Econometric Analysis of Price Index for Home Video Cassette Recorders in the U.S., 1978-1987

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Abstract

This paper conducts an empirical analysis on the U.S. VCR market using a hedonic approach. The paper finds that quality-adjusted price indexes decline at 11-12% per year, with a large annual drop of about 18% from 1982-85. Estimation and data analysis reveal interesting aspects of the evolution of quality and price in the VCR market. Finally the paper estimates a bias of 3.2% per year in the BLS CPI of the *Appliance Including Consumer Electronics* category due to not having priced VCRs until 1986.

Keywords: Home Video Cassette Recorders; Price Index; Hedonics; Panel Data

JEL Classification: C23, C43, and L68.

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1 INTRODUCTION

The home video cassette recorder (hereafter VCR) is an evolving new technology that has gained huge popularity worldwide. In the U.S., the first VCR machine was introduced in 1976 (in Betamax format). Subsequently VCR sales climbed steadily until 1986, notwithstanding the recession of 1981-82. VCR sales almost doubled to 4.8 million units in 1983 alone, and had reached 9.4 million units a year later. VCR sales peaked in 1986, and now more than 80% of the U.S. households have at least one VCR machine.

This paper estimates hedonic equations to construct quality-adjusted price indexes, based on the unique dataset collected by the author. This exercise produces two useful results. First, together with data analysis, it provides information on the relative quality levels of different VCR formats and how quality evolved over time. Contrary to common perceptions, the Beta format was not superior to VHS in major characteristics dimensions. Second, the analysis measures the magnitude of the bias in the BLS CPI of the *Appliance Including Consumer Electronics* attributable to excluding VCRs over 1978-86. By 1987, when the BLS included VCRs in the CPI basket, over 40 million Americans already owned VCRs at home. Many critics contend that a long delay in the introduction of new products into the CPI leads to an upward bias in the index. The CPI commission, appointed by the Senate Finance Committee, has found an upward bias of 0.6% per year in the CPI because of the neglect of new goods and unmeasured quality change. The category contributed the most to the bias was the *Appliance Including Consumer Electronics* category, in which VCRs are classified.

There are some empirical work related with this paper. Gordon (1990) uses data taken from *Consumer Reports* (*CR*) and measures how much U.S. VCR prices declined from 1980 to 1985 by comparing prices of similar models across the period. He classifies VCRs into two types based on a few characteristics identified in *CR*, and tracks prices of the same type over time. Many models, not falling into his categories, are not included in his sample. This paper greatly expands Gordon's data set in terms of the coverage of models and the dimensions of characteristics. I compare my results with Gordon's and discuss the merit of my data set. Liegey and Shepler (1999) employ hedonic analysis using the *CR* data of 1997. They look at the period when the U.S. VCR market was already matured. The official CPI is found not much different from their quality-adjusted index. It is unlikely that their result extends to the period in which most of the technical development happened along with the severe competition between VHS and Beta. This paper analyzes the bias in the CPI due to the long lag of the new product introduction into the index.

The rest of the paper is organized as follows. Section 2 summarizes the VCR industry. Section 3 explains how the price and characteristics data are constructed from various sources. Section 4 describes hedonic estimation and results. A specification incorporating age, brand, and time

dummy variables is chosen using a log-likelihood criterion. Alternative specifications with vintage dummy variables, weighted regression by market share, and network externalities are also discussed in Section 4. Based on the hedonic estimates, Section 5 presents the resulting quality-adjusted price indexes obtained under different assumptions. The quality-adjusted price indexes decline at 11-12% per year, with a particular drop of about 18% from 1982 to 1985. Section 5 also speculates on plausible causes of the 1982-85 price drop with an emphasis on supply-side explanations. It is observed that a sharp drop in VCR unit cost as well as an increase in the number of brand suppliers would account for the price drop. The BLS included VCRs in the CPI in January 1987, long after the introduction in the U.S. market. Section 6 examines a possible bias in the BLS estimate of the *Appliance Including Consumer Electronics* index in 1978-86 by not having priced VCRs until 1987. The upward bias is estimated to be about 3.2% per year. Section 7 concludes.

2 OVERVIEW OF THE VCR MARKET, 1978-87

Today's VCRs were invented by Japanese firms, whose basic technology came from the United States. The Japanese succeeded in downsizing broadcasting video tape recorders developed by the U.S. company, Ampex, and applying these to home use in the 1960s. Two different and incompatible formats had emerged as dominant: Betamax and VHS. Both formats used azimuth helical scanning technique, although for VHS, the effective relative recording speed was 5.8 meters per second, instead of Beta's 6.9 meters. The most prominent differences between the two formats were cassette construction and tape drive mechanisms. The Beta cassette, smaller than the VHS cassette, only played on a Beta machine, and the VHS cassette only on a VHS machine (For more technical details, see Buchsbaum (August 1978)).[1]

Betamax was introduced into the U.S. market in 1976,[2] and VHS was launched less than two years later. Both formats sold under either Japanese brands or U.S. brands, but all the U.S. brands came through Original Equipment Manufacturer (OEM) supplies from Japanese firms. For example, RCA was selling Panasonic VCRs under the RCA brand name in 1978. No U.S. firms have manufactured VCRs to date.

Betamax and VHS were not the only formats in worldwide VCR markets. V-2000, produced by Phillips, was a popular format in Europe. CVC, the first format to make a cassette size almost as

[1] This article focuses on table-top VCRs, which sit close to a television and are not suitable to be moved about. In addition there were three other types of VCRs more or less connected with video photography. Portable-type VCRs are lightweighted and supposed to be carried with a video camera. Dockable or convertible VCRs are similar, except that they can be docked with a tuner-timer portion to make a regular VCR for home use. Finally camcorders (literally a 'camera-cum-recorder') use a smaller video cassette (quarter-inch tape size).

[2] Sony introduced Betamax VCR to the U.S. in 1975, but the purchase was tied with television set. Stand-alone Betamax was introduced in the next year.

small as an audio cassette, was available in Japan. I could not find any evidence of formats other than Betamax and VHS entering the U.S. market in 1978-87.

The VCR market is characterized by a rapid turnover of models. Major VCR companies, however, had a common practice of introducing new VCRs twice a year to display them at the January and June Consumer Electronics Shows. As a result, the average life period of VCR models was less than a year during 1978-87 (The life of a VCR model is on average 10.4 months for major brands whose average market share for the ten years is more than 3.0 %).[3] Frequent model turnover witnessed rapid upgrading of characteristics and significant market growth. One way of summarizing these changes is to look at mean values of VCR attributes over time.

Table 1 lists seven characteristics used in this paper. The first three columns next to price display recording capabilities. The rest are "secondary" features. No doubt these seven characteristics do not cover all the important functions of VCRs. A number of functions, unavailable in a complete form, such as autodubbing, speed scanning, and on-screen programming, were also important attributes in terms of enhancing the convenience and accessibility of VCRs. The number of heads also could give an estimate of VCR quality.[4] Frequency of repairs is another important dimension of new product characteristics that I cannot observe in the data.[5] However, the seven attributes at hand cover the main function of the VCRs in 1978-87, and would highly correlate with the other dimensions of characteristics. The observed characteristics in Table 1 still give us good information on how characteristics evolved over the ten years.

The number of programs indicates how many program times could be preset in a VCR. The number of days shows how many days ahead a model could memorize preset program times. As is seen in Table 1, just one TV program could be set up to 24 hours ahead in 1978. Ten years later, the number of preset programs had increased five times to 5.8 events and the number of days had extended 30 times to 30.7 days. The maximum recording hours in one cassette doubled from 3.2 to 6.5 hours.[6] Actually the length of recording hours is not indeed a function of the VCR itself, but rather a function of the video cassette tape. Some old VCR machines could have actually recorded longer hours than those in Table 1 if video cassette tapes with longer recording capability had been available.[7]

[3] See footnote 22 on the definition of the life of a model.

[4] A problem in the data of the number of heads is that most sources do not mention what they mean by "heads"; either video heads, audio heads or both. Since this classification of heads is important, I do not use the data in this study.

[5] I discuss frequency of repairs in Section 4.

[6] *CR* pointed out in 1980 a trade-off between the quality of the picture and the length of the program. The faster the recording speeds were, the better the picture was. Faster recording speeds, however, resulted in shorter recording hours. A subsequent 1982 *CR* issue, however, mentioned that improvement of VCR machines had resolved this trade-off, and the picture quality no longer varied much with the speed.

[7] The table uses the data on maximum recording hours per cassette when the model was launched in the market.

Regarding remote control availability, initially 75% of VCR models had a wired remote control, instead of no remote. The early corded remote control had only a pause function. As VCRs added more special effects such as freeze motion, speed search and frame-by-frame advance, the available remote control functions increased dramatically. In the meantime wireless infrared remotes appeared in 1981, and all the models had wireless remotes by 1987.

Audio quality had traditionally been poor in TV equipment. With the advent of stereo broadcasts and stereo TV sets, high quality sound became prevalent in VCR specifications. Table 1 includes statistics on high-fidelity sound (hereafter HiFi). HiFi VCR records stereo sound similar to a FM broadcast, so that a tape captures a wider frequency response with lower background noise. HiFi was introduced first on VHS machines in 1982. 67% of the Beta models included this audio function by 1987, while the VHS models achieved about 40%.[8]

"HQ" on the VHS models and "Superbeta" on the Beta format are able to deliver higher quality pictures than other conventional VCR machines through increasing the number of horizontal resolution lines by about 20%. High quality picture system are first observed in 1984, and by 1987, 94% of the VCRs had this system.[9]

There has been a widespread perception that the Beta format was superior to VHS.[10] As is seen in the mean values by format, it is not obvious if this perception is correct. It is true that the Beta format introduced Superbeta first and established it as well as the HiFi system at a much faster rate than VHS did. On the other hand, however, Beta fell behind in recording capabilities. Except for the last two years in the sample, the number of programs for Beta was always fewer than for VHS. Beta could not record as long as two weeks in 1987, whereas VHS achieved two weeks recording in 1985. The maximum recording hours in one Beta cassette was five hours, three hours less than with a VHS cassette in 1986. This observation is also confirmed by looking at frontier models by format, whose characteristics achieve the highest values in each year (Table 2). The frontier model is basically an imaginary model, constructed by putting together the best characteristics across all the models in a year. The frontier Beta models were equal to or behind the frontier VHS in all characteristics dimensions except the available number of programs in 1983 and the picture system

It does not take into account extended recording hours made available later.

[8]There were the other two types of sound systems: Linear stereo system and MTS (Multi-channel TV Sound) decoder. The linear stereo VCR had a problem in being marred by background noise hiss because the stereo VCRs record sound on a narrower strip of tape at slower speed. Dolby noise reduction was known to help just a little. MTS was not yet common as VCR equipment in this period (*CR* (1987)).

[9]Super VHS (so called S-VHS), which came out in late 1987, is classified in HQ. S-VHS was claimed to capture more horizontal lines than HQ, but neither prerecorded tapes nor tapes recorded on non S-VHS models showed any picture improvement on S-VHS machines (*CR* (1988)).

[10]Liebowitz and Margolis (1994) express doubts on this perception. See also references therein. None of them have hard evidence except VCR ratings evaluated by *CR*.

in 1984. Notably after 1985 the frontier VHS was able to program one year ahead, while the frontier Beta achieved just three weeks at most.

The mean nominal price of VCR models first rose and then dropped slightly from 1978 ($793) to 1981 ($782). The price then fell sharply in 1981-85 ($454) and slowly declined subsequently ($425 in 1987). The average percent price change was -6.4% per year, shown in the last column in the table. Except in 1986-87, the average price changes by format were similar (-6.6% for VHS and -6.3% for Beta). What happened to the Beta price in 1987 was that all the Beta brands in the sample except Sony dropped the format. Sony VCR prices were relatively higher than for other Beta machines throughout the period by an average of 41%.

The average annual price change in Table 1, however, probably underestimates the true price decline in the VCR market on account of the substantial characteristics upgrading described above. One useful way of getting a feel for the true price drop is to do hedonic analysis to construct quality-adjusted price indexes. Hedonic analysis basically projects the price onto characteristics space, assuming the characteristics are exogenous. This analysis can be considered as a better approach than a matched model approach, which compares prices of the same models across periods, because the hedonic analysis allows us to compare older and new models under the same framework. Just focusing on the surviving models may still underestimate the true price decline by not correcting for selectivity bias.

I use the nominal price instead of the deflated price in the hedonic analysis, following the tradition of the previous literature. This tradition may come from a general perception that price deflators such as the CPI may be biased due to insufficient consideration of quality improvement in the process of deflator construction. The price deflators may be better constructed by studying hedonic equations for all individual products and services under focus, obtaining quality-adjusted price indexes for each item, and then adding them up with an appropriate weight. Since I do not know the right deflator before conducting the hedonic analysis, it would not be appropriate to use a deflated price on the left-hand side of the hedonic equations. It must be considered a sort of "tautology" to use a deflated price to create quality-adjusted price indexes.

3 DATA CONSTRUCTION

My dataset ranges from January 1978 to December 1987 on a monthly basis. Price data in satisfactory numbers are not available before 1978. I do not collect the data after 1987 mainly because the VCR market looks to be substantially changed around this time. A number of sophisticated VCR functions appeared to be popular toward the end of 1987, such as digital noise reduction, MTS decoder, and index search. Those functions do not exactly fall into my characteristics categories. In view of this consideration, the data set ends in 1987. Throughout the sample covers 829

models/year of 22 brands in total.[11] Frequent turnover of models makes the data set unbalanced.

Price The price data are advertised prices in *New York Times* (*NYT*) and mail order prices in *Sears Catalog*. The advertised data in *NYT* were collected from Sections 1 and 2 on all Sundays in 1978-81, and the last Sunday of each month in 1982-87.[12] Advertised prices in September and October of 1978 are not available due to a strike of *NYT* printmen. Quoted retail VCR prices and brief attribute descriptions of some major brand models were obtained in addition to model names and their brand names. The advertisers were vendors (including discount shops) operating in New York City.[13]

Sears Catalog, a semi-annual mail order pamphlet, started listing VCRs in fall 1978. I assume the VCRs in the spring catalogs were available from February to July, and those in the fall issues were from August to the next January at prices listed in the catalogs.[14] *Sears Catalog* included primarily the Sears brands. The Fall 1987 Catalog started listing RCA and Goldstar VCRs as well as Sears. The total number of collected mail order prices is 476.

An advantage of using advertised and mail-order prices is that the resulting price data closely approximate actual transaction prices. Moreover, unlike personal computers, I do not need to worry much about changes to the "packaged" specification made by vendors or users. It is and was almost impossible to change the packaged combination of VCR characteristics (The only exception may be the availability of a remote control. See footnote 16). A disadvantage of using advertised prices could be that the coverage of the models may be biased toward newer models. It turns out that this is not exactly the case here. Those who advertised in *NYT* were mainly appliance shops, video

[11] The brands in the sample are: Akai, Canon, Emerson, Fisher, GE, Goldstar, Hitachi, JVC, Magnavox, Mitsubishi, Panasonic, Quasar, Radio Shack, RCA, Sharp, Sylvania (all are VHS), NEC (Beta until 1986. VHS since 1985), Sanyo(Beta until 1986. VHS since 1986), Sears (Beta until 1986. VHS since 1983), Sony (Beta), Toshiba (Beta until 1983. VHS since 1986) and Zenith (Beta until 1984. VHS since 1984). The sample covers on average 85% of the market in terms of sales in the ten years.

[12] I collected from all the Sundays for the first three years due to paucity of available data based only on the last Sunday in the month.

[13] I also studied all sections of *Los Angeles Times* and *Chicago Tribune* on the last Sunday of June and July for the ten years. It turned out that neither of them contained much information on VCR products and prices. The number of price quotations is less than a tenth of those in *NYT*, and the advertisements often do not mention model names, but only brand names. The coverage of brands is not much different from that in *NYT*. The model-level information obtained from the two newspapers indicated that the price levels are mostly in the range of those in *NYT*. The two newspapers, especially *Chicago Tribune*, rarely identify model names but only brand names when they post heavily discounted prices. In any event, *Los Angeles Times* and *Chicago Tribune* do not seem to provide significant additional information because of the small number of model-level observations. Therefore I do not pay further attention to these newspaper sources.

[14] The VCRs in the Spring catalogs were available in February at latest, and those in the Fall issues in August.

specialty shops and discount stores.[15] Those shops carried and quoted prices on older but popular models as well as new models to accommodate demands for various types of potential buyers.

11,924 observations on quoted prices are collected in total. Most of the models have more than one price quotation from the vendors. When more than one vendor quoted prices on the same model, I picked the median of them.[16] Summary statistics are in Table 3.[17] The median of the prices are used in subsequent hedonic analysis when more than one shops quoted prices on the same model. Thus the number of observations in Table 3 is 4,054, not 11,924.

Characteristics Characteristics data are the most difficult part of the data work in this project. Unfortunately there exist no sources that give complete information on the VCR characteristics.[18] Moreover some series of characteristics data are different in one source from another, which adds another layer of difficulty to data collection. To increase the reliability and consistency of the data set, I use three external sources to resolve conflicting information. One is information on the OEM relationship. Because there were no U.S. VCR manufacturers, what U.S. companies sold were Japanese-make VCRs through OEM contracts. For example RCA was selling Hitachi VCRs under the RCA brand name in 1984. So even if they were in the market under the RCA brand name, the RCA VCRs were identical to the Hitachi VCRs at this time. The OEM relationships during the sample period are as follows (OEM suppliers in parenthesis): Akai (JVC in 1978-1984), Canon (Matsushita), General Electronic (Hitachi, Matsushita), Magnavox (Matsushita), RCA (Matsushita in 1978-1982 and Hitachi in 1983-1987), Sears (Hitachi, Sanyo), Sylvania (Matsushita) and Zenith (Sony in 1978-March 1984 and JVC in April 1984). The second external source is information on multibrand models. This information applies only to the Panasonic and Quasar models. Same VCR models were marketed by Matsushita under different brand names.

The final outside source is based on information hidden in the VCR model names. The VCR model names consist of two or three letters of the alphabet, followed by a two to five-digit number. The first letters show the brand the model belongs to. For example, a Sony model name always

[15] This composition of shops reflects consumer behavior. More than 70% of consumers purchased VCRs at those stores in this period (according to the annual surveys in 1982-87 conducted by *Wolfman Report on the Photographic Industry in the United States* (1982-88)).

[16] There are two reasons why the median price is used. One is to get around the bias from loss leader models. The other reason comes from consideration of remote control units. Some discount shops removed remote control units from the boxes and sold them separately, regardless of the manufacturers' intention to sell them tied with VCR machines. Although I cannot identify which vendor sold remotes separately, taking the median price may resolve a fair amount of the problem.

[17] Table 3 is different from Table 1 because the frequency of the data is monthly. The characteristics of a model are counted more than once depending on how long it had been in the market.

[18] The Main sources used here are various issues of: *CR, Dearscope Merchandising, Mart Magazine, Merchandising, NYT, Popular Electronics, Sears Catalog,* and *Video News.*

begins with "SL" and JVC begins with either "HR" or "HRD". The number normally shows the quality level within the brand. If several models of a brand came out in the same year, a model with a larger number corresponds to a higher quality model. An exception clearly observed in the dataset is the Panasonic model name construction. Panasonic models begin with "PV", followed by a four-digit number. This four-digit number has two meanings. The first two digits indicate the level of quality and the latter two digits show the introduction year of the model. For example if a model showed up in the market in 1983, its name must end with "20".[19] Although some exceptions are observed especially after 1985, this rule of thumb in the construction of model names confirms and enhances the accuracy of the characteristics data. Seven characteristics variables are eventually available, which are introduced in Table 1.

Variables The variables I employ are as follows: NPRICE (current dollars), PRG (number of programs), DAYS (number of days),[20] HR (maximum recording hours per cassette). The three variables, QWEIGHT (the number of price quotations for a model as a proportion of the total number of quotations for a brand by month), INSTL (the number of VCRs of the same format sold by a given time) and MKTSHR (annual sales brand market share), are used in Section 4. Dummy variables take one if the model has a wired remote (WIRED), a wireless remote (WIRELESS), a high fidelity sound system (HIFI), a high quality picture system (HQ) and zero otherwise. Other sets of dummy variables are: BETA0 takes 0 if the format is Beta and 1 if it is VHS; brand dummy variables equal one if the brand is Fisher (DFISHER), GE (DGE), JVC (DJVC), Magnavox (DMAG), Panasonic (DPAN), Quasar (DQUASAR), RCA (DRCA), Sanyo (DSANYO), Sears (DSEARS), Sharp (DSHARP), Sony (DSONY), Zenith (DZENITH), the other brands (DOTHERS) and zero otherwise.[21] Age dummies are also included to separate the effects of new and older models. As was mentioned in the previous section, the major brands tended to roll out new models twice a year. So I construct age dummy variables on a semi-annual basis. That is, Age 0 takes 1 when the model was observed in the first six months of its life and 0 otherwise, and Age1 takes 1 if the model was observed in the next six months of its life and 0 otherwise, etc.[22] The final series of dummy

[19] TV and radio manufacturers also have a similar practice of naming models. I thank Rob Porter for pointing out this additional evidence.

[20] An early Sony model (SL8200) did not have the programming functions in a basic package. A timer clock, necessary for programming, were sold as an option. Since optional equipment is not counted in the construction of the data, this Sony model is treated as no programming model. This is the reason the minimum values of PRG and DAYS in Table 3 are zero.

[21] Specific brand dummy variables are included if the brand attains an average market share (measured by sales) over ten years of more than 3.0%. The data source of market shares is given in Section 4.

[22] Life of a model is defined as the number of months the model showed up in *NYT* or *Sears Catalog*. Some VCRs disappeared and then reappeared again. In this case, I interpolate their life as if they had been in the market during their disappearance. If a model was in the market before January 1978, I use a date of introduction listed in *Journal*

variables are the following: Time dummy variables take one if the model was in the market in 1978 (T78), '79 (T79), '80 (T80), '81 (T81), '82 (T82), '83 (T83), '84 (T84), '85 (T85), '86 (T86) and '87 (T87);[23] Vintage dummy variables equal one if the model first showed up in 1977 (V77), '78 (V78), '79 (V79), '80 (V80), '81 (V81), '82 (V82), '83 (V83), '84 (V84), '85 (V85), '86 (V86) and '87 (V87). I also divide the vintage dummies into formats. The VHS (Beta) format vintage dummy variables take one if the VHS model first showed up in 1977 (VV(VB)77) and so forth.

Several comments on the dummy variables in Table 3 need to be made. The sum of WIRED and WIRELESS does not equal one because VCRs with no wired remote are observed in the sample. 77% of the observations belong to the VHS format, and the rest are Beta. Regarding the time dummy variables, the number of observations increases up to 1986, and drops in 1987. The vintage dummies basically have the same feature. The numbers of observations of the time and vintage dummies in the same year are quite similar, implying a rapid turnover of models as I pointed out already. A caveat must be made on the age dummy variables: There should not be interpreted as implying that 82% of the models (i.e., the sum of 30% (Age0) and 52% (Age 1)) died within a year. Models, living longer than a year, also take one in Age0 and Age1. Observations where Age 6 or Age 7 takes one are quite small in number (3 and 1 respectively). In terms of brand dummies, Panasonic (2) has the biggest share in the observations, while Sears (9) and Sony (3) rank second and third. Ranks in the parenthesis show order of the average annual market share for the ten years.

4 THE ESTIMATION AND RESULTS

This section examines hedonic equations, incorporating time and age dummy variables. Vintage dummy variables, weighted regression, and network externalities are discussed in the subsequent sections.

The functional form for the hedonic equation is chosen from three candidates: semi-log (dependent variable is logged), log-log (both dependent and independent variables are logged) and linear. These three are frequently used in the hedonic literature (Triplett (1989)). I also allow squared terms of PRG and DAYS (PRGSQ and DAYSQ) in addition to an interaction term (PRGDAYS). It makes sense to include the interaction term because PRG and DAYS are related programming functions; the value of enhancing PRG by one event must depend on how long a machine memorizes programmed contents. HR (maximum recording hours per tape) is dropped from the estimation due to multicollinearity. Another reason to drop HR is that the length of recording hours is ba-

of the Electronics Industry (May 1978).

[23] As for age dummy variables, a model is assumed to be in the market if the model shows up in either *NYT* or *Sears Catalog*.

sically a function of the video cassette tape, not exactly a function of the VCR. Some old VCR machines could have recorded longer hours than those in Table 1 if video cassette tapes with longer recording capability had been available.

I compute log-likelihoods of semi-log, log-log and linear forms, concentrated with respect to a variance parameter.[24] In each of these three forms, I calculate log-likelihoods in three cases; without the squared and interaction terms, with the squared terms but without the interaction term, and with the squared and interaction terms. The semi-log form with the squared and interaction terms is chosen as the estimation model since it achieves the highest log-likelihood in the pooled data for ten years.[25] Because the dependent variable is logged, an estimated coefficient is roughly interpreted as a percentage change in price in response to a unit change in an independent variable.

Table 4 shows estimation results of the overall-year and yearly regressions. The data in 1978 and 1979 are pooled due to scarcity of data, with a time dummy added in 1979 in estimation. Age 6 and Age 7 are excluded from the estimation on account of the small number of observations. The estimated intercept term in the overall-year regression corresponds to that of a model of age 0 in 1978 without remote control, no HiFi nor HQ/Superbeta and of no major brand (i.e., belonged to DOTHERS).[26] The adjusted R-squared measure and the number of observations are given at the bottom. All the estimations fit the data moderately well: The specification explains at least 70% of the variation in the dependent variable in most cases.

There are several points worth noting on the hedonic estimates in Table 4. First look at the characteristics coefficients. The HiFi coefficients are positive and increasing in the last five years, while those of HQ are insignificant in the last three years. As is seen in Table 1, though HiFi was introduced a year ahead of HQ, the diffusion rate of HiFi was much slower than that of HQ. By 1987 HQ was prevalent down to lower-end models, whereas HiFi was still featured only in upper-end and middle machines. It was very rare to find a lower-end machine with HiFi in the sample. The coefficients of HiFi and HQ may reflect this observation.

It is hard to interpret the coefficients of PRG and DAYS due to the inclusion of squared and interaction terms in the equations. In order to evaluate the effects of PRG and DAYS, I compute the derivatives of NPRICE with respect to PRG and DAYS, where all the variables are evaluated at the mean of the corresponding year. Figure 1 shows marginal effects on NPRICE with respect to PRG and DAYS. The straight lines show the point estimates, and the distance between the dotted

[24] In a log-log regression, PRG and PRGSQ are replaced by ln(PRG+1) and $[\ln(\text{PRG}+1)]^2$. Same for DAYS and DAYSQ. PRGDAYS is $[\ln(\text{PRG}+1)]\cdot[\ln(\text{DAYS}+1)]$.

[25] Because of the transformed dependent variable, the log-likelihood functions for the log-log and semi-log forms have an additional term: $-\sum \ln(\text{NPRICE})$, where summation is over the number of observations. Log-likelihoods are also computed for year-by-year data. Seven out of the ten years support the specification of semi-log with the squared and interaction terms.

[26] Since there are no DOTHERS in 1981, the reference brand in this year only is GE in a yearly regression.

and straight lines indicates the standard error.[27] Because PRG and DAYS are basically discrete variables, interpreting marginal effects on NPRICE could be misleading. However, the relative magnitudes of the marginal effects may provide some intuition on the roles of PRG and DAYS.

Two interesting observations can be made in Figure 1. First the marginal effect of PRG declines and that of DAYS increases up to around 1982 and then both stabilize afterwards. The marginal effect of DAYS is negative early on. Second, the standard errors of PRG and DAYS are generally decreasing over time. The mean marginal effect of PRG in 1978-82 is 0.45, twice as much as that in 1983-87 (0.24), and its standard error is one sixth as much (from 0.18 to 0.03). The change in the standard error is much more drastic for the marginal effect of DAYS; from 0.15 to 0.01.

Since hedonic equations estimate an equilibrium locus of hedonic demand and supply curves (Rosen (1974)), one needs to be careful in interpreting the estimates. Hedonic coefficients may reflect a mixture of marginal utility and marginal cost effects. However, it is tempting to make the following interpretation of the preceding estimates. First for several years after the VCR was introduced in the U.S., consumers must have been uncertain about the actual utility of VCR programmability, probably because of less knowledge about the machine itself, and also due to frequent breakdown and difficulty of access to reliable repair shops.[28] As VCRs grew in popularity, more shops dealt with them, more extensive warranties became available[29] and consumers became more familiar with VCR characteristics. Replacement demand also became important over time. Increased reliability of the product and diffusion of information must have led the standard errors to substantially decrease. In the meantime, consumers would at first have perceived additional numbers of programs highly valuable. With a limited number of available programs, consumers did not need additional days of memory in a machine; they might use up all the available preset slots within the available days. The marginal utility of DAYS could be negative for consumers early on. As the available number of programs increased to accommodate the consumers' demand, the marginal effect of PRG declined, and the number of days became effectively important as a VCR function. This may reflect the increase in the marginal effect of DAYS. The marginal benefits to

[27] The derivation of the standard error for PRG is as follows:

$\frac{\partial \mathrm{NPRICE}}{\partial \mathrm{PRG}} = \frac{\partial \mathrm{NPRICE}}{\partial \ln(\mathrm{NPRICE})} \cdot \frac{\partial \ln(\mathrm{NPRICE})}{\partial \mathrm{PRG}} = xb$ where x =NPRICE*[1, 2*PRG, 0, 0, DAYS, 0,...,0] and b is a column vector of the estimates with the same ordering as the explanatory variables listed in Table 4. Suppose x^* is x evaluated at the means of NPRICE, PRG and DAYS. Then the estimated standard error for this linear combination of the estimates evaluated at the mean is computed as the square root of x^*(Estimate of Σ)$x^{*\prime}$, where the estimate of Σ is the variance-covariance matrix of b.

[28] *CR* reported in 1985 that 20% of the two-year-old machines experienced repairs, and the older VCRs were more likely to need repairing. Recording and playback heads were especially prone to trouble.

[29] VCRs cost more to fix than TVs. The standard condition for manufacturers' warranties was twelve months on parts and three months on labor in 1978 (*CR*, various issues). Video heads were added to the coverage in later years, when extended warranty business grew prosperous. In 1986, extended warranties beyond the manufacturers' ranged in length from nine months to five years (*Video Book*, 6th.ed. p.52).

consumers and the marginal costs of manufacturers who supplied PRG and DAYS are sort of on balance after around 1982.

It is also worth mentioning the make coefficients. The VCR inventors, JVC and Sony, have high values on their coefficients for the first three years. The innovator positions eroded subsequently. The hedonic estimation does not tell us clearly whether this observation could be attributable to either price setting behavior by the brands or brand-specific unobserved quality effects. Sears has a quite high coefficient throughout probably because the mail order prices in *Sears Catalog* were set relatively higher than those in *NYT*. As is discussed in footnote 13, the range of price levels in *NYT* do not appear to be much different from other U.S. cities. One would argue that retail outlet markets and mail-order markets were somewhat separated. The mail-order catalogs primarily targeted consumers who did not have time to search for products or who did not have easy access to outlet shops. These consumers would have higher willingness to pay for the products than other consumers. Thus the mail-order catalogs might be able to set prices higher than the outlet shops without contracting demand substantially. In other words, mail-order products might not be directly substitutable for products available in the outlet shops.

Sharp and Sanyo had been known as aggressive price setters in the latter half of the sample (*Video Book*, 4th.ed. p.75). The big negative coefficients on both brands may reflect this fact.

Age dummy variables have negative coefficients, but are mostly insignificant. The interpretation of age coefficients is not unambiguously attributed to obsolescence if they are conditioned on time. As Berndt and Griliches (1993) pointed out, the interpretation is clouded by selectivity. If unmeasured quality presumably makes certain models survive in the market, the age coefficient may capture this unmeasured quality difference among the surviving models. Age coefficients may be more appropriately interpreted as a rate of obsolescence if conditioned on vintage dummies. I perform an estimation replacing vintage with time dummy variables in the pooled estimation.[30] As expected, the age coefficients are declining and significantly different from zero. I would not reject the hypothesis that the rates of decline in age coefficients are same across years. The rate of obsolescence can be computed by exponentiating the difference of adjacent age coefficients, and subtracting one from it. The average annual rate of obsolescence over the first two and a half years of VCRs from 1978 to 1987 is calculated 13.3%.[31]

Issue on vintage dummy The seven characteristics in Table 1 as well as the brand dummy variables for controlling brand-specific quality effects do not probably cover all the important functions of VCRs. During the sample period, small new functions were introduced one after another

[30] V77 is dropped due to the small number of observations.

[31] Frequency of repairs may be taken into account here to the extent that the vintage dummy captures reliability of VCRs on average.

in constant succession, and kept attracting consumers' attention. Actually VCR manufacturers announced new functions about once every three months.[32]

Although I do not have characteristics data beyond the seven variables previously introduced, the vintage dummy variable may serve as a proxy for unobserved characteristics. The reason is as follows. As Itami (1989, p.148) describes, VCR manufacturers in each format shared the same suppliers for quite a wide range of parts. Even VHS and Beta shared the same suppliers for several essential VCR components such as precision motors and connectors. These within- and between-format connections through parts suppliers must have linked technological levels of VCRs to the extent that the technology was not directly related to the format system itself. That is, the introduction year of models must contain information on the level of average characteristics of models rolled out in the same year. If the observed seven characteristics already capture all important dimensions of VCR features, the added vintage dummies may not have any significant information. If the seven fail to capture the important features, however, the vintage dummy variables must give us information on unobserved characteristics. Thus the vintage dummy variables can serve as a test of whether the observed characteristics capture enough characteristics dimensions. This idea is the same as in Berndt and Griliches (1993). Since the level of technology progress could be different between the formats, I also divide the vintage dummy variables into Beta vintage and VHS vintage dummy variables (denoted by VB and VV respectively).[33]

As is seen in Table 3, however, the number of observations by year and by vintage year are pretty much similar. This is another way of noting the high rate of model turnover. This suggests that the vintage dummies might capture much the same year-to-year variation as the time dummies. Thus it is not surprising to get similar estimates for the age-vintage specification; we find that coefficients other than age dummy variables are close to those in the age-time specification in Table 4.

Since interpretation of the vintage dummy variables is quite obscure, I do not pursue the vintage specification any further. One thing worth mentioning is the tests for equality of format vintage coefficients in the pooled sample. I estimated the age-format vintage hedonic equation without time dummies.[34] The specification with time dummies gives similar results. Format vintage coefficients are mostly significant and negative. The negative signs of the format vintage coefficients imply that the vintage dummy variables may capture year-to-year variations like the time dummies. The F tests for equality of format vintage coefficients between Beta and VHS indicate that equality cannot

[32] See Itami (1989, pp.210-218).

[33] Since the age dummy variables are defined semi-annually while vintage and year dummies are on an annual basis, any combination of two dummy variables does not provide the whole information on the rest of the variable. Thus conceptually there is no multicollinearity problem in putting all three dummies in the estimation at once.

[34] VV77 and VB77 are excluded due to the small number of observations. So the reference vintage is an average of VV76, VV77 and VB77.

be rejected in 1978, '85 and '86 at the 1 % significant level. Thus these F test results suggest that the unobserved characteristics might be different across formats in most years.

Weighted Regression I have analyzed up to now unweighted hedonic price equations where all the observations are equally weighted. Since this method equally weights popular brand models and less popular brand models, the resulting quality adjusted price indexes might be biased towards less popular brands, whose characteristics could be inferior to popular brands. In order to come close to the true price, it is desirable to weight the observations by retail model sales. Although I do not have sales data by model, I can create alternative data which hopefully approximates the weights. The weights are constructed using brand market share data and the number of price quotations in *NYT* and *Sears Catalog* on a monthly basis.

Data on estimated annual brand market shares from 1981 to 1987 are from the *Video Book* (1st.ed.-7th.ed.). Shares are measured by sales. The market shares from 1978 to 1980 are computed by the author using the VCR penetration and ownership surveys collected by Media Statistics. The summary statistics are shown in Table 3 under MKTSHR.

I need two assumptions to construct the monthly weights for the models. First the brand market shares in each month are same as the annual level. Secondly, the monthly percentage of sales attributed to a model within a brand is equal to the number of price quotations for the model as a proportion of the total number of quotations for the brand by month. I name this QWEIGHT, for which summary statistics are shown in Table 3. Given these two assumptions, the sales share of model can be computed by the brand market share (i.e., MKTSHR) multiplied by the proportion of price quotations for the model, to the total number of quotations for the brand (i.e., QWEIGHT).

The same specification is used in the weighted regressions as for the unweighted regressions. Since the computed weights are not from the real data, I do not analyze hedonic estimates here. However, the estimates are close to those obtained in the unweighted regressions, and the interpretations of characteristics coefficients and make coefficients qualitatively carry through. The weighted version of Figure 1 also possesses the same features.

Remember that the data I use have monthly frequency. The same model is counted more than once if it survived in the market more than a month. In that sense, my unweighted dataset is actually weighted by the "life period" of the model.[35] If a model with longer life enjoyed more sales, which is very likely, my results for the unweighted regressions already captured most of what I did in this subsection.

[35] Of course the model cannot be counted more than twelve times in a yearly regression.

Issue on Network Externalities The VCR market has been one of the famous examples in network externalities. Network externalities are demand-side scale economies.[36] The essence of network externalities is that consumers place more value on a particular product as more consumers purchase compatible goods. The VCR market may possess network externalities because one can find a wide variety of movie titles for a particular format in rental shops (indirect network externalities), or because one is more likely to find people who own prerecorded tapes of the same format to exchange (direct network externalities).

Several empirical studies document the existence of network externalities by using hedonic regressions. Gandal (1994) and Brynjolfsson and Kemerer (1996) perform hedonic analysis for spreadsheet software and find that file compatibility has a significant value. Berndt, Pindyck and Azoulay (1999) present the evidence of information spillover on diffusion of antiulcer drugs. These papers typically examine the effects of the installed bases of compatible products on their prices. I follow the literature and use format installed base as a proxy for network externalities in the hedonic regressions. The format installed base is defined as the cumulative units of VCRs of the same format sold by a given time. The summary statistics are shown in Table 3 under INSTL.

I construct the monthly format installed base by using two data sources. One is monthly U.S. VCR sales, available in *Appliance* (January 1978-April 1994), and the other is the annual brand market share, MKTSHR, used in the previous subsection. I again assume that the brand market share in each month is same as the annual level. The monthly format installed base is calculated by adding monthly format sales to the cumulative format sales by the last month.

I redo the same exercise, adding a logarithm of the installed base variable to the explanatory variables in Table 4. The log-likelihoods again support the semi-log form with the squared and interaction terms of PRG and DAYS. The pooled and yearly regressions with the age and time dummies show the similar estimates to those in Table 4, and the interpretation of characteristics and make coefficients as well as the feature of Figure 1 show no great difference with the above discussion.

The coefficients of the installed base variable are shown in Table 5. Though the pooled coefficient is significantly positive and might indicate the existence of network externalities, the result from the yearly coefficients show that it may be difficult to confirm the consistent evidence on network externalities: The coefficients are significantly negative in some years (1978-79, '81 and '82), and insignificant in other years (1985 and '87). As discussed above, since hedonic equations estimate the equilibrium, the installed base coefficients may reflect not only network externalities but also some other effects from the supply side particularly in the case of VCRs: Ohashi (2000) finds that the supply side experienced a drastic change during the period. It may be more appropriate to

[36] We talk only about positive network externalities here.

analyze network externalities in the context of demand estimation (See Ohashi (2001) for more details). Since I believe it difficult to pin down the effect of network externalities under the current framework, I do not pursue this issue further.[37]

5 QUALITY-ADJUSTED PRICE INDEXES

This section constructs quality-adjusted price indexes based on the hedonic estimates and considers plausible causes of the resulting price index behavior. Table 6 shows annual quality-adjusted price indexes from 1978 to 1987 under various assumptions. The indexes in the table are constructed without using the installed base variable.

The first row in Table 6 is the arithmetic mean of VCR prices by year. The average annual price change is -6.23%, with large drops in 1982 and 1983. Remember again that this is slightly different from the prices shown in Table 1. The arithmetic mean in Table 6 is weighted roughly by the life period of model since the frequency of the data is monthly, whereas the mean price in Table 1 is unweighted.

The rest of the rows are quality-adjusted price indexes under different assumptions. Indexes are constructed from the all-year pooled regression estimates and from adjacent two-year regression estimates. In addition to a time-age specification (abbreviated as the T-A model), I use a specification without age dummy variables (abbreviated as the T model) to construct different quality-adjusted price indexes.

Pooled unweighted price indexes are computed from the overall-year specification in Table 4. The indexes are constructed by simply exponentiating the time coefficients, with T78 equal to zero, interpreted as the price index holding quality constant over time. The same applies to the weighted version.

Adjacent two-year price indexes are constructed as follows. First do hedonic regressions with the same specification, but pooling just adjacent two years of data with a time dummy in the second year. The index is made by exponentiating the time coefficient and multiplying it by the previous year's quality-adjusted index, interpreted as the price index holding quality constant over two years.

The pooled indexes decline more sharply than the adjacent indexes in general. This implies that the pooled regressions roughly point to a larger annual rate of characteristics improvement than the adjacent two-year regressions. This rate of characteristics improvement can be obtained by just subtracting the average annual quality-adjusted price change, from that of the arithmetic mean index. There seems to be no distinctive difference between the unweighted and weighted

[37] We analyze quality-adjusted price indexes for this specification in footnote 38.

indexes. Given the specification, the T models generally yield a steeper price drop than the T-A models. All in all, the adjacent two-year T-A model gives a conservative price decline over 1978-87.

It may be interesting to look at the rate of quality change using the unweighted adjacent year T-A model as a reference specification. While the quality change in percentage from the previous year shows that quality improved in all the years, the improvement is quite uneven year by year, with 11.57% in 1985 as the highest and 1.12% in 1983 as the lowest. The rate of quality increase is high in 1982 and 1984-85. The 1982 quality increase can be attributed to the introduction of the HiFi system. The 1984-85 quality improvement coincides with the rapid proliferation of HiFi and wireless remote controls across models (See Table 1).

One interesting observation is that all the quality-adjusted price indexes show a particularly large price drop in 1982-85 of 19% on average, more than twice as high as the average drop in the rest of the six years as shown in the last two columns in Table 6.[38] Before I probe this distinctive price movement, I compare the quality-adjusted indexes with matched model index.

5.1 Comparison with Matched Model Indexes

Gordon (1990) constructs a price index in 1980-85 using data from *CR*. He classifies VCRs into two types, and compares prices of the same type across the periods. The first type of VCR he identifies has a wired remote control only able to make the tape action pause but having no other feature, and also the model lacks search and cue capability. The second type has a "full-featured" infrared remote control and fourteen-day programming capability, but just two recording heads. Models, not falling into the above two categories, are not included in his sample.

Surprisingly Gordon's price index drops much more sharply than my indexes. If the nominal VCR prices in my data and *CR* move similarly, this amounts to saying that the rate of quality improvement derived from Gordon's index is much more drastic than that shown by my dataset.

I construct a matched model index using my data set. A matched model is define as having the same model name in the two adjacent years. Different from the case of personal computers, VCR models with the same model name have identical characteristics. I find that the percentage of matches across the two years are less than half for all the years, reflecting the high rates of model turnover in the U.S. VCR market during the time. The matched model index implies that prices of

[38] Quality-adjusted price indexes, obtained by adding the installed base variable in the hedonic regressions, show the similar price declines, if steeper, to those in Table 6. The adjacent two-year indexes do not present as sharp a decline in 1982 as the other indexes, probably because the big negative coefficient of the installed base variable in 1982 (See Table 5) may capture most of the effect of price decline: The VCR annual sales, directly related with the installed base, grew sharply in 1982. This sales expansion may be easily confused by the year dummy of 1982, which is used to construct the price indexes. In view of this consideration, our observation of the 1982-85 price drop may correctly reflect some structural change in the U.S. VCR market.

VCRs declined by about 8.9% on average, with a sharp drop of 14.3% in 1982. Compared with the indexes in Table 6, it is clear that the matched index may overly underestimate true price declines.

A problem in Gordon's index may be that his classification of the VCR models could be too broad. As we saw in Table 1, VCR characteristics dimensions cannot be limited to just PRG, WIRED and WIRELESS. He also excludes many models which cannot be classified in his way. This method of limiting the characteristics dimensions and restricting the sample may generate a biased index. If one sticks to *CR* data, however, one probably would not do better than Gordon. First of all, new VCRs were introduced more frequently than *CR* reviewed VCR prices.[39] Thus one cannot do the matched model approach in a strict sense; almost all the models disappeared between *CR* evaluations. Unfortunately, it is difficult to do a hedonic analysis due to the small number of models listed in *CR* at the time.

5.2 Explanation of the 1982-85 price drop

I now turn to speculating as to the reasons for the price decline in the U.S. VCR market in 1982-1985.

So far, I have used nominal prices of VCRs to construct quality-adjusted price indexes. Since one of the ultimate goals for hedonic analysis is to construct deflators, using nominal price as the dependent variable rather than deflated price is a sensible approach.

When I start to think about the economic causes of movement in quality-adjusted price indexes, however, I need to take account of general price trends, because VCR prices cannot be immune from the macroeconomic environment as a whole in consumers' and producers' points of view. In particular my sample contains an inflationary period due to the Second Oil Crisis in 1979; the annual rate of CPI inflation was 12% on average in 1979-81.

In order to see how striking the 1982-85 price drop is, I compare it with the U.S. television market, the structure of which seems relatively stable during the period.[40] Table 7 shows quality-adjusted price indexes of TV sets in 1978-84, taken from Gordon (1990, table 7.19, p.306). I adjusted his indexes to be 100 in 1978. The table lists two indexes for matched models constructed from *CR* data, both without and with adjustment for reductions in the costs of repairs and energy. Both indexes decline very slowly, about five percent in six years, and there is no clear gap observed

[39] *CR* evaluated VCRs in the U.S. market on average every one and a half years during the period, far less frequent than the actual VCR introductions. The dates of publication are: September 1978, October 1980, May 1982, July 1983, September 1985, January 1987, and March 1988.

[40] One event that could have affected the U.S. TV market was antidumping taxation and subsequent voluntary export restraint on Japanese TVs to the U.S. in 1971-80. However the reduced number of Japanese imports appeared mostly offset by increased imports from Korea and Taiwan as well as the increase number of production by Japanese companies in the United States. (McGee (1994), p.21).

between 1981 and 1982. This comparison of VCR indexes with TV indexes suggests that some structural changes specific to the VCR market might have caused the 1982-85 price drop observed in Table 6.

Changes in the demand side as well as the supply side can potentially explain this decline, but as discussed in the introduction, VCR sales experienced a dramatic increase in this period. Thus it seems difficult to explain the phenomenon only from the demand side. Changes in the supply side must be also important. Since demand side conditions must have had an effect on equilibrium price and output during this period, first I briefly overview two events which plausibly led to a change on the demand side, and then I look at the supply side rather closely.

Demand Side I observe two events that presumably affected VCR demand during the period. The first event was the lawsuit against Sony brought by Universal Studios and Walt Disney Productions in 1976. The studios charged that any taping and replaying of TV programs was a form of copyright infringement, and contended that Sony, Sony's advertisement agency and several retail chains selling Sony VCRs were at fault, since they produced and sold the equipment that was used to violate the studios' copyright by taping movies and other material. While the case ended in 1984 with the Supreme court ruling that home VCR taping did not violate the copyright laws, the possibility of a finding against Sony might have muddled the VCR demand.

The popularity of rental and sale of prerecorded tapes is the second event that could have changed the demand side. The prevalence of prerecorded tapes could increase or decrease the demand for VCRs. It would decrease the demand if the consumers favored videocassette players (VCPs), which were cheaper than VCRs, but did not have the recording function. On the other hand, it would increase the demand if consumers preferred a recording function to no recording. The former case does not seem to apply here, because the VCP market was not big enough in this period. Moreover VCPs were actually preferred by consumers who already had a first VCR (*Video Book* (6th.ed. p.76). See also *Electronic Market Data Book* (1985 ed.)).

I also see how availability of prerecorded tapes affected VCR demand by looking at various kinds of VCR user surveys conducted mainly by TV consulting companies at this time. To the extent of my knowledge, the first time when VCR playback time outpaced recording time was in the Nielsen surveys of 1986 (*Video Book*, 6th.ed. p.58.). The survey conducted a year before by *CR* shows that watching pre-recorded TV programs accounted for two thirds of the playback time. While the respondents were different across the surveys, it looks to us that the availability of prerecorded tapes might have had a bigger impact on VCR demand after 1985.

Supply Side The changes in VCR demand cannot solely explain the large price drop as well as the sales surge in 1982-85. Changes on the supply side must be necessary to fully account for the

1982-85 price drop. I describe as such factors change in VCR unit cost along with an increase in VCR brand suppliers.

The industry-level supply curve probably shifted downward and to the right in this period, because of an increase in the number of available brands in the U.S. market. Table 1 shows that the number of brands (models per year respectively) was on the increase from 13 (92) in 1982 to 20 (171) in 1985. The entry of brand suppliers must have expanded the VCR supply.

As I mentioned in Section 2, almost all VCRs were imported from outside the U.S. in 1978-87. Hence customs data with the VCR dock price and the associated customs duties provide a rough idea on how much U.S. suppliers paid for imported VCRs. Figure 2 shows the trend of annual VCR unit cost from 1978 to 1987. Unit cost is computed as the sum of total CIF import values and the total calculated customs duties, divided by the total amount of U.S. VCR imports by year. These data are collected from Imports for Consumption in Tariff Schedules of the United States Annotated (hereafter *TSUSA*) under the subheading number 685.4052 ("Other than audio machine: Video: Color: Cartridge or cassette"), which is the closest category to my focus.[41] Figure 2 shows that VCR unit cost decreased in general. The average annual decline is 9.5%, with a particular drop in 1982-85; 15.7% on average.[42] This drop in VCR unit cost seems to give us another plausible explanation of a shift in the industry supply curve in 1982-85.

The hedonic regressions and the resulting quality-adjusted price indexes cannot tell us which of the decline in VCR unit cost or the increase in VCR suppliers was important in cutting U.S. VCR prices in 1982-85. I have to take a different approach to answer this question.

6 ESTIMATING THE CPI

The December 1996 Final Report of the Advisory Commission to Study the Consumer Price Index attributed an upward bias of 0.6 % per year in the CPI to unmeasured quality change and new goods (See Boskin, Dulberger, Gordon, Griliches, and Jorgenson (1998) and Liegey and Shepler (1999)). The Advisory Commission estimated that the category contributed the most to their quality change bias was the *Appliance Including Consumer Electronics* category of the CPI, in which VCRs are classified. The BLS included VCRs in the CPI basket in January 1987.

This section makes an inference on how much bias the *Appliance Including Consumer Electronics* CPI would have by not having priced VCRs earlier. This bias must be upward since the quality-adjusted VCR indexes decline as Table 6 shows. The question here is how significant the bias would be.

[41] I am grateful to Roger Pomeroy of the International Trade Association for his assistance in the data construction.

[42] The nominal exchange rate lay between 200-250 Japanese yen/$U.S. in 1978-1985, and then started declining to 142 yen/$U.S. in 1987. Thus the period of VCR cost drop does not coincide with that of yen appreciation.

I recalculate the *Appliance Including Consumer Electronics* CPI by incorporating the quality-adjusted VCR prices. For this purpose, I need to know annual expenditure weights of VCRs among the products in the same CPI category. I use retail value of home appliances and electronics to construct the weights. The retail value represents median price of product times the number of units shipped. The data from *Statistical Abstract of the United States* (1984-90) cover a wide range of home appliances and consumer electronics, such as TVs, telephones and air-conditioners.[43] The VCR share in terms of retail value must approximate the expenditure share on VCRs at the average U.S. household level.

Yearly weights on VCRs are calculated as from 1.2% in 1978 through 7.8% in 1986. I take a weighted average, using retail-value shares, of the VCR price and the BLS estimate of the *Appliance Including Consumer Electronics* CPI to construct a new index of the category. Figure 3 shows the result. The unweighted T-A price index is used for the VCR price, and the annual U.S. city average (seasonally unadjusted) is used for the BLS CPI.[44] The BLS and new CPIs are normalized as 100 in 1978. I do not calculate the new index in 1987, since the BLS included VCRs in the CPI by then. Both indexes moved closely and increased in the first half of the sample, and started diverging in 1981, as the VCR price dropped with its increasing share of the retail value. The distance between the two indexes may indicate a bias of the current CPI. By 1986, the BLS index reached at 106.79, whereas the new index was 101.22, implying an upward bias of 5.21%. The average percentage of the bias is calculated as 3.19%. VCRs were finally included in the CPI in January 1987, and the BLS index dropped by about 2 points this year. The magnitude of the drop, however, shows no great difference from that observed in the past three years after 1983. If the 1987 BLS estimate of the *Appliance Including Consumer Electronics* CPI excluding VCRs had been at the same level as 1986, the index should have been 100.03, roughly five percent lower than the actual index.[45] This observation might be partly attributable to insufficient consideration of unmeasured quality upgrade by the BLS. Another possible reason would be that, since 1987 was the first year to introduce VCRs in the CPI, the BLS did not place on VCRs as much a weight as they should have, so as to smooth out the transition. Information on how the BLS introduced VCRs in the CPI is not readily available to an outside researcher.

Hausman (1999) estimates a bias in the BLS estimate of the telecommunications-services index of between 0.8-1.9% per year due to omitting cellular phones from the CPI in 1988-97. This chapter also finds a significant bias in the *Appliance Including Consumer Electronics* CPI due to new product introduction and unmeasured quality change with an analysis of VCRs in 1978-86.

[43] The retail value of personal computers was not included until 1985.

[44] I am grateful to Sharon Gibson of the BLS for her advice on the data.

[45] We use the 1987 VCR weight of 7.2% in this calculation.

7 CONCLUSION

I construct quality-adjusted price indexes for home video cassette recorders in the U.S. market from 1978 to 1987. I first look at summary statistics and found the common perception of Beta superiority over VHS to be not exactly correct. While Beta established secondary functions such as high fidelity sound and high quality picture systems at a much faster rate than VHS, Beta fell behind in programmability functions such as the number of events and days preset in one time programming. I then estimate hedonic equations using a traditional age-time specification with squared and interaction terms. I observe reasonable estimates reflecting the evolution of the industry in this era. I also discuss the merits of vintage dummy variables, weighted regression, and network externalities. The annual rate of VCR obsolescence is calculated in passing to be about 13.3%.

I then construct the quality-adjusted price indexes under different assumptions. The constructed price indexes decline at 11-12% per year, with a particular drop by about 18% from 1982 to 1985 on average. The magnitude of the price decline is more than twice as much as that of the average price drop in the rest of the years. I discuss the plausible causes of this large price decline.

Lastly I estimate how omitting VCRs from the CPI basket would have generated a bias in the BLS estimates of the *Appliance Including Consumer Electronics* category. I observe a significant upward bias of 3.19% per year over 1978-86.

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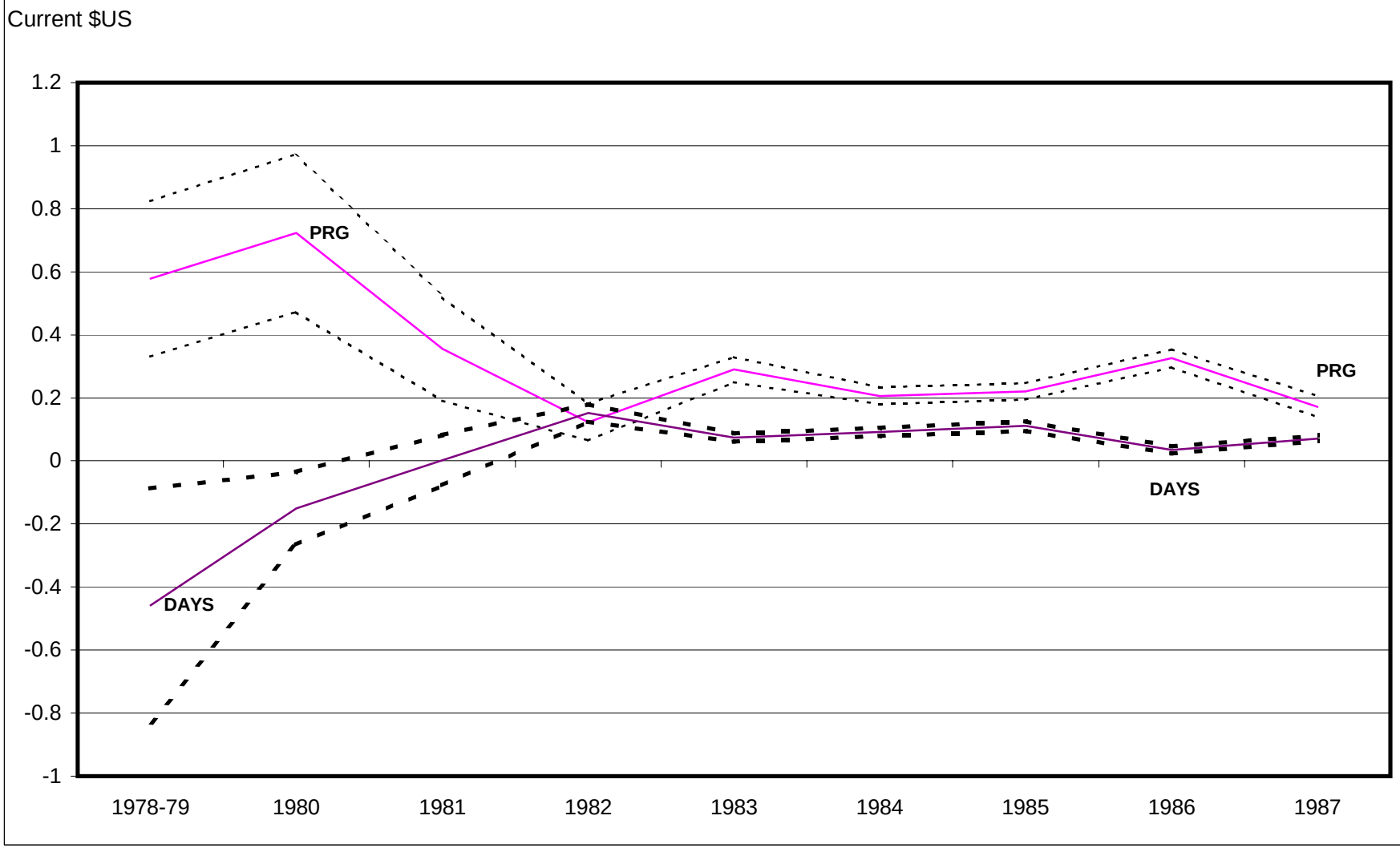
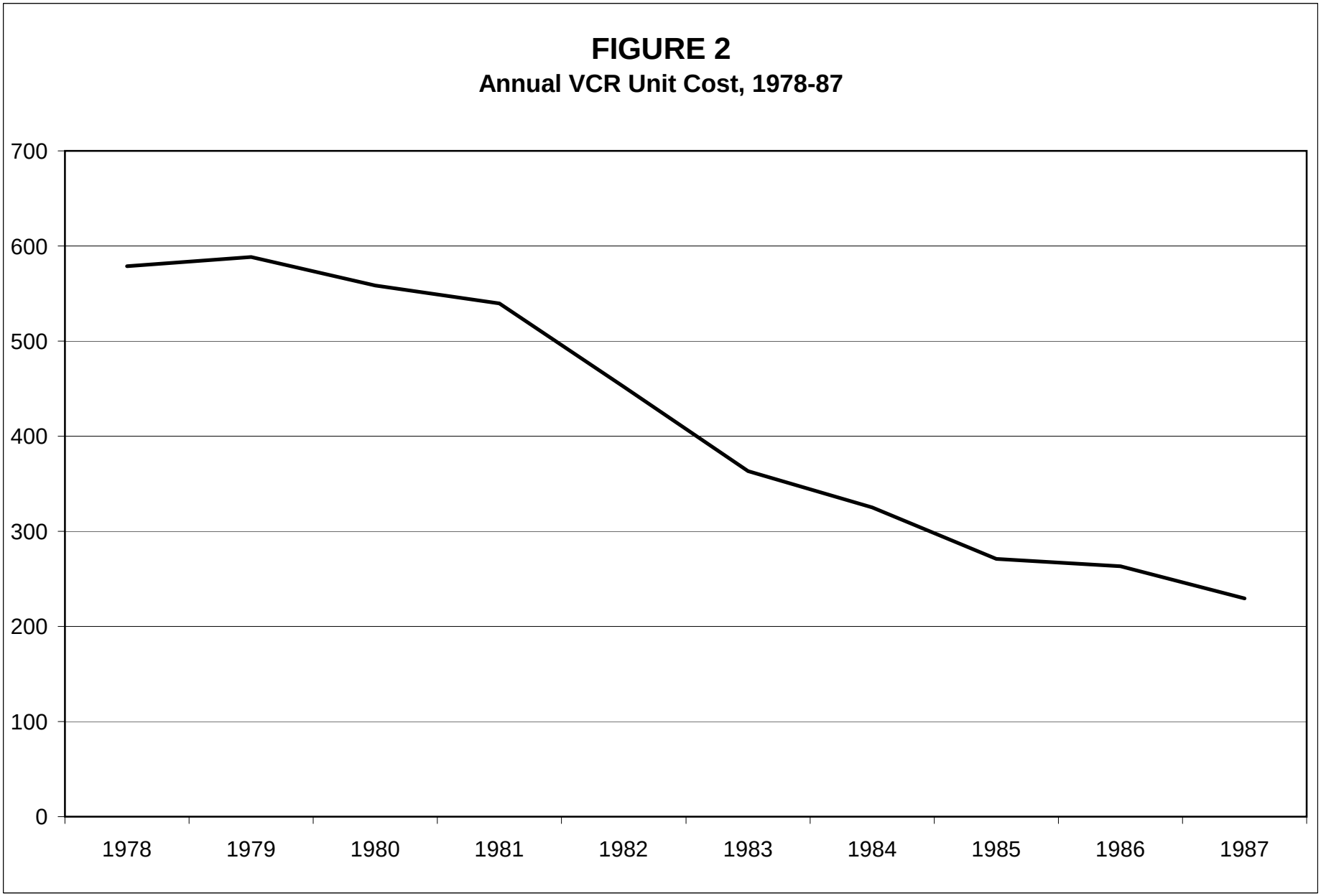
FIGURE 1

Marginal Effects on Nominal Price with respect to PRG and DAYS
Evaluated at the Mean



Notes: PRG: No. programs set in one time. DAYS: No. days ahead preset in one time. The distance between the straight and dotted lines is the estimated standard error. The derivation is explained in footnote 27.

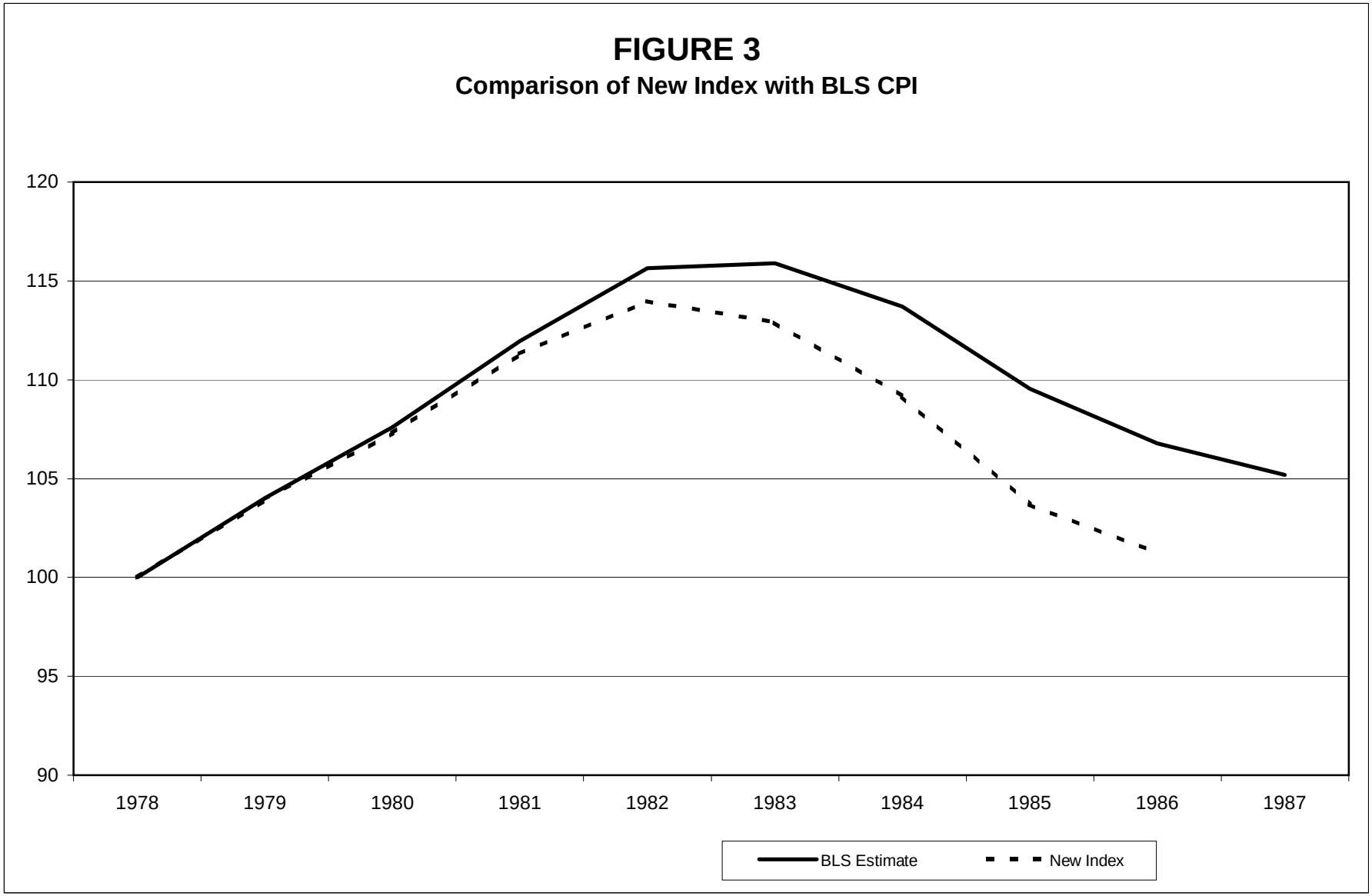
FIGURE 2
Annual VCR Unit Cost, 1978-87



Source: TSUSA, Imports for Consumption (subheading number 6854052). The unit cost is computed dividing the sum total CIF value and the calculated custom duties by the total number of import.

FIGURE 3

Comparison of New Index with BLS CPI



Note: The *Appliance Including Consumer Electronics* index is used for the BLS estimate of the CPI. See section 6 for an explanation of our new index.

TABLE 1

Mean Values of Prices and Attributes of VCR Models/Year in the Market by Year and Format, 1978-1987

Total:

Year	No.of Brands	No.of Models	Nominal price	No. of programs	No. of days	Average Maximum recording hours	Proportion wired	wireless	Hifi	HQ/Superbeta	Average Price change (%)
1978	9	17	792.97	1.00	1.10	3.17	0.75	0.00	0.00	0.00	
1979	11	27	824.53	1.60	2.09	3.82	0.94	0.00	0.00	0.00	3.98
1980	10	31	811.09	3.17	5.44	5.00	0.97	0.00	0.00	0.00	-1.63
1981	10	44	782.14	3.18	7.15	5.39	0.81	0.10	0.00	0.00	-3.57
1982	13	63	648.64	3.35	8.30	5.94	0.58	0.25	0.02	0.00	-17.07
1983	14	92	545.78	3.00	9.03	6.31	0.54	0.38	0.07	0.00	-15.86
1984	16	113	513.35	4.30	11.38	6.45	0.24	0.71	0.28	0.02	-5.94
1985	17	138	453.99	4.53	16.04	6.47	0.12	0.87	0.46	0.19	-11.56
1986	20	171	427.79	5.41	21.35	6.50	0.01	0.97	0.58	0.44	-5.77
1987	19	133	425.81	5.75	30.67	6.50	0.00	1.00	0.51	0.94	-0.46
ean/Total	14	829	622.61	3.53	11.25	5.55	0.50	0.43	0.19	0.16	-6.43

By formats:

VHS

Year		No.of Brands	No.of Models	Nominal price	No. of programs	No. of days	Average Maximum recording hours	Proportion wired	wireless	Hifi	HQ/Superbeta	Average Price change (%)
1978	VHS	6	12	755.88	1.33	1.67	3.67	0.83	0.00	0.00	0.00	
1979	VHS	6	21	816.92	2.19	3.17	4.44	0.89	0.00	0.00	0.00	8.07
1980	VHS	6	22	801.74	4.59	6.38	5.87	1.00	0.00	0.00	0.00	-1.86
1981	VHS	6	30	778.52	4.26	9.13	6.39	0.81	0.19	0.00	0.00	-2.90
1982	VHS	9	40	650.90	4.29	9.51	6.89	0.58	0.27	0.05	0.00	-16.39
1983	VHS	10	59	562.56	3.75	11.20	7.62	0.51	0.47	0.08	0.00	-13.57
1984	VHS	12	78	522.44	4.50	13.52	7.89	0.22	0.76	0.26	0.00	-7.13
1985	VHS	14	121	450.70	4.54	22.61	7.94	0.10	0.89	0.38	0.02	-13.73
1986	VHS	19	154	425.75	4.97	29.70	8.00	0.03	0.97	0.45	0.44	-5.54
1987	VHS	18	124	416.84	5.05	49.66	8.00	0.00	1.00	0.36	0.88	-2.09
ean/Total	VHS	11	661	618.23	3.95	15.65	6.67	0.50	0.46	0.16	0.13	-6.13
											Avg 78-86:	-6.63

BETA

Year		No.of Brands	No.of Models	Nominal price	No. of programs	No. of days	Average Maximum recording hours	Proportion wired	wireless	Hifi	HQ/Superbeta	Average Price change (%)
1978	Beta	3	5	823.97	0.67	0.53	2.67	0.67	0.00	0.00	0.00	
1979	Beta	5	6	833.25	1.00	1.01	3.20	1.00	0.00	0.00	0.00	1.13
1980	Beta	4	9	822.78	1.75	4.51	4.13	0.94	0.00	0.00	0.00	-1.26
1981	Beta	4	14	790.04	2.10	5.18	4.40	0.81	0.00	0.00	0.00	-3.98
1982	Beta	4	23	642.91	2.41	7.10	5.00	0.58	0.23	0.00	0.00	-18.62
1983	Beta	5	33	496.14	2.26	6.86	5.00	0.57	0.28	0.05	0.00	-22.83
1984	Beta	6	35	477.43	4.10	9.24	5.00	0.26	0.65	0.30	0.03	-3.77
1985	Beta	4	17	487.87	4.52	9.47	5.00	0.14	0.86	0.54	0.37	2.19
1986	Beta	4	17	473.32	5.84	13.00	5.00	0.00	0.96	0.71	0.45	-2.98
1987	Beta	1	9	666.81	6.44	11.67	5.00	0.00	1.00	0.67	1.00	40.88
ean/Total	Beta	4	168	651.45	3.11	6.86	4.44	0.50	0.40	0.23	0.18	-1.03
											Avg 78-86	-6.27

Note: The number of VHS and Beta brands does not sum up to the total number of brands in 1983-86, due to the existence of multiformat brands. See footnote 11.

TABLE 2

The Frontier Models by Format, 1978-1987

	Format	No. of programs	No. of days	Maximum recording hours per cassette	Proportion wired	wireless	HiFi	HQ/Superbeta
1978	VHS	4	7	4	1	0	0	0
	Beta	1	0.79	3	1	0	0	0
1979	VHS	6	7	6	1	0	0	0
	Beta	1	3	5	1	0	0	0
1980	VHS	8	14	6	1	0	0	0
	Beta	4	14	5	1	0	0	0
1981	VHS	8	21	8	0	1	0	0
	Beta	8	14	5	1	0	0	0
1982	VHS	8	21	8	0	1	1	0
	Beta	8	14	5	0	1	0	0
1983	VHS	8	21	8	0	1	1	0
	Beta	9	21	5	0	1	1	0
1984	VHS	9	21	8	0	1	1	0
	Beta	9	21	5	0	1	1	1
1985	VHS	9	365	8	0	1	1	1
	Beta	9	21	5	0	1	1	1
1986	VHS	9	365	8	0	1	1	1
	Beta	9	21	5	0	1	1	1
1987	VHS	9	365	8	0	1	1	1
	Beta	8	21	5	0	1	1	1

Note: The frontier model, constructed by putting together the best characteristics across all the models by format and year

TABLE 3

Summary Statistics of Home VCR Data, 1978-1987

sample size:4054

Variables	Descriptions	Mean	Std error	Minimum	Maximum
NPRICE	Current VCR price (in U.S. dollars)	546.91	207.39	189.00	1279.90
PRG	The number of programs preset in a machine	4.18	2.71	0	9
DAYS	The number of days present in a machine	24.30	66.34	0	365
HR	Maximum recording hours per cassette	6.85	1.53	2	8
QWEIGHT	Proportion of price quotations to a VCR model	6.12	11.10	0.16	100
MKTSHR	Annual sales market share by brand	9.47	7.68	0.06	41.32
INSTL	Installed base by format (in million persons)	13.70	14.20	0	40.50

Sample Means of Dummy Variables

WIRED	0.30
WIRELESS	0.66
HIFI	0.24
HQ	0.24
BETA0	0.77

Time dummy variables

T78	0.01
T79	0.04
T80	0.05
T81	0.06
T82	0.08
T83	0.13
T84	0.15
T85	0.16
T86	0.18
T87	0.15

Vintage dummy variables

V77	0.007
V78	0.04
V79	0.04
V80	0.05
V81	0.07
V82	0.10
V83	0.13
V84	0.15
V85	0.15
V86	0.18
V87	0.07

Age dummy variables

AGE0	0.52
AGE1	0.30
AGE2	0.11
AGE3	0.04
AGE4	0.02
AGE5	0.01
AGE6	0.0007
AGE7	0.0002

Brand dummy variables

DPAN	0.18
DRCA	0.11
DJVC	0.09
DSHARP	0.04
DQUASAR	0.05
DGE	0.04
DFISHER	0.03
DMAG	0.02
DSONY	0.11
DZENITH	0.07
DSANYO	0.03
DSEARS	0.12
DOTHERS	0.11

Format vintage dummy variables

VHS

VV77	0.01
VV78	0.02
VV79	0.03
VV80	0.03
VV81	0.05
VV82	0.06
VV83	0.08
VV84	0.12
VV85	0.14
VV86	0.17
VV87	0.06

BETA

VB77	0.001
VB78	0.02
VB79	0.01
VB80	0.03
VB81	0.03
VB82	0.04
VB83	0.04
VB84	0.03
VB85	0.02
VB86	0.01
VB87	0.01

TABLE 4

Pooled and Yearly Regressions, Age-Time Specification

Dependent Variable=ln(NPRICE)

	Pooled		1978-79		1980		1981		1982		1983		1984		1985		1986		1987	
	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values
prg	0.0180	3.10	0.1374	2.38	0.2301	3.19	0.1216	2.48	0.1376	4.46	0.0723	3.52	-0.0117	-0.69	0.0290	1.88	0.0563	3.74	-0.0420	-1.33
prgsq	0.0018	3.07	0.1893	1.53	-0.0396	-4.05	-0.0134	-1.22	-0.0320	-5.02	-0.0090	-4.11	0.0018	0.94	0.0020	1.22	0.0003	0.23	0.0079	2.78
days	0.0144	16.02	-0.1367	-1.46	-0.0610	-1.81	-0.0095	-0.53	0.0250	2.94	-0.0058	-0.81	0.0184	2.05	0.0228	7.86	0.0079	3.45	0.0189	7.82
daysq	0.0000	-14.65	0.1177	1.61	-0.0025	-2.51	-0.0004	-0.17	-0.0036	-2.79	0.0003	0.42	-0.0006	-1.09	0.0000	-6.25	0.0000	-2.90	0.0000	-7.09
prgdays	-0.0001	-5.08	-0.2908	-1.58	0.0217	4.33	0.0042	0.50	0.0157	3.56	0.0036	1.82	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
wired	0.0066	0.40			-0.0204	-0.34	-0.0049	-0.11	0.0502	1.25	0.0507	2.19	0.0092	0.21	-0.5055	-2.64	-0.0725	-0.54		
wireless	0.1131	6.28					0.0158	0.30	0.1804	4.10	0.2125	7.37	0.1653	3.96	-0.3262	-1.71	0.1846	1.43		
hifi	0.3816	43.51							0.1628	2.91	0.1375	4.59	0.1776	9.27	0.3785	18.55	0.4198	21.73	0.5349	25.47
hq	-0.0226	-1.83											-0.1624	-2.69	-0.0063	-0.14	-0.0193	-1.19	-0.0314	-0.80
dpan	-0.0006	-0.05	0.0694	3.20	0.0152	0.26	0.3530	3.11	0.0315	0.52	0.0954	3.35	0.0317	1.15	0.0907	2.89	0.1111	4.58	-0.0854	-3.32
drca	0.0019	0.15	0.0991	4.53	0.0344	0.59	0.3392	2.96	0.0185	0.30	0.0388	1.59	-0.0464	-1.50	0.0726	2.10	0.0009	0.03	0.0276	0.61
djvc	0.0298	2.20	0.1033	4.25	0.1033	2.59	0.2891	2.02	0.0601	0.92	0.1117	3.69	-0.0017	-0.06	0.1500	4.16	-0.0023	-0.08	-0.0303	-0.87
dsharp	-0.1053	-6.41					0.1847	1.70	-0.1471	-1.41	0.1944	4.72	0.0755	2.32	-0.0147	-0.34	-0.1283	-3.99	-0.2068	-5.26
dquasar	-0.0222	-1.38	0.0326	1.38	-0.0496	-0.80	0.2158	1.81	-0.1469	-1.91	0.0907	2.72	0.0458	1.46	0.1401	3.56	0.1565	1.70	0.0263	0.38
dge	-0.0903	-5.25							-0.2084	-3.56	-0.0044	-0.11	0.0490	1.42	0.0302	0.76	-0.0436	-1.01	-0.1217	-2.55
dfisher	-0.0639	-3.15											-0.1939	-3.86	0.0902	1.84	-0.1079	-3.09	-0.1524	-2.86
dmag	0.0108	0.51	0.0975	4.08					0.0816	0.67	0.0313	0.40	0.0638	1.19	0.3323	5.47	0.1423	2.10	-0.1681	-5.06
dsony	0.0148	1.13	0.2192	7.73	0.3142	3.98	0.4600	4.36	0.0343	0.60	0.0094	0.33	-0.0659	-1.99	-0.0088	-0.20	-0.1569	-4.42	0.1146	3.51
dzenith	-0.0381	-2.70	0.1004	3.48	0.1320	1.63	0.4003	3.70	-0.0067	-0.11	-0.0044	-0.13	-0.1707	-3.49	-0.0722	-1.80	-0.0190	-0.63	0.0351	1.15
dsanyo	-0.2643	-13.93	-0.0659	-1.90	-0.0919	-1.44	0.1652	1.22	-0.2771	-4.05	-0.1820	-6.24	-0.2836	-9.14	-0.4281	-5.34	-0.3808	-3.72		
dsears	0.2678	21.30	0.2845	10.00	0.3199	5.41	0.5165	4.58	0.3317	5.27	0.2986	12.75	0.2518	9.47	0.4741	13.75	0.3605	12.82	0.1490	4.21
age1	-0.0013	-0.19	-0.0483	-5.15	-0.0831	-7.61	0.0345	1.60	-0.0140	-0.70	0.0183	1.27	0.0159	1.14	-0.0404	-2.24	-0.0344	-2.21	-0.0058	-0.35
age2	-0.0229	-2.37	-0.0657	-4.12	-0.1447	-9.84	0.0034	0.14	-0.0719	-2.25	0.0137	0.65	0.0395	1.86	-0.0597	-2.32	-0.0512	-1.87	-0.1032	-4.16
age3	-0.0298	-1.93	-0.1262	-4.94	-0.2524	-12.36	-0.0629	-1.69	-0.0740	-1.19	0.0082	0.27	-0.0091	-0.24	0.0327	0.84	-0.1184	-2.73	-0.2415	-4.58
age4	0.0344	1.60			-0.2991	-9.94	-0.1119	-2.34	-0.0604	-1.17	0.0476	1.01	0.1590	3.74	0.0878	1.72	0.0096	0.11	-0.2744	-2.62
age5	0.0219	0.66					-0.1350	-2.65	-0.0736	-1.24	0.0487	0.78	0.1776	2.94	0.2207	1.17	-0.1192	-0.68	-0.2078	-1.17
t79	-0.0346	-1.19	-0.0247	-2.29																
t80	-0.1127	-3.83																		
t81	-0.2200	-7.69																		
t82	-0.4609	-16.54																		
t83	-0.6458	-23.37																		
t84	-0.8550	-30.28																		
t85	-1.1088	-38.49																		
t86	-1.1927	-39.75																		
t87	-1.2323	-38.60																		
constant	6.6099	223.63	6.5286	202.06	6.4471	72.24	6.0538	58.30	6.0192	102.77	5.8811	190.07	5.7577	102.45	5.7293	30.28	5.2856	37.02	5.5482	61.92
N	4052		217		184		236		342		508		616		642		713		594	
Adj Rsq	0.79		0.80		0.86		0.68		0.75		0.82		0.76		0.73		0.76		0.81	

Note: Data in 1978-79 are pooled in estimation due to the small number of observations, with a time dummy in 1979.

TABLE 5

Coefficients of the Installed Base Variable

Pooled		1978-79		1980		1981		1982	
Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values
0.0214	3.58	-0.0133	-4.17	0.4304	2.06	-1.1360	-2.50	-3.3957	-7.12

1983		1984		1985		1986		1987	
Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values	Coeffs	T-values
0.1916	6.50	0.0524	2.22	0.0390	1.17	0.1990	4.19	1.2519	0.96

Note: The T-A specification is used. See section 4 for more discussion.

TABLE 6

Quality-Adjusted Price Indexes of VCRs, 1978-1987

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Average Annual Price Change. (%)	Average of 1982-85	Average of 1978-81 & 1986-87
Nominal Price													
Arithmetic Mean	**100**	**100.05**	**100.58**	**96.80**	**83.70**	**70.84**	**65.34**	**58.42**	**55.12**	**55.13**	**-6.23**	**-11.81**	-1.76
change %		0.05	0.52	-3.75	-13.54	-15.36	-7.76	-10.59	-5.65	0.01			
Hedonic Regressions													
Pooled years:													
Unweighted T-A	**100**	**96.60**	**89.34**	**80.25**	**63.07**	**52.42**	**42.53**	**33.00**	**30.34**	**29.16**	**-12.51**	**-19.89**	-6.60
change %		-3.40	-7.51	-10.18	-21.41	-16.88	-18.87	-22.42	-8.05	-3.88			
Weighted T-A	**100**	**99.28**	**92.13**	**81.62**	**63.43**	**52.74**	**42.90**	**34.05**	**32.24**	**30.92**	**-11.91**	**-19.61**	-5.75
change %		-0.72	-7.20	-11.41	-22.28	-16.85	-18.66	-20.64	-5.30	-4.11			
Unweighted T	**100**	**96.30**	**88.98**	**79.98**	**63.06**	**52.30**	**42.46**	**32.90**	**30.21**	**28.96**	**-12.59**	**-19.89**	-6.75
change %		-3.70	-7.60	-10.12	-21.16	-17.06	-18.81	-22.52	-8.17	-4.16			
Weighted T	**100**	**99.20**	**91.98**	**81.05**	**63.15**	**52.48**	**42.61**	**33.79**	**31.92**	**30.44**	**-12.07**	**-19.62**	-6.03
change %		-0.80	-7.28	-11.88	-22.09	-16.90	-18.81	-20.70	-5.53	-4.64			
Adjacent years:													
Unweighted T-A	**100**	**97.56**	**94.56**	**89.49**	**71.77**	**59.94**	**49.66**	**38.66**	**35.14**	**33.89**	**-11.01**	**-18.90**	-4.71
change %		-2.44	-3.07	-5.36	-19.80	-16.49	-17.15	-22.16	-9.10	-3.55			
Weighted T-A	**100**	**97.56**	**94.46**	**90.02**	**71.40**	**60.97**	**50.26**	**39.59**	**36.47**	**34.75**	**-10.78**	**-18.52**	-4.59
change %		-2.44	-3.17	-4.71	-20.68	-14.62	-17.57	-21.22	-7.88	-4.73			
Unweighted T	**100**	**96.02**	**89.44**	**83.21**	**66.94**	**55.93**	**46.67**	**36.50**	**33.00**	**31.35**	**-11.86**	**-18.59**	-6.48
change %		-3.98	-6.84	-6.97	-19.55	-16.45	-16.55	-21.79	-9.59	-5.01			
Weighted T	**100**	**96.22**	**90.17**	**83.39**	**66.27**	**56.29**	**46.71**	**37.03**	**34.02**	**32.05**	**-11.65**	**-18.33**	-6.30
change %		-3.78	-6.29	-7.51	-20.54	-15.05	-17.02	-20.73	-8.14	-5.78			

Note: T-A is a time-age specification, and T is a time specification. QWEIGHT*MKTSHR is used as a weight in weighted hedonic regressions.

TABLE 7

Matched Model Price Indexes for Television sets (Gordon (1990))

Consumer Reports	1978	1979	1980	1981	1982	1983	1984
Unadjusted for Repairs and Energy	100	100.1	99.2	97.9	97.8	96.0	96.0
change%		**0.09**	**-0.87**	**-1.33**	**-0.05**	**-1.92**	**0.02**
Adjusted for Repairs and Energy	100	96.9	96.0	94.8	96.6	94.8	94.7
change%		**-3.10**	**-0.96**	**-1.23**	**1.95**	**-1.92**	**-0.13**

Source: Gordon (1990). TABLE 7. 19 on page 306.