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Music in the Digital Age: An Analysis of Declining Revenue in the U.S. Recorded Music Industry

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The members of the Honors Thesis Committee appointed
to examine the thesis of Ward Reesman
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ABSTRACT

Music in the Digital Age: An Analysis of Declining Revenue in the U.S. Recorded Music Industry

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At its height, the U.S. recorded music industry brought in annual revenue of $20 billion. Since the turn of the 21st century, there has been a dramatic decline in recorded music revenue, to a level of $7.6 billion in 2016. What has been the cause of this sharp decline? In this paper, I hypothesize that technological advancement and the rise of music piracy via file-sharing technologies have been the primary instruments of this decline. I find empirical evidence that technological advancement is associated with downward pressure on recorded music revenue but find ambiguous results to the impact of music piracy. I reconcile these findings with a summary of a growing expanse of literature that suggests on net, music piracy has a negative impact on aggregate recorded music revenue, though the literature is inconclusive as to the magnitude of this effect. I conclude with suggestions of future research directions to determine the full effects of digitization on musician and consumer welfare.

Keywords: music industry, recorded music revenue, economics, piracy, file sharing, technology

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I. Introduction

The U.S. recorded music industry brought in $20 billion dollars of revenue per year at its height. However, since its peak in the year 1999, revenue has been drastically declining, with total recorded music revenue around $7 billion in the year 2016. While revenue has declined, total units of recorded music sold have increased dramatically from 2004 to 2016. Basic economic theory intuits the price of music must be decreasing—higher quantities sold with lower revenues is consistent with lower prices per unit being offered in the market. Figure 1 illustrates revenue data as obtained from the Recording Industry Association of America (RIAA) over the timespan 1973 to 2016, while Figure 2 illustrates unit sales over the same time. Each shade is representative of a different type of medium through which recorded music can be obtained by the consumer. Figure 3 depicts a rudimentary calculation of the average price of a unit of recorded music found by dividing total revenue in each year by respective unit sales. These figures provide a visual for the general underpinnings of this paper.

Key events and developments in the recorded music industry are denoted on the figures. Napster, LimeWire, and PirateBay are online peer-to-peer file sharing networks that facilitate the unauthorized transfer of copyrighted files, or piracy. The release of Apple, Inc.'s iPod mobile music device and iTunes digital distribution platform occurred in the early 2000s which were both important technological improvements that increased the ease of accessing music. These developments will be discussed in detail in a later section through the development of a proxying method.

Figure 1

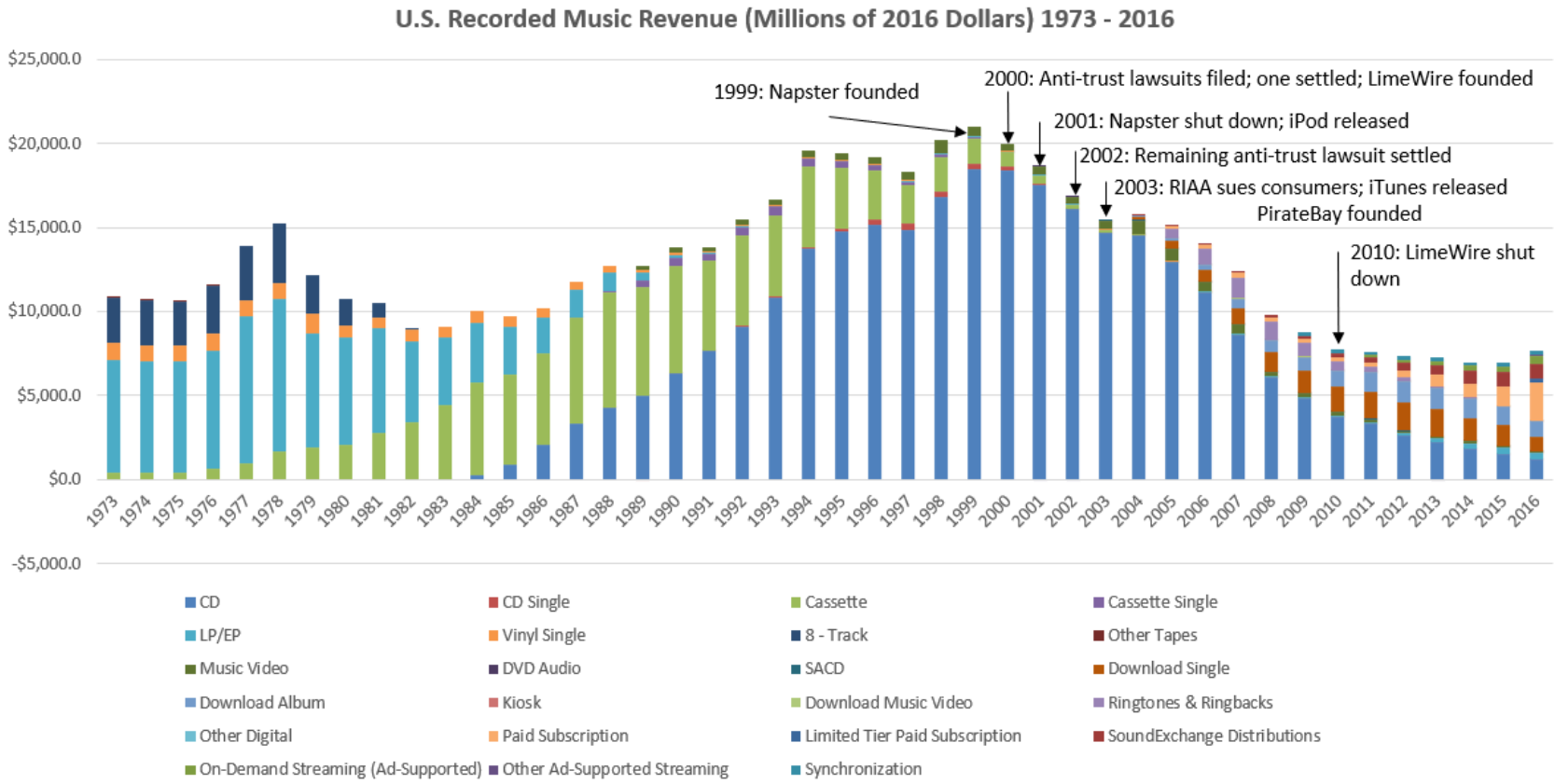

U.S. Recorded Music Revenue (Millions of 2016 Dollars) 1973 - 2016
$25,000.0
$20,000.0
$15,000.0
$10,000.0
$5,000.0
$0.0
-$5,000.0
1999: Napster founded
2000: Anti-trust lawsuits filed; one settled; LimeWire founded
2001: Napster shut down; iPod released
2002: Remaining anti-trust lawsuit settled
2003: RIAA sues consumers; iTunes released
PirateBay founded
2010: LimeWire shut down
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
CD
CD Single
Cassette
Cassette Single
LP/EP
Vinyl Single
8 - Track
Other Tapes
Music Video
DVD Audio
SACD
Download Single
Download Album
Kiosk
Download Music Video
Ringtones & Ringbacks
Other Digital
Paid Subscription
Limited Tier Paid Subscription
SoundExchange Distributions
On-Demand Streaming (Ad-Supported)
Other Ad-Supported Streaming
Synchronization

Figure 2

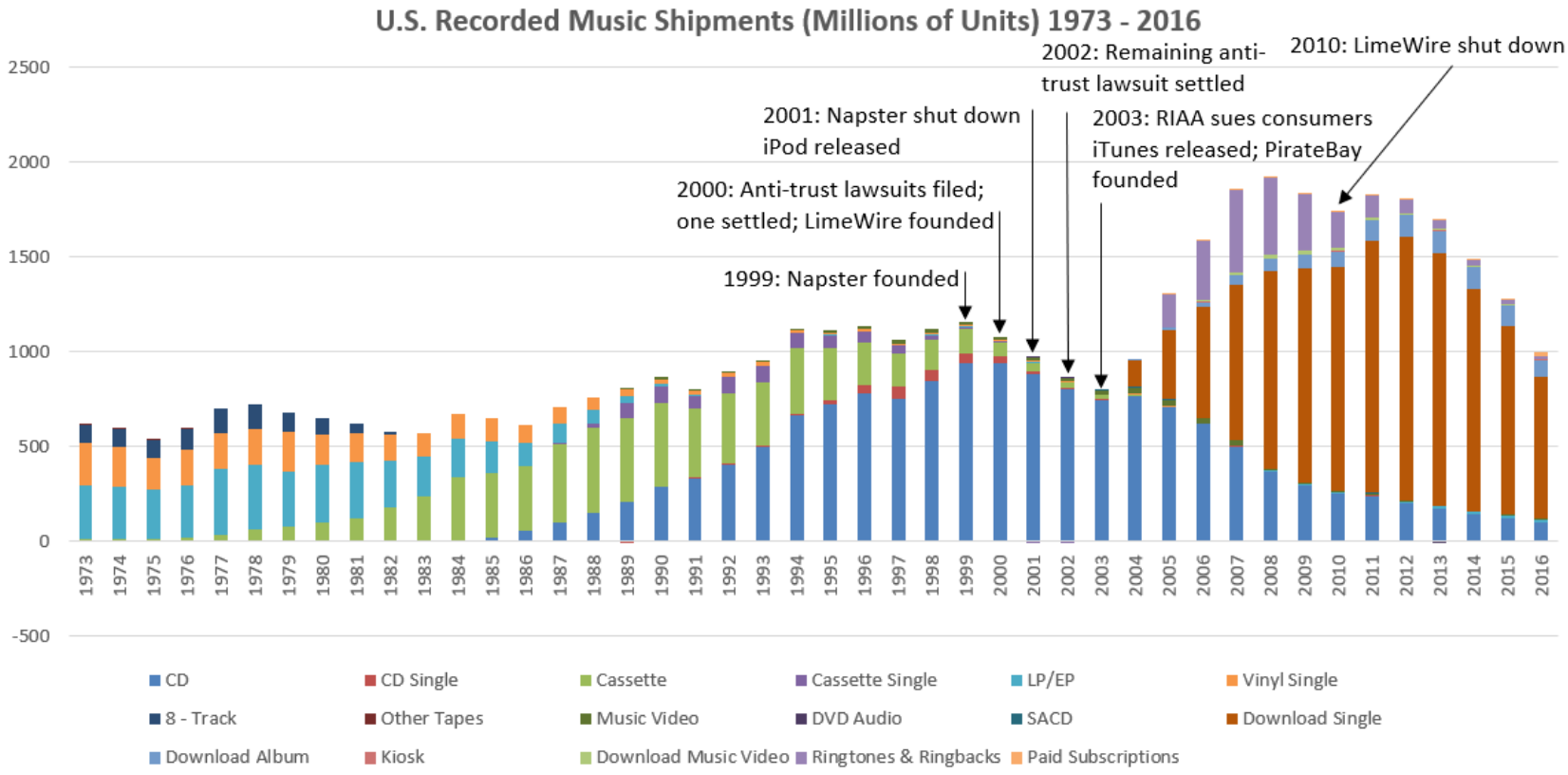
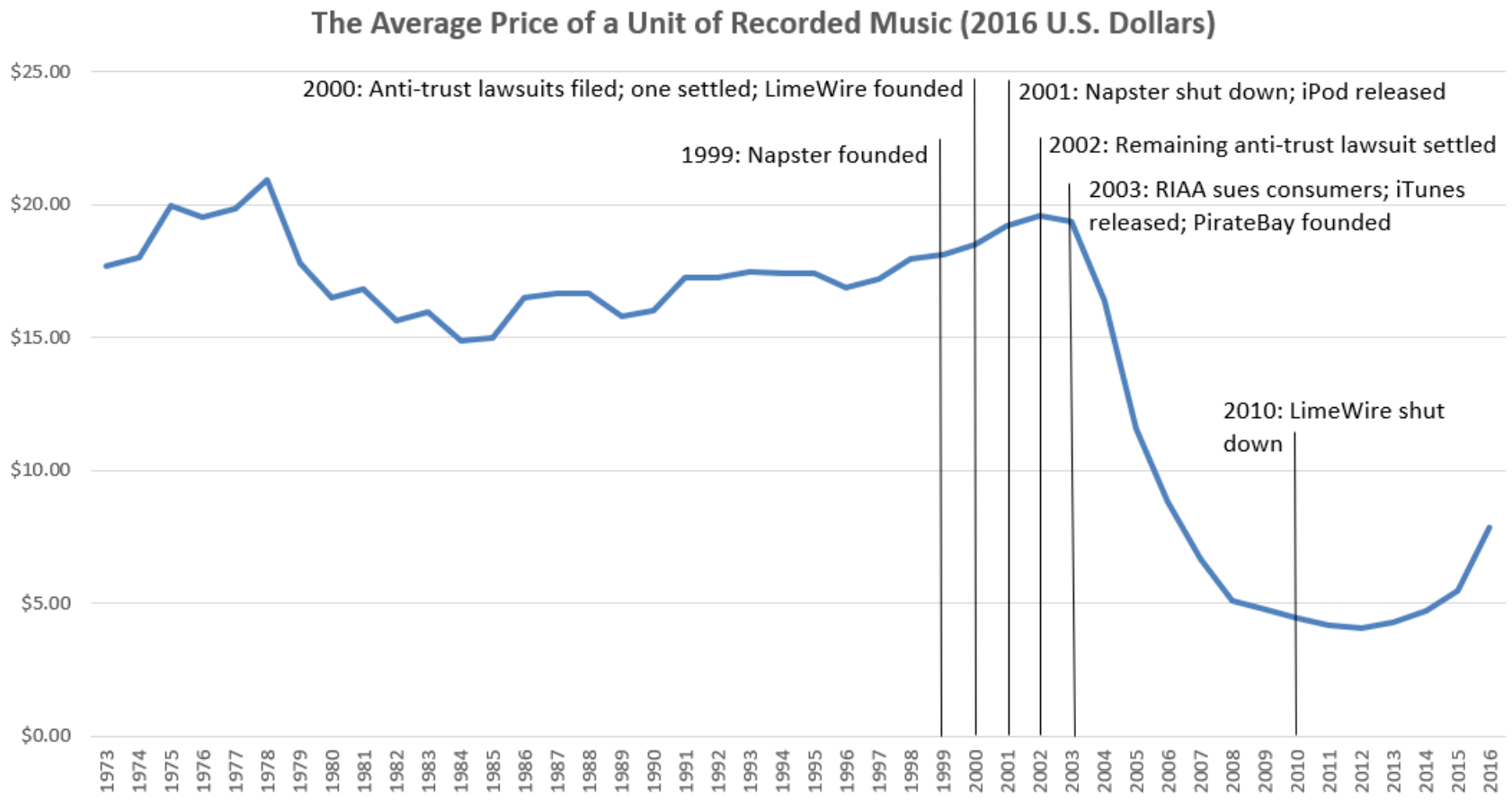

U.S. Recorded Music Shipments (Millions of Units) 1973 - 2016
2010: LimeWire shut down
2002: Remaining anti-trust lawsuit settled
2001: Napster shut down iPod released
2003: RIAA sues consumers iTunes released; PirateBay founded
2000: Anti-trust lawsuits filed; one settled; LimeWire founded
1999: Napster founded
2500
2000
1500
1000
500
0
-500
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
CD
CD Single
Cassette
Cassette Single
LP/EP
Vinyl Single
8 - Track
Other Tapes
Music Video
DVD Audio
SACD
Download Single
Download Album
Kiosk
Download Music Video
Ringtones & Ringbacks
Paid Subscriptions

Figure 3


The Average Price of a Unit of Recorded Music (2016 U.S. Dollars)
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
2000: Anti-trust lawsuits filed; one settled; LimeWire founded
2001: Napster shut down; iPod released
1999: Napster founded
2002: Remaining anti-trust lawsuit settled
2003: RIAA sues consumers; iTunes released; PirateBay founded
2010: LimeWire shut down
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

The legal developments labeled on the figures refer to two lawsuits brought against the five major record label grounds and music retailers in 2000 by 40 states and the Federal Trade Commission (FTC) which charged the organizations with conspiracy to fix CD prices. The suits were supported by an FTC investigation that estimated price fixing practices cost consumers more than $480 million. In May 2000, the FTC settled their suit with decrees requiring the defendants to cease use of policies that required stores to advertise CDs at or above a set price in return for promotional funding (MTV News Staff 2000). In 2002, the record labels and retailers settled the federal suit, agreeing to refund $67.4 million to consumers who purchased CDs from 1995 to 2000 and donate 5.5 million CDs, valued at $75.7 million, to state organizations to be distributed to schools, libraries, and other nonprofit groups (Deutsch 2002). Further, in 2003, the RIAA filed 261 lawsuits against individuals who had each distributed an average of more than 1,000 copyrighted music files via online file-sharing networks, in addition to several other lawsuits against suspected music pirates (La Monica 2003). These legal events could have had a material impact on recorded music revenue, sales, and piracy of music products; as such, have been denoted on Figures 1 through 3 for ease of reference.

While the initial conclusion of falling prices in the last 15 years can be derived from Figure 3, it is flawed as the distribution of mediums apparent in Figures 1 and 2 complicates the narrative and provides a basis for econometric modeling and analysis. As can be observed from the color-coded keys, the landscape of the music industry has changed significantly not only since the turn of the century, but also since recorded music mediums and sales were first tracked and categorized by the RIAA starting in 1973. This

shifting landscape has been amplified by rapid technological progress which now allows consumers to easily access a wide variety of databases containing hundreds of thousands of music audio files.

In addition, technology has exponentially increased the ease of piracy. Piracy occurs when copyrighted files are shared between individuals, sometimes distributed widely, from those who may have legally purchased the good to those who have not paid for the good in the recorded music market. Generally, piracy is a colloquial term for copyright infringement, which is the violation of copyright law. Copyright grants exclusive rights to creators of original works (17 U.S.C. §§ 102-106, 2016). When copyright is violated, the owner of the exclusive rights can pursue legal action: typically, through remedies in civil court; however, criminal charges may be filed if the infringement was committed for private financial gain or with the goal of reproducing or distributing the infringed material (17 U.S.C. §§ 501-506, 2016).

In this paper, I investigate the impact that technological advancement has had on revenue in the recorded music industry. As observed in Figures 1 and 2, the landscape of the industry is rapidly changing in the face of technology and this paper is an inquiry into the relationship between technological advancement and recorded music revenue. In addition, I attempt to model the effects of music piracy and file sharing on recorded music revenue, an illegal activity amplified by the Internet. In a report conducted by the Institute for Policy Innovation advertised on the RIAA website, the economic losses to the sound recording industry are estimated to be $5.33 billion, losses to U.S. worker earnings are estimated to be $2.7 billion, and lost tax revenue to U.S. federal, state, and local governments is estimated to be at least $422 million (Siwek 2007). Thus, the

impact of piracy is claimed to be substantial and warrants econometric investigation. Finally, I test the specific effect that digital music mediums have on total revenue in the industry.

I find that technological innovation has had downward pressure on revenue in the recorded music industry but find ambiguous results from piracy and file sharing in my empirical analysis. Additionally, I find that the shift from physical music mediums to digital music mediums is associated with downward pressure on the price of music, representing the idea that digital mediums carry a lower price than physical mediums and supporting the trend displayed in Figure 3. The remainder of the paper proceeds as follows: Section 2 reviews the existing theoretical and empirical literature on piracy and recorded music sales and revenue. Section 3 outlines the research design and methodology as well as reviews the data used. Section 4 contains the empirical analysis and discusses the results. Section 5 offers a summary and concluding remarks.

II. Review of Related Literature

The impact of piracy and file sharing on recorded music is a difficult measurement to make, given the sparse availability of data depicting illegal music transactions. File-sharing networks rarely share downloading data, and it is impractical and perhaps impossible to accurately measure piracy conducted in offline markets. As such, estimating the effects of piracy on recorded music sales and revenue is a tricky task that requires a solid theoretical base and statistical finesse. Luckily, there exists a sizeable body of work focused on tackling the challenge of estimating piracy's impact on the recorded music industry. Here I will review the existing theoretical and empirical literature concerning this topic to determine what effects other economists have both postulated and found empirical support for. First, I will examine the theoretical component elements of piracy. In the following subsection, I will summarize a growing expanse of empirical work to determine if a consensus exists regarding the magnitude and direction of piracy's effect on recorded music sales and revenue.

A. Theoretical Considerations

Hui and Png (2003) document two distinct positive influences of legitimate music demand by piracy. The first is the potential of demand-side influences. Some individuals simply like to consume the same item as others, and thus the quantity demanded by a typical consumer is positively related to quantities demanded by other consumers (Becker 1991). Thus, consumers of music may benefit from indirect or direct network externalities through the consumption of music. A network externality exists if consumer utility for a product increases as the number of users grow (Conner & Rumelt 1991). In

the case of software usage, as Conner and Rumelt (1991) investigate, the more users who use a software program, the more useful it becomes on a wider scale. A good example of this phenomenon would be the widespread domination of word processing software by Microsoft Word—life is easier trading text files if all parties involved are using the same processing program. In the case of recorded music, it is unlikely network externalities are factors of ease-of-use as in software, and shared value is likely the primary driver. The second major positive influence suggested by Hui and Png are supply-side effects that benefit the legitimate producer. These largely take the form of a concept known as indirect appropriability, which is discussed later. Hui and Png also note the possibility of sampling effects, which is also discussed later.

Liebowitz (2005, 2006) echoes the necessity of derivation of shared value for network effects to exist. Theoretically, file sharing is likely to increase the number of music listeners as the practice provides access to those unwilling to pay for the legitimate good. With more listeners of music, the value of music for all individuals, regardless of whether they consume legally or illegal, would rise and those who consume legally would purchase more music. Thus, for network effects to promote increased sales of music, all consumers must derive value from the consumption of music by others. If this connection is severed, the network effects are lost and those music files that are obtained illegally will have no impact on the demand for music files by legitimate consumers. Additionally, Liebowitz argues, there exists ambiguity in the effect of possible network externalities when isolating global effects from local effects. If shared value drives these effects, it is likely local network effects, as in exchanges between colleagues, friends, and family, may drive the brunt of any possible demand-side influence. Any global network

effects are likely already observable through radio play of music recordings. Finally, it remains to be examined if network effects have the impact of shifting output between existing music goods or the impact of changing the overall size of the market by driving demand for new recorded music.

Besides network externalities, the other predominant positive demand-side influence of piracy on music sales seen in the literature is known as the sampling effect. The sampling effect is widely discussed (Liebowitz 2005, 2006; Hui & Png 2003, Waldfogel 2012; Peitz & Waelbroeck 2004; Gopal et al. 2006; Oberholzer-Gee & Strumpf 2007; Lee 2018) and it can be described theoretically as follows. Music is an experience good, that is, the consumer does not have accurate information on the quality of the good before purchasing it. A consumer does not know the true value of the music recording until after the initial consumption of the recording. As such, there is an inherent amount of risk in the decision to purchase a music recording due to the uncertainty in the product's value, and this risk may prevent some risk averse consumers from purchasing the good, even those with a higher willingness to pay relative to the market price that would receive consumer surplus from consumption. Additionally, some consumers may purchase the good and be unsatisfied with the value after the initial consumption. Thus, the condition of asymmetric information prevents standard utility maximization. However, with the introduction of piracy to the model, a consumer may now sample the music recording for a much lower cost by downloading it illegally off a file-sharing network. Now being able to sample at a cost of essentially zero, the consumer could determine the value of the good prior to purchase and decide with symmetric information, resulting in utility maximization and an efficient market

outcome. This theoretical framework is tested in several empirical studies documented in the following subsection.

Sampling may also benefit music demand through interactions with network effects. An individual that samples a music product may relay the information gained through sampling to social connections. If those social connections are consumption-marginal, the new information presented may elicit consumption that may not have otherwise occurred. This effect may disseminate through the social networks of each consumer, and the information obtained from the one instance of sampling may result in widespread consumption by consumption-marginal agents that may not have consumed the music product when it first became available (Lee 2018). Thus, the sampling effect and network externalities may be interrelated. There exists some empirical evidence investigating this theoretical claim, which will be discussed later.

An element that may alter the effect of sampling via file sharing on legitimate music sales takes the form of the superstar phenomenon. The superstar effect discusses how a superstar, i.e. an extremely popular individual in the field, may owe his or her status to a combination of intrinsic elements of talent, extrinsic elements of circumstance (luck), and user expectations derived from past performance (Rosen 1981). These elements work in conjunction with a general desire by consumers to minimize the search and sampling costs that are necessary to overcome the challenges created by asymmetric information (Alder 1985). Thus, the difficulty to judge the value of music created by relatively unknown artists and the statistical tendency of consumers to correlate past performance with future outcomes lead to a few superstars dominating the market, as the existing knowledge of those prominent artists reduces sampling costs (MacDonald 1988).

However, by reducing sampling costs effectively to zero through the introduction of piracy to the model, we may observe changes to the superstar effect. This is tangentially discussed in the empirical literature.

Besides network externalities and the sampling effect, a third, less well-documented positive influence has been discussed theoretically. This is the impact of indirect appropriability. This concept was first developed in Liebowitz (1985) regarding effects first observed in the copying of academic journals. The idea is that an increase in demand might be observed for the originals from which copies are made as those making the copies capture some of the value from those receiving the copies and in turn transfer this value into their demand for the originals they purchase. However, for this theory to work, the variability in the number of copies must be small, or the seller must be able to distinguish which original products are primarily being used for copies. Liebowitz examines this effect as it applies to academic journals, hypothesizing that the most photocopied copyrighted materials are journals and the heaviest photocopying of journals takes place in libraries. Thus, publishers can charge libraries higher prices than they charge individual subscribers, anticipating those journals sent to libraries will be copied, to indirectly capture value from the photocopying. Liebowitz finds empirical support for this hypothesis, but the same likely cannot be said about indirect appropriability as it applies to music file sharing. This is because there is a great variability in the quality of copies made from original music files and it is extremely difficult for sellers of original music to identify which original recordings will be pirated in order to price discriminate. Empirical work has yet to test the effects of indirect appropriability as it applies to file

sharing, so it is not clear whether the effect exists in the real world or has a positive impact demand for recorded music.

Thus far, we have outlined three major theoretical considerations that suggest piracy has positive influences on demand in the legitimate recorded music market. As for theoretical considerations that suggest piracy has negative influences on revenues in the legitimate recorded music market, there exists one: the substitution effect, which is widely considered the traditional or conventional view of piracy (Lee 2018). The substitution effect is simple in theory and generally easy to analyze. The copy is treated as a direct substitute of the original, and the consumer faces a decision to either obtain the music product legitimately as an original product or obtain a copied version via a file-sharing network. The copied product may carry costs with it, namely quality differentials and the actual cost of making or obtaining the copy. If the quality of the copy is identical or close in quality to the original product, and the cost to make or obtain the copy is low, the copy has a price of zero (Liebowitz 2005). Compared to the price of the original music product, a rational consumer will choose the good with a price of zero to maximize utility. Further, the consumer will have no incentive to purchase the original once they have obtained the copied product which carries a positive price, as suggested in the sampling theory, because they have obtained an identical or close-to-identical product for a price of zero. This effect is most appropriately modeled as a decrease in demand and will thus reduce the quantity sold and price of the good in the legal market, driving revenues down. Empirical evidence analyzing the substitution effect both independently and with respect to potential positive influences is numerous, so I will turn to a discussion of empirical considerations next to understand which of these effects have been found to

dominate in determining the impact piracy has on revenue and sales in the recorded music industry.

B. Empirical Considerations

The empirical literature concerning file sharing and its impact on revenue and sales in the music industry has struggled to come to a consensus on which theoretical framework dominates in the real recorded music market, i.e. whether positive influences outweigh the negative effect of direct substitution. Previous meta-analyses of existing research have come to varying conclusions. Liebowitz (2005, 2006) finds the overall effect is overwhelmingly negative. Other authors find no consensus in the literature (Connolly & Krueger 2006). Deejan (2009) suggests negative empirical impacts have been overestimated and piracy may be beneficial for unknown artists, and Oberholzer-Gee and Strumpf (2010) conclude file sharing has had a negligible impact on creative industries and find no reason to believe file sharing has had a negative impact on supply of music. There is, therefore, a wide range of conclusions about piracy and recorded music demand. Here, I will conduct a review of my own to see if a similar trend emerges from analysis of a wide-ranging selection of work done in the field.

One of the earliest empirical pieces investigating piracy was conducted by Hui and Png (2003). The authors present theoretical models of end-user and re-seller piracy to account for a variety of market factors and then apply the models to international panel data of sales volume and an instrument for price for CDs for the period 1994-1998. Considering the general difficulty of quantitatively measuring piracy and the consideration that pirated quantity, derivable from International Federation of the

Phonographic Industry (IFPI) national piracy rates, is endogenously determined in the model, the authors develop instrumental variables for CD piracy. Two groups of instruments are used: piracy rates of the closely related information products music cassettes and business computer software, and total consumer expenditures and unemployment rates. The rationale for the related piracy rates is that the piracy of those products and that of CDs might be motivated by the same environmental factors, and the rationale for expenditures and unemployment concerns the alteration of reservation utility, a component of the model, via exogenous factors. Using two-stage least squares, the authors find that the coefficient of piracy was negative and marginally significant. On a per-capita basis, a one-unit increase in music CD piracy was associated with a reduction in demand for legitimate music CDs by 0.42 units. Expanding this effect out, they find that the aggregate recorded music industry lost approximately 6.6% of sales to piracy in 1998, assuming prices were not adjusted. They note this figure is 42% less than the figure claimed by the IFPI, suggesting industry organizations are overstating the effects of piracy.

Peitz and Waelbroeck (2004) attempt to add to the empirical literature with their own cross-sectional analysis of U.S. CD sales in the period 2000-2001. Using the percentage of adult Internet users who downloaded music files in MP3 format from the Internet at least once as a proxy variable for piracy, the authors use a difference-in-differences approach to estimate a significant negative impact of piracy on CD sales. They state that MP3 downloads can even fully account for the decline of CD sales in the U.S. market in 2001, depending on the factor of substitutability between MP3s and CDs and the multiplier effect of offline piracy. Peitz and Waelbroeck therefore document a

similar negative effect as Hui and Png, although with far different magnitudes, both using macro-level data and proxies for piracy.

Blackburn (2004) takes a different approach to the problem, identifying the strong possibility that effects of file sharing on sales of recorded music are unlikely to be consistent across artists and incorporating this observation into his analysis. In particular, he notes that the effect of file sharing depends on the ex-ante popularity of the artist in question. Those artists initially unknown can benefit from increased awareness via the earlier-discussed network effect, while ex-ante well-known artists are more likely to lose sales to downloads as they generally already have an established consumer base. Blackburn applies a theoretical analysis including this new effect, which he dubs as the awareness effect, to album-level sales and file-sharing network download data over a period of 62 weeks in 2002 and 2003, including an artist popularity index developed from Billboard's Hot 200.

Using two-stage least squares regression and using RIAA legal action as an exogenous file sharing risk shock, Blackburn finds on an aggregate level file sharing has had approximately zero effect on sales, a surprising finding but one the author regards as naïve and incorrect for a variety of reasons. After interacting ex-ante popularity with file sharing downloads and accounting for album competition effects, he finds that ex-ante unknown artists are likely to see positive effects on sales from file sharing opposed to ex-ante popular artists, who likely see negative effects on sales from file sharing. This analysis suggests that on aggregate, considering ex-ante popular artists generally have significantly more sales than ex-ante unknown artists, file sharing has large, negative impacts on industry sales.

Oberholzer-Gee and Strumpf (2007) offer the most convincing argument that file sharing has had negligible impact on sales through an analysis that has garnered widespread attention for its surprising results. The authors use similarly granular data as Blackburn (2004), observing sales and file-sharing downloads at the album level. The authors instrument album downloads to account for unobserved album-level heterogeneity, such as popularity, that is correlated with both file sharing and sales, thus providing a source of bias to the estimator of interest. The primary instrument used is the number of German secondary school kids on vacation in a given week, as the authors find an exogenous variation in file sharing strongly associated with school holidays (kids on holiday stay at home, where most file sharing takes place, and are typically up later at night which allows them to engage in file sharing at peak U.S. hours). The full instrument of downloads includes the holiday instrument in addition to several interactions between school vacations and album-specific characteristics to account for heterogeneity among albums and the way they are downloaded.

The authors find that without the instrument, an ordinary least squares estimation of their model shows file sharing has a small positive effect on record sales. After instrumenting for downloads in a two-stage least squares regression, the estimated effect of file sharing on sales is practically small and statistically indistinguishable from zero. Re-specifications and robustness checks support the validity of their model. Oberholzer-Gee and Strumpf thus find no evidence to claim the decline in recorded music sales from 2000 to 2002 was primarily due to file sharing, stating that "while downloads occur on a vast scale, most users are likely individuals who in the absence of file sharing would not have bought the music they downloaded" (2007).

Rob and Waldfogel (2006) analyze the effects of file sharing using survey data collected from 500 college students across four campuses, similar to Zentner (2006) who uses European individual-level survey data to develop measures of Internet sophistication and access to broadband as instruments for file sharing downloads. Zentner finds that downloads may explain a 30 percent reduction in the probability of buying music and suggests a back-of-the-envelope calculation, assuming an identical propensity to consume music between downloaders and non-downloaders, that without downloads sales in 2002 would have been 7.8 percent higher. Rob and Waldfogel find that an additional album download is associated with a decrease in album purchases by 0.2 in their sample, and conclude this incomplete sales displacement is supported by the finding that downloaded music is valued much less than purchased music. In a welfare analysis of a subsample, the authors find that while downloading reduces expenditures on hit albums by $25 per capita, it raises consumers' welfare associated with the albums by $70 per capita. They find most of this welfare gain of $45 per capita comes from reductions in deadweight loss created by copyright law.

More recent empirical analyses build off this fundamental literature. Liebowitz (2008) empirically examines the extent to which file sharing has caused declines in U.S. recorded music sales using a data set of album sales, Internet penetration, and demographics from 99 American cities from 1998 to 2003. He finds using Internet penetration, i.e. number of Internet users, as a proxy for file sharing and assuming constant average file sharing propensity across the population that a first-differences regression estimates a large, statistically significant, negative coefficient on the file sharing proxy. Liebowitz finds the estimate of the reduction in sales due to file sharing,

after netting out other generic entertainment impacts of the Internet on record sales, to be larger than the actual measured decline in record sales over the period. This supports the claim that without Internet downloading in the period 1998-2003, there would have been an increase in record sales close to the historical industry average.

Hong (2013) applies a difference-in-differences approach to data covering a similar period as Liebowitz (2008) from the Consumer Expenditure Survey by the U.S. Bureau of Labor Statistics to determine the effect of file sharing, primarily from Napster, on recorded music sales. Hong takes care to address changes in the composition of Internet users as he examines the relationship between household recorded music expenditures and household propensity to adopt the Internet to determine the effects of file sharing in examining the type of natural experiment that the existence of Napster provides. The author finds that file sharing can account for about 20% in the sales decline in recorded music during the Napster period, that is, 1999-2001. This effect, while negative, bears a magnitude consistent with some of the empirical literature covering this timeframe and inconsistent with other studies over the same period.

With album-level data and download data from an anonymous private file-sharing network, Hammond (2014) examines the effect of file sharing on album sales, exploiting an exogenous variability in the availability of file-sharing data prior to the legitimate release of an album, known as a "leak" in the industry. The main research question Hammond investigates is whether an artist should expect legitimate sales to decline given wider pre-release availability of the album in file-sharing networks due to the occurrence of a leak. His findings indicate the answer is no, and generally, file sharing is not harmful to individual artists. However, Hammond points out to beware of the fallacy of

composition, as this individual-level finding does not necessarily mean file sharing is not harmful to the aggregate industry. Additionally, this study finds file sharing has benefited established artists, but not newer, more unknown artists and file sharing trends mirror the retail market rather than provide a platform for unknown artists to benefit from network effects. This is a finding contrary to Blackburn (2004) and also Lee (2018).

Lee (2018) examines a panel dataset of private file-sharing network downloads and U.S. sales for 2,109 albums during 2008, controlling for artist popularity as Blackburn (2004) noted the importance of. Lee finds evidence that private-network sharing results in decreased album purchases, with a larger effect for digital mediums than physical mediums. Additionally, Lee finds that the effects vary significantly for artists of different quality and popularity. Exogenous increases in file sharing result in top-tier artists' sales decreasing, while the same exogenous effect increases album sales for mid-tier artists. These findings suggest the substitution effect dominates for more established artists, while the sampling effect paired with network externalities (dubbed "word-of-mouth effect" by Lee) seems to prevail in the case of less popular artists who can benefit from increased exposure as sampled information travels through social connections and contributes to building a larger fan base. DiCola (2013) provides survey information that offers supplemental evidence to this claim. In a survey of roughly 5,000 musicians on how they earn most of their revenue, DiCola found on average, musicians earned 12 percent of their revenue from sources directly related to copyright (sound recordings), 10 percent from sources with a mixed relationship to copyright (such as studio sessions), and 78 percent from sources indirectly related or unrelated to copyright. However, for the top income bracket of musicians, 68 percent of revenue was directly

related to copyright, 17 percent held a mixed relationship, and 15 percent was indirectly related or unrelated. File sharing is an activity that mainly harms copyright-focused revenue, so it is not surprising after examining these survey results that top-tier artists in the top income bracket of musicians face the largest negative impacts due to file sharing. Meanwhile, lower-tier artists make much less of their income base from copyrighted sources, and as such, the sampling and network effects seem to outweigh the substitution effect.

In the mid-2000s, data became available from Apple's iTunes online music store, which provided a useful tool to examine the impact of digital distribution mediums on file sharing with granular album sales data. Waldfogel (2010) examines survey data of college students focused on this emerging digital distribution medium. He finds that the level of file sharing still exceeds the level of purchased music, and the rate of sales displacement is roughly equivalent to the displacement rate estimated in the period prior to the availability of iTunes. This finding suggests that legal means of digital distribution have little impact on stemming illegal file sharing. Danaher et al. (2012) applies a difference-in-difference approach on iTunes data to examine the impact of the passage of French anti-piracy law HADOPI, finding that increased consumer awareness of anti-piracy measures caused iTunes song and album sales to increase 22.5 percent and 25 percent relative to changes in an international control group. Additionally, the authors find observed sales increase is much higher in genres that were generally pirated more prior to the law implementation than genres that experienced less piracy, making a strong case for well-formed anti-piracy laws in combating file sharing.

Since 1996, concert ticket prices have vastly outpaced inflation. Krueger investigates this trend, suggesting a variety of theories from the superstar effect to cartelization in the recorded music industry as possible causes. He settles on "The Bowie Theory" as the most likely cause, which he defines as "the technology-induced erosion of the complementarity between record sales and concert tickets" (2005). As file sharing has grown, so have concert ticket prices as technology and file sharing have resulted in decreased revenues from recorded music and musicians must now obtain more of their income from live performances. Mortimer et al. (2010) apply empirical analysis to this inquiry and find evidence to support this conclusion. As file sharing and illegal redistribution of digital music products has increased in volume and negatively impacted associated revenue, musicians must find sources for income elsewhere which we can observe in increasing revenue from non-digital complementary products such as live performances. These findings suggest real harm caused by file sharing and a concerted effort by musicians to recover lost income from alternative sources.

Further empirical studies examine changes in supply of music and quality of music, extending beyond the typical focus on demand for legitimate recorded music. Waldfogel (2011) finds from an empirical analysis of chart-topping albums since the 1960s that there has been no statistically meaningful difference in the tendency for new artists to appear on *Pitchfork* Media's best-of album lists since Napster. While the process of music discovery and distribution has changed significantly by the Internet and file-sharing technologies, and demand for legitimate music has arguably declined in the face of piracy, it appears the supply of new music has not changed significantly at all. Perhaps a heightened role of complements helps musicians keep a steady flow of income

in the face of reduced recorded music revenue, or perhaps cost reductions have allowed the supply of new music to remain steady. Another possibility for this lack of supply change is that quality is decreasing. However, Waldfogel (2012) finds in another empirical analysis this is not the case. In this study, he constructs three indices to represent music quality: one created from lists assembled by various music critics, one created from certification-based sales data, and one created from radio airplay data. Regressing index levels from periods prior to the arrival of Napster on post-Napster levels, he finds no decline in music quality; in fact, in the case of the two usage-based indices, recorded music quality seems to increase in the post-Napster period. This finding is puzzling when comparing it to the trend of declining recorded music revenue that this paper has been addressing. A possible explanation Waldfogel suggests is that while some new technologies have reduced revenue, other new technologies have reduced the cost of bringing new music to market. This is an element surprisingly absent from the empirical literature. Waldfogel (2017) has recently begun the foray into examinations of digitization on the costs of creating copyright-protected media with a qualitative analysis that suggests on balance, digitization has increased the number of new entertainment products created and made available to consumers. Perhaps the cost reductions are outweighing the revenue reductions well-documented in the empirical literature so that on net, technological advancements are improving the welfare of not only consumers but producers of often-pirated digital goods. However, there is a severe lack of empirical support for this claim.

Overall the empirical literature, while still far from consensus, appears to suggest that file sharing has a generally negative impact on aggregate recorded music industry

sales and revenue. However, the effects become murkier when the analysis is narrowed to the artist level. File sharing may help relatively unknown artists gain exposure via network externalities and build fan bases via a word-of-mouth effect, while harming popular artists who have well-established revenue bases. Additionally, the magnitude of these effects varies widely between studies, with some claiming file sharing can explain the entire decline in recorded music sales, and others claiming only a fraction of sales lost can be attributed to the rise in online piracy. Variation in magnitude and direction is likely a function of the distinct lack of detailed data regarding piracy and file sharing which has led to the utilization of a wide variety of proxy variables, instruments, and statistical methods that yield somewhat disparate results. Indeed, my own analysis falls victim to this issue with estimated results of piracy, which will be discussed in the following sections. Additionally, most empirical studies on the topic focus primarily on sales or revenue. There is a distinct lack of analysis regarding digitization of music on costs, which is a crucial component to measuring profitability and understanding the broader welfare effects of file sharing, which is of ultimate interest. Unfortunately, estimating changes in the cost of producing music over time is a challenge which I was unable to include in this analysis.

III. Methodology and Data

In my analysis, I am primarily concerned with estimating the effects of technological advancement and piracy on recorded music revenue. The desired estimation equations take the following forms:

(1) $$TotRev_t = \beta_0 + \beta_2 Income_t + \beta_3 Pop_t + \beta_4 Time_t + \beta_5 Piracy_t + \beta_6 TechnologicalAdvancement_t + u_t$$

(2) $$DigRev_t = \beta_0 + \beta_1 PhysRev_t + \beta_2 Income_t + \beta_3 Pop_t + \beta_4 Time_t + \beta_5 Piracy_t + \beta_6 TechnologicalAdvancement_t + u_t$$

(3) $$PhysRev_t = \beta_0 + \beta_1 DigRev_t + \beta_2 Income_t + \beta_3 Pop_t + \beta_4 Time_t + \beta_5 Piracy_t + \beta_6 TechnologicalAdvancement_t + u_t$$

Where *TotRev* signifies total recorded music revenue, *PhysRev* signifies revenue obtained from physical mediums, and *DigRev* signifies revenue obtained from digital mediums. I include as controls population and income. I assume that as population increases, more individuals will consume music products, and as such must control for population trends over time. I include income as a control because music purchases are likely correlated with income levels. Since music is form of entertainment, I consider it a luxury good as opposed to a necessary good. Economic theory suggests that a rise in income will lead to an increase in the consumption of goods and an increase in the consumption of luxury goods proportional to necessary goods (Varian 1992). Further, I assume that luxury goods will be purchased with income that is spent at the consumer's discretion, after required expenditures such as income taxes. Thus, I determine disposable income per capita as the most accurate measure of consumer income as it relates to purchases of recorded music. A time trend is included to avoid the possibility of a spurious regression.

I am concerned primarily with two items: how technological advancement and the existence of piracy and file-sharing technologies have impacted revenue earned in the aggregate recording music market, represented in the desired estimation equations by β_5 and β_6. My hypotheses take the following form:

H1: Technological advancement has contributed to declining revenue in the recorded music industry.

H2: Piracy and file sharing have contributed to declining revenue in the recorded music industry.

I hypothesize that technological advancement has facilitated an increase in the supply of recorded music. Without a corresponding increase of equal magnitude in demand for recorded music, this supply shift will drive the price of music down and thus revenues obtained in the industry. I believe the fact that technology has allowed music to become more widely available from a more diverse set of sources has allowed more musicians who previously would not have a platform to release recorded music. Additionally, I believe the ease with which music can be uploaded and shared on the Internet compared to previous time periods incentivizes musicians to release more recorded music. Thus, I predict these effects have increased the supply of music, an effect that will drive revenue down. This will be observable in the empirical analysis by satisfying the following condition:

$$\beta_6 < 0$$

I hypothesize that piracy and file sharing boasts a large substitution effect with legitimate recorded music that dominates any positive demand-side effects. As mentioned in Section 2, the literature documents three major impacts of piracy on music sales: the sampling effect, network effects, and the substitution effect (Liebowitz 2005, 2006; Gopal et al. 2006; Peitz & Waelbrock 2004; Hui & Png 2003; Lee 2018). The sampling effect and network effect state that piracy may impact music revenue by increasing demand for legitimate music goods. The substitution effect states that pirated music products are direct substitutes of legitimate music products and as such, an increase in the availability of pirated music products will decrease demand for legitimate music products. I hypothesize that while the sampling effect and network externalities may have positive impacts on demand for recorded music, especially for artists with low popularity levels, the substitution effect dominates in magnitude and as such, I should observe the following condition in the empirical analysis:

$$\beta_5 < 0$$

Technological advancement is generally a difficult variable to define and measure in economics due to the lack of concrete metrics and the broad scope of what could be considered technological advancement; for the purpose of this analysis I develop a proxy for technological advancement which consists of several variables signifying major technological improvements in music accessibility throughout the time span of the revenue data: the Sony Walkman player, the portable MP3 player, the Apple iPod, personal computers (PCs), and smartphones. For PCs and smartphones, I use global unit

sales from 1994 to 2016 and 2007 to 2016, respectively[1]. Specific unit sales for Walkman players, MP3 players, and iPods were not available due to data limitations and as such, dummy variables were assigned.

The three inventions of the Walkman player, MP3 player, and Apple iPod each increased the ease of accessing and listening to music in a mobile fashion, which allowed further consumption of music mediums while exercising or traveling. Personal computers ushered in the era of digital music distribution through online platforms such as Pandora Radio and iTunes. More recently, personal computers, in tandem with smartphones, have supported the rise of music streaming platforms—such as Spotify and Apple Music—that proliferate the market for recorded music today. Smartphones compounded on mobile music accessibility innovations, allowing consumers to carry just one device to access all their personal technology needs—including music, with applications for all major streaming and video services readily available for download. The development of the Apple iPhone was specifically noteworthy, as the synergies created between the iPod, iPhone, and Apple's digital music distribution service of iTunes which ran on personal computers allowed seamless integration of music across multiple platforms, an advancement that made widespread consumption of music easier than ever before.

Piracy, or the unauthorized copying of legal music files for personal consumption or redistribution, is an illegal activity and thus is difficult to obtain accurate data on or measurements of. In my circumstances, individual file-sharing network data was not

[1] Obtained from Gartner. Available PC and smartphone data are global figures while all revenue, population, and income data are domestic figures. This provides a potential source of random measurement error.

available, nor were aggregate figures on Internet music file downloading or other copying technologies. To remedy this deficiency, I develop a proxy that consist of four dummy variables representing four landmarks in piracy and file-sharing technology: the CD burner, the online peer-to-peer (P2P) file sharing sites Napster (1999-2001) and LimeWire (2000-2010), and the online BitTorrent index The Pirate Bay (2003-present).

The CD burner is a device that allows the copying of the contents of one CD onto a blank CD. The advent of the CD in 1982 heralded a new era not just for the recorded music industry, but for music pirates as the technology enabled master-quality copying in large quantities via tools such as CD burners and encoding of MP3 files. With burners, a legitimate music CD could easily be copied onto a pressed copy or a CD-Recordable disc (CD-R) for personal use or more widely, distribution to the market for music. Additionally, many personal computers came equipped with CD-ripping software and CD burners built into the hardware around the turn of the 21st century (Janssens et al. 2009). Today, the RIAA permits copying of CDs for strictly personal use, as royalties have already been paid on legitimately purchased CDs, but distribution of those copies can be considered copyright infringement (2019). As such, I felt it would be important to include as a precursor to the era of digital file-sharing networks and to identify if there were noticeable impacts of piracy before the emergence of such networks.

In 1999, Napster was launched by Shawn Fanning with the intent of allowing music files to be shared among strangers (Liebowitz 2006). It was the first online P2P network that specialized in the sharing of MP3 files of music. P2P file sharing networks allow users (peers) to use a software program that locates similar computers in the network that carry the file desired and downloads it to a peer's local computer. Once

obtained, that computer can now be used by other peers in the network as a source for the file (Carmack 2005). Within two short years, Napster faced litigation charges from several record labels that are members of the RIAA, supported by separate lawsuits from metal band Metallica and rapper and producer Dr. Dre, that ultimately ended the site's primary business model of trading copyrighted material through P2P file sharing (*A&M Records v. Napster*, 2001). However, Napster had ushered in the advent of P2P file sharing networks focused on music files that rapidly diffused across the Internet.

LimeWire was one of the first offshoot P2P clients that existed until 2010, when it was forced to cease operations following a federal injunction (*Arista Records LLC v. Lime Group LLC*, 2010). I believe LimeWire, as one of the earliest entrants to the file-sharing market following Napster and longest-standing among the early entrants, was significant to the widespread proliferation of file-sharing networks and as such, include it as a variable in the model.

The final piracy dummy variable represents The Pirate Bay, a decentralized index of torrent files which supports a regime of P2P file sharing known as BitTorrent. BitTorrent is a communication protocol for P2P file sharing that has become the single most common protocol on which peers transfer large files such as music. BitTorrent functions similarly to P2P file sharing, however this protocol sources different pieces of the file simultaneously from multiple computers in the network. Additionally, BitTorrent uses a principal known as tit-for-tat. The tit-for-tat principal states that to receive files, a peer must contribute files to the network, and the more files shared by a peer, the faster that peer's download speed is (Carmack 2005). In 2013, BitTorrent was responsible for 3.35% of worldwide bandwidth, which was more than half of the 6% total worldwide

bandwidth occupied by file sharing at the time (Palo Alto Networks). The Pirate Bay has endured litigation and domain seizure, yet the file-sharing site survives through proxy servers (Gibbs 2014; Van der Sar 2012, 2015). A proxy server (proxy) is a computer system or application that acts as an intermediary between clients in a computer network (Luotonen & Altis, 1994). Proxies offer a wide range of Internet-based functionalities, one of which is acting as a relay between replicated Pirate Bay sites and the main server. This functionality has allowed the index to survive sustained legal pressure, and it still exists today with a large network of peers and digital files. Because of The Pirate Bay's network size and resilience, I have chosen it as a variable to represent the current regime of file-sharing networks.

Substituting the developed proxy variables into my desired estimation equations, I arrive at three equations to be estimated with the available data:

(1) $$TotRev_t = \beta_0 + \beta_1 Income_t + \beta_2 Pop_t + \beta_3 Time_t + \beta_4 Burner_t + \beta_5 Napster_t + \beta_6 LimeWire_t + \beta_7 PirateBay_t + \beta_8 Walkman_t + \beta_9 MP3_t + \beta_{10} iPod_t + \beta_{11} PC_t + \beta_{12} Smartphone_t + u_t$$

(2) $$DigRev_t = \beta_0 + \beta_1 PhysRev_t + \beta_2 Income_t + \beta_3 Pop_t + \beta_4 Time_t + \beta_5 Burner_t + \beta_6 Napster_t + \beta_7 LimeWire_t + \beta_8 PirateBay_t + \beta_9 Walkman_t + \beta_{10} MP3_t + \beta_{11} iPod_t + \beta_{12} PC_t + \beta_{13} Smartphone_t + u_t$$

(3) $$PhysRev_t = \beta_0 + \beta_1 DigRev_t + \beta_2 Income_t + \beta_3 Pop_t + \beta_4 Time_t + \beta_5 Burner_t + \beta_6 Napster_t + \beta_7 LimeWire_t + \beta_8 PirateBay_t + \beta_9 Walkman_t + \beta_{10} MP3_t + \beta_{11} iPod_t + \beta_{12} PC_t + \beta_{13} Smartphone_t + u_t$$

Where each β is estimated at time *t* for each variable. In addition to the data collected to proxy for piracy and technological advancement, I use annual data on recorded music

revenue for the years spanning 1973 to 2016, obtained from the RIAA. These numbers are adjusted for inflation, measured in 2016 dollars.[2] I include as controls U.S. population and disposable income per capita[3] from the same period, with disposable income inflation-adjusted to 2016 dollars.

The key estimators of interest in the above equations are the coefficients on the piracy proxy variables and the technological advancement proxy variables. Estimation of equation (1) will provide insight on aggregate effects of piracy and technological advancement. Estimation of equations (2) and (3) will provide insight on the effects of substitution between physical and digital mediums and the effects of piracy and technological advancement on each medium, permitting a more granular analysis. Summary statistics for all variables are included in Table 3.1 below. Graphical visuals of non-dummy variables are included in Appendix A.

[2] I use the Consumer Price Index for all inflation calculations.

[3] Both obtained from the St. Louis Federal Reserve. Per capita calculations are my own.

Table 3.1

Summary Statistics

Variable	Description	Mean	Standard Deviation	Min	Max
TotRev	Total real revenue in the U.S. recorded music industry (millions of U.S. dollars)	12884.42	4168.67	6955.44	21010.98
DigRev	Real revenue generated by digital mediums (millions of U.S. dollars)	1281.89	1844.23	0	6042.69
PhysRev	Real revenue generated by physical mediums (millions of U.S. dollars)	11602.53	5365.56	1607.86	20468.3
Income	Real U.S. disposable income per capita (U.S. dollars)	33784.42	5617.41	25689.75	43229.31
Pop	U.S. Population (millions)	265.91	34.88	211.91	323.13
PC	Global unit sales of personal computers (millions, 1994-2016)	109.16	129.74	0	365.4
Smartphone	Global unit sales of smartphones (millions, 2007-2016)	159.48	388	0	1495.959
Walkman	Dummy variable for existence of Sony Walkman player	0.84	0.37	0	1
MP3	Dummy variable for existence of portable MP3 player	0.45	0.5	0	1
iPod	Dummy variable for existence of Apple iPod	0.36	0.49	0	1
Burner	Dummy variable for existence of CD burner	0.5	0.51	0	1
Napster	Dummy variable for existence of Napster	0.09	0.29	0	1
LimeWire	Dummy variable for existence of LimeWire	0.25	0.44	0	1
PirateBay	Dummy variable for existence of The Pirate Bay	0.32	0.47	0	1

IV. Results

Table 4.1 displays the results of ordinary least squares regression of equation (1) in column (1). Upon testing for heteroskedasticity, an F-statistic of 2.22 was returned with a p-value of 0.037, indicating heteroskedasticity at the 5% level. As such, equation (1) was estimated with robust errors, which is included in column (2). Using the AR(1) model, no serial correlation was found. However, a RESET test indicated slight misspecification at the 5% level, with $\hat{y}^2$ returning a p-value of 0.048 and $\hat{y}^3$ returning a p-value of 0.045. Attempts to fix model misspecification by logging variables were unsuccessful, thus misspecification may be a result of observed heteroskedasticity [in which case, then should not be an issue by using robust errors as done in specification (2)] or a result of omitted variable bias.

Specifications (1) and (2) confirm my H1: all technological advancement proxy variables have strong negative coefficients and are all statistically significant at the 5% level besides *MP3*. For example, an increase of one million PCs sold is associated with a decrease of $64.7 million in total recorded music revenue, ceteris paribus. Robust errors yield similar statistical significance results, with *MP3* now significant at the 10% level.

Specifications (1) and (2) failed to confirm my H2: the piracy proxy variables returned ambiguous coefficients. While *Limewire* returned a negative coefficient as hypothesized, *Burner*, *Napster,* and *PirateBay* returned positive coefficients of varying degrees of magnitude. Additionally, none of the estimators were significant at the 5% except for *Limewire* when estimated with robust errors.

Table 4.1

Effects on Total Recorded Music Revenue

Variables	(1)	(2)
Income	.452 (.3217)	.452 (.238)*
Pop	1,154.157 (289.463)***	1,154.157 (448.189)**
Time	-2,408.229 (778.594)***	-2,408.229 (1102.079)**
Burner	1,855.422 (1313.563)	1,855.422 (2150.146)
Napster	1,328.087 (1438.488)	1,328.087 (852.472)
Limewire	-2,097.771 (1145.527)*	-2,097.771 (661.497)***
PirateBay	131.611 (2131.534)	131.611 (1695.306)
Walkman	-3,669.495 (1320.393)***	-3,669.495 (1565.072)**
MP3	-1,806.526 (1292.889)	-1,806.526 (897.798)*
iPod	-3,548.99 (1341.327)**	-3,548.99 (1211.395)***
PC	-64.736 (7.800)***	-64.736 (6.658)***
Smartphone	-7.878 (1.152)***	-7.878 (.867)***
Constant	4,506,851 (1472257)***	4,506,851 (2077704)**
R^2	.9393	.94
F-stat	39.97	194.47
n	44	44

(*) $\rho < 0.1$
(**) $\rho < 0.05$
(***) $\rho < 0.01$

Estimation of equation (2) using ordinary least squares resulted in a model that was heteroskedastic at the 1% level with a F-statistic of 4.26 and mis-specified through the RESET test at the 1% level, with $\hat{y}^2$ returning a F-statistic of 4.44 and $\hat{y}^3$ returning a F-statistic of -4.10. As such, I will not discuss this model, though it is included in Appendix B. Indeed, some of the estimators are interesting; however statistical tests are unreliable, and the model is of dubious functional form.

Table 4.2 displays the results of ordinary least squares regression of equation (3). This specification was not heteroskedastic, was not serially correlated, and maintained functional specification at the 5% level by the RESET test. As in specifications (1) and (2) in Table 4.1, the technological advancement proxy variables carried consistently negative estimators that are all significant at the 1% level, besides *MP3*. For example, a one-million-unit increase in smartphones sold is associated with a decrease of $5.79 million in recorded music revenue generated through sales of physical mediums, holding all else constant including recorded music revenue generated by digital mediums. This *DigRev* control indicates that these technological advancements are not just causing consumers to substitute music purchases towards digital mediums, which could be inferred from Table 4.1, and instead directly associated with declining revenue.

Additionally, the coefficient on *DigRev* is interesting: an increase of $1 million in revenue generated by digital mediums is associated with a decrease of $2.1 million in revenue generated by physical mediums, ceteris paribus. This suggests a disproportionate effect in the substitution to digital mediums away from physical mediums and could suggest the price of digital mediums is lower.

Table 4.2

Effect on Recorded Music Revenue Generated by Physical Mediums

Variables	(3)
DigRev	-2.100 (.615)***
Income	.600 (.322)*
Pop	1,204.107 (281.078)***
Time	-2,575.356 (758.077)***
Burner	990.492 (1358.073)
Napster	225.038 (1520.388)
Limewire	-1,804.61 (1118.9)
PirateBay	-685.811 (2109.58)
Walkman	-3,495.734 (1279.498)***
MP3	-1,987.967 (1253.341)
iPod	-3,934.362 (1313.796)***
PC	-50.664 (10.891)***
Smartphone	-5.792 (1.612)***
Constant	4,822,259 (1433418)***
R^2	.9669
F-stat	67.39
n	44

(*) $\rho < 0.1$
(**) $\rho < 0.05$
(***) $\rho < 0.01$

Indeed, if the price of a digital unit of music is lower than the price of a physical unit of music, the substitution of a digital unit of music for a physical unit of music would have a net negative effect, as the revenue lost from the foregone purchase of the physical medium would outweigh the revenue gained from the purchase of the digital medium. The coefficient on *DigRev* suggests that, on aggregate, an increase in revenue from digital products is associated to a disproportionate decrease in revenue for physical products. This finding seems to confirm the tertiary hypothesis that the price of a unit of music from a digital medium is less than the price of a unit of music from a physical medium and is contributing towards downward pressure on overall recorded music revenue.

Table 4.2 also displays ambiguous results of piracy on recorded music sales, as observable in Table 4.1. While *Limewire* and *PirateBay* return negative coefficients, *Burner* and *Napster* return positive coefficients, and none of the estimators are statistically significant. It may be the case in both Tables 4.1 and 4.2 that *PC* is picking up some omitted variable bias attributable to piracy. The estimator on *PC* may include effects associated with piracy, as the increase in availability of piracy technology via file-sharing networks is directly correlated with the rising ubiquity of personal computers in the American household, and the selected piracy proxies may not be adequately controlling for piracy effects due to the loose fit of the dummy variables. However, this is not an observable phenomenon in this analysis and I find no strongly supported empirical evidence to confirm my H2 that piracy is associated with declining recorded music revenue.

V. Conclusion

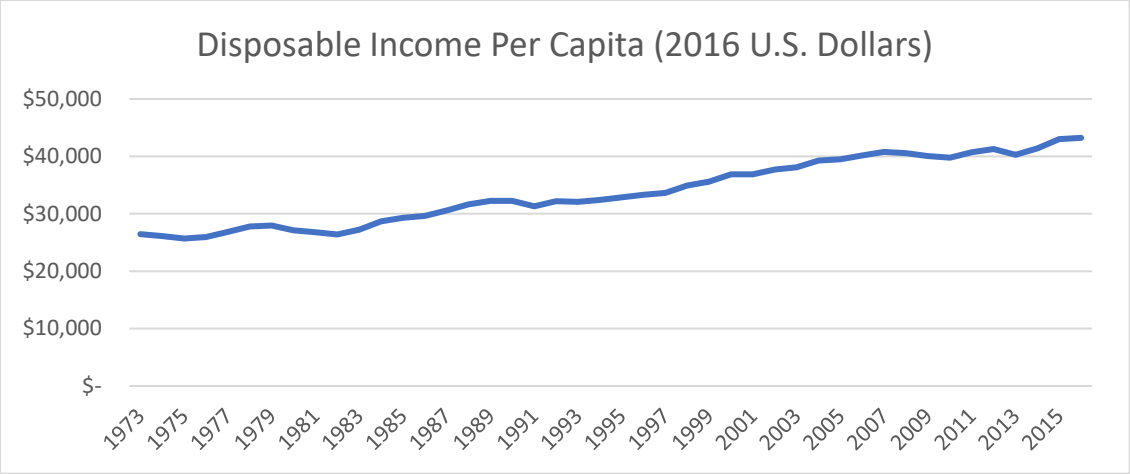
Through the empirical analysis presented in this paper, I can confirm the hypothesis that technological advancement has contributed to declining revenue in the music industry, but I cannot confirm the hypothesis that piracy has contributed to declining revenue. My empirical analysis suggests the presence of prominent copying technologies and file-sharing networks has had an ambiguous and potentially negligible effect on recorded music revenue. This finding can be contrasted with the literature review conducted, which largely suggests that piracy has negative effects on aggregate revenue in the music industry. However, as there are complicating effects when examining the industry at the artist level—some artists may benefit from piracy dependent on their status and popularity, while others are harmed—piracy effects seem to differ dependent on the scope of the analysis. Additionally, magnitudes of estimated impacts have a broad spread, making it difficult to estimate a true monetary loss to piracy. The disparity in magnitudes raises questions about the validity of piracy studies conducted by the recorded music industry. Another issue is the distinct lack of empirical analysis of the impact of digitization and file sharing on the costs of producing and distributing music—this consideration is essential to understand how digitization has affected profitability and welfare. The rise of digital distribution has complicated the narrative, especially considering the meteoric rise of streaming platforms that offer unlimited access to a massive base of music for relatively low monthly subscription fees such as Apple Music or Spotify. These services may prove to disrupt file sharing much more than previous digital distribution mediums such as iTunes; however, this is an untouched topic in the empirical literature so far. In conclusion, while the existing

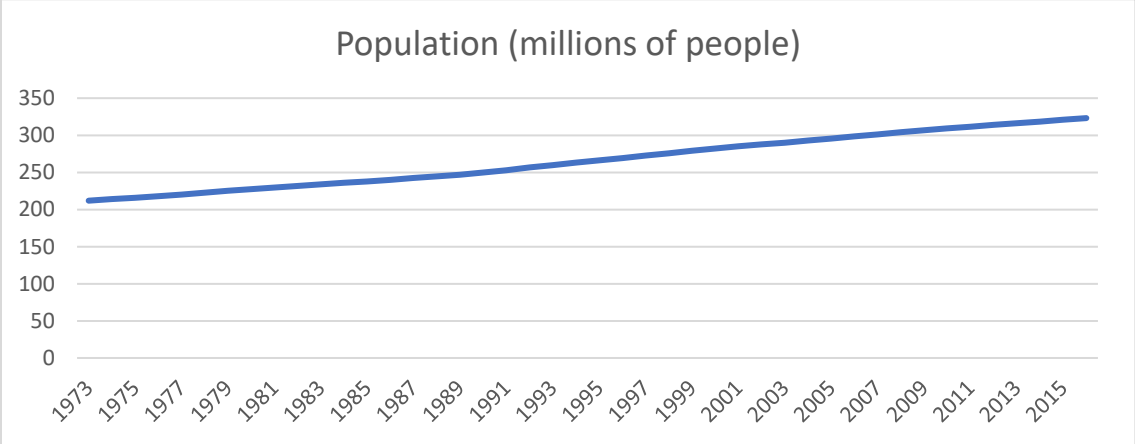
literature can make somewhat consistent causal inferences regarding the general welfare of consumers and musicians under increased music piracy, the data currently available is likely not detailed enough to make an accurate causal inference regarding the impact of broader technological advancement on the welfare of musicians through the lens of profitability and producer surplus. Thus, to assemble an accurate picture of the effect technological advancement and the rise of digital distribution have had on the broader welfare of musicians, the age-old adage holds—further research is required.

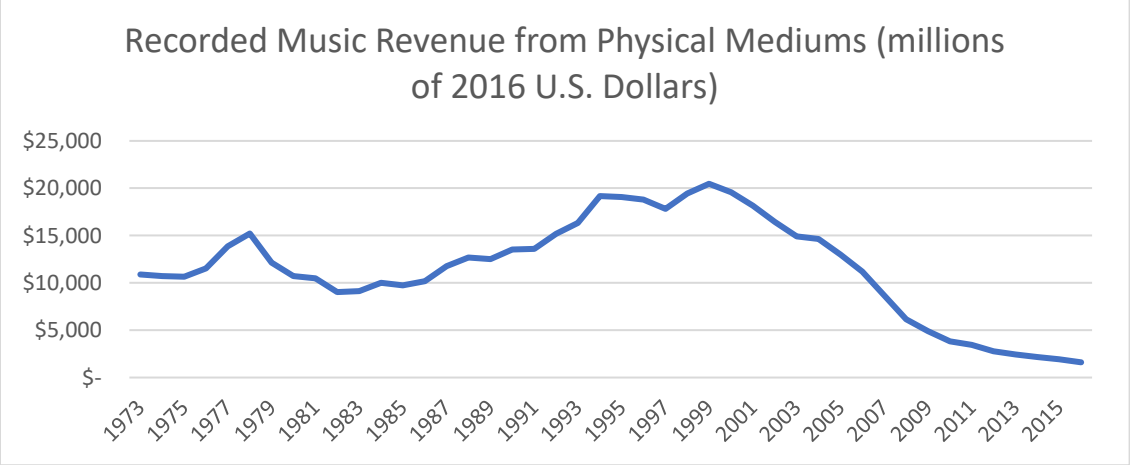
APPENDICIES

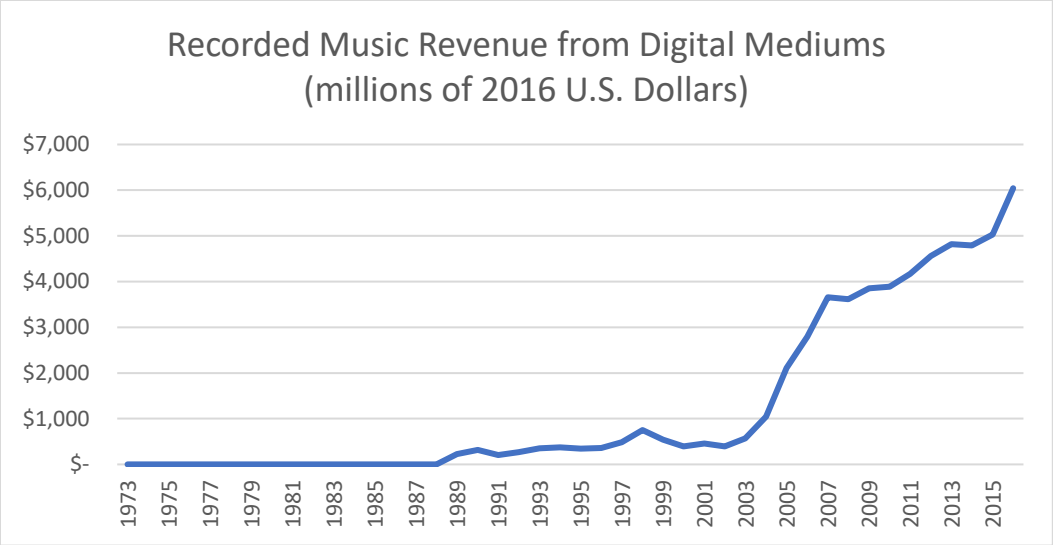
APPENDIX A

Graphical Representation of Data 1973-2016








Recorded Music Revenue from Digital Mediums
(millions of 2016 U.S. Dollars)
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
1973
1975
1977
1979
1981
1983
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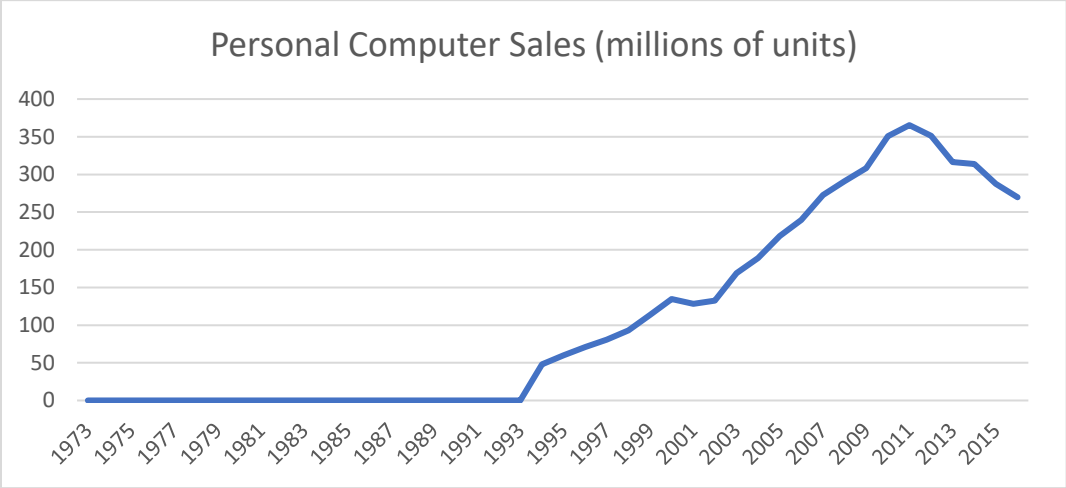
2007
2009
2011
2013
2015


Personal Computer Sales (millions of units)
400
350
300
250
200
150
100
50
0
1973
1975
1977
1979
1981
1983
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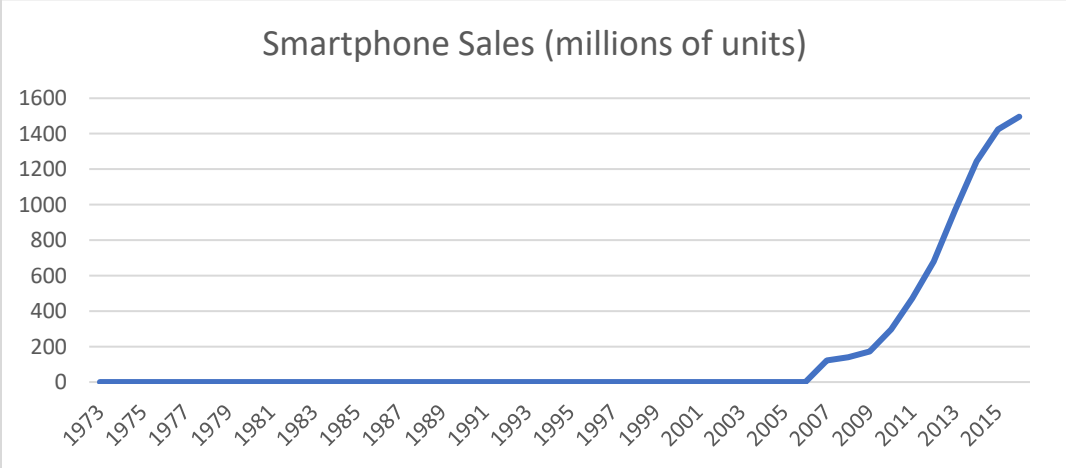
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015


Smartphone Sales (millions of units)
1600
1400
1200
1000
800
600
400
200
0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

APPENDIX B

Table B.1

Effects on Digital Recorded Music Revenue

Variables	(2)
PhysRev	-.133 (.039)***
Income	.177 (.079)**
Pop	193.343 (82.729)**
Time	-452.977 (209.091)**
Burner	-433.797 (336.135)
Napster	-691.739 (361.971)*
Limewire	-48.956 (293.868)
PirateBay	-626.373 (520.259)
Walkman	-352.724 (354.608)
MP3	-383.97 (321.341)
iPod	-777.11 (349.739)**
PC	2.448 (3.574)
Smartphone	.592 (.474)
Constant	849,798 (394614.7)**
R^2	.9822
F-stat	127.30
n	44

(*) $\rho < 0.1$
(**) $\rho < 0.05$
(***) $\rho < 0.01$

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