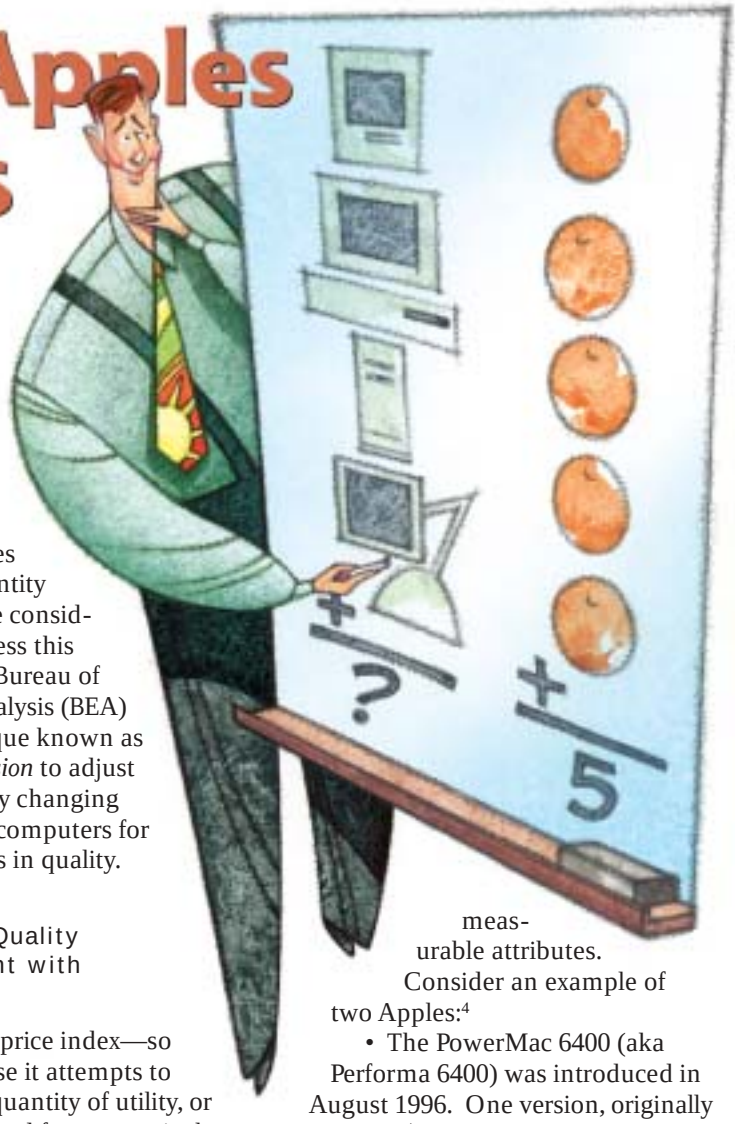
Comparing Apples and Oranges

When measuring prices, it's not easy dealing with rapidly evolving products like computers.

By Michael R. Pakko



The most comprehensive and often-cited statistic about the U.S. economy is gross domestic product (GDP), the sum of all goods and services produced in the United States. Estimates of GDP are the featured statistics in the National Income and Product Accounts, the construction of which involves the collection and aggregation of an immense amount of data.

In the construction of real GDP, complicated issues arise when adding up quantities of vastly different types of goods and services. These problems, which lie at the heart of national income accounting, can be thought of in simple terms as a problem of comparing apples and oranges. A Florida frost that raises orange prices might result in higher expenditures on oranges, even though the number of oranges produced has fallen. A period of inflation might increase total spending on both apples and oranges, even if quantities are unchanged. To convert total dollar sales (nominal GDP) into a measure of the total *quantity* of fruit (real GDP), price indexes are used to adjust for price changes both across goods and over time.

But what if the *quality* of some goods is changing over time? Consider a particular variety of apples for which quality change has been evident: the products of Apple Computer Inc.[1] The iMac produced in 2002 is a far cry from the Apple II computer of the late 1970s. More generally, the quality of computers—in terms of speed, data storage capacity, etc.—has advanced dramatically in recent years. Indeed, the celebrated Moore's Law, proposing that microchip capacity doubles every 18 months, has held true since at least the mid-1970s.

In an environment where technological progress gives rise to improvement in the quality of goods, particularly high-tech goods like computers, accurate measurement of economic output requires that both quantity and quality be considered. To address this problem, the Bureau of Economic Analysis (BEA) uses a technique known as *hedonic regression* to adjust sales of rapidly changing products like computers for improvements in quality.

Measuring Quality Improvement with Hedonics

A hedonic price index—so named because it attempts to measure the quantity of utility, or pleasure, derived from a particular good—is a statistical technique that adjusts the price of an item to reflect improvements in quality. For example, a personal computer purchased in 2002 might cost the same as one purchased a decade earlier, but the newer model is clearly superior in terms of overall computing power. Hedonic indexes incorporate quality change into the measurement of price so that the computer component of GDP in 2002 is comparable to those in previous years.

Computers provide an illuminating example, but are not the only component of GDP for which quality change is measured using hedonic methods. One of the earliest applications of hedonic methods compared automobile quality across model years in the 1930s.[2] A recent study by the BEA reports that 18 percent of GDP is constructed using hedonic techniques.[3]

The hedonic method is particularly well-suited for comparing goods that can be thought of as comprising a bundle of underlying attributes, each of which is assumed to have its own intrinsic value. In the case of personal computers, the components inside the "box" itself have several independent, measurable attributes.

Consider an example of two Apples:[4]

- The PowerMac 6400 (aka Performa 6400) was introduced in August 1996. One version, originally priced at $2,399, had a processor that operated at 180 megahertz and a bus speed of 40 megahertz. It came with 8 megabytes of RAM (expandable to a maximum of 136 megabytes) and was equipped with a 1.6 gigabyte hard drive.
- The PowerMac G4 (Quicksilver) came out in July 2001. The mid-range option was priced at $2,499, only 4 percent higher than the aforementioned 1996 model and less than the older computer in inflation-adjusted dollars. (Nondurable consumption goods prices rose 9 percent over the same period.) The processor speed for this version of the G4 was 867 megahertz, and it had a bus speed of 133 megahertz. It had 128 megabytes of RAM (expandable to 1.5 gigabytes) and included a 60 gigabyte hard drive. The newer computer also included a DVD-R drive, while the older model had only an 8x CD.

Clearly, by each of these quantifiable measures, the 2001 computer is far superior to the 1996 computer. If sales of the 6400 and G4 were included in the national accounts in terms of price per computer, the data would understate the quantity of computing power represented by

the newer model. The hedonic approach addresses this problem by using a statistical model that relates the price of computers to measures of the specific features they include.

By comparing prices and features of various 1996 computers, a hedonic regression model attributes values to each of the particular features (e.g., processor speed, memory, disk capacity). These values can then be applied to the new computer to construct a hypothetical cost— the price that the 2001 computer would have commanded in 1996. The difference between this hypothetical price and the actual market price of the computer in 2001 can, therefore, be interpreted as measuring the decline in the cost per unit of computing power, equivalently, as an increase in the quantity of computing power available for a given price.

Suppose that the hedonic valuation exercise revealed that the 2001 computer was twice as valuable as the 1996 computer, even though they have nearly the same dollar price. Counting sales of the new model in the same units as the old model would clearly be inappropriate. Using hedonic regression techniques, however, we can say that each computer sold in 2001 counted for two older computers or, equivalently, that the price of computing power had fallen by half.

Computer Quality in the National Accounts Data

As a result of the hedonic regression technique, estimates of real production and sales are expressed in quality units, rather than strictly in terms of quantity. In the case of computers, this means that the production and sales of computers are not measured by the number of computers, but by units of computing power that are comparable across different models of computers and over time.

The price index for computers in GDP measures price in terms of these units of computing power. It reflects overall inflation trends—changes in the price of all goods and services produced in the economy—as well as changes in relative price, which includes changes in the *quality* of computers. By comparing the price index of computers to that of a basket of other goods (in order to control for the effects of inflation), we can obtain a direct measure of the price component that is unique to computers, which can be interpreted as an estimate of the quality of computing power represented in total computer sales.

The accompanying charts illustrate such a measure, comparing the price of computers to the price of nondurable consumption goods (representing a market basket of such standard items as clothing and food—and including oranges). The upper panel shows the price of computing power relative to this collection of basic consumption goods. It reveals a dramatic decline: For each dollar spent on computers in 1996, the figure shows that an equivalent amount of computing power would have cost over $13 in 1981, but cost less than 30 cents in 2001 (in inflation-adjusted 1996 dollars).

A decline in the price of computers relative to other goods is equivalent to an improvement in the quality of computers. The lower panel of the chart shows the inverse of the relative price, representing a direct estimate of the change in the computer quality. The computer-quality index is constructed using 1996 as the base year—so, at a value of 3.6 in 2001, this implies that computers in 2001 had 3.6 times the computing power of a 1996 model. A typical computer produced in 2001 has twice the quality of a computer produced as recently as 1998, and a 1998 computer, in turn, contained more than twice as much computing power as a vintage 1995 computer.

By representing the quantity and price of computers—as well as other high-tech goods—in units of constant quality over time, the national accounts provide a more accurate reflection of the economic significance of improvements in technology than would simple measures of unit quantity. This use of hedonics in the national accounts recognizes that is important to measure not only the quantity of oranges and apples, but their quality as well.

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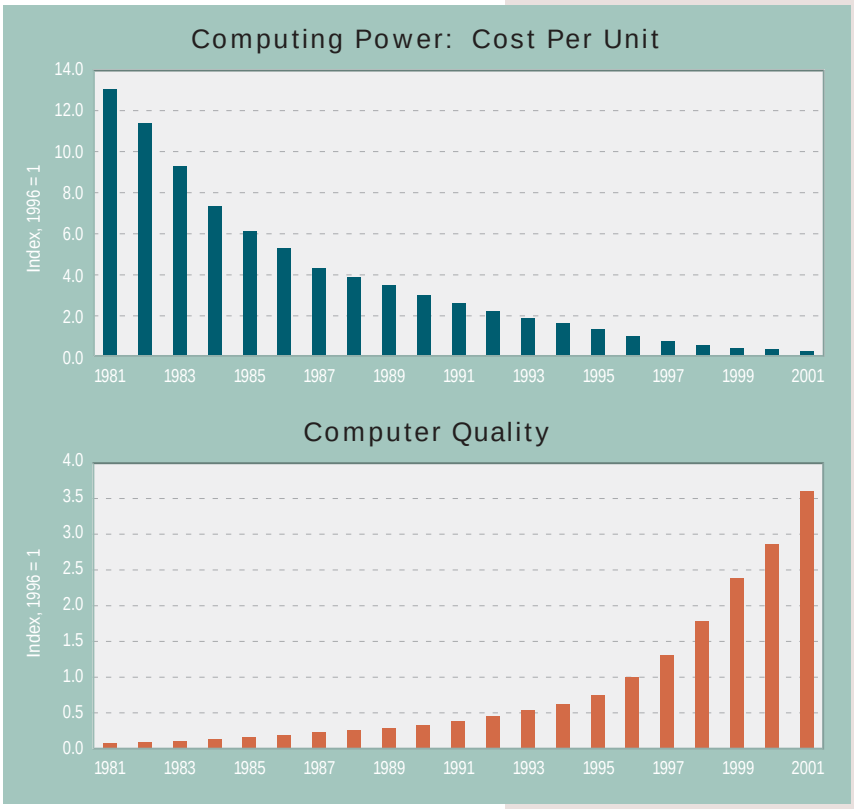

ENDNOTES

1. The use of Apple computers in this illustration is not intended to ignore or disparage the producers, users or fans of the competing PC platform.
2. Triplett (1986) attributes the origin of hedonics terminology to the study of automobiles by Court (1939).
3. Landefeld and Grimm (2000).
4. All information about the specific attributes of these two computers was found at http://www.apple-history.com, posted by Glen Sanford.

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