

Lonnie K. Stevans
Associate Professor
Department of BCIS/QM
Zarb School of Business
134 Hofstra University
Hempstead, NY 11549-1340
Home: 631 598-8518
Office: 516 463-5375
Fax: 631 264-0730
E-Mail: acslks@hofstra.edu

David N. Sessions
Associate Professor
Department of BCIS/QM
Zarb School of Business
134 Hofstra University
Hempstead, NY 11549-1340
Home: 516 676-2123
Office: 516 463-5719
E-Mail: david@sessionsdp.com

An Empirical Investigation into the Effect of Music Downloading on the Consumer Expenditure of Recorded Music: A Time Series Approach

Abstract

The downloading of music from the internet has been proliferating over the past three years. The recording industry believes that this phenomenon is responsible for the decline in recorded music sales since the year 2000 and to a certain extent; this is supported by consumer surveys and previous studies that have used panel or cross-sectional data. In this analysis, an econometric, time-series model of consumer spending on tapes, LPs, and CDs is estimated which takes into account factors that are posited as effecting the consumption of recorded music, but not used in previous studies. The most significant finding is that music downloading, subsequent to 2000, affects consumer spending on tapes, LPs, and CDs through the price elasticity of demand. Falling DVD prices have also served to reduce the demand of recorded music during this same period.

Introduction

The downloading of music from “peer to peer” file-sharing networks has increased dramatically since the advent of Napster in 1999. It was estimated that in 2003 three billion MP3 files were downloaded each month.¹ Coincidentally, sales of cassette tapes, LPs, and CDs have also “suffered” since 2000. We state, “coincidentally,” because the empirical evidence is sparse as to the cause and nature of these lagging sales. The Recording Industry of America (RIAA) believes that downloads and piracy are the major reasons why, according to their stated statistics, the dollar value of music shipments of cassette tapes, LPs, and CDs, fell 4.5 percent in 2001 and 8.1 percent in 2002.² However, if one uses a different data source and formula to calculate the growth rates, spending on tapes, LPs, and CDs by consumers declined in 2001 and 2002 by an average quarterly rate of .8 and .56 percent, respectively.³

The problem with this diverse information lies in the frequency and type of data that is used to compute the relevant statistics. In this paper, an economic analysis of recorded music consumption will be approached from an economic perspective by accomplishing two objectives: first, we use data from the U.S. Bureau of the Census, National Income and Product Accounts (NIPA), which is a non-industry and reputable source; and second, we will attempt to ascertain the factors that have been responsible for waning recorded music sales by positing and estimating an econometric demand model of consumer spending on tapes, LPs, and CDs using quarterly data from 1990 to 2004. Most of the data were downloaded from www.haverselect.com. Variable descriptions

¹ Willcox, James K., Where Have All the CDs Gone? **Sound and Vision**, June 2003, p. 87.

² RIAA, 2002 Yearend Statistics, http://www.riaa.com/news/marketingdata/pdf/year_end_2002.pdf.

³ U.S. Bureau of the Census, National Income and Product Accounts, Personal Consumption Expenditures by Type of Expenditure, www.haver.com. We calculate growth rates as a one period percent change and then average them over the four quarters to get the average annual rate.

and the associated descriptive statistics may be found in Appendix I and Table I, respectively.

[Insert Table I Here]

Discussion

There has been a number of issues raised and quite a bit of controversy generated over the past few years regarding the initiation of the peer-to-peer file-sharing networks. The recording industry is strident in its assertion that downloading copyrighted music is the main cause of declining recorded music sales, especially CDs. In a survey by Peter D. Hart Research Associates in May 2002 of 860 consumers who downloaded music in the last six months, 41 percent reported buying less music. Moreover, the RIAA's Table of Yearend Statistics, 2002 indicates a 4.1 percent decline in the total dollar value of all formats between 2000-2001 and an 8.2 percent drop between 2001-2002.

Zentner (2003) uses two data sources, aggregate music sales by country between 1997 and 2002 and a European cross-section of 15,000 people from October 2001, to examine the effect of music downloading on music sales. Using a panel dataset, he finds that there is a large impact of piracy on music sales. Utilizing an instrumental variables approach on the cross-sectional data, Zentner (2003) also finds that the downloading of MP3 files reduces the probability of buying music by 30 percent. Finding similar results, Peitz and Waelbroeck (2003) discovered that music downloading has resulted in a ten percent decline in 2001 CD sales. They estimate an OLS regression for $n = 16$ countries over a two year period, 2000-2001, using the number of CDs sold as the dependent variable and GDP, MP3 downloads, broadband, and sale of CD players as the explanatory variables.

We believe that there are problems with these and other previous studies that have attempted to assess the role of downloading music on recorded music sales, (Liebowitz (2003), Hui and Png (2003)). None of these studies used price as an explanatory variable. Liebowitz (2003) states that the prices of CDs have been constant over recent years, but the RIAA's own statistics show that CD prices have risen from \$14.31 in 1998 to \$17.09 in 2002—an increase of 19.4 percent over the five year period.⁴ It is our contention that omitting price in a model predicting music sales would lead to serious misspecification error. Another source of misspecification error would be a failure to account for the price of substitutes and/or complements, e.g., the increasing competition resulting from DVDs and videogames. U.S. consumers spent \$7 billion on computer games in 2002 and at least one third of all households have a DVD player. There is not much of a price difference between DVDs and CDs, therefore it is certainly plausible that consumers may prefer a newer format that offers not just music (DVD audio) but also video that can include many additional options. Finally, while the estimation of econometric models of cross-sectional and panel data is useful, it is also important to examine the empirical issues concerning music downloading utilizing data that is time series, since many of the assertions made by the RIAA and the recording industry are based on statistics that are calculated using time series data.

Model Specification

It is clear that no matter what data is used, recorded music sales have been falling since 2000. In Figure 1, consumer spending on tapes, LPs, and CDs, (from the National Income and Product Accounts), is depicted. The change in trend after 2000 from positive to negative is clearly evident. A simple trend-growth model with a piecewise break at

⁴ Willcox, James K., Where Have All the CDs Gone? **Sound and Vision**, June 2003, p. 88.

year 2000 is fit to the recorded music series (Table II). Prior to 2000, the growth in consumer spending on recorded music was 2.3 percent. However, after 2000, the growth rate was -1.1 percent. What is the cause of this decline? Indeed, part of this change in trend could be due to the proliferation of broadband usage which enabled the surge in music downloading since 2000. Over 10 percent of U.S. households subscribed to broadband in 2001--in 2000 it was five percent.⁵ An MP3 that is downloaded in 12 minutes with a standard dial-up connection would take 20 seconds with a household broadband connection (Zentner (2003)).

[Insert Figure 1 Here]

[Insert Table II Here]

The advent of music downloading could have influenced the consumption of recorded music by changing the price elasticity of demand. For example, prior to 2000, the price index for tapes, LPs, and CDs was declining by an average annual rate of -.35 percent, while subsequent to 2000, this growth turned positive: .37 percent. We could argue that if demand became more price elastic (or less price inelastic) after 2000, then this could be due to the substitute good, music downloading, becoming more profuse after 2000.⁶ Thus, higher prices for CDs during this period would lead to a larger percentage decline in the quantity of recorded music purchased.

There are other factors, such as income and the prices of substitutes and complements, which may have had an effect on recorded music purchases. Consumers are purchasing more videogames and DVDs than ever before. One hypothesis is that the decline in recorded music purchases is a direct result of the growth in videogame and

⁵ Vanston, Lawrence K., Residential Broadband Forecasts. **Technology Futures, Inc.**, 2002.

⁶ We would like to thank one of the referees for pointing this out.

DVD sales since 2000.⁷ Of course, this depends upon the nature of the substitute relationship that exists between videogames, DVDs, on one hand and recorded music purchases, on the other. We might expect both videogames and DVDs to be strong net substitutes for recorded music after 2000, that is, decreases in the price of a DVD or videogame would be associated with a decrease in recorded music purchases (*ceteris paribus*). It is important to note that using our data (see Appendix I), the price of computer software and DVDs has declined by 2.0 and 1.3 percent, respectively, since 2000. In order to capture the nature of this relationship, we used the price index of computer software and the unit price of DVDs as predictors of real consumer spending on recorded music. The price index of software is used as a proxy for the price of videogames, since quarterly data on the latter is not available. Finally, we also included disposable personal income as an explanatory variable in order to capture changes in the economy.

Music downloads may not be the primary cause of declining sales in the music recording industry. The issue of whether it is the *major* cause is an empirical question, and one to which we will now address.

In an attempt to incorporate all of the factors mentioned above, the following equation models personal consumption spending on cassette tapes, LPs, and CDs,

$$\begin{aligned}
 RTD_t = & \beta_0 + \beta_1 TIME + \beta_2 DPI_t + \beta_3 PRICE_t + \beta_4 PRICE_SOFT_t \\
 & + \beta_5 PRICE_DVD + \beta_6 (TIME - 40) \cdot D_t + \beta_7 DPI_t \cdot D_t \\
 & + \beta_8 PRICE_t \cdot D_t + \beta_9 PRICE_SOFT_t \cdot D_t \\
 & + \beta_{10} PRICE_DVD_t \cdot D_t + \varepsilon_t,
 \end{aligned} \tag{1}$$

⁷ Between 2000 and 2004, DVD and software sales have increased 10.4 and 2.9 percent, respectively.

where,

RTD_t	- log of consumer spending on cassette tapes, LPs, and CDs,
DPI_t	- log of disposable personal income,
$PRICE_t$	- log of chained price index of tapes, LPs, and CDs,
$PRICE_SOFT_t$	- log of chained price index of software,
$PRICE_DVD_t$	- per unit price of DVDs,
$TIME$	- time trend,
$D_t = 0$	when $TIME \geq 40$ (2000Q1)
$= 1$	when $TIME < 40$

The variable, D_t , represents the period throughout which the downloading of music increased dramatically (2000Q1–2004Q3). In the interaction, $(TIME - 40) \cdot D_t$, $TIME = 40$ corresponds to the first quarter of the year 2000 and the term in the equation $-40 \cdot \beta_6$ represents the necessary shift in the intercept term after 2000. $PRICE_DVD$ was not logged since it contained zeroes. As mentioned previously, DPI_t , disposable personal income, is incorporated to capture changes in economic activity. RTD_t and DPI_t have been deflated by their appropriate chained price index, so they are expressed in “real” quantities.

If there is no structural change in the demand function after 2000, then we would fail to reject the null hypothesis,

$$H_0 : \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = 0. \quad (2)$$

Otherwise, we would have to inspect the nature and magnitude of the parameter shifts. Inspection of Figure 1 reveals that the type of downward adjustment that occurred in

recorded music sales was a change from a positive trend before 2000 to a negative trend after 2000. This change is captured in equation (1) by the interaction term, $(TIME - 40) \cdot D_t$, and the parameter, β_6 , measures just how much less the slope of the trend line was after 2000, e.g.,

$$\begin{aligned}\beta_{TIME < 212} &= \beta_1 && \text{when } D_t = 0, \\ \beta_{TIME \geq 212} &= \beta_1 + \beta_6 && \text{when } D_t = 1.\end{aligned}\tag{3}$$

There are four remaining interactions in equation (1), which are represented by the last four terms. They represent the interaction of each explanatory variable with the dummy variable, D_t , that symbolizes the period of music downloading. These terms are included in order to determine whether there were any structural changes in the parameters of the explanatory variables over the period 2000 to 2004. For example, one of the explanations given earlier had to do with the effect of rising prices on music consumption. We would expect the relationship between price and quantity demanded to be inverse both before and after 2000. Of course, one of the empirical questions is what happened to the elasticity of demand, e.g.,

$$\begin{aligned}\beta_{PRICE, TIME < 212} &= \beta_3 && \text{when } D_t = 0, \\ \beta_{PRICE, TIME \geq 212} &= \beta_3 + \beta_8 && \text{when } D_t = 1.\end{aligned}\tag{4}$$

Since it is assumed that $\beta_3 < 0$, if $\beta_8 < 0$, then demand is more elastic (or less inelastic) after 2000 due to the increased availability of the substitute good, music downloading. We will discuss the remaining interaction terms in the empirical results section below.

Estimation

The estimation of equation (1) is more difficult than it seems because of two problems:

1. The postulation of the classical regression model requires that all variables be stationary, e.g., all are $I(0)$, or integrated of order zero,
2. The explanatory variables may not be exogenous variables and therefore may be correlated with the error term.

Problem (1) requires that all variables be cointegrated, or that a linear combination of them is stationary. If so, then equation (1) may be referred to as the cointegrating relationship and the estimated parameters as the cointegrating vector. Ignoring the problems posed by (1) leads to what is known as a “spurious” regression (Granger and Newbold (1974)). A “spurious” regression will have t-statistics that are significant and high R-squares, yet the relationships among the variables are meaningless.

The question is whether the variables, RTD_t , DPI_t , $PRICE_t$, $PRICE_SOFT_t$, and $PRICE_DVD_t$ are cointegrated in the presence of a break in trend, $TIME \cdot D_t$. Since it is known that the standard procedures for detecting cointegration are not appropriate in the presence of structural change (Saikkonen and Lutkepohl (2000a)), we will use a method that has been proposed by Saikkonen and Lutkepohl (2000b). These authors suggest to first estimate the deterministic components (dummy variable, trend), subtract them from the original series, and then utilize any of the multivariate, maximum likelihood tests for cointegration (Johansen (1988), Stock and Watson (1988)).⁸ Following this procedure,

⁸ Each variable was first tested for a unit root using Perron’s (1989) test of structural change. Results will be made available upon request from the authors.

we created the “adjusted” series w_{1t} and \bar{w}_{2t} prior to conducting the multivariate cointegration test,

$$\begin{aligned} w_{1t} &= RTD_t - \hat{\beta}_0 - \hat{\beta}_1 TIME - \hat{\beta}_6 (TIME - 40) \cdot D_t - \hat{\beta}_2' D_t \bar{X}_t, \\ \bar{w}_{2t} &= \bar{X}_t - \hat{\mu}_0 - \hat{\mu}_1 TIME - \hat{\kappa} (TIME - 40) \cdot D_t, \end{aligned} \quad (5)$$

where,

$$\bar{X}_t' = (DPI_t, PRICE_t, PRICE_SOFT_t, PRICE_DVD_t)',$$

$\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_6$ are estimated parameters and $\hat{\beta}_2', \hat{\mu}_0, \hat{\mu}_1, \hat{\kappa}$ are all estimated parameter vectors. All five equations denoted in (5) above were estimated using OLS (Ordinary Least Squares).

Using $\bar{w}_t' = (w_{1t}, \bar{w}_{2t})'$ from the above estimated model, \bar{w}_t is a VAR(2) with ECM representation,

$$\Delta \bar{w}_t = \Pi \bar{w}_{t-1} + \Delta \bar{w}_{t-1} + \bar{\varepsilon}_t, \quad (6)$$

and the Johansen procedure (Johansen (1988)) is used to test for the rank of Π and thus the presence and order of cointegration among the variables.⁹

The results of the maximum eigenvalue cointegration test are in Table III. We reject the null hypothesis of no cointegration in favor of the alternative of exactly one cointegrating vector. Thus, we can safely assume that our results are not spurious and proceed to estimate equation (1) taking into account the endogeneity issues raised in problem (2) above.

[Insert Table III Here]

⁹ VAR is *Vector Autoregressive Model* and ECM is *Error Correction Model*. The lag order ($p = 4$) is chosen optimally in the program, EViews 5.

If any of the explanatory variables are correlated with the error term in equation (1), then it well known that OLS estimators are both biased and inconsistent. In this case, the fully modified least squares procedure, (Phillips and Hansen (1990)), should be used to adjust for endogeneity by including both leads and lags of the first differences of each explanatory variable in equation (1). Essentially, this would “purge” the potential correlation between any of the explanatory variables and the error term in the equation by controlling for innovations in the explanatory variables. In order to examine the endogeneity issue and concomitantly whether we should include the leads and lags in equation (1), the following null hypothesis was tested,

$$H_0 : \bar{\gamma}_1 = \bar{\gamma}_2 = \bar{\gamma}_3 = 0,$$

where,

$$\begin{aligned} RTD_t = & \beta_0 + \beta_1 TIME + \beta_2 DPI_t + \beta_3 PRICE_t + \beta_4 PRICE_SOFT_t \\ & + \beta_5 PRICE_DVD + \beta_6 (TIME - 40) \cdot D_t + \beta_7 DPI_t \cdot D_t \\ & + \beta_8 PRICE_t \cdot D_t + \beta_9 PRICE_SOFT_t \cdot D_t \\ & + \beta_{10} PRICE_DVD_t \cdot D_t + \bar{\gamma}'_1 \Delta \bar{X}_{t+1} + \bar{\gamma}'_2 \Delta \bar{X}_t + \bar{\gamma}'_3 \Delta \bar{X}_{t-1} + \varepsilon_t, \end{aligned} \quad (7)$$

and, as before, $\bar{X}'_t = (DPI_t, PRICE_t, PRICE_SOFT_t, PRICE_DVD_t)'$. We found that we could not reject this null hypothesis, so we estimated equation (7) controlling for serial correlation and without the last three terms, $\Delta \bar{X}_{t+1}, \Delta \bar{X}_t, \Delta \bar{X}_{t-1}$. The results of this test and the regression estimates may be found in Table IV.

[Insert Table IV Here]

Empirical Results

It is clear that there has been structural change in the demand for recorded music subsequent to the year 2000. Testing of hypothesis (2) above has prompted us to reject the null hypothesis of no structural change (see Table IV).

Prior to 2000, the coefficient on *TIME* indicates a 2.3 percent growth rate in the consumption of recorded music. This is not different from the results of the simple trend-growth model (Table II). However, after 2000 and controlling for the other factors that influence the demand for recorded music, the growth is .77 percent--which is different from the rate estimated using the simple trend-growth model found in Table II (-1.1 percent).¹⁰ In other words, the *adjusted* growth in the consumption of recorded music is actually larger than it would be in the absence of the other variables that influence demand, such as income and the prices of substitute and/or complementary goods. As mentioned previously, this time trend could be representative of the proliferation of broadband usage, or it could be capturing the affects of other omitted explanatory variables that change over time. Notwithstanding this, it is clear from these results that, *ceteris paribus*, the consumption of recorded music has actually increased modestly since 2000.¹¹

Since the actual growth in the demand for recorded music is negative, the question remains as to what has contributed to this decline? As discussed previously, the latent variables contributing to the trend did not force a negative growth rate, *ceteris paribus*, so it must be that music downloading and some of the remaining explanatory variables in the model have all contributed to the decline. We find that the advent of music downloading after 2000 has reduced the demand for recorded music through its

¹⁰ As a reminder, $\hat{\beta}_{TIME \geq 212} = \hat{\beta}_{TIME < 212} + \hat{\beta}_6$.

¹¹ The coefficients of the logged variables are interpreted as elasticities, e.g., a one percent change in "X" is associated with a $\hat{\beta}_j$ percent increase in "Y." The coefficients of the non-logged variables, such as

the time trend and dummy variables, must first be converted using the formula: $100(e^{\left(\hat{\beta}_j - \frac{Var(\hat{\beta}_j)}{2}\right)} - 1)$ before they may be interpreted as the percent change in "Y" for a unit change in "Y" (Halvorsen and Palmquist (1980) and Kennedy (1981)).

influence on price elasticity (see Table V). Prior to 2000, the price elasticity of demand for recorded music was inelastic: -.64 percent. However, since music downloading is a substitute for recorded music, after 2000 this price elasticity yielded an elastic response: -1.4 percent. Thus, due to the increased availability of the substitute good, downloaded MP3s, a one percent increase in the price of recorded music after 2000 was associated with a more than proportionate decline in the quantity purchased--decreasing consumption and sales.

[Insert Table V Here]

Although music downloading has reduced recorded music consumption after 2000, our results also indicate that DVDs are a strong substitute for tapes, LPs, and CDs. A one percent decline in the price of DVDs is associated with a 2.1 percent decline in the demand for recorded music. As can be seen in Table V, this elasticity coefficient is the largest. However, the price of software after 2000 is no more a substitute for recorded music as it was prior to 2000—the coefficient on the interaction term is statistically insignificant (Table IV). This unexpected result may be due to the fact that we are using the price of computer software as a proxy for the price of videogames.¹²

Conclusion

It is a plausible tenet that the advent of music downloading and lower prices for DVDs and software all served to reduce the consumption of tapes, LPs, and CDs after the year 2000. As mentioned previously, consumer purchases of DVDs and videogames

¹² It should be noted that videogame sales and quantity data were available, but only annually from the Interactive Digital Software Association. In order to see whether the results would change substantially, the above regression was estimated using the price of videogames imputed from annual to quarterly values. The estimated coefficients and their associated statistical inferences did not change substantially. The elasticity coefficient for the price of videogames was negative (a complement), but statistically insignificant. Results will be made available upon request from the authors.

have really “taken-off” since 2000. In the same vein, the price of CD, tapes, etc. is also an important determinant of what consumers will spend on these music formats. Prior to 2000, it has the largest effect with an elasticity coefficient of -.64 percent and it has the second largest effect with an elasticity of -1.4 percent after 2000. It does appear that more of the substitute good, music downloading, has reduced spending on recorded music more than proportionately after 2000 by changing the “slope” of the demand curve.

The empirical evidence presented in this paper does support the assertion that the proliferation of peer-to-peer file sharing networks since 2000 has led to a decline in music format sales, **but it is neither the primary nor the only cause of this decline.** The price of DVDs has the largest elasticity coefficient after 2000. The results of this study actually delineate a paradox created by music downloading. Further legal restrictions and interference with consumers who make use of these networks to download music would reduce the price elasticity of demand for recorded music, making it easier for music suppliers to increase prices and sales. However, there is no reason to expect that the introduction of *legal* music downloading services would not affect the price elasticity for recorded music in the same way, albeit there is a price charged for the service. According to our results and from the music suppliers’ point of view, the optimal policy would be to discourage *all* music downloading if the recording industry wants to protect recorded music sales. On the other hand and from an alternative perspective, consumers would reap benefits from a market for music formats that exhibited price stability, diffused technological change and was more attuned to changing tastes and preferences.

References

- Elliot, G., T. Rothenberg, and J.H. Stock. *Efficient Tests for an Autoregressive Unit Root*, **Econometrica**, 64, 1996, pp. 813-839.
- Granger, Clive, and Paul Newbold. *Spurious Regressions in Econometrics*, **Journal of Econometrics**, 2, 1974, pp. 111-120.
- Halvorsen, R. and P. Palmquist. *The Interpretation of Dummy Variables in Semilogarithmic Equations*, **American Economic Review**, 70, 1980, pp. 474-475.
- Hart, Peter D. and Associates, **Survey for RIAA**, May 2002
- Hui, Kai-Lung and I.P.L. Png. *Piracy and the Legitimate Demand for Recorded Music*, **Contributions to Economic Analysis and Policy**, 2(1), 2003, Article 11.
- Johansen, Soren. *Statistical Analysis of Cointegration Vectors*, **Journal of Economic Dynamics and Control**, 12, June-September 1988, pp. 231-254.
- Kennedy, P. *Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations*, **American Economic Review**, 71, 1981, p. 801.
- Leibowitz, Stan. *Will MP3 Downloads Annihilate the Record Industry? The Evidence So Far*, **Advanced in the Study of Entrepreneurship, Innovation, and Economic Growth**, Gary Libecap, ed., JAI Press, 2003.
- Peitz, Martin and Patrick Waelbroeck. *The Effect of Internet Piracy on CD Sales: Cross Section Evidence*, **Working Paper**, November 2003.
- Perron, Pierre. *The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis*, **Econometrica**, 57, November 1989, pp. 1361-1401.
- Phillips, Peter, and Bruce Hansen. *Statistical Inference in Instrumental Variables Regression with $I(1)$ Processes*, **Review of Economic Studies**, 57, 1990, pp. 99-125.
- Recording Industry Association of America, **Yearend Statistics**.
http://www.riaa.com/news/marketingdata/pdf/year_end_2002.pdf, 2002.
- Saikkonen, Pentti, and Helmut Lutkepohl. *Testing for the Cointegrating Rank of a VAR Process with Structural Shifts*, **Journal of Business and Economic Statistics**, 18(4), October 2000, pp. 451-464

References (Continued)

- Saikkonen, Pentti, and Helmut Lutkepohl. *Trend Adjustment Prior to Testing for the Cointegrating Rank of a VAR Process*, **Journal of Time Series Analysis**, 21(4), July 2000, pp. 435-456.
- Stock, James, and Mark Watson. *Testing for Common Trends*, **Journal of the American Statistical Association**, 83, December 1988, pp. 1097-1107.
- Vanston, Lawrence K. *Residential Broadband Forecasts*, **Technology Futures, Inc.**, Austin, TX: 2002.
- Wilcox, James K. *Where Have All the CDs Gone?* **Sound and Vision**, June 2003, pp. 87-89.
- Zentner, Alejandro. *Measuring the Effect of Online Music Piracy on Music Sales*, **Working Paper-Preliminary Version**, University of Chicago, 2003.

Appendix I – Data Sources

All data was downloaded from <http://www.haverselect.com> except for PRICE_DVD

RTD	Consumer Spending on Cassette Tapes, LPs, and CDs, (Millions of Chained 2000 \$)
DPI	Disposable Personal Income, (Billions of Chained 2000 \$)
PRICE	Chained Price Index of Cassette Tapes, LPs, and CDs, (Index, 2000=100)
PRICE_SOFT	Chained Price Index of Software, (Index, 2000 \$)
PRICE_DVD	Average Price of DVDs (Per Unit Price, \$, http://www.riaa.com/news/newsletter/pdf/2003yearEnd.pdf)

Figure 1

Consumer Spending on Tapes, LPs, and CDs

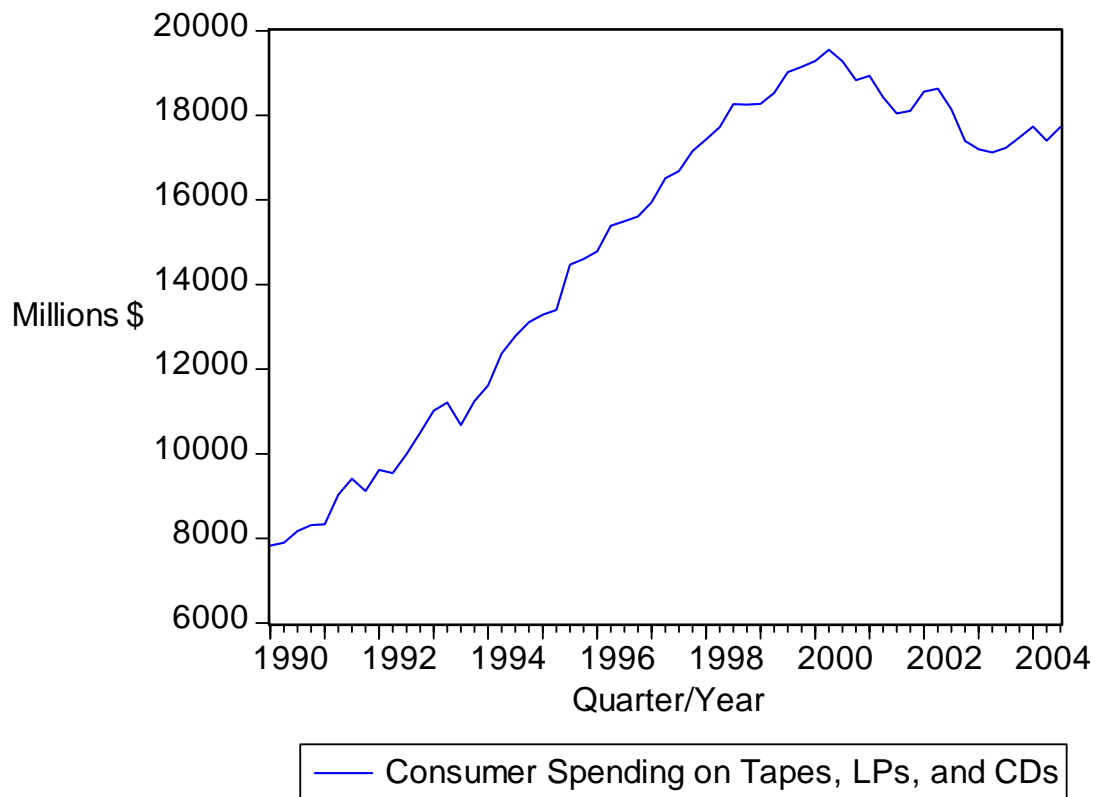


Table I

Descriptive Statistics
(not in natural logs)

	RTD (Mil\$)	DPI (Bi\$)	PRICE	PRICE_SOFT	PRICE_DVD
Mean	14862.32	6450.249	104.2614	283.4590	10.81297
Median	16514.00	6251.900	105.6180	144.6980	0.000000
Maximum	19551.00	7990.100	110.3330	885.5130	26.52000
Minimum	7829.000	5306.600	97.10800	72.83700	0.000000
Std. Dev.	3806.871	877.1197	4.026139	248.4308	11.93853
Observations	59	59	59	59	59

Variables are explained in Appendix I.

Table II
Simple Trend-Growth Model

Dependent Variable: RTD

Sample (adjusted): 1990Q1 2004Q3

Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.000757	0.083887	59.61278	0.0000
TIME	0.023226	0.000434	53.56407	0.0000
DOWN_MUSIC*(TIME-212)	-0.034598	0.001489	-23.22847	0.0000

Table III
Johansen Cointegration Test
Max-Eigenvalue

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.472549	35.82311	30.43961	0.0097
At most 1	0.333109	22.68716	24.15921	0.0781
At most 2	0.264327	17.19033	17.79730	0.0615
At most 3	0.085939	5.032038	11.22480	0.4728
At most 4	0.028763	1.634334	4.129906	0.2361

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Table IV

Regression Model

$$H_0 : \bar{\gamma}_1 = \bar{\gamma}_2 = \bar{\gamma}_3 = 0$$

F-statistic = 1.0026

Prob(F-statistic) = .4675

$$H_0 : \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = 0$$

F-statistic = 2.4711

Prob(F-statistic) = .0456 **

Dependent Variable: RTD (Consumer Spending on Records, Tapes, and CDs)**Sample (adjusted): 1990Q2 2004Q3****Included observations: 58 after adjustments**

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	13.31244	2.260127	5.890132	0.0000*
TIME	0.022524	0.003124	7.210982	0.0000*
LOG_DPI	0.591679	0.305287	1.938107	0.0526***
LOG_PRICE	-0.638012	0.229656	-2.778115	0.0055*
PRICE_SOFT	0.000168	7.68E-05	-2.189870	0.0285**
PRICE_DVD	1.52E-05	0.000252	0.060170	0.9520
DOWN_MUSIC*(TIME-212)	-0.014797	0.005542	-2.670026	0.0076*
DOWN_MUSIC*LOG_DPI	0.326594	0.131816	2.477649	0.0132**
DOWN_MUSIC*LOG_PRICE	-0.759862	0.260814	-2.913427	0.0036*
DOWN_MUSIC*PRICE_SOFT	0.000470	0.003360	0.139917	0.8887
DOWN_MUSIC*PRICE_DVD	0.020830	0.010032	2.076227	0.0379**
AR(1)	0.568426	0.114039	4.984492	0.0000*
R-squared	0.995784	F-statistic	661.2613	
Adjusted R-squared	0.994278	Prob(F-statistic)	0.000000	
S.E. of regression	0.021154			
Durbin-Watson stat	2.108511			

* - statistically significant at .01 level

** - statistically significant at .05 level

*** - statistically significant at .10 level

Table V
Elasticity Coefficients

Variable	Prior to 2000	After 2000
TIME	2.30 %	.77 %
DPI	.59 %	.92 %
PRICE	- .64 %	-1.40 %
PRICE_SOFT	.02 %	.02 %
PRICE_DVD	0	2.10 %