of both CD player ownership and personal disposable income were large, indicating that the countries had different income and demographic characteristics. The worldwide per capita MTV subscription was low, but increased steadily over the years.

Table 1. Descriptive Statistics

Variable	Unit	Mean	Std. dev.	Max	Min
Price	US$	11.745	5.542	42.222	1.515
Legitimate sales	Per capita	1.175	0.971	3.727	0.003
Pirated quantity	Per capita	0.105	0.317	3.553	0.000
Personal disposable income	US$'000	9.728	6.789	28.088	0.250
CD player ownership	Per capita	0.116	0.098	0.362	0.002
Worldwide MTV subscriptions	Per capita	0.032	0.007	0.042	0.022

Table 2 reports the average music CD price and per capita consumption of legitimate and pirated CDs by country over the studied period. The demand for both legitimate and pirated CDs varied widely across the countries, which could possibly be attributed to different national cultures and incomes. The per capita purchases of legitimate music CDs was highest in the United States and lowest in India over all five years. By contrast, the United States exhibited

[14] The IFPI estimates and formulae are proprietary. As far as we know, the IFPI is the only organization that systematically publishes data on music CD piracy across countries.

low consumption of pirated CDs. The consumption of pirated CDs was high in both Hong Kong and Singapore. With a few exceptions (e.g., India and Japan), the average price of music CDs varied moderately across the countries.

Table 2. Music CD Price, Demand and Piracy

Country	Average Price (US$)	Legitimate Sales	Pirated Quantity
Argentina	15.6246	0.499	0.0875
Australia	7.1111	2.033	0.1423
Brazil	10.9207	0.535	0.0642
Canada	8.2747	1.690	0.0459
Chile	6.3662	0.229	0.0220
Colombia	6.9367	0.312	0.0324
Czech Republic	11.4035	0.427	0.0191
Finland	9.9780	1.522	0.0900
France	9.7958	1.764	0.0521
Greece	21.8498	0.544	0.1030
Hong Kong, China	9.8069	1.849	1.0751
Hungary	13.3122	0.263	0.0625
India	1.6846	0.007	0.0013
Indonesia	11.8857	0.012	0.0007
Ireland	14.3721	0.896	0.0000
Israel	14.7473	0.623	0.1971
Japan	30.3430	2.070	0.0022
Malaysia	10.9944	0.106	0.0416
Netherlands	16.4854	2.215	0.1849
New Zealand	9.3485	1.616	0.0054
Norway	9.9202	2.746	0.1212
Poland	10.7263	0.170	0.0882
Portugal	9.6209	0.833	0.0020
Singapore	9.7979	1.571	0.3780
Sweden	9.5164	2.480	0.0450
United Kingdom	12.0726	2.487	0.0314
USA	12.0875	3.255	0.0139
Venezuela	13.8789	0.153	0.0244

3.3 Instruments

The price of music CDs might be endogenously determined. Accordingly, we sought an instrument that could capture the variations in CD price while not being correlated with the quantity demanded. The ideal candidate would be supply-side cost shifters, but such data were not available. Lacking compelling cost data, we used the price of non-tradeables as our price instrument. Presumably, the effect of music demand on the price of non-tradeables would be minimal, while the price of non-tradeables would reflect the cost of land and labor. These determine the cost of retailing, which in turn influences the price of music CDs.

We constructed this instrument as the ratio of each country's purchasing power parity (PPP) rate to its exchange rate relative to the US dollar. As defined, PPP rates reflect differences in purchasing power. By contrast, exchange rates depend on differences in the prices of tradeables. Accordingly, the ratio of the PPP to exchange rates should reflect differences in the prices of non-tradeables. We obtained data on PPP and exchange rates from *EIU Country Data*, which contains major economic indicators published by the Economic Intelligence Unit.[15]

Like the price of music CDs, the pirated quantity might be endogenously determined – from (13), $Q_{C,it}$ is directly related to u_{it}, which is part of the composite error ψ_{it} in (14). Our challenge was to acquire instruments that would be correlated with the pirated quantity but not the legitimate sales.

We selected two groups of instruments based on different reasons. First, we used the piracy rates of two other information products, music cassettes and business computer software. Since the piracy of these two information products and music CDs would be influenced by the same set of national characteristics (including expected penalty for selling or using pirated items and culture), it is quite likely that they are correlated with but not affected by the demand for each other. Second, by (5), the pirated quantity is a function of the reservation utility, r. Any exogenous factors changing r would affect the cut-off value v_2 but not v_1, and hence, are suitable instruments for the pirated quantity.[16] We included the unemployment rate and total consumer expenditure, which are related to the reservation utility, as such instruments.

Data on music cassette piracy rate and business computer software piracy rate were obtained from the IFPI and BSA/SIIA respectively.[17] We acquired the consumer expenditure and unemployment data from the *GMID*.

4. Results

We estimated equation (14) for the music CD market using ordinary least squares (OLS) and two-stage least squares (2SLS). In the 2SLS estimations, we applied the price of non-tradeables as the instrument for the music CD price, and the music cassette piracy rate, BSA/SIIA software piracy rate, total consumer expenditure and unemployment rate as instruments for the pirated quantity.

---

[15] http://www.eiu.com/.

[16] Essentially, we seek exogenous variables that shift the pirated quantity, but that are not affected by the legitimate demand for music CDs. When the reservation utility r is high, the opportunity cost of getting a pirated music CD is high. Hence, a variable that is reflective of r would correlate with the pirated quantity, making it a suitable instrument for the latter.

[17] The BSA/SIIA business computer software piracy rates are available at http://www.bsa.org/.

We first estimated a baseline model, which included all model variables except piracy. The OLS and the 2SLS estimation results are reported in the first and second columns of Table 3 respectively. For 2SLS, the R^2 of the first stage regression was 0.94, and the coefficient of the price of non-tradeables was significant ($p < 0.01$). Hence, the price instrument was effective. The price coefficient was consistently negative, and its magnitude was larger in 2SLS as compared with OLS, supporting the view that 2SLS provided consistent estimations of the model parameters. In subsequent analysis, we focus on the 2SLS estimates.

The four model variables, p_{it}, Y_{it}, N_{it} and M_t, were jointly significant ($\chi^2 = 111.14$, $p < 0.01$). All parameters exhibited the expected signs. The coefficient of price was negative, while the coefficients of CD player ownership, personal disposable income, and MTV subscriptions were all significant and positive. Hence, we retained all variables (price, CD player ownership, personal disposable income, and MTV subscription) for the baseline CD model.

We next estimated the full research model, which included the piracy variable. Estimation results using OLS and 2SLS are shown in Table 3, columns three and four. The R^2 of the first stage regression in 2SLS was 0.58. The coefficients of both unemployment rate ($p < 0.10$) and total consumer expenditure ($p < 0.01$) were significant, but the coefficients of music cassette and BSA software piracy rates were not significant. These indicate that the instruments could explain only part of the variations in the pirated quantity. The five independent variables in equation (14), p_{it}, Y_{it}, N_{it}, M_t and $Q_{C,it}$, were jointly significant ($\chi^2 = 100.35$, $p < 0.01$). The coefficient of income was positive and significant. Recalling (17), this implies that

$$\gamma_3 \equiv \frac{1}{\eta}\left[\alpha_3 + \frac{\alpha_2\beta_3}{\beta_2}\right] > 0\,. \qquad (17')$$

Since income has a positive effect on the legitimate and pirate demands, i.e., $\alpha_3 > 0$ and $\beta_3 > 0$, the finding that $\gamma_3 > 0$ implies that $\eta > 0$. Likewise, the results that $\gamma_4 > 0$ and $\gamma_5 > 0$ also suggest that $\eta > 0$.

From Table 3, column three, the coefficient of piracy was negative and marginally significant (coefficient = –0.4205, $p < 0.10$). Referring to (17), since $\eta > 0$, we infer that piracy was a significant and negative factor in the demand for legitimate music CDs. A one-unit increase in per capita piracy was associated with a fall in per capita legitimate sales by 0.42 (±0.25) unit.

The negative impact of piracy was comparable to that of price. Specifically, a one standard deviation change in the piracy variable would have resulted in per capita demand changing by 0.13 (±0.08) unit, while a one standard deviation change in price would have changed the per capita demand by 0.15 (±0.08) unit.

It should be noted from (14) that the coefficients of price, income, CD player ownership, MTV subscriptions, and piracy combine the direct effect of each variable on the legitimate demand with the indirect effect through the demand for the pirated item. Accordingly, the coefficients *cannot* be directly associated with elasticities of the legitimate demand.

Table 3. Demand for Music CDs[a]

Variable	Baseline model OLS (1)	Baseline model 2SLS[b] (2)	Full model OLS (3)	Full model 2SLS[c] (4)	Fixed Constant 2SLS[c] (5)	Split-income 2SLS[c] (6)	Non-zero obs. 2SLS[c] (7)	Year-dummies 2SLS[c] (8)
Price	-0.0260***	-0.0355**	-0.0204**	-0.0277**	-0.0495***	-0.0326**	-0.0209	-0.0251*
	(0.0099)	(0.0174)	(0.0079)	0.0135)	(0.0091)	(0.0124)	(0.0219)	(0.0134)
Personal disposable	0.0713***	0.0852***	0.0668***	0.0842***	0.1050***	0.0903***	0.0811***	0.0902***
income	(0.0202)	(0.0315)	(0.0181)	(0.0297)	(0.0100)	(0.0282)	(0.0233)	(0.0317)
CD player	3.1288***	3.1777***	3.0003***	2.8529***	3.9880***	2.9057**	2.6644**	2.7483***
ownership	(0.8806)	(0.8687)	(0.9168)	(0.9405)	(0.4373)	(1.1582)	(1.0481)	(1.0132)
Worldwide MTV	8.5108***	7.3245***	10.2757***	11.3409***	8.0345**	10.4065**	9.6973**	
subscriptions	(3.0127)	(2.6426)	(2.6911)	(3.3473)	(3.6321)	(4.6203)	(3.7700)	
Piracy			-0.1475***	-0.4205*	-0.5273*		-0.3585***	-0.4438[c]
			(0.0542)	(0.2508)	(0.2882)		(0.1275)	(0.2684)
Piracy						-0.3740[d]		
(High income countries)						(0.2278)		
Piracy						-0.3839		
(Low income countries)						(1.2064)		
Y95								0.0230
								(0.0414)
Y96								0.0976**
								(0.0482)
Y97								0.1285**
								(0.0495)
Y98								0.2463***
								(0.0809)
N	140	140	140	140	140	140	125	140
Adjusted-R^2	0.9761	0.9758	0.9774	0.9710	0.9149	0.9719	0.9756	0.9701

[a] White's heteroscedasticity-consistent standard errors in parentheses. All significance levels calculated using two-tailed tests. Country fixed effects and constants are not reported for brevity.
[b] Cross-country price of non-tradeables was used as instrument for music CD price.
[c] Music cassette piracy rate, BSA/SIIA software piracy rate, unemployment rate, per-capita expenditure and cross-country price of non-tradeables were used as instruments for the piracy and price variables.
[d] *p*-values slightly exceeded 0.10.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As already reviewed, in theory, piracy may raise the demand for a legitimate information product (H2). If the positive influences were strong enough, they could outweigh the negative effect of piracy due to the theft of customers. However, our results for music CDs suggest otherwise. The coefficient of the piracy variable was negative and significant. Apparently, even if such positive effects existed, they were more than offset by the harm caused by the loss in sales due to "theft". In terms of our hypotheses, the results were consistent with H1 (Theft).

Our analysis further allowed us to investigate in detail the presence of an indirect network effect, by which higher piracy increases the ownership of CD players, which in turn stimulates the demand for legitimate music CDs. Consistent with Gandal et al. (2000), our results in Table 3 showed that the demand for legitimate music CDs was indeed positively associated with higher CD player ownership. However, the correlation between the pirated quantity and CD player ownership was quite modest, and not statistically significant (Pearson correlation = 0.0513, p = 0.55). Apparently, pirated music did not have a significant complementary effect on the demand for CD players, and hence it might not have contributed to raising the legitimate demand through an indirect network effect.

To assess the robustness of our empirical analysis, we estimated alternative specifications of equation (14). First, we regressed the legitimate demand on one constant instead of 28 country fixed effects. The 2SLS estimation results are reported in column five of Table 3. All model parameters maintained the same signs and similar statistical significance. Compared with the results in column four, the adjusted R^2 dropped substantially from 0.97 to 0.91, indicating that the country fixed effects accounted for substantial variations in music CD demand. A Wald test suggested that the country fixed effects were preferred over an overall constant ($\chi^2 = 450.78$, $p < 0.01$).

Next, because the countries exhibited wide variations in income, and income affects music CD consumption, we split the countries into two groups according to their income levels. The high-income group consisted of fourteen countries that had personal disposable income exceeding $10,000 per year; the rest of the countries were classified as low-income countries. Two separate piracy parameters were then estimated according to the income levels, and the 2SLS results are reported in Table 3, column six. The piracy parameter for the low-income countries was not significant, but the one for the high-income countries was near significant at p = 0.1037. A Wald test suggested that the two piracy parameters could be combined ($\chi^2 < 0.01$, p = 0.99). Hence the full 2SLS model (column four) was preferred.

Further, our dataset contained a number of country-year observations with zero piracy. Since zero piracy seems implausible, we repeated the full model estimation without the zero-piracy observations. The results are reported in Table 3, column seven. The signs of the coefficients were identical to those obtained with the complete dataset (Table 3, column four). The (absolute) magnitudes of all parameters were slightly smaller than those estimated with the complete data set. The piracy coefficient dropped around 15% from –0.4205 to –0.3585, and increased in significance to the 99% level.

Finally, we used the worldwide MTV subscriptions to gauge the overall consumer exposure to music. Because the MTV subscription variable (M_t) was time- (but not country-)

dependent, an alternative approach was to use yearly dummy variables in estimating equation (14). The results of such estimation are reported in Table 3, column eight. Generally, the parameters were similar to those estimated using MTV subscriptions. The piracy coefficient was close to significant at $p = 0.1012$, and it was negative at –0.4438 (cf. –0.4205 in column four). The year dummies indicated an increasing trend of music CD purchases, which was consistent with the positive coefficient of MTV subscriptions in the full 2SLS model (Table 3, column four).

5. Implications

Given the prevailing piracy levels, how many units of legitimate music CD sales were lost to piracy? Table 4 reports the estimated losses in the year 1998 based on the IFPI piracy data and the assumption that every pirated CD caused a unit loss in legitimate sales. By this calculation, the average loss in per capita CD demand due to piracy was 0.2270 unit.[18]

By contrast, we estimated the true loss to be only around 42% of this quantity, or specifically 0.0954 (±0.0569) unit per capita.[19] Our method was, for each country, to multiply the coefficient of piracy in the demand equation, –0.4205, by the extent of piracy in that country. The estimate by this method was 42 (±25) % of the IFPI number.

By Table 4, column one, legitimate sales were 1.3456 units per capita. Hence, assuming that prices remained constant, the average revenue lost to piracy would have been 0.0954/(0.0954 + 1.3456) = 6.6 (-3.8 or +3.5) %. This estimate *under-estimates* the actual revenue loss because, as we discuss below, we expect the recording studios to have reduced prices in response to piracy. The prices that we observed were the outcomes of such adjustments. Accordingly, the actual revenue loss to publishers would have been larger than 6.6%.

The difference between the IFPI's estimates and ours can be attributed to several factors. First, end-users differ in their benefit from music CDs and hence their response to the possibility of copying and availability of pirated items. Absent piracy, some are priced out of the market and do not switch to buying the legitimate item. Second, the positive influences of piracy might offset part of the substitution ("theft") from legitimate to pirated items. Finally, if publishers follow a limit-pricing strategy, lowering their prices where piracy is high, then a higher piracy level would induce a lower price, which stimulates legitimate sales.

How would recording studios adjust prices in response to piracy? We consider two cases – where the national industry is a monopoly and where it is an oligopoly. In both cases, we suppose, for simplicity, that production requires zero fixed and marginal cost.

---

[18] Table 4 reports averages for 1998 only, hence these differ from the averages for 1994-98 as reported in Table 1.

[19] The extent of piracy in Hong Kong was substantially higher than that in the rest of the countries. We also estimated the full model without the Hong Kong observations. The coefficient of piracy was negative, but with reduced significance. With the omission of Hong Kong for 1998, the average international sales was 1.3368 units, the average pirated quantity was 0.1038 unit, and the impact of piracy was to reduce legitimate sales by 4.8%.

Table 4. Losses in Per-Capita CD Sales, 1998

Country	Sales	IFPI[a]	Model[b]
Argentina	0.8791	0.1522	0.0640 (0.0382)
Australia	2.1846	0.1913	0.0804 (0.0480)
Brazil	0.7602	0.2169	0.0912 (0.0544)
Canada	1.9497	0.0486	0.0205 (0.0122)
Chile	0.3282	0.0335	0.0141 (0.0084)
Colombia	0.3027	0.0380	0.0160 (0.0095)
Czech Republic	0.4760	0.0120	0.0051 (0.0030)
Finland	1.8731	0.2250	0.0946 (0.0564)
France	2.4298	0.0725	0.0305 (0.0182)
Greece	0.6595	0.0737	0.0310 (0.0185)
Hong Kong, China	1.5841	3.5531	1.4942 (0.8911)
Hungary	0.3658	0.0373	0.0157 (0.0094)
India	0.0091	0.0039	0.0016 (0.0010)
Indonesia	0.0146	0.0017	0.0007 (0.0004)
Ireland	1.4000	0.0000	0.0000 (0.0000)
Israel	0.6181	0.5362	0.2255 (0.1345)
Japan	2.2594	0.0000	0.0000 (0.0000)
Malaysia	0.0945	0.0842	0.0354 (0.0211)
Netherlands	2.1646	0.1897	0.0798 (0.0476)
New Zealand	1.9575	0.0000	0.0000 (0.0000)
Norway	3.0041	0.1508	0.0634 (0.0378)
Poland	0.3414	0.2393	0.1006 (0.0600)
Portugal	1.2828	0.0034	0.0014 (0.0009)
Singapore	1.4822	0.3839	0.1614 (0.0963)
Sweden	2.5760	0.0023	0.0010 (0.0006)
United Kingdom	2.7467	0.0197	0.0083 (0.0049)
USA	3.7269	0.0440	0.0185 (0.0110)
Venezuela	0.2066	0.0418	0.0176 (0.0105)
Average	1.3456	0.2270	0.0954 (0.0569)

[a] Calculated from music CD sales and the IFPI music CD piracy rates.
[b] Calculated using the estimated piracy parameter, -0.4205 × (pirated quantity). Standard errors in parentheses, computed using the standard error of the piracy parameter, 0.2508.

5.1 Monopoly

Consider a monopoly publisher facing the legitimate demand (14). Its revenue and profit would be

$$R = pQ_L = p\gamma_0 + \gamma_1 p^2 + \gamma_3 pY + \gamma_4 pN + \gamma_5 pM + \gamma_6 pQ_C + p\psi \,, \qquad (23)$$

where, for brevity, we omit the indexes for country and time. It maximizes profit at the price where $dR/dp = 0$, i.e.,

$$\gamma_0 + 2\gamma_1 p + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 \left[Q_C + p \frac{dQ_C}{dp} \right] + \psi = 0 . \qquad (24)$$

By (13) and (12),

$$\frac{dQ_C}{dp} = \beta_1 + \beta_6 \frac{dQ_L}{dp} = \beta_1 + \beta_6 \left[-\alpha_1 + \alpha_6 \frac{dQ_C}{dp} \right].$$

Hence, by (16), (20), and (22),

$$\frac{dQ_C}{dp} = \frac{\beta_1 - \alpha_1 \beta_6}{1 - \alpha_6 \beta_6} = \frac{\gamma_1 + \alpha_1}{\alpha_6 - \gamma_6}. \qquad (25)$$

Let p^* represent the profit-maximizing price. Using (25), the first-order condition (24) simplifies to

$$\left[2\gamma_1 + \frac{\gamma_1 + \alpha_1}{\alpha_6 - \gamma_6} \gamma_6 \right] p^* = -[\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi],$$

or

$$p^* = -\left[\frac{\alpha_6 - \gamma_6}{\alpha_1 \gamma_6 + 2\alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] . \qquad (26)$$

Substituting into (14), the profit-maximizing sales is

$$Q_L^* = \left[\frac{\alpha_1 \gamma_6 + \alpha_6 \gamma_1}{\alpha_1 \gamma_6 + 2\alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] . \qquad (27)$$

By Table 3, column four, empirically, the coefficient of price in (14), $\gamma_1 = -0.0277 < 0$, and the coefficient of piracy in (14), $\gamma_6 = -0.4205 < 0$. Since α_1 and α_6 are positive, it is easy to verify that the marginal effects of Q_C in (26) and (27),

$$-\gamma_6 \left[\frac{\alpha_6 - \gamma_6}{\alpha_1 \gamma_6 + 2\alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] < 0 \qquad (28)$$

and

$$\gamma_6 \left[\frac{\alpha_1 \gamma_6 + \alpha_6 \gamma_1}{\alpha_1 \gamma_6 + 2\alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] < 0 . \qquad (29)$$

Therefore, both p^* and Q_L^* are decreasing in the extent of piracy.

5.2 Cournot Oligopoly

As our data set did not include business-level information, we could not study actual pricing under conditions of price competition. The best that we could do was to consider the impact of piracy on pricing and sales in a Cournot-Nash equilibrium.

Specifically, suppose there are n music CD publishers in each country. Then, the aggregate demand is

$$Q_L = \sum_{i=1}^{n} Q_i \,. \tag{30}$$

From (14), the inverse demand function can be written as

$$p = \frac{\gamma_0 - \sum_{i=1}^{n} Q_i + \gamma_3 Y + \gamma_4 N + \gamma_5 M_t + \gamma_6 Q_C + \psi}{-\gamma_1} \,. \tag{31}$$

For each seller *i*, the revenue and profit would be

$$R_i = pQ_i = \frac{\gamma_0 - \sum_{i=1}^{n} Q_i + \gamma_3 Y + \gamma_4 N + \gamma_5 M_t + \gamma_6 Q_C + \psi}{-\gamma_1} Q_i \,. \tag{32}$$

It maximizes profit at the quantity where $dR_i / dQ_i = 0$, i.e.,

$$\gamma_0 - 2Q_i - \sum_{j \neq i}^{n} Q_j + \gamma_3 Y + \gamma_4 N + \gamma_5 M_t + \gamma_6 Q_C + \gamma_6 Q_i \frac{dQ_C}{dQ_i} + \psi = 0 \,. \tag{33}$$

By (13) and (12),

$$\frac{dQ_C}{dQ_i} = \beta_1 \frac{dp}{dQ_i} + \beta_6 = \beta_1 \left[\frac{-1}{\alpha_1} + \frac{\alpha_6}{\alpha_1} \frac{dQ_C}{dQ_i} \right] + \beta_6 \,.$$

Hence, by (16), (20), and (22),

$$\frac{dQ_C}{dQ_i} = \frac{\alpha_1 \beta_6 - \beta_1}{\alpha_1 - \alpha_6 \beta_1} = \frac{\gamma_1 + \alpha_1}{\alpha_6 \gamma_1 + \alpha_1 \gamma_6} . \tag{34}$$

Then, (33) simplifies to

$$2Q_i + \sum_{j \neq i}^{n} Q_j - \gamma_6 \frac{\gamma_1 + \alpha_1}{\alpha_6 \gamma_1 + \alpha_1 \gamma_6} Q_i = [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] . \tag{35}$$

In a symmetric equilibrium, the sellers select identical quantities. Therefore, we have

$$\left[(n+1) - \gamma_6 \frac{\gamma_1 + \alpha_1}{\alpha_6 \gamma_1 + \alpha_1 \gamma_6} \right] Q_i = [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] ,$$

or

$$Q_i^* = \left[\frac{\alpha_1 \gamma_6 + \alpha_6 \gamma_1}{n \alpha_1 \gamma_6 + (n+1) \alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] . \tag{36}$$

Substituting this into (14), the equilibrium price is

$$p^* = - \left[\frac{\alpha_6 - \gamma_6}{n \alpha_1 \gamma_6 + (n+1) \alpha_6 \gamma_1 - \gamma_1 \gamma_6} \right] [\gamma_0 + \gamma_3 Y + \gamma_4 N + \gamma_5 M + \gamma_6 Q_C + \psi] . \tag{37}$$

Again, the marginal effects of Q_C on price and quantity are negative, which means that the publishers tend to reduce price and sell fewer CDs in the presence of piracy. Also, compared with (26) and (27), the negative effects due to Q_C are smaller. Each Cournot publisher loses less revenue from piracy as compared with a monopoly. Obviously, for *n* sufficiently large, the whole industry would also lose less revenue than the monopolist.

6. Concluding Remarks

In this study, we demonstrated that piracy reduced the demand for legitimate music CDs across a number of countries during the period 1994-98. Specifically, we estimated the impact of piracy on legitimate music CD sales to be 6.6 (-3.8 or +3.5) % of sales, or 42 (±25) % of the music industry's estimate. We believe that publishers would have reduced prices in the presence of piracy, suggesting that the true revenue loss would have been higher.

In our empirical estimation, we characterized the effect of piracy by a single variable, which was common to all countries. While we employed a fixed-effect specification to capture national differences in overall demand, it did not account for national differences in the impact of piracy on demand. A more complete model that incorporates interaction variables or random coefficients across countries might help uncover such differences. Unfortunately, with our small sample size and short time frame of study, it was not practical to estimate such a model.

In our estimated demand equations, the coefficient of the piracy variable was negative and significant. We note that the coefficient is subject to bias arising from errors in the measurement of piracy. To the extent that the IFPI's music piracy rates are subject to error, the coefficient of piracy would be biased towards zero, hence *under*-state the actual impact of piracy. Further, if the IFPI's music piracy rates are inflated by a fixed proportion, then the true impact of piracy on the legitimate demand would be our estimated coefficient multiplied by the inflation factor. The first stage regression in the 2SLS estimation also shows that our piracy instruments may not be satisfactory. Clearly, finding good measures of piracy and appropriate instruments is a major challenge in any research into piracy of information products.

We inferred from the negative piracy coefficient that the "positive" influences of piracy on legitimate demand were outweighed by substitution of pirated items for the legitimate product ("theft"). However, we admit that our empirical analysis did not effectively address the impact of piracy through direct network and demand-side externalities, where piracy increases the user base and thereby directly stimulates the demand for the legitimate item (Conner and Rumelt 1991; Nascimento and Vanhonacker 1988; Shy and Thisse 1999; Takeyama 1994). These are unlikely to arise in the case of music CDs. More suitable testing grounds for the impact of piracy through direct network externalities would be the markets for communications software and hardware.[20]

Further, several of the positive theories emphasize that piracy helps the legitimate producer by enabling more effective price discrimination (Bakos et al. 1999; Besen and Kirby 1989; Jacob and Ben-Shahar 2002; Liebowitz 1985; Takeyama 1997; Varian 2000). It is possible that this gain may be independent of an increase in the potential users' willingness to pay for the legitimate product. To this extent, our empirical estimates may not have completely tested these theoretical arguments. We would need a more detailed data set to investigate the impact of piracy on price discrimination.

[20] Givon et al. (1995) applied aggregate data for sales of business PC software in an innovation diffusion framework to estimate the impact of pirated software on legitimate sales in the United Kingdom. They, however, had no data on pirated software, and their results relied on an interpretation of coefficients of lagged legitimate sales in the diffusion equation.

Finally, our data set did not extend beyond 1998, owing to a change in Euromonitor's statistics of music CD sales volume and revenue. The data pre-date the widespread adoption of broadband Internet connections and the related boom in online file-sharing. Accordingly, our results do not address the impact of Napster and other online file-sharing systems on sales of legitimate recorded music (Fader 2000; Hall 2000). An important direction for future work is to compile data for the more recent period so as to investigate this issue.

References

Bakos, Yannis, Erik Brynjolfsson and Douglas G. Lichtman "Shared Information Goods," *Journal of Law and Economics*, Vol. 42 No. 1, April 1999, 117-155.

Besen, Stanley M. "Private Copying, Reproduction Costs, and the Supply of Intellectual Property," *Information Economics and Policy*, Vol. 2 No. 1, 1986, 5-22.

---- "New Technologies and Intellectual Property: An Economic Analysis," *RAND Report* N-2601, 1987.

---- and Sheila N. Kirby "Private Copying, Appropriability, and Optimal Copying Royalties," *Journal of Law and Economics*, Vol. 32, October 1989, 255-280.

Burnkrant, Robert E. and Alain Cousineau "Informational and Normative Social Influence in Buyer Behavior," *Journal of Consumer Research*, Vol. 2 No. 3, December 1975, 206-214.

Chen, Yehning and I.P.L. Png "Software Pricing and Copyright Enforcement: Private Profit vis-a-vis Social Welfare," *Proceedings*, 20th International Conference on Information Systems, December 1999, 119-123.

---- and ---- "Information Goods Pricing and Copyright Enforcement: Welfare Analysis," *Information Systems Research*, Vol. 14 No. 1, March 2003, 107-123.

Conner, Kathleen R. and Richard P. Rumelt "Software Piracy: An Analysis of Protection Strategies," *Management Science*, Vol. 37 No. 2, February 1991, 125-139.

Deutsch, Morton and Harold B. Gerard "A Study of Normative and Informational Social Influences Upon Individual Judgment," *Journal of Abnormal Social Psychology*, Vol. 51, November 1955, 629-636.

Economist Intelligence Unit. *EIU Country Data*. (http://www.eiu.com/)

Euromonitor International. *Global Market Information Database*. (http://www.euromonitor.com/)

Fader, Peter S. Expert Report, *A&M Records, Inc. v. Napster, Inc.* 114 F. Supp. 2d 896, 2000. (http://dl.napster.com/fader_070300.pdf)

Festinger, Leon "An Analysis of Compliant Behavior," in M. Sherif and M.O. Wilson, eds., *Group Relations at the Crossroads*, New York, NY: Harper, 1953, 232-256.

Gandal, Neil, Michael Kende and Rafael Rob "The Dynamics of Technological Adoption in Hardware/Software Systems: The Case of Compact Disc Players," *RAND Journal of Economics*, Vol. 31 No. 1, spring 2000, 43-61.

Givon, Moshe, Vijay Mahajan and Eitan Muller "Software Piracy: Estimation of Lost Sales and the Impact on Software Diffusion," *Journal of Marketing*, Vol. 59 No. 1, January 1995, 29-37.

Gopal, Ram D. and G. Lawrence Sanders "Preventive and Deterrent Controls for Software Piracy," *Journal of Management Information Systems*, Vol. 13 No. 4, spring 1997, 29-47.

---- and ---- "International Software Piracy: Analysis of Key Issues and Impacts," *Information Systems Research*, Vol. 9 No. 4, December 1998, 380-397.

---- and ---- "Global Software Piracy: You Can't Get Blood Out of a Turnip," *Communications of the ACM*, Vol. 43 No. 9, September 2000, 83-89.

Hall, Robert E. Expert Report, *A&M Records, Inc. v. Napster, Inc.* 114 F. Supp. 2d 896, 2000. (http://dl.napster.com/Hall_report_final.pdf)

Holm, Håkan J. "Can economic theory explain piracy behavior?" *Topics in Economic Analysis & Policy*, Vol. 3 No. 1, 2003, Article 5 (http://www.bepress.com/bejeap/topics/vol3/iss1/art5).

Husted, Bryan W. "The Impact of National Culture on Software Piracy," *Journal of Business Ethics*, Vol. 26 No. 3, August 2000, 197-211.

International Federation of the Phonographic Industry (IFPI). *The Recording Industry Commercial Piracy Report 2003*, July 2003.

International Planning and Research Corporation. *Eighth Annual BSA Global Software Piracy Study*, June 2003.

Jacob, Assaf and Danny Ben-Shahar "Preach for a breach: selective enforcement of copyrights as an optimal monopolistic behavior," *Working Paper*, Radziner School of Law, Interdisciplinary Center Herzliya, Israel, August 2002.

Karaca-Mandic, Pinar "Network Effects in Technology Adoption: The Case of DVD Players," *Working Paper*, Department of Economics, University of California, Berkeley, June 2003.

Liebowitz, Stanley J. "Copying and Indirect Appropriability: Photocopying of Journals," *Journal of Political Economy*, Vol. 93 No. 5, October 1985, 945-957.

Marron, Donald B. and David G. Steel "Which Countries Protect Intellectual Property? The Case of Software Piracy," *Economic Inquiry*, Vol. 38 No. 2, April 2000, 159-174.

Nascimento, Fernando and Wilfried R. Vanhonacker "Optimal Strategic Pricing of Reproducible Consumer Products," *Management Science*, Vol. 34 No. 8, August 1988, 921-937.

Rodrigues-Andres, Antonio "The European Software Piracy: An Empirical Application," *Working Paper*, University of Southern Denmark, 2002.

Shapiro, Carl. *Economic Effects of Home Copying*, mimeo, Princeton University, May 1988.

---- and Hal R. Varian "Versioning: The Smart Way to Sell Information," *Harvard Business Review*, Vol. 76 No. 6, November/December 1998, 106-114.

Shy, Oz and Jacques-Francois Thisse "A Strategic Approach to Software Protection," *Journal of Economics and Management Strategy*, Vol. 8 No. 2, summer 1999, 163-190.

Takeyama, Lisa N. "The Welfare Implications of Unauthorized Reproduction of Intellectual Property in the Presence of Network Externalities," *Journal of Industrial Economics*, Vol. 62 No. 2, June 1994, 155-166.

---- "The Intertemporal Consequences of Unauthorized Reproduction of Intellectual Property," *Journal of Law and Economics*, Vol. 40 No. 2, October 1997, 511-522.

Varian, Hal R. "Buying, Sharing, and Renting Information Goods," *Journal of Industrial Economics*, Vol. 48 No. 4, December 2000, 473-488.