

COTS Desktop PC Performance & Price Estimation

Presented to

SCEA National Conference

Scottsdale, Az

June 2002

Presented by

Jason T. Lee

1111 Jefferson Davis Highway
Suite 612, West Tower
Arlington, VA 22202
Voice (703) 412-0602

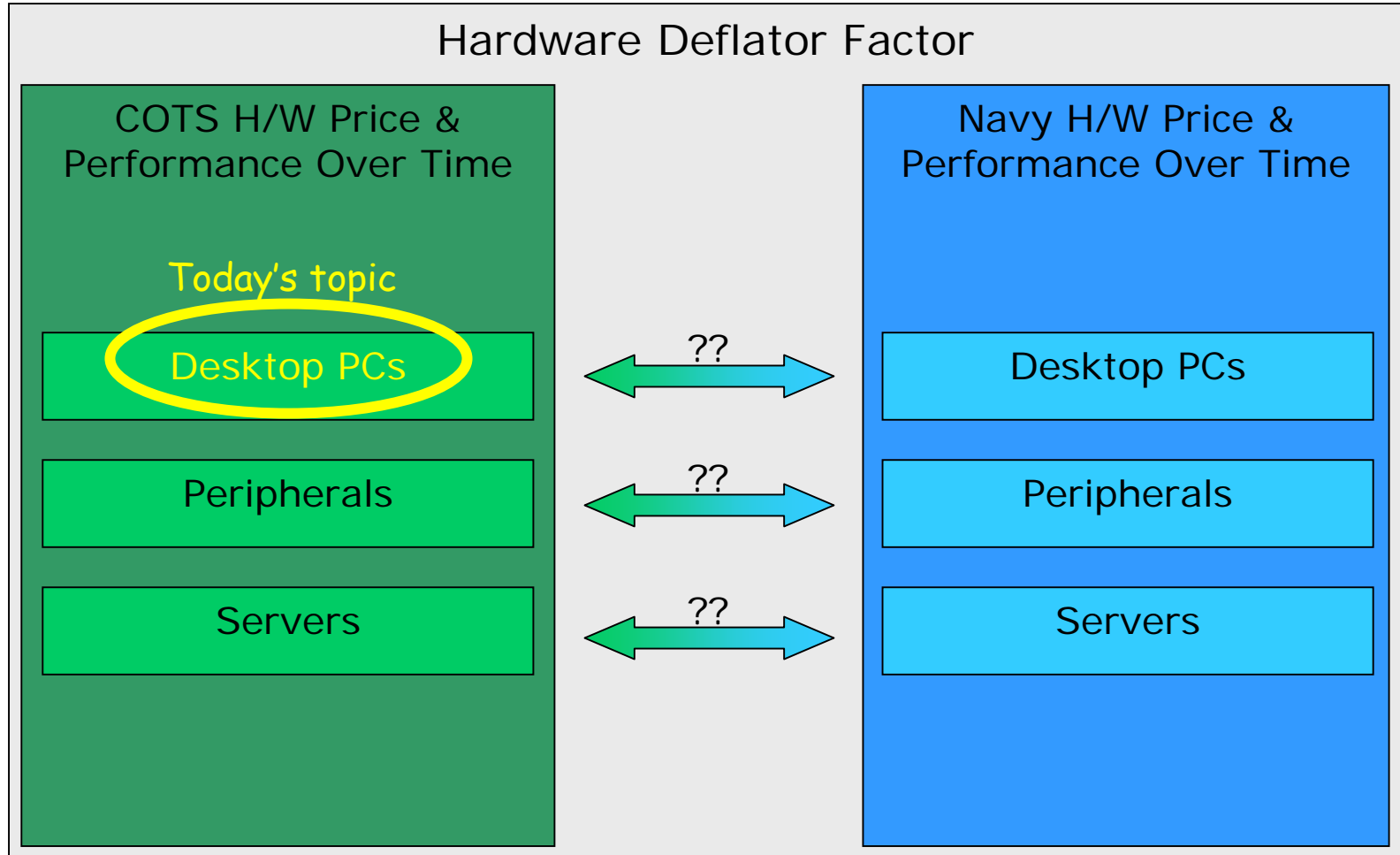
5290 Overpass Road, Suite 206
Santa Barbara, CA 93111
Voice (805) 964-9894

 Technomics

Outline

- Research Goals & Problem Statement
- Hedonic Theory
- Database
- Forecasting Methodology
 - Implicit Price Prediction (Beta Forecasts)
 - Performance Estimation
- Validation

Project Overview



Estimation Problems

- Purchases in the short-run (6 mos.)
for a specific system model
- Purchases in the short-run when only
performance is known (1-2 yrs)
- Purchases in the long run (3+ yrs)
& performance is not known

Estimation Methods

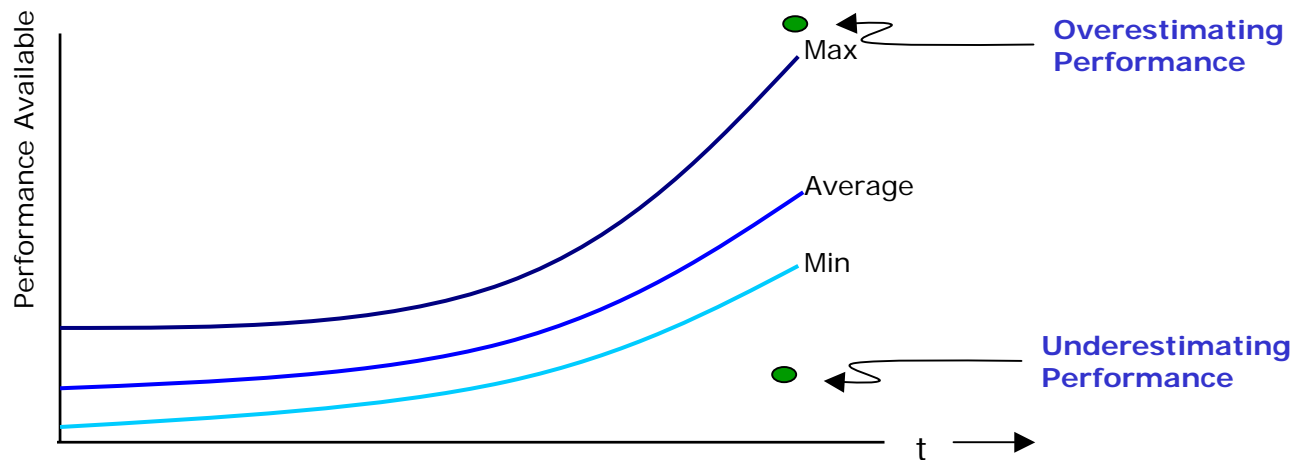
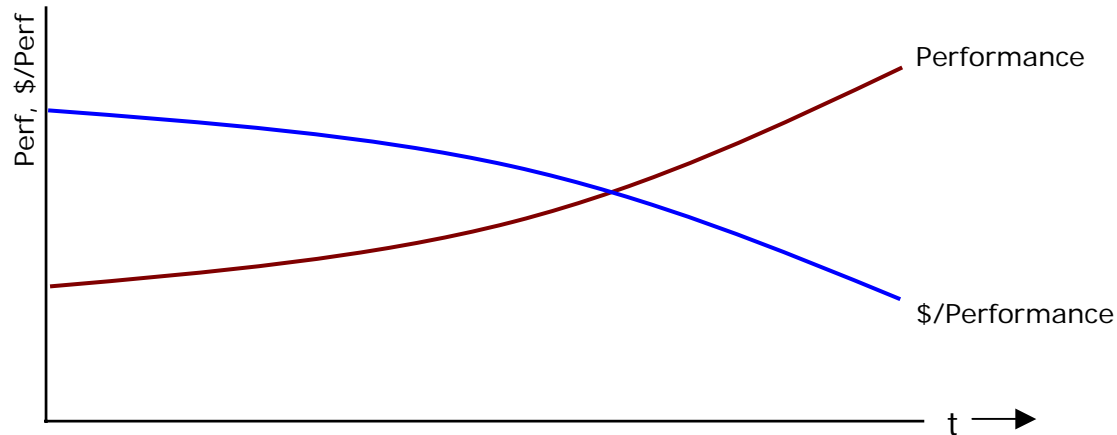
Matched model indices

Industry-average indices

Hedonic price estimation

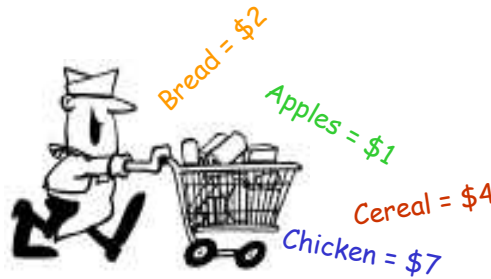
The Problem

Q: What performance should the government expect and at what price?



Hedonic Price Theory

The price of a market good is related to the prices of the individual characteristics of that good.



Cart total = \$50

Hedonic Price Theory

A computer desktop system is a bundle of separate goods, or characteristics. Its price is simply an aggregation of the prices of those characteristics.

We can therefore estimate a system's price by disaggregating the prices of its characteristics:

$$\$/\text{System} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k$$

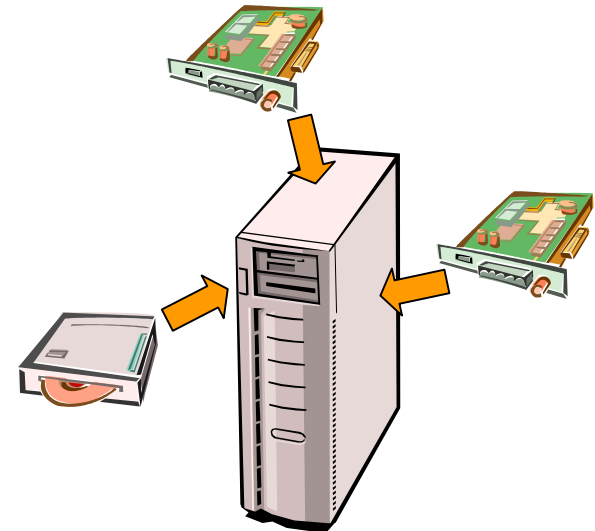
$\$/\text{System}$ is the aggregate price

x_k is a quantifiable performance measure

β_0 is an intercept term

β_k is an "implicit" price change

i.e., the mean implicit price change in the total system price for every unit change of x_k , holding all other x 's constant.



Since β_k is the implicit price change, each characteristic must be economically meaningful: it must represent a producer's output and a buyer's input.

Database Description

COTS PC Detail

Variables Collected

- ☑ Vendor/Brand/Price
- ☑ Memory
- ☑ Processor Specs
- ☑ Monitor Specs
- ☑ ROM Drive Specs
- ☑ Network Specs
- ☑ Sound
- ☑ Software

Price & performance data collected on desktop PCs from trade magazines, every January from year 1985 thru 2002.

- ✓ 27 Variables
- ✓ 2,099 data points

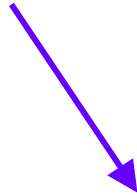
Consistently significant variables:

- ✓ Processor Speed
- ✓ Amount of RAM
- ✓ Hard Drive Size
- ✓ Monitor Size

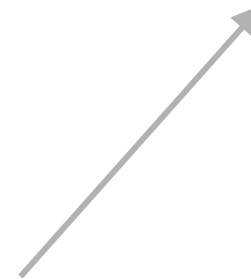
Forecasting Methodology

Desktop Computer Hedonic Price Relationship

Step 1: Fit and forecast implicit prices



$$$/System = f \left(\sum_i \text{Implicit Price}_i * \text{Characteristic}_i \right)$$



Step 2: Fit and forecast characteristic performances

Implicit Price Estimation Methodology

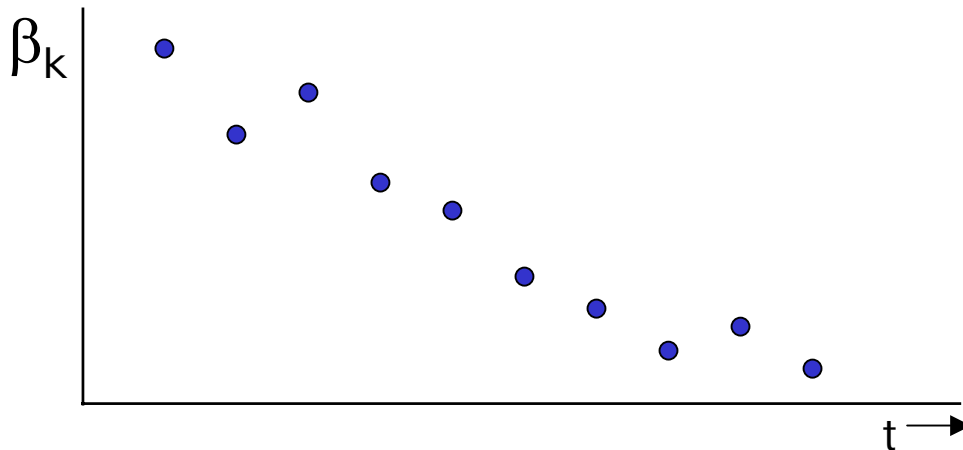
Implicit Price Hypothesis

Implicit prices are estimated for each year to construct a series of betas for each characteristic over time:

$$\$/\text{System}_{t=0} = \beta_{0,t=0} + \beta_{1,t=0}x_{1,t=0} + \beta_{2,t=0}x_{2,t=0} + \dots + \beta_{k,t=0}x_{k,t=0}$$

⋮

$$\$/\text{System}_{t=T} = \beta_{0,t=T} + \beta_{1,t=T}x_{1,t=T} + \beta_{2,t=T}x_{2,t=T} + \dots + \beta_{k,t=T}x_{k,t=T}$$



Hypothesis: As technology advances over time we would expect to see a downward trend in the implicit price of the characteristic

Hedonic Regression

Historic Desktop Computer Fits

$$1993 \text{ PC Price} = 80 + (3,384 * \text{HD}) + (18.7 * \text{MHz}) + (117.6 * \text{RAM}) + (0.9 * \text{Sqln})$$

$$1994 \text{ PC Price} = 550 + (1,013 * \text{HD}) + (16.3 * \text{MHz}) + (63 * \text{RAM}) + (1.0 * \text{Sqln})$$

$$1995 \text{ PC Price} = 130 + (406.5 * \text{HD}) + (16.5 * \text{MHz}) + (50.4 * \text{RAM}) + (4.8 * \text{Sqln})$$

$$1996 \text{ PC Price} = -100 + (411.4 * \text{HD}) + (9.2 * \text{MHz}) + (62.9 * \text{RAM}) + (2.7 * \text{Sqln})$$

$$1997 \text{ PC Price} = -390 + (158.9 * \text{HD}) + (10.6 * \text{MHz}) + (17.6 * \text{RAM}) + (0.6 * \text{Sqln})$$

$$1998 \text{ PC Price} = -604 + (38.1 * \text{HD}) + (9.6 * \text{MHz}) + (0.4 * \text{RAM}) + (2.1 * \text{Sqln})$$

$$1999 \text{ PC Price} = -625 + (4.5 * \text{HD}) + (4.3 * \text{MHz}) + (6.1 * \text{RAM}) + (1.5 * \text{Sqln})$$

$$2000 \text{ PC Price} = -1005 + (21 * \text{HD}) + (3.5 * \text{MHz}) + (3.5 * \text{RAM}) + (0.9 * \text{Sqln})$$

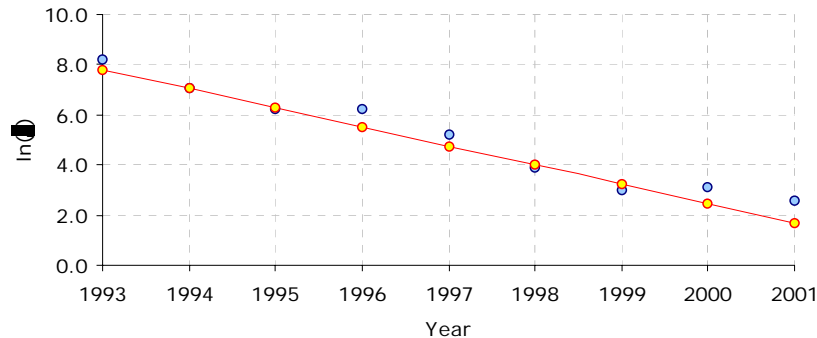
$$2001 \text{ PC Price} = -54 + (11.1 * \text{HD}) + (0.6 * \text{MHz}) + (5.3 * \text{RAM}) + (1.3 * \text{Sqln})$$

Based on 1,169 desktop systems

Implicit Price Estimation Methodology

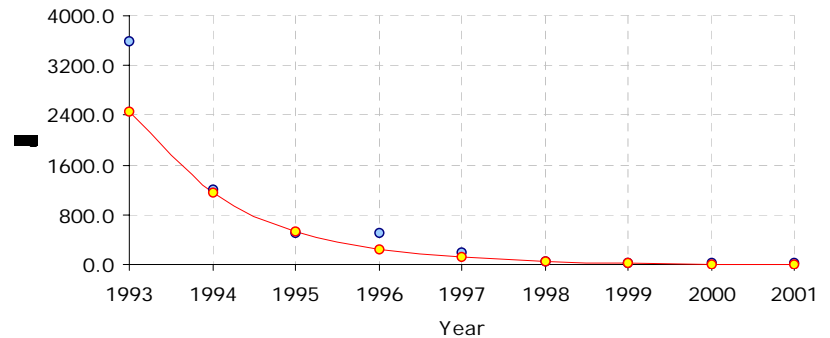
Findings of $\beta_{\text{Hard Drive(GB)}}$

Beta Approximation
Hard Drive Capacity, GB



○ Observed —○ Predicted

Beta Approximation
Hard Drive Capacity, GB



○ Observed —○ Predicted

$$\ln \beta_{\text{HD}} = 13.92 - 0.76(\text{Year} - \text{Base Year}_{1985})$$

$$\beta_{\text{HD}} = 1,112,282 e^{-0.76(\text{Yr} - \text{BY}_{1985})}$$

Where

β_{HD} : average implicit price change of hard drive capacity per GB

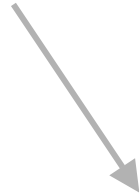
- ☑ $R^2_{\text{SLR}} = 89\%$
- ☑ $t_{\text{Year}} = -7$

Note on rounding: transformations performed to fifth significant digit.

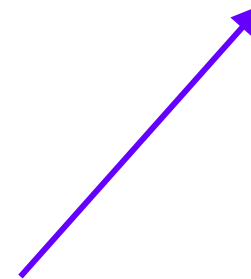
Forecasting Methodology

Desktop Computer Hedonic Price Relationship

Step 1: Fit and forecast implicit prices



$$$/System = f \left(\sum_i \text{Implicit Price}_i * \text{Characteristic}_i \right)$$

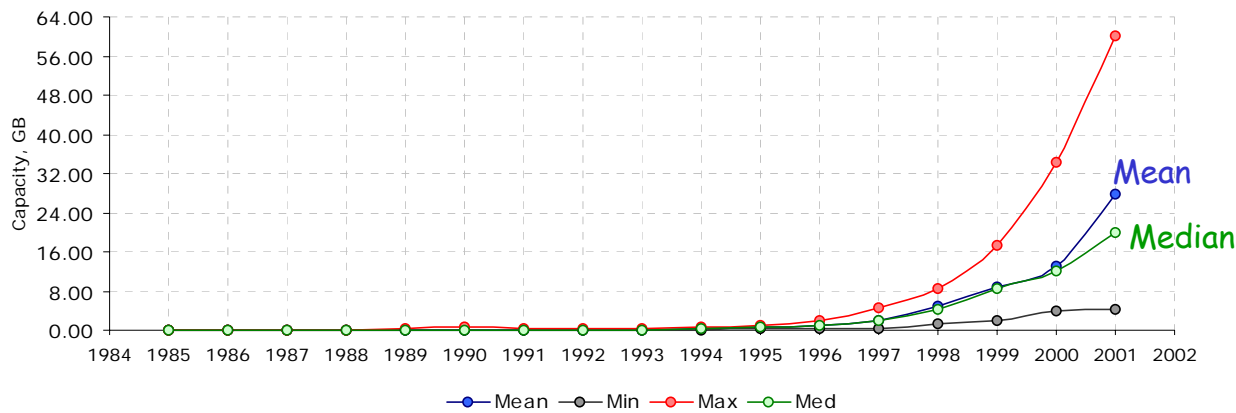


Step 2: Fit and forecast characteristic performances

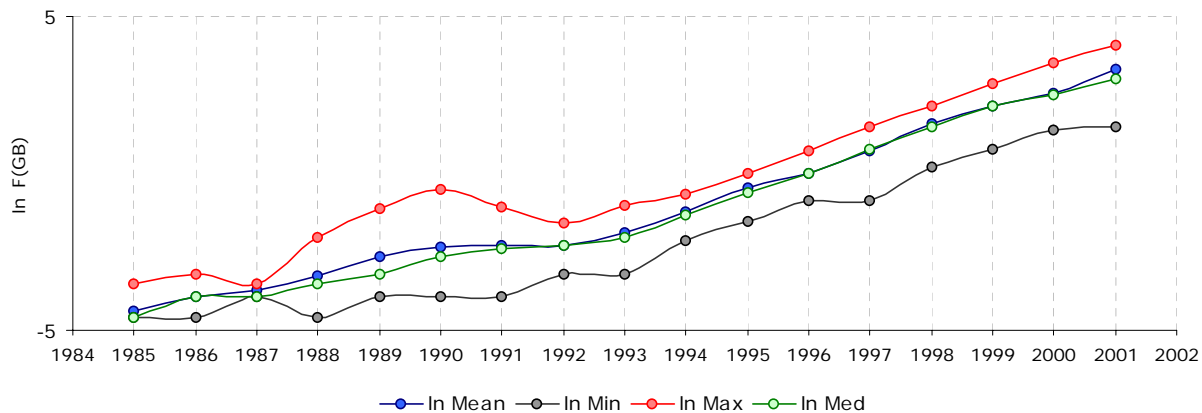
Performance Estimation Methodology

Hard Drive Capacity by Year

System Hard Drive Capacity



System Hard Drive Capacity



Performance Estimation Methodology

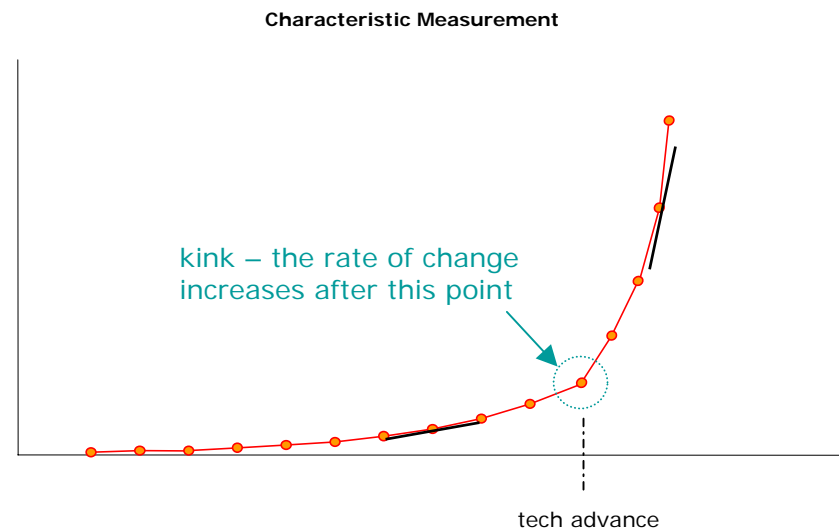
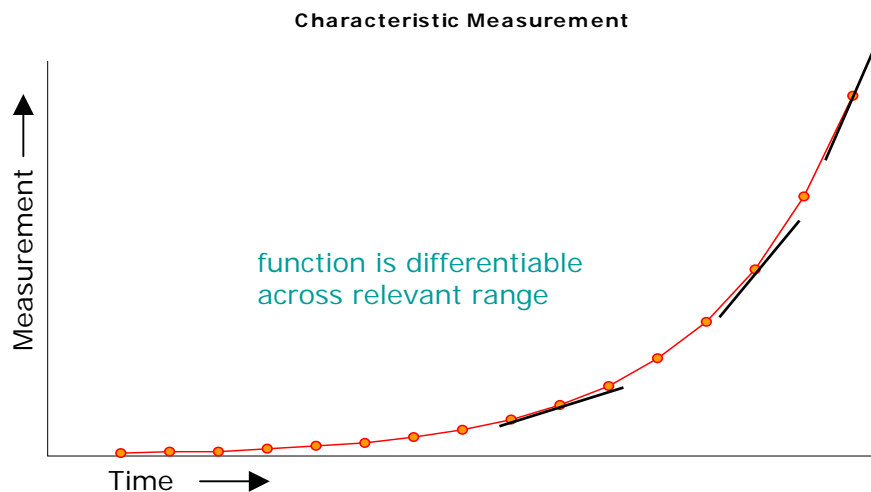
Model Assumptions

We can model performance growth with the function

$$y = \alpha e^{\beta x}$$

We need to assume that our performance characteristic is a smooth and continuous function; i.e. for the foreseeable future there will be...

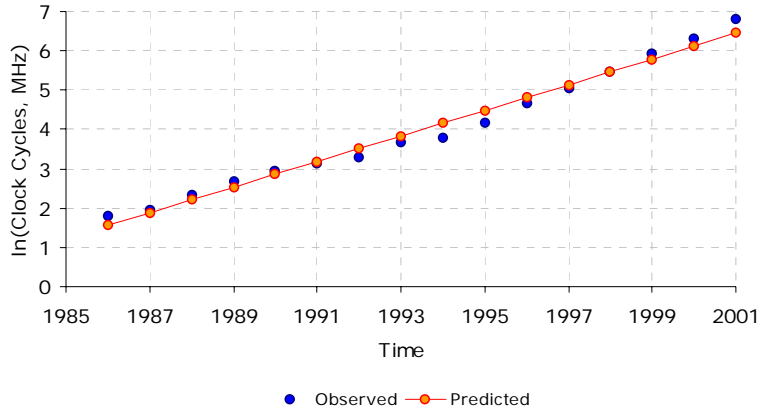
- 1) No rapid technology advances
- 2) No market shocks.



Performance Estimation

Mean Speed for System Processors

Processor Speed

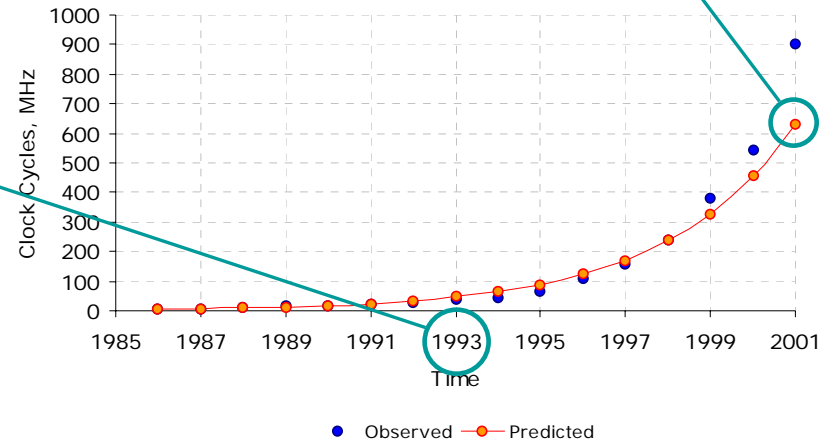


Change in technology causes a kink in the parameter function. Aggregation of the data leads to an underestimation of capabilities.

Intel introduced the Pentium chip in 1993, doubling the number of transistors...

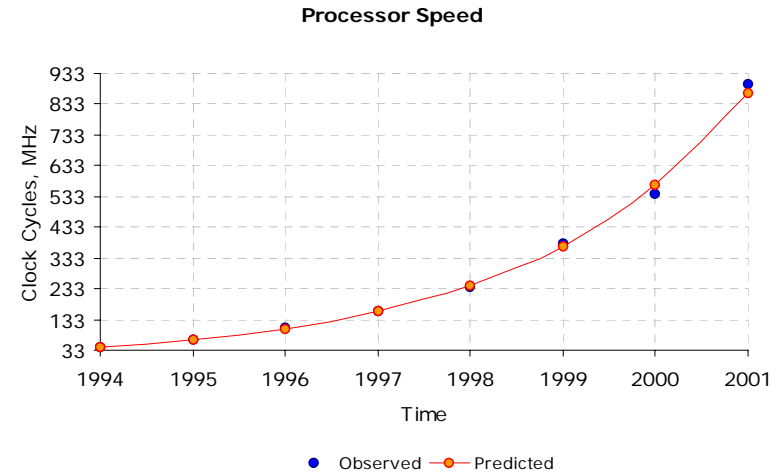
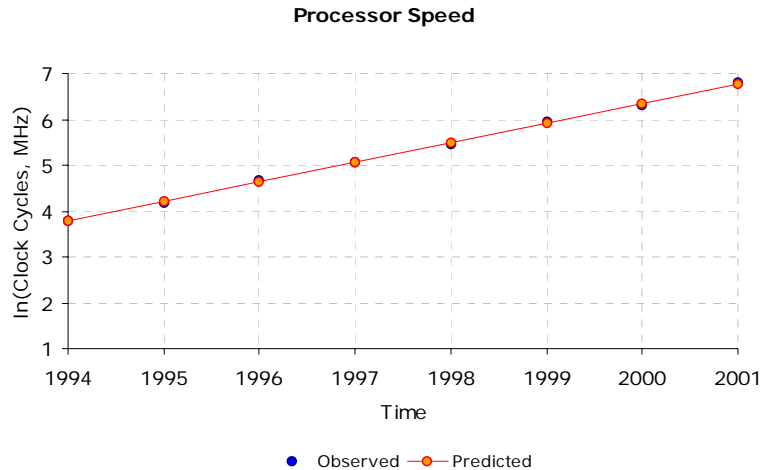
- 386™ SL (1990): 855 thousand
- 486™ SX (1991): 1.2 million
- 486™ SL (1992): 1.4 million
- Pentium™ 60 MHz (1993): 3.1 million
- Pentium™ 75 MHz (1994): 3.2 million

Processor Speed



Performance Estimation

Mean Speed for System Processors, 1994-2001



$$\ln \text{MHz}_{post} = -0.06 + 0.43(\text{Year}-\text{BY}_{1985})$$

$$\text{MHz}_{post} = 0.94e^{0.43(\text{Yr}-\text{BY}_{1985})}$$

Where

MHz_{post} : average clock cycles in megahertz after 1993

- ☑ $R^2_{\text{SLR}} = 99\%$
- ☑ $t_{\text{Year}} = 82$

Note on rounding: transformations performed to fifth significant digit.

Forecasting System Price

Step 1: Implicit Price Inputs

$$2002 \text{ PC Price} = \beta_0 + (\beta_{\text{HD}} * \text{HD}_{2002}) + (\beta_{\text{MHz}} * \text{MHz}_{2002}) + (\beta_{\text{RAM}} * \text{RAM}_{2002}) + (\beta_{\text{SqlIn}} * \text{SqlIn}_{2002})$$

$$\beta_0 = 1218.85 - 120.26(2002-1985) = -826$$

$$\beta_{\text{HD}} = 1,112,282 e^{-0.76(2002-1985)} = 2.53$$

$$\beta_{\text{MHz}} = 452e^{-0.35(2002-1985)} = 1.25$$

$$\beta_{\text{RAM}} = 5,941e^{-0.5(2002-1985)} = 1.12$$

$$\beta_{\text{SqlIn}} = 2.99 - 0.1(2002-1985) = 1.24$$

$$2002 \text{ PC Price} = -826 + (2.53 * \text{HD}_{2002}) + (1.25 * \text{MHz}_{2002}) + (1.12 * \text{RAM}_{2002}) + (1.24 * \text{SqlIn}_{2002})$$

Note on rounding: Significant figures used in calculations are not shown

Forecasting System Price

Step 2: Characteristic Inputs

$$2002 \text{ PC Price} = -826 + (2.53 * HD_{2002}) + (1.25 * MHz_{2002}) + (1.12 * RAM_{2002}) + (1.24 * SqIn_{2002})$$

$$HD_{post91} = 0.001e^{0.64(2002-1985)} = 53 \text{ GB}$$

$$MHz_{post93} = 0.94e^{0.43(2002-1985)} = 1,336 \text{ MHz}$$

$$MB = 0.23e^{0.39(2002-1985)} = 169 \text{ MB}$$

$$SqIn = -4.12 + 34.33 \ln(2002-1985) = 93 \text{ in}^2$$

$$2002 \text{ PC Price} = -826 + (2.53 * 53) + (1.25 * 1336) + (1.12 * 169) + (1.24 * 93)$$

$$2002 \text{ PC Price} = \$1,282$$

Note on rounding: Significant figures used in calculations are not shown

Price & Performance Validation

January, 2002 Characteristics

	Observed	Predicted	Delta
Supplied RAM (MB)	185	169	-9%
Processor Speed (MHz)	1,611	1,336	-17%
Hard Drive Capacity (GB)	38	53	39%
Monitor Size (Sq In)	108	93	-14%

Jan 2002 Observed Mean System Price: \$1,346

2002 Predicted Mean System Price: \$1,282 ($\Delta = -5\%$)

n = 144 systems for Jan 2002

Next Steps

- Apply methodology to Navy-specific data
- Compare Navy results to COTS results
- Analyze servers & data storage hardware

Final Thoughts

Benefits...breaks down the price of a computer system into the prices of its characteristics, & allows us to analyze the price trend of each characteristic

Limitations...we can't predict technology advances.

Possible improvements....

- ① Computer performance increases with power on base 2. Our predicted memory and HD capacity could be based on a step function instead of a continuous function.
- ② Model predicts processor prices to increase in a few years. Is this feasible? We'll let you know in a few years.