

Quality-Adjusted Price Indexes for Home Video Cassette Recorders in the US, 1978-1987

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Abstract

We construct quality adjusted price indexes for Home Video Cassette Recorders in the US from 1978 to 1987. The constructed price indexes decline at 11-12% per year, with a particular drop by about 18% from 1982-1985. The magnitude of this decline is more than twice as much as the average price drop in the rest of the years. We discuss plausible causes of this large price decline. We incidentally find, contrary to the common perceptions, that the Beta format was not superior to the VHS format in major characteristics dimensions.

1 Introduction

Home video cassette recorders (hereafter VCRs) are a consumer durable that can receive TV programs off the air and record them on a magnetic cassette tape. The recorded tapes can be replayed on a picture tube at any time. VCRs have freed people from being restricted to watching television during the actual time of broadcasting, and also made it possible to watch one program while recording another on a different channel. VCRs clearly have given users greatly increased control over the allocation of their leisure time¹.

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¹Of course, playing back recorded TV programs is not the only use for VCRs. Playing back prerecorded tapes also became important for VCR users in later years, especially after 1985. See also Section 5.

From the outset, VCRs met a consumer need and soon gained huge popularity worldwide. In the US, the first VCR machine was introduced in 1976 (in Betamax format)². Subsequently VCR sales climbed steadily until 1986, notwithstanding the recession of 1981-1982. VCR sales almost doubled to 4.8 million units in 1983 alone, and had reached 9.4 million units a year later (Figure 1). VCR sales peaked in 1986, and now more than 80% of the US households have at least one VCR machine.

The VCR industry has attracted considerable attention in Industrial Organization, especially in theoretical work on network externalities³. This literature was stimulated by a story on competition between two different and incompatible VCR formats: Betamax, introduced by Sony and VHS developed by Japan Victor (JVC). Despite being the first format to enter the market, Beta eventually started losing market share, and exited the US market in 1989. Compared with the number of theoretical papers inspired by the VCR industry, there have, to the best of my knowledge, been few empirical studies on the industry of this period. An exception is Gordon's work (1990). His brief analysis uses data taken from *Consumer Reports* (*CR*) and attempts to measure how much VCR prices declined from 1980 to 1985 by comparing prices of similar models across the period.

There is reason to believe that the *CR* data may not reflect general trends in the VCR industry. *CR* evaluated VCRs in the US market on average every one and a half years during the period⁴. 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

²Sony introduced Betamax VCR to the US in 1975, but the purchase was tied with a television set. Stand-alone Betamax was introduced in the next year.

³See Liebowitz and Margolis (1994), for example.

⁴The dates of publication are: September 1978, October 1980, May 1982, July 1983, September 1985, January 1987 and March 1988.

was less than a year during 1978-1987 as shown in Table 1⁵ (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 %). In order to look at the VCR industry squarely, we surely need to collect more data on VCR prices and characteristics.

In this paper, we estimate hedonic price equations to construct price indexes, using detailed data from the US VCR market (The literature on hedonic analysis is substantial. See Berndt, Griliches and Rappaport (1995) and Gordon (1990) for example). Advertised prices in *New York Times* and mail order prices from Sears, Roebuck Co. are used in the analysis. Characteristics data are from various consumer electronics trade journals in addition to the above two sources. The data sources and their construction are recounted in Section 3. We first overview the VCR industry in the next section.

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 lightweight 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 Overview of the VCR Industry, 1978-1987

VCRs were invented by Japanese firms, whose basic technology came from the US. The Japanese succeeded in downsizing broadcasting video tape recorders developed by the US company, Ampex, and applying these to home use in the 1960s. There were

⁵See footnote 26 on the definition of the life of a model.

initially two different and incompatible formats: 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 only played on a Beta machine, and the VHS cassette only on a VHS machine (For more technical details, see Buchsbaum (August 1978)).

Betamax was introduced into the US market in 1976, and VHS was launched less than two years later. Both formats sold under either Japanese brands or US brands, but all the US brands were made from Original Equipment Manufacturer (OEM) supplies from Japanese firms. No US firms have manufactured VCRs to date⁶.

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 small as an audio cassette, was available in Japan. I could not find any evidence of formats other than Betamax and VHS entering the US market in 1978-1987.

The VCR industry is characterized by a rapid turnover of models. As Table 1 shows, the average life time of a model was less than a year, and major VCR brands like Matsushita, RCA and Sony had a practice of showing new models at the Consumer Electronics Show held in January and June every year. Frequent model turnover witnessed rapid upgrading of characteristics and significant market growth.

⁶Major Japanese consumer electronics companies, such as Matsushita, Toshiba and NEC started assembling VCRs in the US in 1986, though industry sources indicate that production costs in the US were 15% higher than in Japan (*Japan Economic Journal* (June 13, 1987)). This development was fostered by the Ministry of International Trade and Industry in Japan in its fear of the trade friction with the US. Units assembled in the US totaled 200,000-250,000 in 1987, from virtually zero in 1986.

One way of summarizing these changes is to look at mean values of VCR attributes over time.

Table 2 lists six characteristics used in this paper. The first three columns next to price display recording capabilities. The rest are “secondary” features. No doubt these six characteristics do not cover all the important functions of VCRs. A number of functions, unavailable to us 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 quality⁷. Frequency of repairs is another important dimension of new product characteristics that we cannot observe in the data⁸. However, the six attributes at hand 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 2, 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 hours⁹. 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

⁷I actually have data on the number of heads for most VCR models. The problem, however, 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.

⁸We briefly discuss frequency of repairs in Section 4.

⁹*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.

have actually recorded longer hours than those in Table 2 if video cassette tapes with longer recording capability had been available¹⁰.

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, and accordingly VCRs started from conventional monophonic recording. With the advent of stereo broadcasts and stereo TV sets, high quality sound became prevalent in VCR specifications. Table 2 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%¹¹.

“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 system¹².

¹⁰Table 2 uses the data on maximum recording hours per cassette when the model was launched in the market. It does not taken into account extended recording hours made available later.

¹¹There 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)).

¹²Super 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

There has been a widespread perception that the Beta format was superior to VHS¹³. 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 3). 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 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 (\$790) to 1981 (\$782). The price then fell sharply in 1981-1985 (\$454) and slowly declined subsequently (\$423 in 1987). The average percent price change was -6.4% per year, shown in the last column in Table 2. Except in 1986-1987, 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 on non S-VHS models showed any picture improvement on S-VHS machines (*CR* (1988)).

¹³Liebowitz and Margolis (1994) express doubts on this perception. See also references therein. None of them have hard evidence except VCR ratings evaluated by *CR*.

machines throughout the period by an average of 41%.

Notice that the price levels in Table 2 are quite lower than that in the *CR* source used by Gordon (1990). This is because *CR* tabulated manufacturers' suggested retail prices. Table 4 documents the *CR* prices of major brand models in 1978 and 1987, and compares them with the data used in this paper¹⁴. The five largest brands in terms of sales market share are selected and the price ratios of *CR* to our data are calculated in the last column. On average, the *CR* price is 34% higher than our price series in 1978 and 60% higher in 1987. The price ratio of the Sharp model stands out in 1987; the Sharp price in *CR* is more than twice as much as that in our data. As we shortly confirm with brand coefficients in Section 4, Sharp was famous as an aggressive price discounter at this time (*Annual Consumer Electronic Video Data Book* (hereafter *Video Book*) 4th, p.75). In fact, the average ratio after deleting the Sharp model is 1.42, similar to the 1978 ratio. These observations lead us to believe that, although the price levels are different, the general trend of the *CR* price movement may look similar to our price data. We discuss Gordon's index again in Section 5.

The average annual price change in Table 2, however, probably underestimates the true price decline in the VCR industry 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

¹⁴See Section 3 for details on the price data.

framework. Just focusing on the surviving models may still underestimate the true price decline by not correcting for selectivity bias.

We 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 we 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.

The rest of the paper is organized as follows. Section 3 explains how the price and characteristics data are constructed from various sources. Section 4 describes hedonic estimations and results. A specification incorporating age, brand and time dummy variables is chosen using a log-likelihood criterion. Alternative specifications with vintage dummy variables and weighted regression by market share 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 1982-1985 price drop with an emphasis on supply-side explanations. It is observed that a sharp drop in VCR unit cost and an inventory pileup caused by EC-Japan trade friction as well as an increase in the number of brand suppliers would account for the price drop.

Section 6 concludes our analysis.

3 Data Construction

Our 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 our characteristics categories. In view of this consideration our data set ends in 1987.

Throughout the sample covers 829 models/year of 22 brands in total¹⁵. Frequent turnover of models makes the data set unbalanced.

Price data 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 1982-87¹⁶. 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

¹⁵The 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 85% of the market in terms of sales on average in the ten years.

¹⁶I 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.

New York City¹⁷.

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 catalogs¹⁸. *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, we 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 20). 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 specialty shops and discount stores¹⁹. Those shops carried and

¹⁷I 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*, however, some Beta models in 1982 and 83 and several major VHS models in 1984-86 are observed to be more expensive in the two newspapers than the highest prices in *NYT*. On the other hand, some shops in *Los Angeles Times* and *Chicago Tribune* list lower prices than the lowest prices 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.

¹⁸The VCRs in the Spring catalogs were available in February at latest, and those in the Fall issues in August.

¹⁹This 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* (1982-1988)).

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 them²⁰.

Characteristics data 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 characteristics²¹. 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 US VCR manufacturers, what US 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 my sample periods 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

²⁰There 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.

²¹The Main sources used here are various issues of: *CR*, *Dearscope Merchandising*, *Mart Magazine*, *NYT*, *Popular Electronics*, *Sears Catalog* and *Video News*.

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 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”²². 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. Six characteristics variables are eventually available, which are introduced in Table 2. Summary statistics are in Table 5²³. As mentioned above, 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 5 is 4,054, not 11,924.

The variables we employ are as follows: NPRICE (current dollars), PRG (number

²²TV and radio manufacturers also have a similar practice of naming models. I thank Rob Porter for pointing out this additional evidence.

²³Table 5 is different from Table 2 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.

of programs), DAYS (number of days)²⁴, HR (maximum recording hours per cassette). The two variables, QWEIGHT (the number of price quotations for a model as a proportion of the total number of quotations for a brand by month) 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 otherwise²⁵. 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 life²⁶ and 0 otherwise, and Age1 takes 1 if the model was observed in the next six months of its life and 0 otherwise, etc. The final series of dummy 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)²⁷;

²⁴An 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 5 are zero.

²⁵Specific 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.

²⁶Life 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 of the Electronics Industry* (May 1978).

²⁷As for age dummy variables, a model is assumed to be in the market if the model shows up in

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). We 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 5 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 we 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 average annual market share for the ten years.

4 The Estimation and the Results

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

either *NYT* or *Sears Catalog*.

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 (Jack Triplett (1989)). We 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 basically 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 2 if video cassette tapes with longer recording capability had been available. Table 6 tabulates correlation matrixes of major characteristics by year and pooled years.

We compute log-likelihoods of semi-log, log-log and linear forms, concentrated with respect to a variance parameter²⁸. In each of these three forms, we 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 our estimation model since it achieves the highest log-likelihood in the pooled data for ten years²⁹. The log-likelihoods of each specification are in Table 7. Because the

²⁸In a log-log regression, PRG and PRGSQ are replaced by $\ln(\text{PRG}+1)$ and $[\ln(\text{PRG}+1)]^2$. Same for DAYS and DAYSQ. PRGDAYS is $[\ln(\text{PRG}+1)] \cdot [\ln(\text{DAYS}+1)]$.

²⁹Because 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. These log-likelihoods are also listed in Table 7.

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 8 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)³⁰. 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.

Stability of parameters over adjacent two-year regressions is mostly rejected at the 1 % significant level. The list of F values is presented in Table 9. The constant term and time dummy variables are excluded from the restrictions.

There are several points worth noting on the hedonic estimates in Table 8. 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 2, 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

³⁰Since there are no DOTHERS in 1981, the reference brand in this year only is GE in a yearly regression.

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 2 shows marginal effects on NPRICE with respect to PRG and DAYS. The straight lines show the point estimates, and the distance between the dotted and straight lines indicates the standard error³¹. 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 2. 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 1978-1982 is 0.45, twice as much as that in 1983-1987 (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 US, consumers

³¹The derivation of the standard error for PRG is as follows:

$\frac{\partial \text{NPRICE}}{\partial \text{PRG}} = \frac{\partial \text{NPRICE}}{\partial \ln(\text{NPRICE})} \cdot \frac{\partial \ln(\text{NPRICE})}{\partial \text{PRG}} = xb$ where $x = \text{NPRICE}^* [1, 2 \cdot \text{PRG}, 0, 0, \text{DAYS}, 0, \dots, 0]$ and b is a column vector of the estimates with the same ordering as the explanatory variables listed in Table 6. 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 $x^*(\text{Estimate of } \Sigma)x'^*$, where the estimate of Σ is the variance-covariance matrix of b .

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 shops³². As VCRs grew in popularity, more shops dealt with them, more extensive warranties became available³³ 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 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

³² *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.

³³ 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).

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 15, the range of price levels in *NYT* do not appear to be much different from other US 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. In Table 10 we perform an estimation replacing vintage with time dummy variables in the pooled estimation³⁴. As expected, the age coefficients are declining and significantly

³⁴V77 is dropped due to the small number of observations.

different from zero. We would not reject the hypothesis that the rates of decline in age coefficients are same across years, as the F-test results Table 10 indicates. The rate of obsolescence can be computed by exponentiating the difference of adjacent age coefficients, and subtracting one from it. We do not need to take a difference of coefficients in the first year of obsolescence. Remember that the age dummy variables are constructed on a semi-annual basis. The average annual rate of obsolescence over the first two and a half years of VCRs from 1978 to 1987 is 13.3%³⁵.

We conduct an analysis to see how different sets of independent variables contribute to explaining estimated price, using the estimates of yearly regressions in Table 8 regardless of their standard errors. We construct four annual average estimated prices as in Figure 3 using sets of mean characteristics in each year. The bold line shows the estimated price using all the independent variables listed in Table 8, and the other three use different subsets of independent variables. We omit actual average VCR prices because they are indistinguishable from the bold line. The estimated price leaving out main programming functions (that is, PRG, DAYS, PRGSQ, DAYSQ and PRGDAYS), shown in the broken line in Figure 3, lies always below the bold line. The distance between the lines starts at \$74, peaks at \$195 and ends at \$126. The dotted line represents the estimated price without the secondary VCR functions (that is, WIRED, WIRELESS, HIFI and HQ when applicable). Due to multicollinearity, we did not use the secondary functions in the hedonic estimation of 1978-1979. Thus the dotted line starts at 1980.

An interesting observation is made on the thin solid line, the estimated price omitting the make dummies. First the average make premium (i.e., the distance

³⁵Frequency of repairs may be taken into account here to the extent that the vintage dummy captures reliability of VCRs on average across the brands.

between the bold and thin solid lines) begins at about \$62 in 1978, peaks at \$238 in 1981 (Notice that all the make dummy coefficients are positive in this year), and then generally diminishes to virtually zero. The average make effect appears less important in explaining estimated price as the VCR market develops over time. This is consistent with our explanation of Figure 2: As more consumers became acquainted with VCRs, and the products became more reliable with extended warranties, brand image alone, like for example, JVC and Sony as the originators of VHS and Betamax respectively, was not able to sustain price premium on average.

Issue on vintage dummy The six characteristics in Table 2 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 in constant succession, and kept attracting consumers' attention. Actually VCR manufacturers announced new functions about once every three months³⁶.

Although we do not have characteristics data beyond the six 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

³⁶See Itami (1989, p.p. 210-218).

characteristics of models rolled out in the same year. If the observed six characteristics already capture all important dimensions of VCR features, the added vintage dummies may not have any significant information. If the six 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, we can also divide the vintage dummy variables into Beta vintage and VHS vintage dummy variables (denoted by VB and VV respectively)³⁷.

As is seen in Table 5, 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 in Table 10; coefficients other than age dummy variables are close to those in the age-time specification in Table 8.

Since interpretation of the vintage dummy variables is quite obscure in our case, we 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. We estimated the age-format vintage hedonic equation without time dummies³⁸. The specification with time dummies gives similar results. The results are in Table 10.

³⁷Since 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. So conceptually there is no multicollinearity problem in putting all three dummies in the estimation at once.

³⁸VV77 and VB77 are excluded due to the small number of observations. So the reference vintage is an average of VV76, VV77 and VB77.

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 are also shown in Table 10. Equality cannot 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 We 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 we do not have sales data by model, we 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.)³⁹. Shares are measured by sales. The market shares for 1978 and 79 are computed by the author using the VCR penetration and ownership surveys collected by Media Statistics. The method of computation is in the Appendix. The market share for 1980 is obtained by linearly interpolating the shares for 1979

³⁹The data are based on questionnaire in which VCR brand marketers were asked to estimate competitors' market shares. The data are medians of the estimates. The questionnaire did not clarify a distinction among VCRs, VCPs and camcorders. *Video Book* started surveying camcorders separately from VCRs in 1985. Thus it might be possible that our market share data include VCPs in later years, and also include camcorders before 1985.

and 1981⁴⁰ The summary statistics are shown in Table 5 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. We name this QWEIGHT, for which summary statistics are shown in Table 5. 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, we do not analyze hedonic estimates here. However, the estimates are close to what we obtained in the unweighted regressions, and the interpretations of characteristics coefficients and make coefficients qualitatively carry through. The weighted version of Figure 2 also possesses the same features.

Remember that the data we 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, our unweighted dataset is actually weighted by the “life period” of the model⁴¹. If a model with longer life enjoyed more sales, which is very likely, our results for the unweighted regressions already captured most of what we did in this subsection.

⁴⁰The 1980 brand market shares could possibly be constructed using the VCR ownership survey conducted by Nielsen in 1980 (*Video Book*, 1st ed. p.50.). To the best of my knowledge, this is the only information on the 1980 market shares. The computed market shares were, however, hardly believable (for example, Sony’s market share were negative). So I chose the interpolation.

⁴¹Of course the model cannot be counted more than 12 times in a yearly regression.

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.

The first row in Table 11 is the arithmetic mean of VCR prices by year. The average annual price change is -6.43%, with large drops in 1982 and 1983. Remember again that this is slightly different from the prices shown in Table 2. The arithmetic mean in Table 11 is weighted roughly by the life period of model since the frequency of the data is monthly, whereas the mean price in Table 2 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), we 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 8. 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 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 1978-1987.

It may be interesting to look at the rate of quality change using the unweighted adjacent year T-A model as a reference specification. Table 12 shows the quality change in percentage from the previous year. While the table shows quality improvement 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 2).

One interesting observation is that all the quality adjusted price indexes show a particularly large price drop in 1982-85 of 18% 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 11). Before we probe this price movement, we should compare our quality adjusted indexes with Gordon's index.

5.1 Comparison with Gordon's Index

Gordon (1990) constructs a price index in 1980-1985 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. The first row in Table 13 is taken from Gordon (1990, table 7.21, p.312). The second row is the percentage rate of the price change computed by the author.

Surprisingly Gordon’s price index drops much more sharply than our indexes. If, as we discussed in Section 2, the nominal VCR prices in our 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 our dataset.

A problem in Gordon’s index may be that his classification of the VCR models could be too broad. As we saw in Table 2, VCR characteristics dimensions cannot be limited to just PRG, WIRED and WIRELESS. He also excludes several 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, recall that new VCRs were introduced more frequently than *CR* reviewed VCR prices. 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 1982-1985 price drop

We now turn to speculating as to the reasons for the price decline in the US VCR market in 1982-1985.

So far, we 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 we start to think about the economic causes of movement in quality adjusted price indexes, however, we 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 our sample contains an inflationary period due to the Second Oil Crisis in 1979; the annual rate of CPI inflation was 12% on average in 1979-1981.

In order to see how striking the 1982-1985 price drop is, we may compare it with the US television market, the structure of which seems relatively stable during the period⁴². Table 14 shows quality adjusted price indexes of TV sets in 1978-1984, 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 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 1982-1985 price drop observed in Table 11.

Changes in the demand side as well as the supply side can potentially explain this decline, but we need to remember Figure 1: VCR sales experienced a dramatic increase in this period. Thus it seems difficult to explain the phenomenon only from

⁴²One event that could have affected the US TV market was antidumping taxation and subsequent voluntary export restraint on Japanese TVs to the US in 1971-1980. 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 US (McGee (1994), p.21).

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 we briefly overview two events which plausibly led to a change on the demand side, and then we look at the supply side rather closely.

Demand Side We can 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 the 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.)).

We can 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 1982-1985. Changes on the supply side must be necessary to fully account for the 1982-1985 price drop. We describe two such factors: One is a change in VCR unit cost, and the other is the effect of inventory pileups due to aftermath of EC-Japan trade friction.

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 US market and also a decrease in marginal cost. Our dataset shows that the number of brands (models per year respectively) was on the increase from 13 (92) in 1982 to 20 (171) in 1985.

As we mentioned in Section 2, almost all the VCRs in the US market were imported from outside the US. Hence customs data with the VCR dock price and the associated customs duties provide a rough idea on how much US suppliers paid for imported VCRs. Figure 4 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 US 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 our focus⁴³. Figure 4 shows that VCR unit cost decreased in general. The average annual decline is 9.5%, with a particular drop in 1982-1985; 15.7% on average⁴⁴.

So far we have seen that a shift in the industry supply curve, due to the drop in VCR unit cost and the increase in the number of brand suppliers, might generate the price decline and the sales surge in 1982-1985. We also observe another quite interesting event outside the US, which would have a substantial effect on the US VCR market in this period.

In 1982, the EC made a dumping complaint against Japanese VCRs to the General Agreement on Tariffs and Trade (GATT). The EC had eleven manufacturers and marketers of the Phillips-developed V-2000 format, which was incompatible with Betamax and VHS. In the complaint, the EC contended that the prices of Japan-made VCRs had dropped 60% over the last two years, and that their retail prices were less than the cost of production. In the meantime, the EC countries started imposing nontariff restrictions on Japanese VCR imports. For example, France required all VCR imports to be processed through a small island customs station. The effect is reflected in figures showing that France cleared only about 1,000 VCRs in November 1982, against 53,000 in August of that year (*Video Book*, 2nd.ed. p.18).

In response to the complaints from the EC, Japanese manufacturers agreed to self-restrict their export quantities to the EC for three years, from 1983-1985. The quota ended up limiting 4.55 million units for 1983 (including kits for overseas assembly

⁴³I am grateful to Roger Pomeroy of the International Trade Association for assistance in the data construction.

⁴⁴The nominal exchange rate was between 200-250 Japanese yen/\$US in 1978-1985, and then started declining to 142 yen/\$US in 1987. Thus the period of VCR cost drop does not coincide with that of yen appreciation.

only for this year), 3.95 million for 1984 and 2.25 million for 1985.

This EC-Japan trade friction and subsequent Japan's concessions seemed to have a considerable effect on the US VCR market. Industry people worried that Japan would concentrate its VCR shipments on the US. Trade data show the clear shift of Japanese VCR exports from the EC to the US: From 1981 to 1985, the share of the EC in Japanese VCR exports changed from 38.8% to 12.8%, while the share of the US shifted from 32.3% to 62.5%. During those four years the total units of VCR exports from Japan increased by more than 50% per annum⁴⁵.

US trade journals started warning and worrying about the level of pipeline inventory (i.e., the sum of distributors' and factories' inventory) in 1983, and kept waving the red flag until 1986. Unfortunately we do not have inventory data, but a simple calculation may be enough to see how large the inventory pileup was. Roughly speaking the inventory can be calculated by subtracting US sales from US imports. The calculated inventory level shows a dramatic change: The annual mean of the calculated inventory level was 2.6 million units from 1981 to 1986 while from 1978 to 1980 it was 0.1 million. Since the Japan's share in US VCR imports was always over 95 % and did not fluctuate much⁴⁶, this dramatic change in the inventory level can be roughly attributed to Japan's export shift from the EC to the US. The sharp price drop of VCR unit cost we discussed in Figure 4 also seems to be associated with this inventory pileup.

The large inventory level may push the industry supply curve downward to the right: Given a price, each brand vendor wants to sell more than it does without inventory. It is also easy to imagine that the large inventory level as well as the

⁴⁵The data are from *Electronics Industry Almanac of Japan* (1978.ed.-1989.ed.).

⁴⁶Japan's share in US imports was over 99% from 1978 to 1984, 96% in 1985 and 95% in 1986 (The author's calculation based on *TSUSA*).

high turnover rates of models⁴⁷ can change the way the brands compete with one another, triggering severer price competition: In order to catch up with technological progress, each brand marketer had to clear their inventories as soon as possible with cutting-edge prices in sacrifice of their profit before the products in their inventories went obsolete.

The hedonic regressions and the resulting quality adjusted price indexes cannot tell us whether our speculation above is valid. Neither can they tell how important were the decline in VCR unit cost and the inventory effect in cutting US VCR prices. We have to take a different approach to answer these questions.

6 Concluding Remarks

We constructed quality adjusted price indexes for home video cassette recorders in the US market from 1978 to 1987. We first looked 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. We then estimated hedonic equations using a traditional age-time specification with squared and interaction terms. Although we found little evidence supporting stability of the estimates over the period, we observed reasonable estimates reflecting the evolution of the industry in this era. We also discussed the merits of vintage dummy variables and weighted regression. The annual rate of VCR obsolescence was calculated in passing to be about 13.3%.

⁴⁷The rapid turnover rates of models seemed to be maintained during this period: The average life of VCR models by year is as follows (months): 14.4 (1978), 15.7 (1979), 15.8 (1980), 14.4 (1981), 12.0 (1982), 12.0 (1983), 12.2 (1984), 8.6 (1985) and 7.5 (1986).

We then constructed 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. We discussed the plausible causes of this large price decline.

7 Data Appendix on market share for 1978 and 1979

This data appendix explains how the annual brand market share data for 1978 and 1979 are constructed.

The 1978 market share data are computed based on the following observations: Sony Betamax was in the market by February 1976. Zenith Beta machines were introduced in November 1977. Panasonic, RCA and the other Matsushita VHS machines were launched in the fall of 1977, but they seemed to have a hard time at first in selling VCRs. JVC models entered the market in September 1977⁴⁸. Obviously Sony was the only seller in 1976. On consideration of the introduction dates and the slow start for VHS sales, it is not a far-fetched assumption that all the VCRs sold in 1977 were attributed to Sony models. I computed the 1978 market share based on this assumption using two data series: Factory unit shipment data released by the Electronics Industry Association (*Fortune* (July 19, 1979)) and Home VCR penetration studies conducted by Media Statistics in first quarter of 1979. I calculated the cumulative sales of each brand using the penetration data, and then subtracted Sony's sales of 1976 and 1977. Finally each brand market share is obtained by dividing by

⁴⁸The introduction dates for the brands mentioned above are obtained from Cusumano, Mylonadis and Rosenbloom (1992, p.p.89-90), Grindley (1995, p.84) and *Journal of the Electronics Industry* (May 1978).

the total annual VCR sales of 1978.

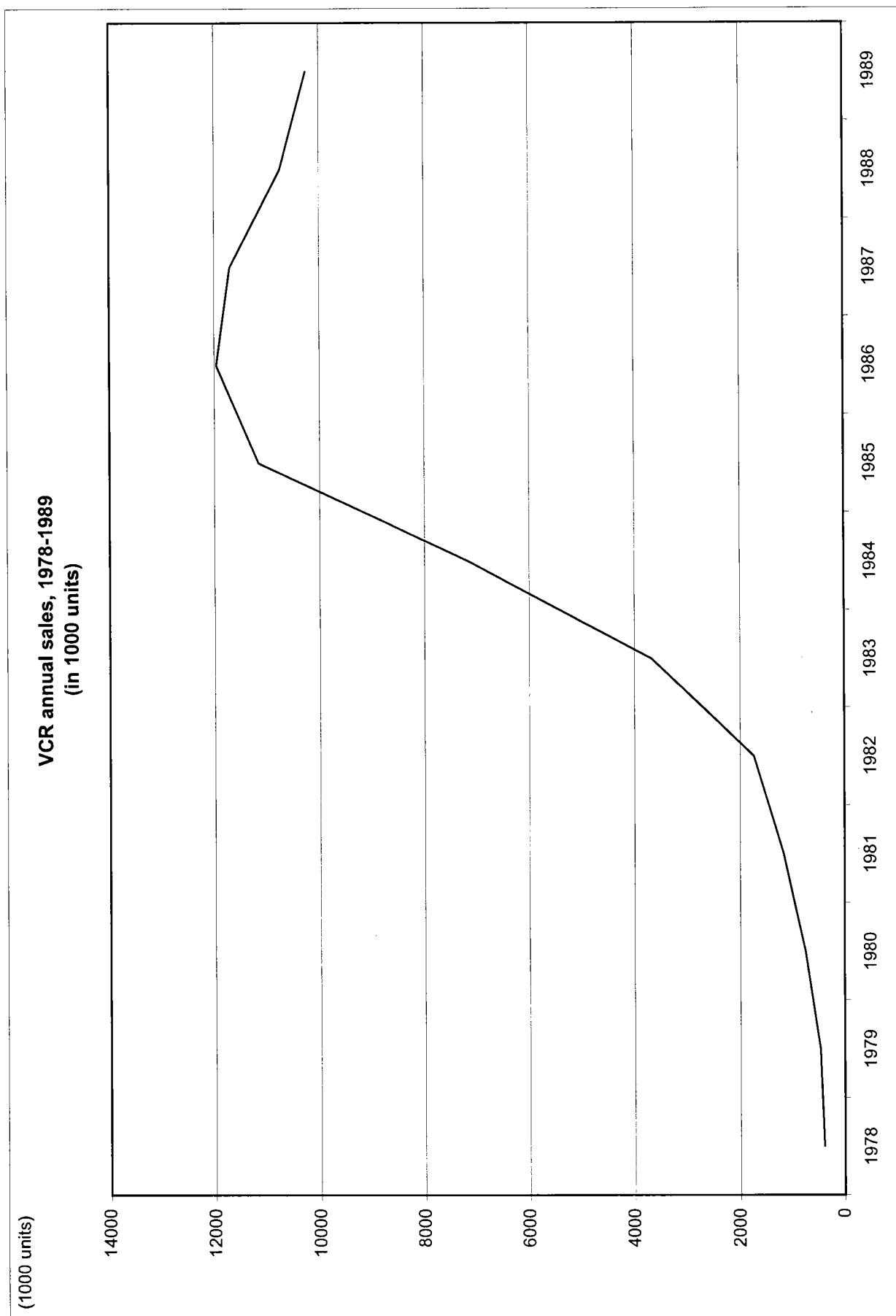
The 1979 market share data are constructed from the change in the VCR penetration rates in the first and fourth quarter of 1979 from Media Statistics ⁴⁹.

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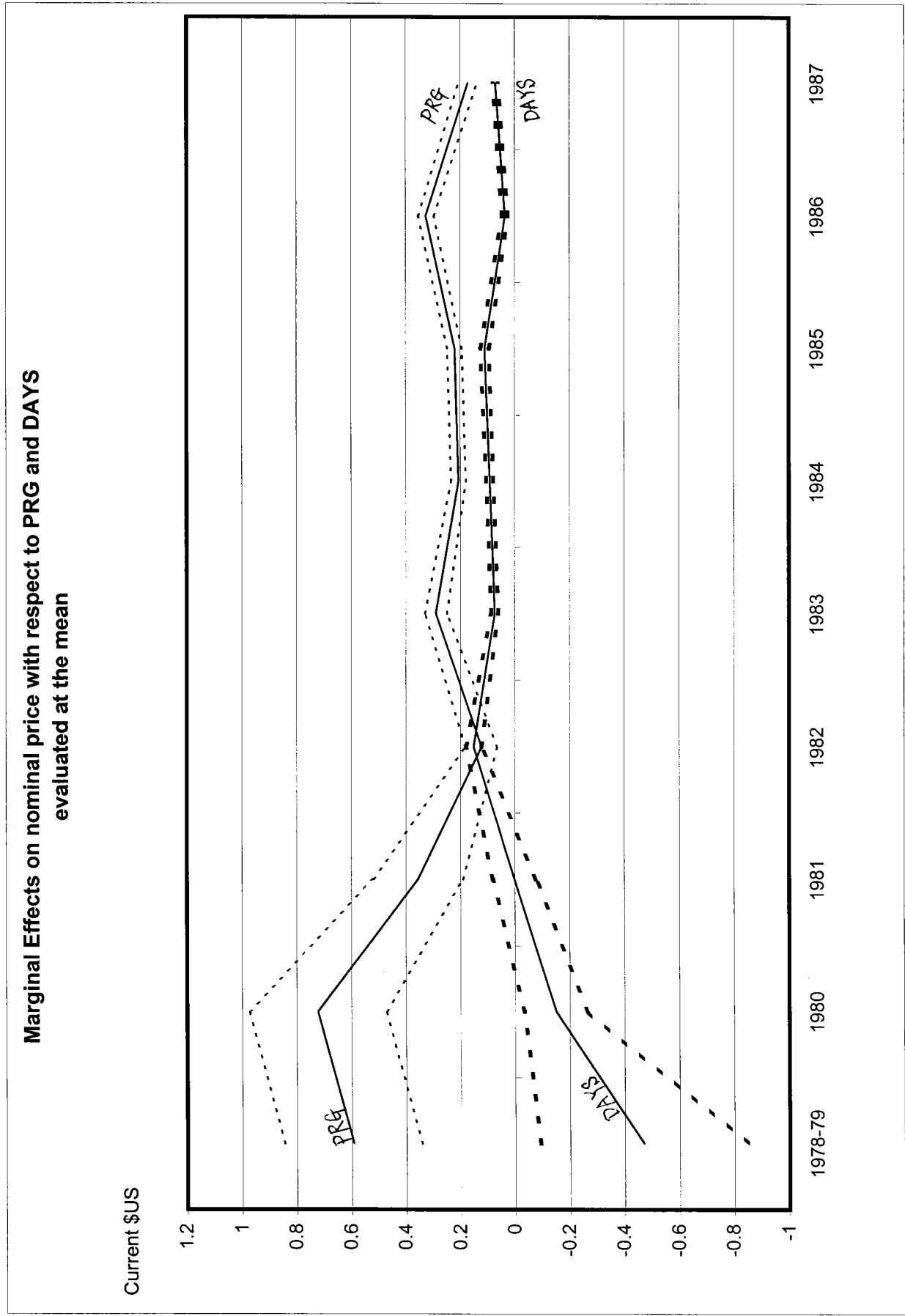
⁴⁹This VCR penetration survey is available in *Economic World* (February, 1980).

Figure 1



Source: *Appliance* (January 1978-April 1994)

Figure 2



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 31.

Figure 3

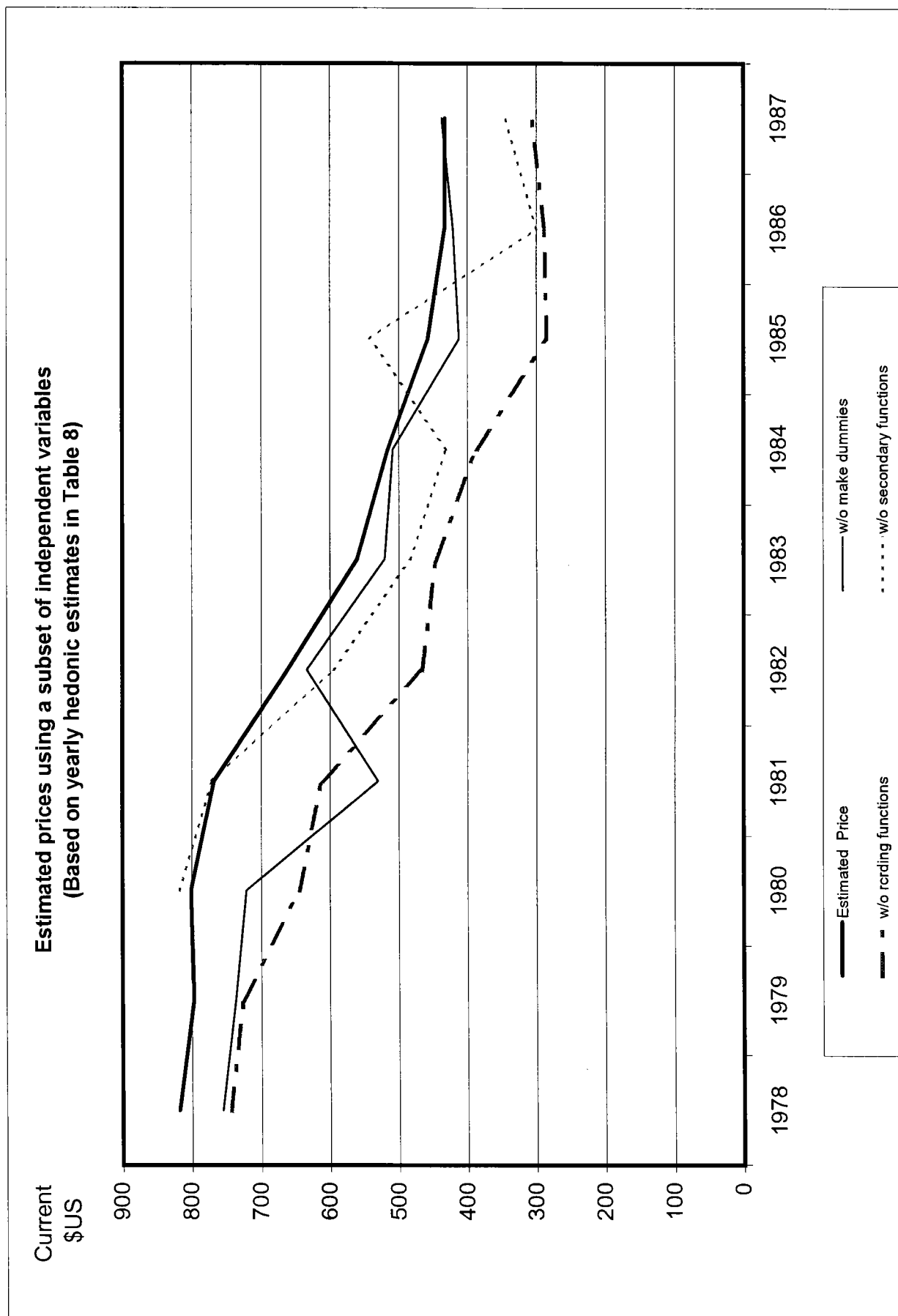
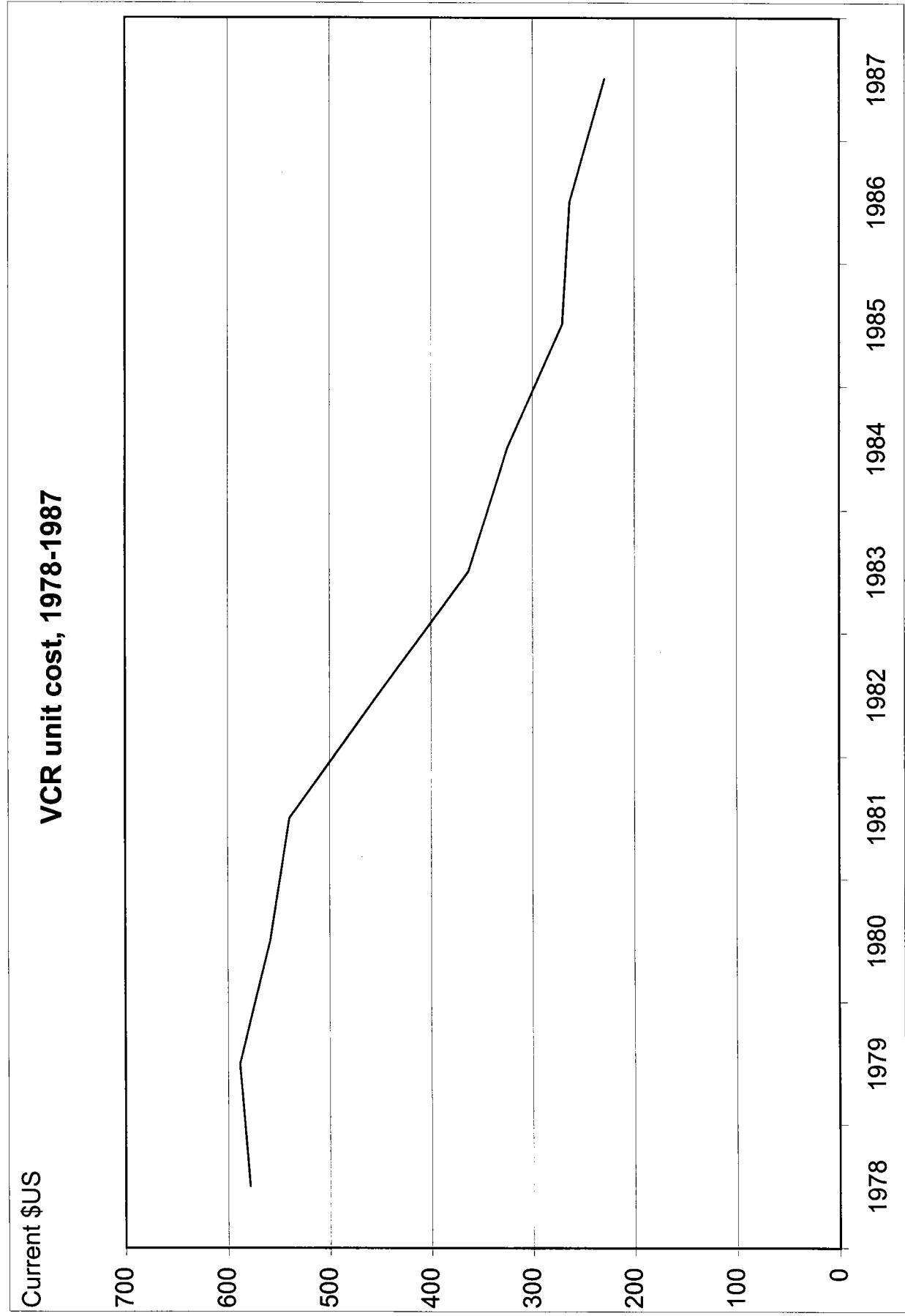


Figure 4



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

Table 1

Number and Average Life of Models, for Selected Brands, 1978-1987

Brands	No. models	Life (month)
RCA	57	9.5
Sony	38	14.3
Panasonic	66	12.3
Fisher	20	7.4
Magnavox	23	5.6
Quasar	31	7.7
Zenith	30	14.5
GE	22	8.0
Sanyo	18	8.9
Sears	47	11.2
JVC	27	17.2
Sharp	25	8.3
Average	34	10.4
Total	404	

Note: Definition of Life is given in footnote 26. The brands are selected if the average of the market shares from 1978 to 1987 is greater than 3.0%. The brands are in descending order of average market share.

Table 3

The Frontier Models by format, 1978-1987

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

Note. The frontier model is a fictitious model, constructed by putting together the best characteristics across all the models by format and year.

Price comparison of major VCR models between our data and Consumer Reports in 1978 and 1987

1978		Our Price Data (1)		Consumer Reports(2)		Ratio (2) / (1)	
Model names	Brand	1978	1978	1978	1978	1978	1978
Major VCR models							
VBT200	RCA	776.5	1000.0	1.29			
PV1000	Panasonic	745.6	1095.0	1.47			
SL8200	Sony	843.7	1055.0	1.25			
JR9000W	Zenith	731.0	995.0	1.36			
HR3300U	JVC	750.0	995.0	1.33			
On average		769.3	1028.0	1.34			
1987		Our Price Data (1)		Consumer Reports(2)		Ratio (2) / (1)	
Model names	Brand	1987	1987	1987	1987	1987	1987
Major VCR models							
VMT670HF	RCA	735.0	899.0	1.22			
VMT295	RCA	314.0	399.0	1.27			
PV1742	Panasonic	785.0	1250.0	1.59			
PV1364	Panasonic	278.2	500.0	1.80			
VC6846UB	Sharp	207.5	550.0	2.65			
FVH-960	Fisher	579.5	850.0	1.47			
VR9565AT	Magnavox	716.3	855.0	1.19			
On average		516.5	757.6	1.60			
On average except Sharp		568.0	792.2	1.42			

Notes:

- 1) The five brands are selected and ordered by highest market share.
- 2) The models in 1987 are selected from the CR ratings chart.
- 3) Our price data (1) are from advertisement prices in New York Times and Sears Catalogs. Consumer Reports list manufacturers' suggested retail prices.

Summary Statistics of home VCR data, 1978-1987 (sample size:4054)

Variables	Descriptions	Mean	Std error	Minimum	Maximum
NPRICE	advertisement price in NYT (\$)	546.91	207.39	189.00	1279.90
PRG	programs (counts)	4.18	2.71	0	9
DAYS	days	24.30	66.34	0	365
HR	maximum recording hours	6.85	1.53	2	8
QWEIGHT	proportion of price quotations	0.06	0.11	0.002	1.00
MKTSHR	annual brand market share	0.09	0.08	0.001	0.41

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 6

Correlation Matrixes of main VCR characteristics, 1978-1987

Pooled

obs=4054

	prg	days	wired	wireless	hifi	hq
prg	1.00					
days	0.19	1.00				
wired	-0.44	-0.17	1.00			
wireless	0.50	0.19	-0.92	1.00		
hifi	0.48	0.04	-0.37	0.40	1.00	
hq	0.22	0.22	-0.37	0.40	0.24	1.00

1978-79

obs=219

	prg	days	wired
prg	1.00		
days	0.98	1.00	
wired	0.30	0.26	1.00

1980

obs=184

	prg	days	wired
prg	1.00		
days	0.83	1.00	
wired	-0.03	-0.13	1.00

1981

obs=236

	prg	days	wired	wireless
prg	1.00			
days	0.88	1.00		
wired	-0.28	-0.36	1.00	
wireless	0.41	0.34	-0.71	1.00

1982

obs=342

	prg	days	wired	wireless	hifi
prg	1.00				
days	0.84	1.00			
wired	-0.52	-0.54	1.00		
wireless	0.68	0.66	-0.81	1.00	
hifi	0.22	0.14	-0.19	0.24	1.00

Variables:

prg: the number of preset program times a VCR can remember. days: the number of days a VCR can preset program times. wired, wireless, hifi and hq take one respectively if they are available in a VCR, and 0 otherwise respectively.

Note: Some variables are excluded in some years because those characteristics were not observed. The data in 1978 and 79 are pooled due to the small number of observations.

1983

obs=508

	prg	days	wired	wireless	hifi
prg	1.00				
days	0.67	1.00			
wired	-0.42	-0.29	1.00		
wireless	0.56	0.46	-0.81	1.00	
hifi	0.41	0.23	-0.26	0.33	1.00

1984

obs=616

	prg	days	wired	wireless	hifi	hq
prg	1.00					
days	0.52	1.00				
wired	-0.54	-0.26	1.00			
wireless	0.56	0.33	-0.93	1.00		
hifi	0.48	0.24	-0.31	0.34	1.00	
hq	0.11	-0.03	-0.06	0.06	0.01	1.00

1985

obs=642

	prg	days	wired	wireless	hifi	hq
prg	1.00					
days	0.22	1.00				
wired	-0.38	-0.06	1.00			
wireless	0.39	0.06	-0.99	1.00		
hifi	0.48	0.09	-0.27	0.27	1.00	
hq	0.27	-0.04	-0.08	0.08	0.29	1.00

1986

obs=713

	prg	days	wired	wireless	hifi	hq
prg	1.00					
days	0.19	1.00				
wired	-0.19	-0.05	1.00			
wireless	0.19	0.05	-0.96	1.00		
hifi	0.60	-0.10	-0.15	0.16	1.00	
hq	0.08	0.04	-0.19	0.20	0.02	1.00

1987

obs=594

	prg	days	hifi	hq
prg	1.00			
days	0.09	1.00		
hifi	0.80	-0.13	1.00	
hq	-0.11	-0.26	0.06	1.00

Table 8

Pooled and Yearly Regressions

Dependent Variable= $\ln(\text{NPRICE})$

	1978-79		1980		1981		1982		1983		1984		1985		1986		1987	
	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values	Coefs	T-values
prg	0.0180	3.10	0.1382	2.40	0.2301	3.19	0.1216	2.48	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	0.1891	1.53	-0.0396	-4.05	-0.0134	-1.22	-0.0090	-4.11	0.0018	0.94	0.0020	1.22	0.0003	0.23	0.0079	2.78
days	0.0144	16.03	-0.1366	-1.47	-0.0610	-1.81	-0.0095	-0.53	-0.0058	-0.81	0.0184	2.05	0.0228	7.86	0.0079	3.45	0.0189	7.82
daysq	0.0000	-14.85	0.1176	1.62	-0.0025	-2.51	-0.0004	-0.17	0.0036	0.42	-0.0000	-0.09	0.0000	-6.25	0.0000	-2.90	0.0000	-7.09
prgdays	-0.0001	-5.08	0.1176	1.62	-0.0025	-2.51	-0.0004	-0.17	0.0036	0.42	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
wired	0.0065	0.40	-0.2906	-1.59	0.0217	4.33	0.0042	0.50	0.0036	1.82	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
wireless	0.1131	6.28	-0.2906	-1.59	0.0217	4.33	0.0042	0.50	0.0036	1.82	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
hifi	0.3816	43.52	-0.2906	-1.59	0.0217	4.33	0.0042	0.50	0.0036	1.82	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
hq	-0.0226	-1.84	-0.2906	-1.59	0.0217	4.33	0.0042	0.50	0.0036	1.82	0.0026	1.96	-0.0005	-3.19	-0.0001	-3.82	-0.0002	-4.96
dian	-0.0006	-0.05	0.0693	3.21	0.0152	0.26	0.0315	0.52	0.0954	3.35	0.0317	1.15	0.0907	2.89	0.1111	4.58	-0.0854	-3.32
dica	0.0019	0.15	0.0989	4.54	0.0344	0.59	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	0.1032	4.26	0.1033	2.59	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	-6.42	0.1032	4.26	0.1033	2.59	0.0601	0.92	0.1117	3.69	-0.0017	-0.06	0.1500	4.16	-0.0023	-0.08	-0.0303	-0.87
dquasar	-0.0222	-1.38	0.0324	1.38	-0.0496	-0.80	0.1847	1.70	0.1944	4.72	0.0755	2.32	-0.0147	-0.34	-0.1283	-3.99	-0.2088	-5.26
dge	-0.0903	-5.26	0.0324	1.38	-0.0496	-0.80	0.1847	1.70	0.1944	4.72	0.0755	2.32	-0.0147	-0.34	-0.1283	-3.99	-0.2088	-5.26
dfisher	-0.0639	-3.15	0.0324	1.38	-0.0496	-0.80	0.1847	1.70	0.1944	4.72	0.0755	2.32	-0.0147	-0.34	-0.1283	-3.99	-0.2088	-5.26
dimag	0.0108	0.51	0.0973	4.09	-0.0831	-5.41	0.0165	4.58	-0.0044	-0.11	0.0490	1.42	0.0302	0.76	-0.0436	-1.01	-0.1217	-2.55
dsony	0.0148	1.13	0.2193	7.77	0.3142	3.98	0.4600	4.36	0.0313	0.40	-0.1939	-3.86	0.0902	1.84	-0.1079	-3.09	-0.1524	-2.86
dzenith	-0.0380	-2.70	0.1004	3.49	0.1320	1.63	0.4003	3.70	0.0094	0.33	-0.0659	-1.19	0.3323	5.47	0.1423	2.10	-0.1681	-5.06
dsanyo	-0.2643	-13.93	-0.0659	-1.91	-0.0919	-1.44	0.1652	1.22	-0.0044	-0.13	-0.1707	-3.49	-0.0722	-1.80	-0.1569	-4.42	0.1146	3.51
dsears	0.2677	21.32	0.2866	10.31	0.3199	5.41	0.5165	4.58	-0.1820	-6.24	-0.2836	-9.14	-0.4281	-5.34	-0.3808	-3.72	0.0351	1.15
age1	-0.0013	-0.19	-0.0486	-5.23	-0.0831	-5.41	0.0345	1.60	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	-0.0665	-4.22	-0.1447	-9.84	0.0034	0.14	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	-4.96	-0.2524	-12.36	-0.0629	-1.69	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	-0.1262	-4.96	-0.2524	-12.36	-0.0629	-1.69	0.0082	0.27	-0.0091	-0.24	0.0327	0.84	-0.1184	-2.73	-0.2415	-4.58
age5	0.0219	0.66	-0.1262	-4.96	-0.2524	-12.36	-0.0629	-1.69	0.0082	0.27	-0.0091	-0.24	0.0327	0.84	-0.1184	-2.73	-0.2415	-4.58
t79	-0.0338	-1.18	-0.0255	-2.41														
t80	-0.1118	-3.86																
t81	-0.2192	-7.78																
t82	-0.4601	-16.79																
t83	-0.6449	-23.75																
t84	-0.8541	-30.75																
t85	-1.1079	-39.09																
t86	-1.1919	-40.31																
t87	-1.2314	-39.08																
constant	6.6092	226.32	6.5287	203.01	6.4471	72.24	6.0538	58.30	5.8811	190.07	5.7577	102.45	5.7293	30.28	5.2856	37.02	5.5482	61.92
N	4054		219		184		236		508		616		642		713		594	
Adj Rsq	0.79		0.81		0.86		0.68		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.

The F tests for structural changes, $F(n_1, n_2)$

Note: The F tests allow different constant terms (i.e., constant and time dummies are not in the set of restrictions).

	1978-79	1980	1981	1982	1983	1984	1985	1986
Adjacent year								
n1	17	18	21	24	24	26	26	23
n2	366	382	534	800	1074	1204	1301	1259
F-values	4.78	5.11	3.26	5.18	2.75	8.78	4.24	8.63

5% significance level: $F(n_1=20, n_2>00) \sim 1.57$; $F(n_1=30, n_2>00) \sim 1.46$.

1% significance level: $F(n_1=20, n_2>00) \sim 1.88$; $F(n_1=30, n_2>00) \sim 1.70$.

Overall-year Regression
with age-vintage specification
Dependent Variable= $\ln(\text{NPRICE})$

	overall years	
	Coeffs	T-values
prg	0.0137	2.32
prgsq	0.0019	3.17
days	0.0139	15.35
daysq	-0.00003	-14.14
prgdays	-0.0001	-4.03
wired	0.0662	3.95
wireless	0.1853	9.81
hifi	0.3919	44.74
hq	0.0126	0.93
dpan	0.0006	0.05
dcca	0.0049	0.38
dvc	-0.0042	-0.31
dsharp	-0.0642	-3.93
dquasar	-0.0401	-2.50
dge	-0.1153	-6.72
dfisher	-0.0525	-2.61
dmg	0.0146	0.69
dsorny	-0.0075	-0.57
dzenith	-0.0326	-2.31
dsanyo	-0.2675	-14.21
dsears	0.2768	22.19
age1	-0.0783	-11.90
age2	-0.1593	-16.60
age3	-0.2402	-15.82
age4	-0.3055	-14.38
age5	-0.3432	-10.50
v78	-0.0635	-2.47
v79	-0.0912	-2.44
v80	-0.1703	-4.56
v81	-0.4537	-12.57
v82	-0.5879	-16.26
v83	-0.7962	-21.76
v84	-1.0594	-28.78
v85	-1.2203	-32.59
v86	-1.3027	-32.98
v87	-1.3715	-33.47
constant	6.6639	185.14
N	4054	
Adj Rsq	0.79	

F tests for age dummy variables

null hypotheses	F-value
1) age1=age2=age3=age4=age5	0.04
2) age2=age1=age3=age4=age5	0.00
3) age3=age2=age4=age5=age1	0.19
4) age4=age3=age5=age1=age2	0.27
5) Joint hypo of 1) through 4)	0.62

F(1,4017)=3.84 (5%), 6.63 (1%)
F(4,4017)=2.37 (5%), 3.32 (1%)

Note: Inside the parenthesis shows the significance level.

Overall-year Regression
with age-format vintage specification
Dependent Variable= $\ln(\text{NPRICE})$

	overall years	
	Coeffs	T-values
prg	0.0122	2.07
prgsq	0.0023	3.79
days	0.0115	12.52
daysq	-0.0001	-11.36
prgdays	-0.0001	-4.31
wired	0.0843	4.90
wireless	0.2148	10.88
hifi	0.3951	46.54
hq	0.0270	1.90
dpan	0.0015	0.14
dcca	0.0027	0.21
dvc	-0.0066	-0.50
dsharp	-0.0770	-4.85
dquasar	-0.0585	-3.73
dge	-0.1253	-7.51
dfisher	-0.0680	-3.47
dmg	0.0210	1.02
dsorny	-0.0089	-0.51
dzenith	-0.0540	-3.81
dsanyo	-0.2459	-11.32
dsears	0.2743	21.16
age1	-0.0806	-12.69
age2	-0.1629	-17.54
age3	-0.2424	-16.43
age4	-0.3140	-15.15
age5	-0.3699	-11.58
w78	-0.1248	-3.21
wb78	-0.0617	-1.52
w79	-0.1319	-3.57
wb79	-0.0020	-0.05
w80	-0.1971	-5.16
wb80	-0.1141	-2.92
w81	-0.4726	-12.97
wb81	-0.4083	-10.90
w82	-0.6164	-17.36
wb82	-0.5445	-14.24
w83	-0.7493	-20.67
wb83	-0.8694	-23.05
w84	-1.0139	-28.17
wb84	-1.2160	-30.65
w85	-1.2123	-33.19
wb85	-1.2433	-27.35
w86	-1.3030	-33.55
wb86	-1.3518	-28.06
w87	-1.4110	-34.78
wb87	-1.1192	-21.40
constant	6.6626	191.17
N	4054	
Adj Rsq	0.81	

F tests for format dummy variables

null hypotheses	F-value
V78=VB78	4.28
V79=VB79	15.71
V80=VB80	9.35
V81=VB81	7.02
V82=VB82	11.3
V83=VB83	36.76
V84=VB84	90.52
V85=VB85	1.08
V86=VB86	2.32
V87=VB87	56.2

F(n1=1,n2=4004)=3.84 (5%), 6.63 (1%)

Note: Inside the parenthesis shows the significance level.

Table 11

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													
Raw data													
Arithmetic Mean change %	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
		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 change %	100	96.54	89.37	80.35	63.18	52.51	42.61	33.05	30.39	29.21	-12.49	-19.89	-6.58
		-3.46	-7.43	-10.09	-21.37	-16.90	-18.85	-22.43	-8.05	-3.88			
Weighted T-A change %	100	96.82	90.48	79.65	65.40	53.81	43.05	35.43	33.27	31.10	-11.96	-18.33	-6.86
		-3.18	-6.55	-11.96	-17.89	-17.73	-19.99	-17.71	-6.08	-6.53			
Unweighted T change %	100	96.39	89.06	80.05	63.11	52.35	42.50	32.93	30.24	28.98	-12.58	-19.89	-6.73
		-3.61	-7.60	-10.12	-21.16	-17.06	-18.81	-22.52	-8.17	-4.16			
Weighted T change %	100	96.83	89.33	77.69	64.87	53.04	42.37	34.58	32.55	30.39	-12.19	-18.31	-7.29
		-3.17	-7.74	-13.03	-16.50	-18.24	-20.11	-18.39	-5.87	-6.63			
Adjacent years:													
Unweighted T-A change %	100	96.68	93.66	88.64	71.09	59.37	49.19	38.29	34.80	33.56	-11.12	-18.90	-4.89
		-3.32	-3.12	-5.36	-19.80	-16.49	-17.15	-22.16	-9.10	-3.55			
Weighted T-A change %	100	96.88	94.88	88.13	72.31	58.79	48.17	39.32	36.14	33.42	-11.22	-18.27	-5.58
		-3.12	-2.07	-7.11	-17.96	-18.70	-18.05	-18.39	-8.08	-7.52			
Unweighted T change %	100	95.82	89.26	83.03	66.80	55.81	46.57	36.42	32.93	31.28	-11.88	-18.59	-6.52
		-4.18	-6.84	-6.97	-19.55	-16.45	-16.55	-21.79	-9.59	-5.01			
Weighted T change %	100	95.40	90.03	81.70	68.70	55.91	45.86	37.05	34.09	31.39	-11.90	-17.93	-7.08
		-4.60	-5.63	-9.25	-15.92	-18.61	-17.98	-19.22	-7.98	-7.93			

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

The Rate of quality change using Unweighted T-A model in adjacent two years, 1978-1987 (%)

1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
-	3.38	3.64	1.61	6.26	1.12	9.39	11.57	3.45	3.57

Note: The index is constructed by subtracting the rate of change in the arithmetic mean index in Table 11 from the rate of change in the quality adjusted price index based on the unweighted T-A model in adjacent two years in Table 11.

Matched Model Price Index from CR data (Gordon (1990))

CR	1980	1981	1982	1983	1984	1985
Gordon's index	154.3	124.2	100	74.4	55.4	41.2
change %		-19.5	-19.5	-25.6	-25.5	-25.6

Source: Gordon (1990). Table 7.21 on page 312.

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

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

Source: Gordon (1990). Table 7.19 on page 306.