Hedonic Price Measurement: The CCC Method

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by

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Abstract

An accurate measurement of general price inflation is an essential prerequisite for sound economic analysis and prudent policy-making. Numerous hedonic regression studies (predominately focusing on computers) have suggested that due to significant product quality changes over time, driven onward by technical progress, national statistical agencies are not compiling and releasing unbiased price-trend estimates. This paper argues, however, that the estimation method commonly applied in hedonic studies is an unsatisfactory one. Therefore, an alternative estimation procedure is introduced. Utilizing this novel technique, a quality-adjusted twelve-year price-trend for laser printers (1992 to 2003) is estimated and compared with the officially published price-trend.

Keywords: Hedonic Regression, Price Index, Measurement Bias, Technical Progress, Laser Printer, Information Technology

JEL Classification: C23, C43, L63

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1 Introduction

An accurate measurement of general price inflation is an essential prerequisite for sound economic analysis and prudent policy-making. It is a matter of great concern then, when numerous hedonic regression studies conclude that national statistical agencies are finding it difficult to precisely incorporate the quality improvements that are occurring in certain products into the computation of their officially published price-trends. To date, the majority of the published research, however, has focused primarily upon computers (e.g., Berndt and Rappaport, 2001) and, unfortunately, no such comparable studies have been done on the other Information Technology (IT) products (e.g., printers, monitors, etc.). Moreover, the quality-adjusted long-term price-trends calculated in these studies have commonly relied on the Adjacent Year Regression (AYR) method, a technique developed in a pioneering study performed by Court (1939). Although it is the generally accepted technique, the AYR method has some serious theoretical shortcomings.

Recognizing these problem areas, the aim of this paper is to contribute in two important ways. Firstly, it demonstrates that the AYR method is an unsatisfactory hedonic regression technique. As a result of this fact, it introduces an alternative procedure called the Continuously Changing Coefficient (CCC) method. Secondly, it applies the CCC regression technique to a database containing information on the operational performance and quality of laser printers. The long-term price-trend of these laser printers was estimated over a twelve-year period (1992 to 2003) and compared to the officially published price-trend.

The paper proceeds as follows. In Section 2, the database that was utilized in this study is described and the basic hedonic equation is introduced. Section 3 outlines the reasons why the AYR method is an unsatisfactory procedure. In Section 4, the CCC method is introduced. Section 5 presents the empirical findings concerning the long-term price-trend of laser printers and relates these to the officially reported price-trend. Concluding remarks are contained in Section 6.

2 The Database and the Hedonic Equation

A German computer magazine entitled *c't - magazin für computertechnik* has published test reports for many years regarding the quality and performance characteristics of laser printers. Many experts in the field have concluded that this magazine's test results are particularly reliable. The database utilized in this study was derived from the published test reports concerning 232 different printers over a twelve-year period (1992 to 2003). During this time period, eleven qualitative performance characteristics were recorded for each of the printers considered. Five of these characteristics were measured as continuous variables and the remaining six were reported dichotomously. The continuous variables measure such characteristics as: (1) printing speed, (2) memory size, (3) maintenance cost per page, (4) paper storage capacity, and (5) printing resolution. The dichotomous variables indicate such printer features as: (6) equipped with postscript, (7) upgraded with postscript, (8) equipped with network connectivity, (9) upgraded with network connectivity, (10) equipped with extra interface (provided that the printer has no network connectivity), and (11) Graphical Device Interface (GDI) printers (these printers are lower quality because they do not have their own processor but use instead the computer's processor).

The database identifies each printer by its brand name and qualitative characteristics. Furthermore, the printer's selling price is recorded together with the month in which the observation was made. Many of the printers considered were observed in two or three different months. For the purpose of price measurement, these additional observations provide valuable information. By including these additional observations, the database was increased to $N = 378$ observations covering 144 months (January 1992 to December 2003).

Between 1992 and 2003, the average quality and operational performance of laser printers improved significantly. For example, as Figure 1 demonstrates, in 1992 none of the models tested could print more than eight pages per minute, whereas in 2003 none of the models tested printed less than that amount. Figure 1 also indicates that in the years 1996 and 1997 primarily "low quality" printers were tested, whereas in the years 1998 and 1999 many of the "top-of-the-line" models were included in the sample.

Waugh (1928) was the first to recognize that for a given time period t (e.g., a month) the price of a specific product could be functionally related to certain observable product quality characteristics inherent in the product. His object of study was asparagus. This basic idea, however, can be applied to many other products and laser printers, the product investigated in this study, are no exception. For this product, the diagnostic tests that were conducted indicated that the relationship between price and the qualitative characteristics could be formalized by the following

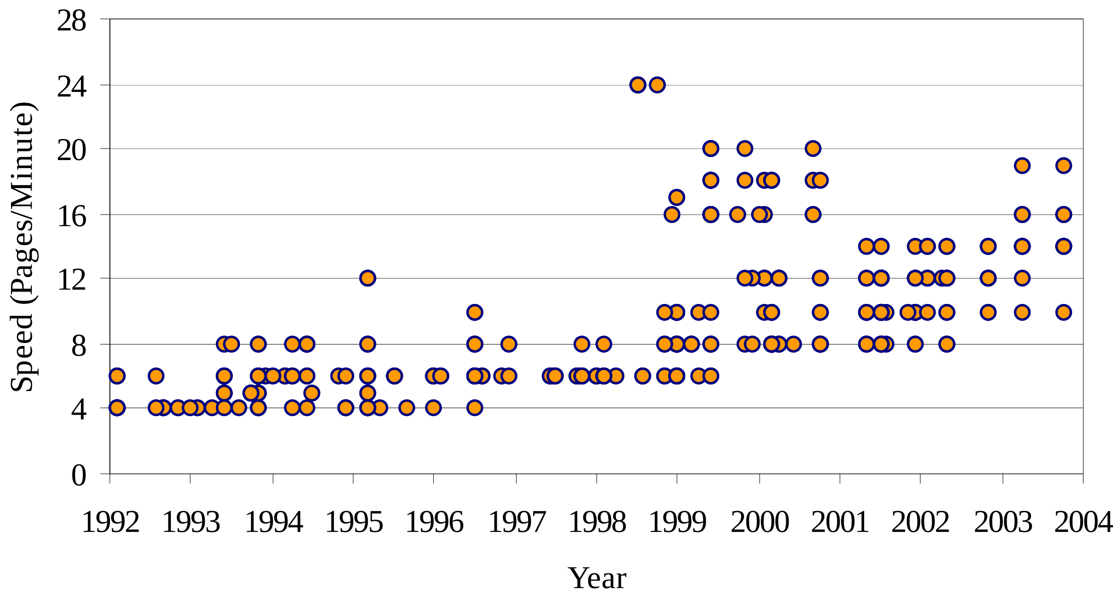

Figure 1: The Printing Speed of Laser Printers

hedonic equation:

$$\ln p_i^t = \beta_0^t + \sum_{k=1}^{11} \beta_k^t q_{ki} + u_i^t \,, \qquad t = 1, 2, \ldots, T \,. \tag{1}$$

The dependent variable in this equation, $\ln p_i^t$, is the natural logarithm of the observed price of model i during time period t, where $t = 1$ is January 1992 and $t = 144 (= T)$ is December 2003. The qualitative characteristics of model i are represented by the eleven heretofore defined variables, q_{ki} $(k = 1, 2, \ldots, 11)$. The intercept term β_0^t can be interpreted as measuring those factors in the marketplace that determine the logarithmic price of model i other than the model's own inherent product quality features. The eleven slope coefficients, β_k^t $(k = 1, 2, \ldots, 11)$, on the other hand, can be interpreted as the semi-elasticities of a printer's price with respect to the k^{th} qualitative characteristic. The stochastic variable u_i^t is a random error term.

The time index t attached to the coefficients β_k^t $(k = 0, 1, \ldots, 11)$ indicates that their numerical values change over time. In order to estimate Equation (1) for each of the 144 months considered, however, a sufficient amount of cross sectional data must be available. Unfortunately, this is often not the case. When attempting to measure the long-term price-trend of a product researchers are regularly confronted with data limitation problems and this study is no exception.

3 The AYR Method

Traditionally, data shortage problems have been solved by utilizing the Adjacent Year Regression (AYR) method. Initially, all the available observations are sorted according to the year in which the price of the product was observed. This subdivides the complete database into 12 annual samples. Next, a pooled regression is run using the first two annual samples, namely for the years 1992 and 1993. In this regression it is assumed that the slope coefficients remain constant over the pooled two-year time period considered:

$$\ln p_i^{92/93} = \beta_0^{92} + \gamma^{93} d_i^{93} + \sum_{k=1}^{K} \beta_k^{92/93} q_{ki} + u_i^{92/93} , \tag{2}$$

with

$$d_i^{93} = \begin{cases} 0 & \text{if model } i \text{ is observed in year 1992} \\ 1 & \text{if model } i \text{ is observed in year 1993} . \end{cases}$$

The dummy variable, d_i^{93}, indicates whether the price of model i was observed in the year 1992 or in 1993. The estimated coefficient $\hat{\gamma}^{93}$ approximately measures the overall percentage price change between the years 1992 and 1993. The semi-logarithmic functional form implies that this overall price change is identical for all models.

Subsequently, the heretofore-explained pooled regression procedure is applied to the annual samples 1993 and 1994. This generates an estimate $\hat{\gamma}^{94}$ that measures the overall percentage price change between the years 1993 and 1994. Following this same pooled regression procedure for each subsequent pair of years, a time series of estimated coefficients $\hat{\gamma}^{93}, \hat{\gamma}^{94}, \dots, \hat{\gamma}^{03}$ is obtained. This time series, in turn, can be used to calculate the long-term price-trend of laser printers between the years 1992 and 2003:

$$I^t = 100 \cdot \prod_{s=92}^{t} \exp(\hat{\gamma}^s) , \qquad t = 92, 93, \dots, 03 , \tag{3}$$

with $\hat{\gamma}^{92} = 0$.

This study, however, does not utilize the AYR method. There are four major reasons for avoiding this generally accepted hedonic regression technique:

1. The AYR method is often subject to estimation bias caused by the omission of relevant variables problem. In those exceptional cases when the AYR method does not produce biased estimated coefficients, the procedure is not efficient.

The AYR method's deficiencies are caused by the overlapping nature of the sequential two-year pooled regressions that are utilized. A detailed discussion of these deficiencies along with possible remedies is provided by Auer and Brennan (2004).

2. In many hedonic studies, a lack of sufficient data necessitates an estimation procedure that reduces the number of coefficients to be estimated. This present study is no exception. The AYR method as outlined above does reduce the number of coefficients to be estimated, but sometimes insufficiently. Usually, some of the two-year pooled regressions conducted utilizing the AYR method still suffer from too many coefficients relative to the regression's degrees of freedom. As a result, many of the estimated coefficients obtained are not robust. Adding or excluding even a single observation can often significantly alter the estimation results.

3. A related problem inherent in the AYR method is that it neglects some of the valuable information contained within the database. The database used in this study can be used to illustrate this deficiency. As heretofore mentioned, some of the printers appear in the database more than once because they were available for longer than just a few months. Accordingly, their prices were recorded in two or even three different months, generating additional observations for the database. For example, Brother's laser printer, model HL 2060, was recorded twice (in June 1999 and in November 1999). For purposes of estimating price changes over time, the price difference between these two observations is of particular value because it represents a price change that can be purely attributed to the passage of time. This is precisely what one is looking for in quality-adjusted price-trend analysis. The AYR method is not able to utilize this kind of information. There is no coefficient that takes into account the fact that prices could change within a given year. As a consequence, the price difference is treated as a disturbance that affects the value of the error term but does not provide any information concerning the price change over time.

4. The AYR method not only ignores information contained within the database, it also does not take into account an important piece of information that can be found outside of the database. It is reasonable to assume that the slope coefficients, β_k^t, are likely to vary with time. These changes, however, do not occur randomly and are not likely to be characterized by large upward

or downward swings. Instead, they tend to change over time in a gradual manner. Empirical evidence regarding this gradual change can be found in a comprehensive study conducted by Heravi and Silver (2002). Utilizing scanner data for various products and utilizing hedonic regression methods, they demonstrate that these coefficients undergo systematic gradual changes over time rather than random fluctuations.

A superior hedonic regression technique would be one that exploits all of the information that is available to the researcher. This fact, together with the theoretical shortcomings inherent in the AYR method, indicates that a search for an alternative hedonic estimation technique would be appropriate. The following section is devoted to developing such an improved technique.

4 The CCC Method

Equation (1) is a valid relationship for each time period t. As a consequence, a time series of values for each of the $K+1$ coefficients, $(\beta_k^1, \beta_k^2, \ldots, \beta_k^T)$, must be estimated. In empirical work, however, data shortage limitations usually necessitate a reduction in the number of coefficients that can be estimated. The AYR method accomplishes this reduction by pooling data from adjacent time periods. An alternative hedonic regression technique can be specified that accomplishes a reduction that goes far beyond that accomplished by the AYR method. Moreover, this novel technique avoids the other heretofore-mentioned deficiencies inherent in the AYR method. This technique is called the Continuously Changing Coefficient (CCC) method.

The basic idea behind the CCC method is the following. The numerical values of the coefficients in each of the time series $(\beta_k^1, \beta_k^2, \ldots, \beta_k^T)$ are assumed to change gradually. Therefore, this change is modeled by utilizing a general polynomial of degree Z_k:

$$\beta_k^t = \left(\beta_k + \sum_{z=1}^{Z_k} \theta_k^z t^z\right) , \qquad \text{with } k = 0, 1, 2, \ldots, K , \tag{4}$$

where the parameters, θ_k^z, are the coefficients of the polynomial and t represents a trend variable that runs from 1 to T. Polynomials of degree five, $Z_k = 5$, are capable of approximating very general time series patterns. Dhrymes (1971) and Oliner (1993) applied this idea to the time series of intercept coefficients $(\beta_0^1, \beta_0^2, \ldots, \beta_0^T)$, but they did not apply it to the time series of slope coefficients. Nonetheless, their work can be viewed as an early predecessor of the CCC method.

Utilizing the polynomials specified by Equation (4), the T relationships expressed in Equation (1) can now be pooled into a single equation:

$$\begin{aligned} \ln p_i^t &= \sum_{k=0}^{K} \left(\beta_k + \sum_{z=1}^{Z_k} \theta_k^z t^z \right) q_{ki} + u_i^t & \text{(5a)} \\ &= \sum_{k=0}^{K} \beta_k q_{ki} + \sum_{k=0}^{K} \sum_{z=1}^{Z_k} \theta_k^z \left(t^z q_{ki} \right) + u_i^t \, , & \text{(5b)} \end{aligned}$$

where $q_{0i} = 1$ $(i = 1, 2, \ldots, N)$ and N represents the total number of observations. In Equation (5a), the expression in brackets is a semi-elasticity that may change over time.

Estimation of the hedonic equation (5b) generates the estimated coefficients $\hat{\beta}_k, \hat{\theta}_k^1, \hat{\theta}_k^2, \ldots, \hat{\theta}_k^{Z_k}$ $(k = 0, 1, \ldots, K)$. These estimates can be used to calculate the overall price-trend of each laser printer for the twelve-year time span 1992 to 2003. It should be noted that Equation (5b) is general enough to allow for price-trends that vary from printer to printer.

5 The Estimated Price-Trend of Laser Printers

Equation (1) represents the starting point for the empirical analysis of this study. This equation is specified with a semi-logarithmic functional form. In order to test for the appropriateness of this specification, in December 2003, data for 183 printers were collected and a test-database was compiled. Utilizing this test-database, a Box-Cox test suggested the use of a semi-logarithmic specification for the hedonic equation associated with that month. This finding was taken as being representative for all of the months between January 1992 and December 2003.

The test-database, drawn from information available on the Internet, was exclusively used for testing the appropriateness of the functional form. The definitions of some of variables in this test-database, however, were a bit different from those in the database that was compiled from the German computer magazine's test results. These definitional differences unfortunately precluded the pooling of these two databases. For that reason, the hedonic regression analysis conducted in this study is based solely upon the database compiled from the computer magazine.

The eleven qualitative characteristics included in Equation (1) were those described in Section 2. They included five continuously measured qualitative characteristics and six dichotomous ones. In addition, dummy variables were introduced to represent those brands that appeared at least 25 times in the complete database

($N = 378$ observations). This was the case for eight brands: Brother, Canon, Epson, Hewlett Packard, Kyocera, Lexmark, Minolta, and Oki. Each of the other manufacturers had 14 or fewer observations in the database. The brand name dummy variables proved useful, for they captured those product features that are specific to particular branded products, but are not directly observable (e.g., consumer perceptions, brand image, expected performance, etc.). The relationship between prices, qualitative characteristics, and the brand name dummy variables during month t were specified according to the following form:

$$\ln p_i^t = \sum_{k=0}^{11} \beta_k^t q_{ki} + \sum_{m=1}^{8} \delta_m^t b_{mi} + u_i^t \ , \qquad t = 1, 2, \dots, T \ , \tag{6}$$

where $q_{0i} = 1$, b_{mi} is the brand name dummy variable and δ_m^t is its respective coefficient. Utilizing the CCC method with polynomials of degree five, the $T(= 144)$ equations of the form (6) could be pooled into the following equation:

$$\ln p_i^t = \sum_{k=0}^{11} \left(\beta_k + \sum_{z=1}^{5} \theta_k^z t^z \right) q_{ki} + \sum_{m=1}^{8} \left(\delta_m + \sum_{z=1}^{5} \phi_m^z t^z \right) b_{mi} + u_i^t \ , \tag{7}$$

where ϕ_m^z are the coefficients of the polynomial.

The estimated coefficients $\hat{\theta}_0^4$ and $\hat{\theta}_0^5$ proved to be insignificant at a five percent level of significance. The time series of slope coefficients associated with the eleven qualitative characteristics, on the other hand, were able to be modeled using much simpler polynomials. In fact, a polynomial of degree one ($Z_k = 1$) proved to be adequate. The exceptions were the characteristics "printing resolution" ($Z_5 = 3$), "equipped with postscript" ($Z_6 = 2$), and equipped with network "connectivity" ($Z_8 = 3$). Similarly, the time series associated with the brand name dummy variables could be approximated by a polynomial of degree one. The exceptions were the brands Epson ($Z_3 = 2$), Kyocera ($Z_5 = 3$), and Lexmark ($Z_6 = 3$). With these modifications, the estimated hedonic equation simplified to

$$\begin{aligned} \ln \hat{p}_i^t \;&=\; \left(\hat{\beta}_0^t + \theta_0^1 t + \theta_0^2 t^2 \right) \\ &\quad + \Big[\sum_{k=1}^{11} \hat{\beta}_k q_{ki} + \sum_{k=1}^{11} \hat{\theta}_k^1 (t\, q_{ki}) + \sum_{k=3,5,8} \hat{\theta}_k^2 (t^2\, q_{ki}) + \sum_{k=5,8} \hat{\theta}_k^3 (t^3\, q_{ki}) \Big] \\ &\quad + \Big[\sum_{m=1}^{8} \hat{\delta}_m b_{mi} + \sum_{m=1}^{8} \hat{\phi}_m^1 (t^z\, b_{mi}) + \sum_{m=3,5,6} \hat{\phi}_m^2 (t^2\, b_{mi}) + \sum_{m=5,6} \hat{\phi}_m^3 (t^3\, b_{mi}) \Big] \ . \end{aligned} \tag{8}$$

The least squares estimation results are presented in Equation (10) (see Appendix). The adjusted coefficient of determination was equal to 93.7 percent. The computation of the variance-covariance matrix of the estimated coefficients was adjusted to account for heteroscedasticity and autocorrelation. F-Tests revealed that each of the qualitative characteristics q_k ($k = 1, 2, \ldots, 11$) had estimated coefficients $\hat{\beta}_k$ and $\hat{\theta}_k^z$ that were jointly significant on the one percent level. The same was true for the estimated coefficients $\hat{\delta}_m$ and $\hat{\phi}_m^z$ associated with the brand dummy variables ($m = 1, 2, \ldots, 8$), the only exception being Minolta.

If one were interested in the individual numerical values of the estimated coefficients, then the multicollinearity present in the data would represent a serious problem. The CCC method does not offer a solution to this problem. The only possible solution would be additional (valid) information. In this respect, the CCC method fares much better than the AYR method. Furthermore, for the calculation of a long-term price-trend, the individual numerical values of the coefficients are of minor interest. Instead, accurate estimates of the printers' prices are required. In this respect, the presence of multicollinearity is much less of a problem.

Using the estimated coefficients (Equation (10), Appendix), for each of the 232 printers in each of the 144 months considered, an estimated price $\hat{p}_i^t$ could be computed from relationship (8). These calculations provide a time series of 144 estimated prices for each printer i. All of the 232 printers show a significant downward trend in prices. These price-trends differ, however, from printer to printer.

As is well known, the least squares estimation of Equation (8) implies that the values of the coefficients associated with earlier time periods (e.g., January 1992 to December 1993) are mainly determined by those printers that were available during those early periods. Therefore, the estimated prices of the early printers are most reliable during those early periods. For that reason, one should not put too much faith in these printers' estimated prices computed for the subsequent time periods (e.g., January 2002 to December 2003). Conversely, one should be sceptical about the more recent printers' estimated prices computed for the early periods. For each month, the values of the estimated coefficients, and therefore the estimated prices, are most reliable for those printers being sold at that month. This should be taken into account when one tries to calculate an overall price-trend for laser printers.

For this reason, each of the 232 printers had a "time span of relevance" assigned to it. For example, the printer NEC Superscript 660 was observed only once, namely in month $t = 39$ (March 1995). For this printer, the time span of relevance extended from month $39 - 6 = 33$ to month $39 + 6 = 45$ (i.e., from September 1994 to September 1995). The printer Canon LBP 460 was observed twice, namely in month $t = 49$ and in month $t = 55$. Accordingly, this printer's time span of relevance extended from month $49 - 6 = 43$ to month $55 + 6 = 61$ (i.e., from July 1995 to January 1997).

Since different laser printers posses different estimated price-trends, some average of these price-trends must be calculated. In order to get the average price change of laser printers between month $t = 1$ and month $t = 2$, an arithmetic average of the individual price ratios $\hat{p}_i^2/\hat{p}_i^1$ of those printers was computed with time spans of relevance covering both of these month. This average price ratio is denoted by $\hat{r}^2$. The same procedure was accomplished for the months $t = 2$ and $t = 3$, and also for each subsequent pair of adjacent months. This approach generates a time series of price ratios $(\hat{r}^2, \hat{r}^3, \ldots, \hat{r}^{144})$. The price ratio $\hat{r}^1$ is defined to be one. From the estimated price ratios, the monthly percentage changes in prices can be computed. The resulting percentage changes are depicted in Figure 2. The price changes are always negative and lie between 0 and -4 percent. Figure 2 also shows the officially released price changes as calculated by the *Statistisches Bundesamt* (Federal Statistical Office of Germany). The official numbers indicate much smaller decreases in printer prices. Furthermore, the price changes are much more volatile and they exhibit some implausible upward and downward jumps, especially during the year 2003.

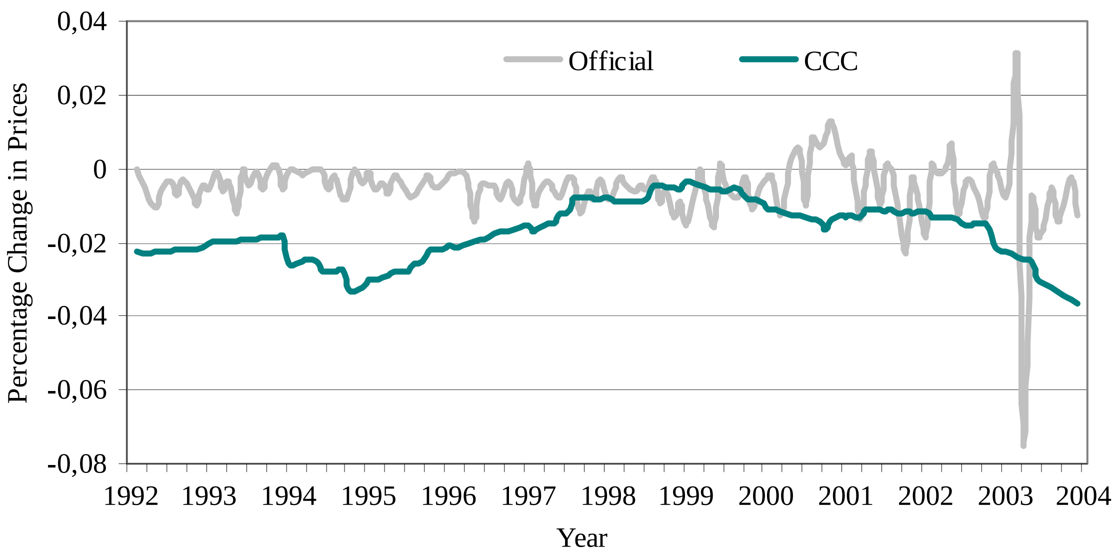

Figure 2: Percentage Price Change of Laser Printers between 1992 and 2003 (Computed on a Monthly Basis).

The pronounced differences between the hedonic CCC-results and the officially released numbers lead to huge deviations in the respective long-term price trends of printers. These price trends can be obtained from

$$I^t = 100 \cdot \prod_{s=1}^{t} \hat{r}^s \,, \qquad \text{with } t = 1, 2, \ldots, 144 \,. \tag{9}$$

The resulting price index is depicted in Figure 3. The quality-adjusted price-trend of laser printers calculated using the CCC method declines by more than 90 percent. Figure 3 also shows the official price index of printers published by the *Statistisches Bundesamt*. The officially published price index shows a lesser decline of 50 percent in the price of printers over this same time period. The results of this study suggest that the procedure applied by the national statistical agency was not able to accurately account for the significant changes that occurred in the quality and performance enhancement characteristics that occurred in laser printers over this time period.

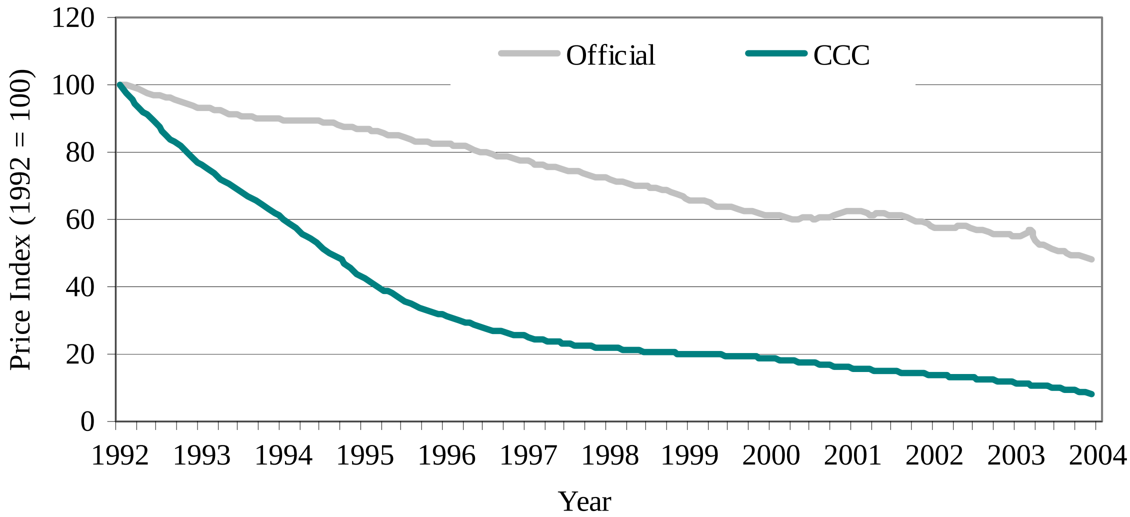

Figure 3: The Price-Trend of Laser Printers between 1992 and 2003.

6 Concluding Remarks

The phenomenon of underestimating the affect that quality improvements and performance enhancements have exerted upon the observed price-trend of computers over time has been empirically demonstrated by numerous hedonic regression studies. By analogy, it is often assumed that the same relationship between quality improvements and price applies equally well to all other IT-products (e.g., laser printers, monitors, etc.). This generalization, however, is less than self-evident. The quality improvements that are observed in computers are mainly the result of advances in chip technology. Quality improvements in laser printers, on the other hand, are much less dependent upon chip technology. It might be argued, therefore, that the technological advances leading to performance enhancements in these other IT-products would be considerably less. This study has discovered, however, that the performance of laser printers has significantly benefited from technological progress over time. Over the twelve years considered, continual improvements in performance (i.e., speed, capacity, resolution, etc.) resulted in a steady fall in the quality-adjusted price index of laser printers, measured by the CCC method, by more than 90 percent as compared to the officially reported decline of 50 percent. This finding indicates that technical progress is not solely confined to chip technology but it is occurring in other important areas as well. In the case of laser printers, advances in such diverse areas as fine mechanics, available materials, industrial design, software, as well as manufacturing methods must be considered. Not only the price-trend of computers, but also the price-trend of other IT-products require accurate quality-adjusted measurement.

For the computation of reliable official price statistics, it is necessary to obtain a comprehensive picture of how the performance characteristics of products that are subject to fast technical progress are changing. These products are particularly prone to bias in quality-adjusted price measurement. In this respect, hedonic regression analysis is a useful tool because it allows for the calculation of quality-adjusted long-term price-trends. Steeply declining price-trends suggest that strong technical progress is significantly affecting the quality and operating performance of the product being considered. This study has argued, however, that the AYR hedonic technique when used for computing long-term price-trends is not satisfactory because it has some serious theoretical shortcomings. Moreover, it is an estimation technique that does not utilize all of the information that is available. For this reason, an alternative procedure called the CCC method was introduced. It was demonstrated that this method is easy to implement and that it generates plausible results. It deserves careful consideration and a wider application.

Appendix

Levels of significance: $^{*} = 5$ percent; $^{**} = 1$ percent.

$$
\begin{array}{llllll}
\ln p_i = & + 5.6181^{**} & & & + 0.0281^{**} & \text{Trend}_i \\
& - 0.0005^{**} & (\text{Trend}_i)^2 & & + 2.0 \cdot 10^{-6\,**} & (\text{Trend}_i)^3 \\
& + 0.0459^{*} & \text{Speed}_i & & + 3.1 \cdot 10^{-5} & (\text{Trend}_i \cdot \text{Speed}_i) \\
& + 0.0864^{**} & \text{Memory}_i & & - 0.0007^{**} & (\text{Trend}_i \cdot \text{Memory}_i) \\
& - 0.0927^{**} & \text{Cost}_i & & + 0.0007^{**} & (\text{Trend}_i \cdot \text{Cost}_i) \\
& + 4.8 \cdot 10^{-5} & \text{Capacity}_i & & + 5.9 \cdot 10^{-6\,**} & (\text{Trend}_i \cdot \text{Capacity}_i) \\
& + 0.0057^{**} & \text{Dpi}_i & & - 0.0002^{**} & (\text{Trend}_i \cdot \text{Dpi}_i) \\
& + 2.1 \cdot 10^{-6\,**} & [(\text{Trend}_i)^2 \cdot \text{Dpi}_i] & & - 7.5 \cdot 10^{-9\,**} & [(\text{Trend}_i)^3 \cdot \text{Dpi}_i] \\
& + 0.2368 & \text{Ps-Stan}_i & & + 0.0051 & (\text{Trend}_i \cdot \text{Ps-Stan}_i) \\
& - 7.5 \cdot 10^{-5\,*} & [(\text{Trend}_i)^2 \cdot \text{Ps-Stan}_i] & & & \\
& + 0.2882^{**} & \text{Ps-Upgrade}_i & & + 0.0008 & (\text{Trend}_i \cdot \text{Ps-Upgrade}_i) \\
& - 64.8244^{**} & \text{Net-Stan}_i & & + 1.8458^{**} & (\text{Trend}_i \cdot \text{Net-Stan}_i) \\
& - 0.0172^{**} & [(\text{Trend}_i)^2 \cdot \text{Net-Stan}_i] & & + 5.2 \cdot 10^{-5\,**} & [(\text{Trend}_i)^3 \cdot \text{Net-Stan}_i] \\
& + 0.2910^{**} & \text{Net-Upgrade}_i & & + 0,0017 & (\text{Trend}_i \cdot \text{Net-Upgrade}_i) \\
& + 0.0622 & \text{Interface}_i & & + 5.9 \cdot 10^{-5} & (\text{Trend}_i \cdot \text{Interface}_i) \\
& - 0.1383 & \text{Gdi}_i & & - 0.0014 & (\text{Trend}_i \cdot \text{Gdi}_i) \\
& - 0.3268^{**} & \text{Brother}_i & & + 0.0026^{**} & (\text{Trend}_i \cdot \text{Brother}_i) \\
& - 0.5400^{**} & \text{Canon}_i & & + 0.0071^{**} & (\text{Trend}_i \cdot \text{Canon}_i) \\
& - 0.1515^{*} & \text{Epson}_i & & + 0.0077^{**} & (\text{Trend}_i \cdot \text{Epson}_i) \\
& - 5.3 \cdot 10^{-5\,**} & [(\text{Trend}_i)^2 \cdot \text{Epson}_i] & & & \\
& + 0.2384^{**} & \text{HP}_i & & - 0.0011 & (\text{Trend}_i \cdot \text{HP}_i) \\
& - 11.6947^{**} & \text{Kyocera}_i & & + 0.3848^{**} & (\text{Trend}_i \cdot \text{Kyocera}_i) \\
& - 0.0041^{**} & [(\text{Trend}_i)^2 \cdot \text{Kyocera}_i] & & + 1.5 \cdot 10^{-5\,**} & [(\text{Trend}_i)^3 \cdot \text{Kyocera}_i] \\
& + 0.7038^{*} & \text{Lexmark}_i & & - 0.0315^{*} & (\text{Trend}_i \cdot \text{Lexmark}_i) \\
& + 0.0005^{*} & [(\text{Trend}_i)^2 \cdot \text{Lexmark}_i] & & - 2.1 \cdot 10^{-6\,**} & [(\text{Trend}_i)^3 \cdot \text{Lexmark}_i] \\
& - 0.0747 & \text{Minolta}_i & & + 0.0006 & (\text{Trend}_i \cdot \text{Minolta}_i) \\
& - 0.2737^{**} & \text{Oki}_i & & + 0.0028^{**} & (\text{Trend}_i \cdot \text{Oki}_i)
\end{array}
\qquad (10)
$$

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