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TRENDS IN COMMERCIAL OFF-THE-SHELF COMPUTER EQUIPMENT PRICES

Two phenomena occur simultaneously in the computer and electronics industries: (1) average prices decrease over time, and (2) average performance increases over time. In this paper, we present an analysis of the trends in commercial off-the-shelf (COTS) computer prices. For cost estimates of programs with future procurement of hardware, it is necessary to account for decreasing average cost and increasing average performance of COTS computer equipment. In this study, we developed forecasting equations for price trends in nominal (then-year) and real (constant-year) dollars; both industry-average and hedonic (quality-adjusted) computer price trends are reported. The nature of a particular estimate will determine whether it is appropriate to deflate COTS computer prices according to industry-average trends, which will allow for growth in performance, or to deflate according to quality-adjusted trends, which will freeze the performance baseline.

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TRENDS IN COMMERCIAL OFF-THE-SHELF COMPUTER EQUIPMENT PRICES

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Introduction

Two phenomena occur simultaneously in the computer and electronics industries: (1) average prices decrease over time, and (2) average performance increases over time. This paper presents an analysis of the trends in commercial off-the-shelf (COTS) computer prices. For cost estimates of programs with future procurement of hardware, this study provides relationships for discounting COTS computer equipment prices. Forecasting equations are presented in nominal (then-year) and real (constant-year) dollars; both industry-average and hedonic (quality-adjusted) price trends are reported. The nature of a particular estimate will determine whether it is appropriate to deflate COTS computer prices according to industry-average trends, which will allow for growth in performance, or to deflate according to quality-adjusted trends, which will freeze the performance baseline.

Data

Historical data on PC prices were obtained from two sources. Industry-average PC price indices (weighted by market share and not adjusted for quality) were obtained from the Bureau of Economic Analysis (BEA) [1], and hedonic (quality-adjusted) price indices were obtained from a National Bureau of Economic Research (NBER) study [2]. The BEA PC price indices include producer price index data for all domestic PC vendors and matched-model data for imported PC equipment. Figure 1 shows the trends in the BEA Nominal Price Index (NPI) for PCs and our calculated Real Price Index (RPI) for PCs. (The effect of inflation in the overall economy is removed from the NPI by dividing the NPI by the Consumer Price Index (CPI), as reported by the Bureau of Labor Statistics (BLS).) The result of normalizing the NPI to the CPI is the RPI, which may be interpreted as providing the expected PC deflation rate if the rest of the economy were held in constant dollars.

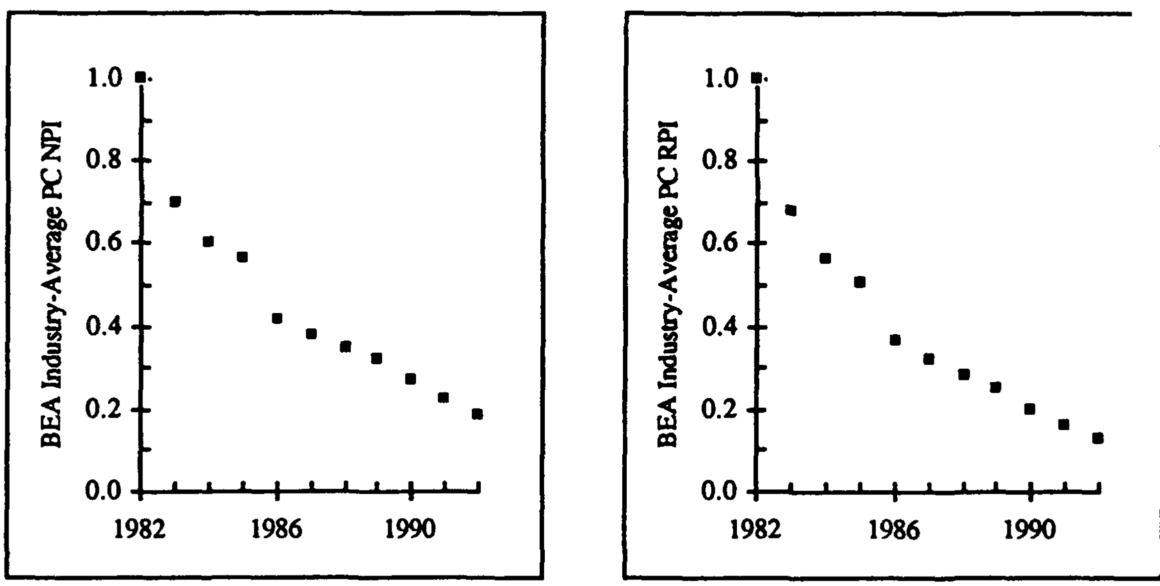

Figure 1. Historical Trends in the BEA Industry-Average PC Price Indices

Hedonic PC price indices were computed by the NBER in a study by Berndt and Griliches [2]. The data included 1265 observed PC prices from 1976 through 1988, and the data were quality adjusted for a number of different characteristics, including RAM size, clock speed, hard disk size, number of floppy disk drives and expansion board slots, and age of model. Also included were a number of dummy variables, such as processor word size, black-and-white vs. color monitor, portable vs. desktop, and producer. Figure 2 shows the nominal and real hedonic PC price indices, with RPIs calculated by normalizing the NPI to the CPI, as above. Berndt and Griliches have recently updated their data, and though the results were not yet available, they indicate that the forecasting equations shown in the next section provide reasonable deflation rates [3].

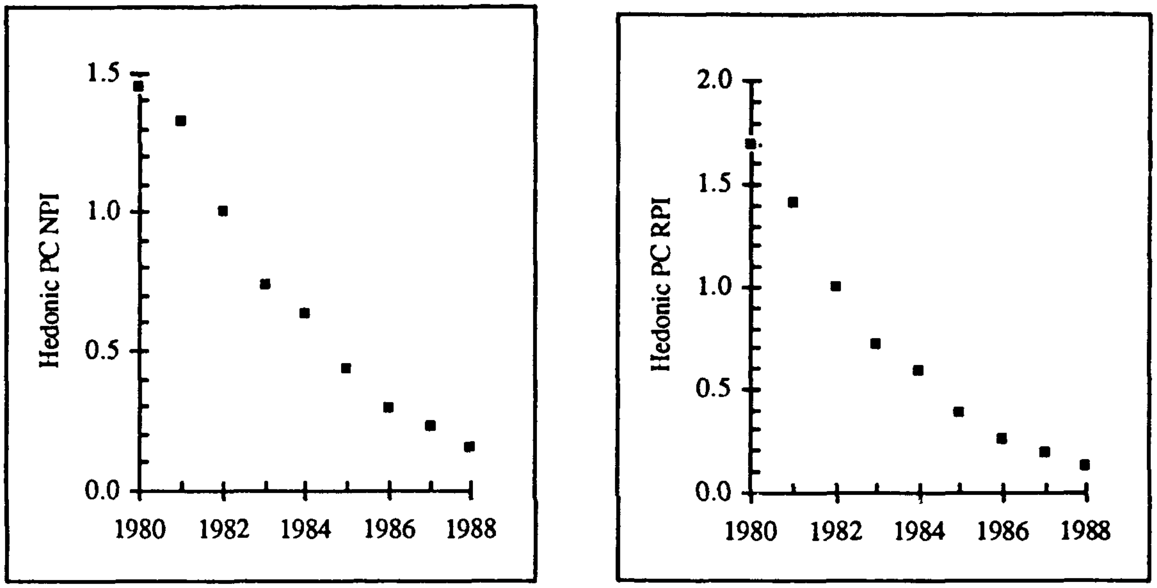

Figure 2. Historical Trends in the NBER Hedonic PC Price Indices

We collected data on industry-average workstation prices from International Data Corporation (IDC), which specializes in analyses of the workstation market. The basic defining features of a workstation, according to IDC, are shown in table 1. Although the distinction between PCs and workstations is becoming blurred, table 1 characterizes the current major differences between the two. Figure 3 shows the trends in industry-average workstation prices from 1982, the year that workstations came into existence, through 1992. As for PCs, real price (RP) is calculated by dividing nominal price (NP) by the CPI.

Although no hedonic price index data were available for the workstation market, it was nonetheless desired to provide some assessment of price-per-performance trends. Workstation performance has continued to grow at a considerable rate, perhaps even faster than PC performance. Ken Anderson, president of a workstation industry consulting company called Anderson Consulting, provides the information that most workstation customers are paying the same amount for a usable workstation configuration from year to year, but the performance that they are buying for that money doubles every year and a half [4], and that rule of thumb was used to generate the results in the next section.

Mainframe computer data were also examined. Because processor speed is the dominant performance measure for mainframe computers, we collected data on trends in price-per-processor speed (measured in dollars per MIPS) from three different sources [5, 6, 7], including studies from Digital Equipment Corporation study, The Yankee Group, and NASA Ames. The data are not shown here, but the results of analysis of the trends are consistent, as shown in the next section.

Table 1. Features of Workstations vs. PCs

Feature	PC	Workstation
Primary application	Text	Graphics
Inherent ability to network	Optional	Included
Primary distribution	Retail	Direct
Primary market focus	Commercial/home	Technical
Integer performance (MIPS)	1 – 15	3 – 100
Floating point coprocessor	Optional	Included
Typical screen resolution	640 x 480	1024 x 1024
Typical monitor size	12" – 14"	≥ 14 "
Graphics capability	None or 2D	2D and 3D
Operating system	Single tasking	Multitasking
Operating system examples	DOS, System 7	Unix, VMS
Price (FY92 $K)	0.3 – 12	3.9 – 100+

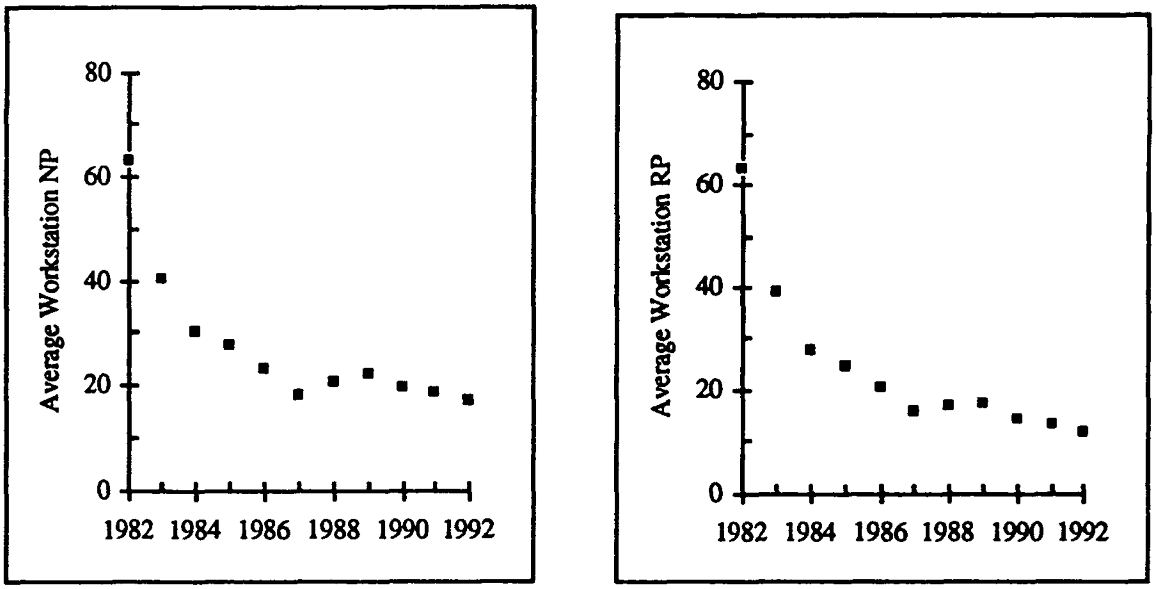

Figure 3. Historical Trends in Industry-Average Workstation Prices

Results

One classical approach for developing a forecasting equation is known as double exponential smoothing, which is described in most texts on time series analysis [8]. Exponential smoothing may be applied to any functional form of the time variable. We have chosen the forecasting equation for exponential smoothing to be in the form of an exponential (decay). This is accomplished by performing the standard linear-form process on the semi-logarithmic transformed data. We justified the following exponential form of the forecasting equation by performing Gaussian least-squares regression on the semi-logarithmic transformed data reported in the previous section:

$$P = P_0(1 + AAGR)^t \tag{1}$$

In equation (1), P is the predicted price at time t years after the reference year, P_0 is the price in the reference year, and $AAGR$ is the average annual growth rate of the price, which is a negative number in our case. It should be noted that in equation (1), P can be hedonic price, price-per-performance, industry-average price, or a price index. Regression analyses on the semi-logarithmic transformed data from the previous section resulted in coefficients of determination no lower than 0.96.

The forecasting equation resulting from double exponential smoothing would resemble a least-squares regression equation with the more recent data points weighted more heavily. However, the forecasting equation should not be thought of in the same way as a regression equation; for example, it should not be used to predict prices within the domain of the time over which data are available. It is used specifically for predicting future values of price. In the exponential smoothing process, we chose the functional form (1) that minimizes the sum of the squared one-year-ahead prediction errors. This minimization criterion and the mathematical details of the exponential smoothing process are described in reference [8]. The resulting AAGRs, or deflation rates, from the forecasting equations that were developed are summarized in table 2 as percentages.

Table 2. Summary of AAGR (Percentages) for the Computer Industry

	Industry Average NPI	Hedonic NPI	Industry Average RPI	Hedonic RPI
PC	-14	-29	-18	-31
Workstation	-6	-35	-9	-38
Mainframe	N/A	-20	N/A	-24

Coefficients, P_0, from the exponential smoothing process have not been reported. It is assumed that only the AAGR is of use to the cost analyst for his or her purposes. As an illustrative example, say that it is desired to estimate the cost of a laptop computer that is to be procured three years in the future. If the performance baseline is to be held constant, then it is appropriate to deflate according to a hedonic price index. If the FY92 price of the desired model is found to be $4.0K, and the future price is desired in FY92 dollars, then it is appropriate to deflate at 31 percent per year. Thus, one would estimate the price of the laptop in three years to be $1.3K, FY92.

Conclusions

This study presents computer price deflation rates for the three main portions of the computer industry, as summarized in table 2. The analyst should use the nominal price index AAGR for deflating an estimate in then-year dollars and the real price index AAGR for deflating an estimate in constant-year dollars. The context of a particular cost analysis will determine whether it is appropriate to deflate COTS computer equipment prices according to industry-average or hedonic trends.

If a cost estimate is to allow for requirements growth in the hardware baseline or is to reflect the possibility that at the time of the hardware purchase, the customer may be willing to upgrade to a similar model with greater performance, then it is correct to deflate computer equipment prices at the industry-average rather than the hedonic rate. The result of using a quality-unadjusted or industry-average price index for deflation is a cost estimate for a computer whose price has fallen and whose performance has risen at the industry-average rate.

On the other hand, if a cost estimate is to reflect one particular technical solution to a problem, and the customer wants to "freeze" the performance of the computer equipment to some baseline level, then it is inappropriate to deflate computer equipment prices at the industry-average rate. A particular PC may cost 5.0K in FY92 dollars, and the nominal deflation rate for PCs may be 14 percent per year, but to say that the same PC would cost 2.4K in FY97 dollars is to ignore the fact that the industry-average PC will have improved dramatically in such performance characteristics as processor speed, RAM size, hard disk capacity, and monitor resolution. Moreover, the particular baseline model in 1992 may not even exist in 1997 due to the phenomenon of fast model entry and exit in the market place. In a cost estimate where it is desired to hold performance to some baseline level, it is instead correct to deflate computer equipment prices according to a quality-adjusted, or hedonic, price index.

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