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ORIGINAL ARTICLE

How much of the decline in sound recording sales is due to file-sharing?

Stan J. Liebowitz

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Abstract Although most studies of file-sharing have concluded that file-sharing has decreased record sales, the extent of the decreased sales often seems uneven. This paper demonstrates that the results are more uniform than previously understood once a consistent metric is used to provide easy comparability across studies. This paper uses the percent of the decline in record sales that is due to file-sharing as a metric to translate the results of the literature into a common framework and then summarizes those results. What has not been previously noted is that the estimates from most studies imply that the impact of file-sharing was sufficient to have caused the *entire* decline in record sales that occurred from the advent of Napster up to about 2005. A smaller number of studies using post-2005 data indicate that the shift to digital formats may also have contributed to the sales decline that continued after 2005.

Keywords File-sharing · Piracy · Sound recordings · Music · iTunes · Napster

JEL Classification Z1 · O3 · L8

1 Introduction

How much of the highly publicized post-1999 decline in the sales of authorized sound recordings is due to file-sharing? Although it is generally accepted that a large majority of empirical studies have found that file-sharing has caused a decline in the sales of

S. J. Liebowitz (✉)
School of Management, University of Texas—Dallas, Mail Station SM31,
800 W Campbell Road, Richardson, TX 75080-3021, USA
e-mail: liebowit@utdallas.edu

prerecorded music, it is difficult for someone reading this literature to find a useful summary of the empirical estimates of the decline caused by file-sharing that might provide an answer to this question. This difficulty is due, in large part, to the different metrics of sales decline used in these studies as well as their use of differing empirical methodologies, different time periods and different geographic regions.

Although several articles, such as Connolly and Krueger (2006), DeJean (2009), Liebowitz (2005) and Oberholzer-Gee and Strumpf (2009), offer lengthy literature reviews, most of them, as well as the many obligatory literature reviews that are contained in studies of file-sharing, are generally focused mainly or entirely on the sign of the results—i.e., whether file-sharing has a negative impact on the sales of sound recordings. That focus may have made sense when the debate was largely about whether file-sharing had any negative effect at all on the sales of sound recordings. Nevertheless, the size of the estimated piracy-induced declines is of interest in and of itself and should be of greater interest than the sign, in part because the size of a coefficient contains more information than its sign, and also because the policy implications of file-sharing are likely dependent on the size of the estimates.

The purposes of this paper are threefold. First, it is to show that differences in the metric chosen to report the effect of file-sharing lead to important differences in the information conveyed. Second, it is to identify a metric that directly informs legal and economic consideration of the consequences of file-sharing regardless of the time period or the countries used in the analysis. Lastly, I convert the estimates found in the literature into this metric so as to provide a meaningful comparison of the various estimated sizes of file-sharing's impact on record sales. The metric that I use for this comparison is the share of the sales decline over a particular time period that is due to file-sharing.

As I show below, when the results of these studies are made comparable in this manner, the estimates from a majority of studies imply that file-sharing had caused the *entire* decline in sound recording sales that had occurred since the ascendance of Napster through the time period of most of the data sources that were used in these studies, about 2005.[1] I believe this finding is likely to surprise even those who have been keeping up with this literature, since the strength and consistency of this result seem not to have been previously noted. After 2005, the market has experienced the growth in digital formats and a severe recession. The few studies using later data imply that some other factors besides piracy, most likely the shift to digital formats and the recession, are responsible for some of the post-2005 decline, although there are not enough of these studies to have much confidence in this conclusion.

2 Candidate metrics

Most econometric examinations of file-sharing (piracy) tend to perform a regression of the form:

[1] Napster (the initial popular file-sharing site) was born in 1999, grew to prominence in 2000, and was shut down in 2001, as documented in Liebowitz (2006).

$$\mathrm{RS} = a + b\mathrm{FS} + \boldsymbol{cZ} \tag{1}$$

where RS stands for record sales, FS stands for file-sharing and **Z** is a vector of covariates that are thought to influence record sales.[2] These regressions can be run across geographic regions, individuals or albums, at a moment in time or as a time-varying panel. The coefficient b, which would be negative if file-sharing decreases record sales, represents the extent to which a unit of the measure of file-sharing displaces the sales of prerecorded music.

There are at least three potential metrics measuring the impact of file-sharing on sales that might be proposed.

The most common method of measuring the impact of file-sharing is to create an estimate of the size of the decline in sales that is caused by file-sharing and then form a ratio of this decline as a percentage of overall sales:

$$\text{Metric 1} = \text{Share of sales} \equiv \frac{\left(b \cdot \overline{\mathrm{FS}}\right)}{\mathrm{RS}}$$

Although this is a natural measure and the one most commonly adopted by researchers in the field, it does not allow comparability with other studies using the same measure, in spite of the fact that it is easy to simply compare percentage changes as a matter of arithmetic. The problem with comparing these percentages is that they will change not only as the amount of file-sharing changes but also as the closeness of the substitutability between originals and unauthorized copies, which is a function of the technology in use by consumers.[3] This means that the same degree of file-sharing by the same people at different points in time will have different values for metric 1. This metric will also vary across countries and populations, for the same reasons.

A second metric could be coefficient b from the above equation:

$$\text{Metric 2} = \text{`'Displacement rate''} \equiv b$$

If the measure of file-sharing is the number of songs being shared, then metric 2 represents the number of pirated songs it takes to reduce the sales of legitimate

[2] In most instances, there is no direct measure of file-sharing. Instead, a proxy, such as Internet usage, is often used. This may overstate the impact of organized file-sharing because other uses of the Internet that might reduce record sales (such as exchanging music files using email) cannot be separated from the impact of programs allowing organized and anonymous file-sharing. The results for these studies should probably be understood either to include a wider aspect of sharing files than organized file-sharing systems, or else to indicate an estimated result that is biased upward. Using the Internet, particularly for other forms of entertainment, might also usurp a user's time that would otherwise be used listening to music, causing a different upward bias in the estimated impact of file-sharing, although Liebowitz (2008) has estimated this bias to be quite small.

[3] The substitutability between originals and copies depends on how easy it is for unauthorized mp3 files to be played on the same audio devices and in the same locations as the legitimate purchased music that was available on CDs. In the early days of file-sharing, MP3 files could not be played on most audio systems and converting MP3 files into the WAV files found on CDs required a CD burner which many users did not yet own. Over time, CD and DVD players gained the ability to play MP3 files, CD burners became commonplace, and MP3 players, such as the iPod, became the centerpiece of home and auto audio systems although the timing differed by country. These advances in technology increasingly made illicit downloads better substitutes for purchased originals.

songs by one unit. Rob and Waldfogel, in their 2006 article, are the only authors of whom I am aware that use this particular measure which they label as the "displacement rate."[4] This metric looks at the share of downloaded music that replaces the sale of music ("We find that each album download reduces purchases by about .2 in our sample, although possibly by much more"[5]). The problem with this measure is that translating it into an actual decrease in sales requires knowing how large the illicit download market is relative to the legitimate market. So the .2 reduction found by Rob and Waldfogel (2006) would imply a 20 % reduction in sales if the legitimate and illicit markets were the same size, but would imply a 40 % reduction if the illicit market were twice as large as the legitimate market.[6] The ratio of the sizes of the licit to the illicit market is likely to differ across countries and over time, increasing the complexity of comparisons. This may be one of the reasons that this metric is so uncommon among the papers on file-sharing.

A common question asked by many analysts is the extent to which the current decline (illustrated in Table 1) has been caused by file-sharing. Answering this question provides the third candidate metric for the impact of file-sharing: the share of any given decline that is due to file-sharing. This can be represented as:

$$\text{Metric 3} = \text{Share of loss} \equiv \frac{(b \cdot \overline{\text{FS}})}{\Delta \text{RS}}$$

This third metric has the advantage of allowing comparisons over time and across regions. For example, as illicitly downloaded files become better substitutes for legitimate versions (because of the increased penetration of MP3 players, say), both the decline in legitimate sales and the decline in sales due to file-sharing will become larger even if the amount of file-sharing were to remain constant. But if the only reason for the decline in sales were file-sharing, then Metric 3 will remain unchanged at a value of 1, indicating that the role of file-sharing in causing the decline has not changed. This is particularly useful in comparing the decline across countries which will experience different diffusions of technologies that influence the substitutability of illicit and legitimate files.

Notice how confusion about the metric might affect comparisons of different studies. If file-sharing caused a 20 % decline in sales (Metric 1), that would be a very large share of the sales decline in the years shortly after Napster's introduction (say 2002 in Table 1, below), leaving very little room for other factors to have had a serious impact on the sales decline. By conflating the metrics used, however, the same 20 percent value, if erroneously defined as Metric 3, would leave the reader with the impression that the actual sales reduction due to file-sharing was quite small relative to the overall decline, with other factors being responsible for 80 % of the decline. Unfortunately, this is exactly the form of analysis used by Oberholzer-

[4] Oberholzer-Gee and Strumpf (2009) apply the identical term "displacement rate" to metric 3.

[5] This statement is taken from the abstract of Rob and Waldfogel (2006).

[6] Liebowitz (2006) discusses various estimates of the relative size of the illicit download market (FS) relative to the legitimate market (RS) and concludes that the estimates of relative size are wildly disparate and that many estimates of the illicit market indicate that it is considerably larger than the legitimate market.

Table 1 Cumulative decline in music sales after 1999

	US units (%)	US real revenue (%)	Non-US real revenue (%)
2000	−4.8	−5.0	−5.4
2001	−13.5	−11.4	−8.6
2002	−22.5	−19.9	−15.5
2003	−28.3	−26.4	−24.1
2004	−24.8	−25.4	−28.4
2005	−26.3	−30.7	−32.7
2006	−30.9	−37.9	−36.4
2007	−36.8	−47.3	−42.5
2008	−46.3	−59.2	−46.6
2009	−51.5	−63.9	−49.6
2010	−54.1	−67.9	−54.5
2011	−52.2	−67.6	−57.4
2012	−53.3	−69.2	−58.2
2013	−53.6	−70.0	−61.6

Units = full-length albums, digital singles divided by 10 and number of subscribers multiplied by 10. Revenues exclude performance rights and synchronization. Non-US revenues include ringtones, US revenues do not. US Data from RIAA database (online); Non-US data from IFPI database

Gee and Strumpf (2009) who treat different incompatible metrics as if they were the same. Their intermingling of metrics then leaves the reader with the mistaken impression that the impact of file-sharing in the literature was much smaller than it actually was estimated to be.

The use of Metric 3 could be problematic under certain circumstances. For example, file-sharing could be harming sales but sales could still be growing. In this case, it would be meaningless to try to use Metric 3 to compare the estimated impacts of file-sharing over time since it would not even be possible to define the share of the decline that was due to file-sharing if there was no decline in sales.[7]

Fortunately, as Table 1 indicates, the almost monotonic decline in USA and worldwide record sales since the appearance of Napster in 1999 makes the use of Metric 3 feasible. Table 1 shows the size of the decline in the USA, in both units and real revenues[8] (in the first two columns) as well as the decline in real revenues for the non-US portion of the world in the third column (labeled

[7] One might generalize this to try to account for a decline from any trendline, not just zero. If the actual growth of sales fell below trend, then even with an increase in sales, it would be reasonable to consider the deviation from trend as lost sales and we could then examine the fraction of lost sales, measured in this way, that is due to file-sharing. However, because those lost sales are conjectural, I have not recommended that approach here. Nevertheless, as we will see below, it is not unreasonable to encounter an effect of file-sharing that exceeds 100 % of the observed decline in legitimate sales, implying that an upward trendline would have continued if not for file-sharing.

[8] The US data on unit sales and revenues come from the RIAA Web site. Because subscriptions do not easily translate into CD sales, unit sales become less reliable after 2010 due to the growth of subscription and streaming revenue which first surpassed 5 % of total consumer revenue in 2011 and rose to 14 % of consumer revenue in 2013.

"non-USA").[9] Liebowitz (2007) provides evidence that each of the top national markets has experienced a severe decline in sales which would allow its use for almost any developed country.

The declines in Table 1 are extremely large, although the decline appears to be ending in the USA. This table also shows that unit declines are slightly less in the USA than are revenue declines (columns 1 and 2), indicating a fall in prerecorded music prices since 1999. The non-US revenues (column 3) follow a similar pattern to the US revenues but show a somewhat more moderate decline after 2006, although there is also less evidence of stabilization.

Because of the ease, Metric 3 allows in making comparisons across time and geographies, and because it directly answers the question as to the importance of file-sharing in the recent industry decline, Metric 3 will be the common denominator I will use to compare all results. With this metric chosen as the common denominator, comparisons can be made across the various types of studies to see how similar or dissimilar the results are from one another.

3 Applying the metric to the literature

The point of this section is to compare the results of papers finding that file-sharing caused harm (in the next section, I discuss papers that do not find harm). The published papers of which I am aware are Hong (2007, 2013), Liebowitz (2006, 2008), Michel (2006), Peitz and Waelbroeck (2004), Rob and Waldfogel (2006), Waldfogel (2010) and Zentner (2005, 2006). Two unpublished papers of seemingly similar quality to those that are published are Blackburn (2004) and Zentner (2009).

In order to compare the results of these papers to one another, I translate the amount of file-sharing-induced decline that these papers find into a percentage of the decline in sound recording sales that had occurred at the time of their measurement. Naturally, there is going to be some imprecision within many of these original estimates, and that imprecision will necessarily carry over to the translated results. For one thing, many of these papers have multiple point estimates. In such cases, I take the one preferred by the authors when their preference seems justified, or if none is listed as "preferred," I use the average of the proffered estimates. Even with just a single-point estimate, however, these papers use different years and different countries for their analyses and Table 1 makes clear that there are differences in sales declines depending on which years and which countries are used as the basis of analysis. Also, there are confidence intervals around the point estimates, although I ignore those in this analysis.

[9] The non-US revenues come from an IFPI database that is used to produce their yearly "Recording Industry in Numbers" report. The numbers for the non-US portion of the world are only approximations because the IFPI converts all foreign currencies to US dollars at a single year's exchange rate. This will not cause problems as long as inflation rates in the rest of the world are similar to those in the USA In fact, Japan has had considerably lower inflation, the Eurozone a slightly lower rate and developing countries a higher inflation rate. The further the average inflation rate in the rest of the world (weighted by record sales) from the US rate, the less reliable will be the inflation adjustment for non-US countries. With no adjustment for inflation, nominal non-US sales fell by 46 %.

Table 2 Results of studies finding that piracy caused harm

Published/unpublished studies	Share of decline due to file-sharing (%)	Original metric	Final data year	Geography
Zentner (2006)	>100	1	2001	7 European
Hong (2007)	>100	1	2002	USA
Peitz and Waelbroeck (2004)	>100	1	2002	World
Zentner (2005)	100	1	2002	World
Hong (2013)	20–40	3	2002	USA
Blackburn (2004)	>100	1	2003	USA
Liebowitz (2008)	>100	3	2003	USA
Michel (2006)	45	1	2003	USA
Rob and Waldfogel (2006)	35 or >100	1	2004	USA
Liebowitz (2006)	100	3	2005	USA
Zentner (2009)	75	3	2008	World
Waldfogel (2010)	65	2	2009	USA

Table 2 lists the results from ten published articles and two unpublished studies (listed by the last year of data used in the study) finding some degree of harm due to file-sharing (the details of the calculations underlying Table 2 are found in the "Appendix"). Seven of these studies have results indicating that the entire decline in sales is due to file-sharing. Another study has two results, with one of those results consistent with the full decline being due to file-sharing and the other result about a third of the decline. Two other studies indicate that file-sharing is responsible for either about half or two-thirds of the decline, and one study finds the smallest result, between 20 and 40 % of the decline.[10] It is clear that the average of these studies is not the 20 % "typical estimate" claimed by Oberholzer-Gee and Strumpf since only one of the twelve studies has a result as low as 20 %.

In summary, and allocating partial results from studies with mixed results, 7.5 of the 12 studies find that file-sharing explains the entire decline.[11] The average estimated value of Metric 3, for the other 4.5 studies that do not find that the entire decline is due to file-sharing, is 50 % of the decline. When the raw numbers from all

[10] Professor Hong, in his 2013 article, prefers a result of 20 % although he found that the overall result after trying to control for compositional changes in his data was 40 %. His preference for the 20 % value is based in large part on the fact that when he subdivides his population data into cohorts, some of the coefficients are statistically insignificant even though their values still imply an overall 40 % decline. He chooses to set these insignificant coefficients to zero, thus lowering the overall impact to 20 %. But having less than typical statistical confidence in a result does not imply that a result of zero is more appropriate than the measured coefficient. Thus, I list both numbers.

[11] Professor Hong, in correspondence, suggested that his 2007 result not be given equal consideration to those from his 2013 paper because he did not try to control for compositional changes in his 2007 paper (although his 2007 paper appears to be written after his 2013 paper). Because he has not withdrawn or repudiated his 2007 paper, however, and because we cannot know whether he has truly been successful in controlling for compositional changes in his 2013 paper, I include the paper in Table 2. Even if his 2007 paper were removed from the Table, however, it would merely lower the share of papers finding that the entire decline was due to file-sharing from 63 % (7.5/12) to 59 % (6.5/11). Also, the average value of Metric 3 for all papers would still be over 100 %.

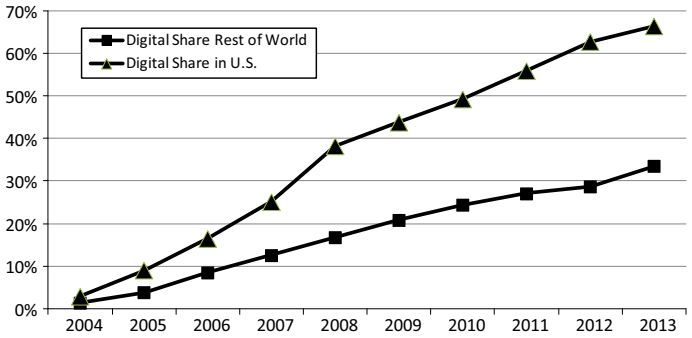

Fig. 1 Digital formats' share of consumer revenue

these studies (found in the "Appendix") are averaged, the mean value of Metric 3 is slightly over 100 %, further indicating that file-sharing has been estimated to be responsible for the entire decline in sales.

But we also need to be aware of time-period limitations in these studies. Most of the studies use data that end before 2005, when overall sales had declined by about 30 % relative to 1999, as seen in Table 1. There were two important market changes that took place after 2005. First there was the movement toward digital sales initiated most successfully by iTunes. Second, there was the very serious recession that began in 2008.

The iTunes store opened in the USA in 2003 (later in other parts of the world) and first started to have a notable effect on industry sales in 2005. In addition, streaming and subscription revenues also began at about that time although streaming and subscription revenues are on average only about a third of all digital revenues.[12] Figure 1 indicates the share of digital sales in the overall prerecorded music sales market for the USA and the rest of the world.[13] Most of the studies in Table 2 used data from years before digital sales were a serious factor in the market. It is natural to wonder whether the digitization of music has played a separate role in the continued revenue decline of the industry after 2005.

The digital delivery of music should reduce the cost of music because it avoids several important expenses involved with putting music onto a physical media, such as the media cost and the warehousing, shipping and delivery costs.[14] This lower cost of digital music (leading to an increase in supply) should reduce the market price of music and possibly its revenue, if the price elasticity of demand for music were inelastic.[15] On the other hand, if the demand for music were elastic, the lower

[12] See page 7, "Recording Industry in Numbers," 2014, IFPI.

[13] Figure 1 is based on a data set from the IFPI titled "Recorded Music Sales by Territory 1997–2012", and updated for 2013 using the IFPI "Recording Industry in Numbers," 2014. Performing Rights and Synchronization Fees are not included since they do not represent sales of prerecorded music to consumers. In the European market the share of digital is 37 %.

[14] The RIAA revenue figures for the USA are based on an estimate of final retail price and thus include all these costs. The IFPI values are wholesale prices and do not include the retailing costs.

[15] News stories indicated that iTunes pressured the record companies to keep prices below those preferred by the record companies, making the possibility of inelastic demand more likely.

cost (increased supply) would be expected to increase revenues.[16] Regardless of elasticity, however, the increase in supply would be expected to increase the quantity of sound recordings sold.

The possibility that digital sales would decrease revenues would seem to receive some support by the confluence of the US digital sales having a greater market share than in the rest of the world and the USA experiencing a greater decline in revenues compared to the rest of the world, as seen in Table 1. The problem with the idea that digital sales led to a large portion of the decline in sales after 2005, however, is the fact that US *unit* sales continued to significantly decline after 2005. The decline in both units and revenues is consistent with a decline in demand due to piracy, but it is not consistent with an increase in supply due to a switch toward lower cost digital sales.

Thus, even if a switch to digital sales did lead to some portion of the decline in revenues (assuming demand was inelastic), we know that the positive impact on units sold brought about by the lower cost of digital sales was overwhelmed by the negative impact of piracy because of the continued overall decline in units shipped.

The birth of iTunes not only engendered the switch to digital, but also allowed singles to be unbundled from albums.[17] When vendors move from selling pure bundles (albums) to mixed bundles (singles and albums), it is normally expected to increase profits, although the impact on revenues is unclear. That result is somewhat questionable in this instance because Apple required the unbundling of singles before an album was allowed on iTunes, meaning that it did not appear to be the desire of the record companies to unbundle. Because the record company motivation is unclear, we cannot conclude that record companies expected the unbundling to be profitable.[18] With regard to streaming, record companies must believe that such business models will increase their profits because they voluntarily allowed their music on streaming services.

Another factor expected to have a *temporary* impact on sound recording sales is the business cycle (e.g., Liebowitz 2004). It is not yet clear that the very strong recession that began in 2008 has been replaced by normal economic activity, however, so it might still be having a lingering impact on sales. The numbers in Table 1, however, show a particularly sharp drop in sales in the USA at the time of the recession, but no similar pattern in the rest of the world.

Keeping these various additional factors in mind, the two studies using post-2005 data show results indicating that about 70 % of the decline from the 1999 sales levels that had occurred was due to file-sharing. These numbers imply that a sizable portion of the revenue decline that occurred after 2005 may not have been due to

[16] It is well known that only a competitive industry could be operating in an inelastic region of the demand curve because industry profit maximization (as would occur with a monopoly or cartel) requires that the industry operate in the elastic portion of demand.

[17] ITunes insisted that companies wishing to sell albums also make available as singles all individual songs from the album. In addition, news articles indicated that Apple wanted lower prices for singles than did record companies and that Apple prevailed, at least for the first few years.

[18] They must have concluded that allowing iTunes to sell music was profitable but they may have preferred to be able to choose if and when to unbundle the songs contained in albums.

piracy, although we should resist drawing too firm a conclusion from only two data points.

An additional point worth mentioning is the possibility that file-sharing has disparate impacts on the sales of superstars versus more ordinary musical groups. It has sometimes been claimed that file-sharing will help the little guy relative to the superstar. Although Blackburn (2004) found some support for this claim, a later and more extensive study by Hammond (2014) found exactly the opposite impact. He finds that piracy hurts smaller artists.

Finally, the Metric 3 values greater than 100 % probably need a word of explanation. Many of the studies have Metric 3 values of greater than 100 % and as seen in the "Appendix"; some values are as high as 200 %. A value this large may seem odd at first glance, but such a seemingly high number is not necessarily unreasonable once properly understood. This is best illustrated through the use of a simple example.

> Example: Assume that a firm sells 10 CDs in year 0, whereupon file-sharing begins. By year 5, sales have dropped to 8 CDs, a 20 % decline. Assume as well that in the absence of file-sharing that sales would have increased by 4 % per year, leading to counterfactual sales in year 5 of 12.17 units. The apparent decline, the one reported by the record companies and appearing in RIAA-type statistics, is 2 units (10-8). The actual decline, determined from a perfect econometric examination, is 4.17 units (12.17-8). Metric 3 would state that 208 % of the measured decline was due to file-sharing (4.17/2). This is close to what Liebowitz (2008) found, where a counterfactual growth rate of 3.6 % was sufficient to explain his Metric 3 result of 200 %. A 3.6 % yearly growth rate of sound recording revenues was fairly typical during the three decades prior to the advent of file-sharing, indicating that a value of 200 % for Metric 3 is well within the realm of reasonableness.

4 What about the papers that do not find harm?

There are no published articles in academic journals that find a positive impact of file-sharing on sound recording sales, although there is a study (Andersen and Frenz 2007), conducted for a Canadian Ministry, which concludes that file-sharing had a positive impact on sound recording sales.[19]

The two published studies that do not find that file-sharing harms sales are Oberholzer-Gee and Strumpf (2007) and a revised version of the Canadian government study using the original data, Andersen and Frenz (2010). Obviously, when studies find no impact of file-sharing on sound recording sales, there is no need to discuss metrics, since all of the metrics will be zero.

This short list of papers finding a benign impact of file-sharing may appear rather puzzling to those who have read the literature review in Oberholzer-Gee and

[19] Andersen and Frenz estimated that each illicitly downloaded song increased sales by slightly less than half a unit (.44) which would imply that would have been no sales of prerecorded music at all if file-sharing did not exist. It is difficult to take such a result seriously.

Strumpf (2009) which contained a considerably longer list of studies with zero or positive impacts of file-sharing. For example, Oberholzer-Gee and Strumpf claim that "[w]hile the majority of papers reports some sales displacement, the four studies using actual measures of file-sharing find that file-sharing is unrelated to changes in sales" and the Andersen and Frenz study is not even included in this group. The studies that Oberholzer-Gee and Strumpf reference in this quote (in addition to their own 2007 article) are as follows: Bhattacharjee et al. (2006), Tanaka (2004) and Smith and Telang (2008). The reader may ask why I am not including these three studies in the list of studies not finding harm from file-sharing. A few words are in order.

First, I did not include Bhattacharjee et al. (2006) because that article does not conclude that the impact of file-sharing on sales is benign. Here is how Dr. Bhattacharjee characterized his article's results:

> "It is not correct to say that our work shows file sharing is unrelated to changes in sales," said the Management Science paper's lead author, Sudip Bhattacharjee, in an e-mail message to The Chronicle. "The paper did not look directly at sales, only at chart longevity, also known as chart survival." And "we did report a decrease in survival over all" said Mr. Bhattacharjee… [Glenn 2010].

Second, I chose to exclude Tanaka (2004) because it was very far from being finished. Tanaka lists the paper as version "0.1". His conclusion begins "This research is very preliminary because we have not yet tried sufficient instrumental variables." His main econometric technique is based on instrumental variables, and yet, he does not even discuss the properties of the instruments that he uses. Finally, Dr. Tanaka has stated in correspondence that his paper will never be finished nor submitted to a journal, whereas the two unpublished papers listed in Table 2 have both been completed and submitted to journals. I invite readers to examine Dr. Tanaka's paper and judge for themselves.

Finally, I leave Smith and Telang (2008) out of the current analysis because that article attempts to measure the impact of file-sharing on video sales of older movies when they are rebroadcast on television. Because the literature that I examine in this paper is focused on the full impact of file-sharing on *music*, and the Smith and Telang paper measures a partial impact on one small segment of the *video* market, the Smith and Telang result, interesting though it might be, did not seem relevant.

Oberholzer-Gee and Strumpf list one more paper, Gopal et al. (2006), as finding a positive impact of file-sharing on record sales but I believe they have misread this paper's conclusions just as they misread Bhattacharjee et al. (2006).[20]

[20] Gopal et al. (2006) find that the act of 'sampling,' by itself, has a positive impact on sales but they do not claim that the impact of file-sharing, although it may contain a sampling component, is positive. This judgment is directly supported by their statement "This [positive sampling result] has major implications for the music industry, in that the industry can potentially reverse the effects of online audio piracy." This quotation makes it clear that Gopal et al. (2006) believe that piracy is likely to have an overall negative impact on the industry that might be overturned if the industry would try to encourage sampling in various venues (although one does have to read the paper fairly carefully to understand some of its conclusions).

Thus, the only study listed by Professors Oberholzer-Gee and Strumpf that can legitimately be used to provide information about the impact of file-sharing on sound recording sales is their own 2007 paper.[21] Oberholzer-Gee and Strumpf (2007) and Andersen and Frenz (2010) are, to my knowledge, the only two published articles that find a benign impact of file-sharing.

If the two papers that actually claim a zero impact of file-sharing are included in the sample of studies when calculating average values of Metric 3, it is still the case that a majority of studies finds that the entire decline is due to file-sharing and the average value of Metric 3 is still a very high 89 %, although as we have seen, this value may be lower for the years after the 2008 recession.[22]

5 Conclusion

Although there have been numerous literature reviews discussing empirical estimates of the impact of file-sharing on sales of sound recordings, none have successfully compared the results on a consistent basis. I have endeavored to fill this lacuna by proposing a simple metric—the share of the sales decline that is explained by file-sharing—and translating the empirical results of the literature into that metric. That translation allows a useful comparison of the many efforts to identify the effect of file-sharing.

The results indicate that the majority of all studies support a conclusion that the entire decline in sound recording sales can be explained by file-sharing. Because most of these papers are based on data from prior to the ascent of digital music and the recent severe recession, however, the results hold most specifically for the period of time prior to 2006. The two studies using data that include some later years find a somewhat lower portion (although still a large majority) of the decline to be due to file-sharing. Two studies are not enough to draw any strong conclusions about the extent to which piracy explained the sales decline in these later years, however, and studies with more recent data are clearly needed to help refine this conclusion.

Because a comparison using compatible metrics has not been previously made, the profession appears to have failed to understand the nature of the results that have appeared in this literature. I believe that many interested individuals, many researchers in the area and even many members of the industry are likely to be surprised that the overall result from economic studies on the subject supports a view that file-sharing has caused so much of the enormous decline in sound recording sales.

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[21] See Liebowitz (2007) and Liebowitz (2010) which question the analysis and factual claims found in Oberholzer-Gee and Strumpf (2007).

[22] The raw results used in these calculations can be found in the "Appendix".

Appendix: The creation of Metric 3 for various studies

Below is the version of Table 2 that gives more information about the exact results from calculations of Metric 3. A brief description of the calculations for each paper then follows. I tried to contact each of the authors to make sure I understood and fairly represented their papers. I heard back from all but Peitz and Waelbroeck and Blackburn.

Published/unpublished studies	Share of decline due to file-sharing (%)	Metric used	Time frame	Geography
Hong (2007)	110	1	1997–2002	USA
Hong (2013)	20–40	3	1997–2002	USA
Liebowitz (2006)	100	3	2005	USA
Liebowitz (2008)	200	3	1998–2003	USA
Michel (2006)	45	1	2003	USA
Peitz and Waelbroeck (2004)	125	1	1998–2002	World
Rob and Waldfogel (2006)	35 or 140	1	2003/4	USA
Waldfogel (2010)	66	2	2008/9	USA
Zentner (2005)	40–160	1	2002	World
Zentner (2006)	190	1	2001	7 European
Blackburn (2004)	>115	1	2003	USA
Zentner (2009)	58–92	3	1997–2008	World

Hong (2007): He looks at the impact of the Internet on several activities, including purchases of sound recordings. Col 2 of his Table 4 directly measures the percentage change in sound recordings due to the Internet, which he finds to be 26 %. At that time (2002), US sales units had fallen by 23 %, as can be seen in Table 1 above. This leads to the ratio of 26/23.

Hong (2013): This is discussed in footnotes 10 and 11. He adjusts his initial estimates to control for the possibly changing composition of the populations used in his difference-in-difference estimates. When he makes this adjustment, he finds an overall decline of 40 % due to file-sharing. He then tries to separate these results into subcategories of users/households and although the overall results do not change, the statistical significance for some subsets of the population does change and he sets the results from the insignificant groups to zero, lowering his overall result to 20 %. As I explain in the footnotes, I do not believe that setting these values to zero is an appropriate action. He then, as an additional test, mixes two inconsistent data sets and gets results similar to 20 %.

Liebowitz (2006): The approach in this paper was to examine whether alternative hypotheses could explain any of the decline. He concluded that no alternative explanation held up very well with most being completely rejected by the data. New

evidence has further confirmed this conclusion. Thus, the entire decline is attributed to file-sharing.

Liebowitz (2008): Liebowitz discusses his results in terms of Metric 3 but only to indicate that more than the entire decline is due to file-sharing (or somewhat more precisely, that Internet activities that promote piracy, which may overstate the effect of organized file-sharing narrowly defined). In Table 1, overall album sales fell by .58 units. In Table 5, line 5, file-sharing is claimed to have led to a decline of 1.19 units. This works out to almost exactly 200 % as the share of the decline that file-sharing was responsible for. Liebowitz calculated that the growth rate in sales implied by his results, in the counterfactual world without file-sharing, was 3.6 %, which seemed reasonable given the historical growth of sales in the prior three decades.

Michel (2006): He uses US data through 2003. He found a decline of 13 % that he attributes to file-sharing although the cause is likely to be somewhat broader since he does not measure file-sharing per se. Unit sales had fallen by 28 % at that time, leading to a value of 45 % for Metric 3 (13/28).

Peitz and Waelbroeck (2004): They used data for 16 large markets from 1998 through 2002. They find a 20 % decline in unit sales. Assuming that an average of the USA and non-USA (based on revenues) would mimic somewhat their sample of countries implies a decline in sales of 16 %. This leads to a value for Metric 3 of 125 % (20/16) although there is some uncertainty in this construction. Still, their estimate is almost certainly over 100 % since the USA had an early and very high drop in units the first few years after Napster, and its decline was just slightly greater than 20 %, giving slightly under 100 % as the low end estimate of Metric 3.

Rob and Waldfogel (2006): Although the text discusses their results in terms of Metric 2, they also present a result in terms of Metric 1 in which their OLS estimate translates to a 9 % decline in sales in the 2003/2004 period (this can be found on their page 53 ("downloading reduced purchases by individuals in the sample by about 9 percent"). The average sales decline in those two years is about 26 % so that Metric 3 is 35 % (9/26). Their instrumental variable approach provides an estimate that is four times as large, which thus becomes 140 %. They conservatively lead with their OLS result but always mention both, so I included both as well. Their results are based on a sample of students that is likely to overstate the impact of file-sharing.

Waldfogel 2010: He uses Metric 2 and finds that the share of each downloaded song that replaces a purchased song averages 27 %. From his Table 2, the size of the illicit market is 6.7 relative to the legitimate market's 5.5, giving a ratio of 122 %. Multiplying 27 by 122 % indicates an overall decline due to file-sharing of 33 %. The average 2008/2009 decline in the USA was about 50 %, giving a Metric 3 value of 66 %. His results are based on a sample of students that is likely to overstate the impact of file-sharing.

Zentner (2005): He uses 2002 IFPI world unit sales across countries. The average of the 6 coefficient in his Table 2 is 15.5. In 2002, according to Table 1, the worldwide decline in real revenue was about 16 %. This gives a Metric 3 value of about 100 %.

Zentner (2006), using 2001 survey data from 7 European countries, found that without file-sharing sales would have been 8 % higher, or, in other words, that file-sharing appeared to decrease sound recording sales by roughly 7.4 %. European unit sales were down by 3.8 %, although there are more European countries than his seven. Nevertheless, the Metric 3 value is 195 % (7.4/3.8).

Blackburn (2004): In his Table 7, a 40 % reduction in file-sharing leads to a 17 % increase in sales and a 50 % reduction leads to a 26 % increase. Since US units sales had fallen by 23 % in 2003 and a 100 % decrease in file-sharing would have a larger impact than a 50 % decrease, the implication is that Metric 3 would be considerably larger than 115 %.

Zentner (2009): Since Zentner uses Metric 3 in his paper, one merely needs to read his discussion surrounding his Table 3. The range he presents is 58–92 %.

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