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Quality Change in Price Indexes

William D. Nordhaus

Price indexes are one of the great inventions of economics. They allow us to measure in a timely fashion the movement of the general price level and, through deflation of nominal magnitudes, to calculate real incomes and real output. Fundamental breakthroughs in index number theory put a solid microeconomic foundation beneath this impressive edifice. The recent report of the Boskin Commission reviews a wide variety of studies and provides an expert judgement on the extent to which the Consumer Price Index accurately measures changes in the cost of living (Boskin, 1996). The report estimates that the CPI has an upward bias of 1.1 percentage points per annum. The most solid component of this estimate is that 0.4 percentage points per annum are due to use of fixed expenditure weights in the index. This comment addresses their view that the bias from underestimating quality change is 0.7 percentage points per year.

Quality change includes many elements: new and improved products, changes in the distribution network, and disappearance of old goods. I begin with some general background on the treatment of quality change and discuss procedures used by the Bureau of Labor Statistics (BLS) to deal with quality change. I then discuss the Boskin Commission assessment and other evidence and conclude with a proposal on how to resolve the formidable uncertainties in this area.

Theoretical Background: Goods, Characteristics, and the Cost of Living

At the most fundamental level, the problem of quality change arises because conventional price indexes measure the prices of commodities that consumers buy

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rather than the cost of attaining a given level of economic well-being or utility. It is of course impossible to measure utility directly, so the next best approach would be to measure the prices of the fundamental characteristic services that consumers value. These would include transportation, communication, good health, entertainment, and so forth. In reality, the CPI moves yet another logical step away from measuring economic well-being by measuring the prices of inputs that consumers buy to produce fundamental services. For example, the CPI measures the prices of automobiles, electricity, and hospital days rather than the costs of travel, lighting, or delivering a baby. One goal of improved measures of the cost of living, therefore, is to measure the prices of fundamental characteristic services rather than the prices of inputs.

Measuring the prices of fundamental services raises practical obstacles because these prices are almost never observed in the marketplace. Consider the difficulties of measuring the prices of such characteristics as the timeliness and safety of transportation modes, the enjoyment delivered by various forms of entertainment, or the change in health status provided by the wide array of medical services.

Additionally, dealing with quality change in the CPI is a mammoth practical problem because of its sheer size. We can illustrate this point by explaining how the Bureau of Labor Statistics presently deals with quality change (Armknecht, Lane, and Steward, 1997; Moulton and Moses, 1997). During 1993, BLS price examiners gathered 813,074 price quotations. Examiners found that 3.4 percent, or 27,304 quotations, involved goods that were no longer available. For each of these vanished products, BLS finds a substitute product and makes a determination about whether there is any quality change. For most of the vanished products (56 percent) BLS found ''comparable products,'' which were judged to involve no quality change. Many of these changes were presumably inconsequential or trivial, perhaps involving only a change in the color of a shirt.

No directly comparable products could be found for the remaining 43 percent of vanished products. Of this group, 34 percent of the price changes were ''linked in.'' As I indicate below, this procedure assumes that relative prices between vanished and replacement goods reflect relative quality differentials. The remaining 9 percent of vanished products received direct quality adjustment by the Bureau of Labor Statistics; this occurs for example when the price is adjusted by the cost of added features (such as a second airbag) in a new model automobile. Two-thirds of the direct quality adjustments were in two sectors: new cars and trucks and women's apparel. Therefore, of the 27,304 quality change decisions required in 1993, there were only 844 quality adjustments in the entire CPI in 1993, outside of the two sectors. The fact that, outside of the two sectors, only 0.1 percent of all priced commodities were deemed to experience quality change is compelling evidence that BLS does not adequately address quality change in the Consumer Price Index.

In addition to the run-of-the-mill quality changes that occur on a daily basis, an even deeper issue concerns radical new products, or what I later will describe as ''tectonic shifts in technology.'' It is not widely appreciated that price indexes incorporate revolutionary technological changes by linking new goods or product

categories into the price index. When two goods are linked together, it is assumed that their price differential exactly reflects their quality differential. For major inventions, such as the polio vaccine or VCRs, the improvement in well-being is basically ignored.

The problem with linking can be illustrated using the case of light bulbs. Compact fluorescent bulbs deliver illumination at about one-quarter the total cost of a standard incandescent bulb. Let's compare a ''true'' or characteristic price index with the traditional linking procedure to see how traditional approaches completely miss major efficiency improvements. Suppose that an incandescent light bulb delivers light at a cost of $10 per million lumen-hours in year 1 and $12 in year 2, after which the old technology disappears from the marketplace. Compact fluorescent bulbs appear in year 2; they produce light at $2.40 per million lumen-hours in year 2 and at $1.80 in year 3. Assuming a complete transition from the old to the new technology between periods 1 and 3, the ''cost of lighting index'' would equal 100 in year 1 and 18 in year 3.

Linking works by chaining the price increases of different products. Hence the link index rises from 100 to 120 = 100 × ($12/$10) in period 2; and then to 90 = 120 × ($1.8/$2.4) in the third period. In other words, the price change of the old bulb determines the movement of the price index between years 1 and 2, and the price change of the new bulb would determine the price change between years 2 and 3. However, the linking procedure never estimates the change in the price of the fundamental service as we move from the old to the new good. The fact that revolutionary changes in technology have drastically lowered the cost of illumination gets lost in the linking.

Quality change poses severe problems for a statistical agency. It is nonmechanical in the sense that there is no way to determine quality change on a routine basis. It is heterogenous in the sense that each quality change is *sui generis* and, like a child, requires individual attention. It is informationally demanding because it may require vast quantities of data that are expensive to obtain and often do not pass the test of a market transaction. Even though routine procedures are established to handle quality change, in the end quality decisions require the subjective judgment about the extent of quality change, and agencies are reluctant to make subjective judgments.

The Boskin Commission's Assessment

The Boskin Commission argues that current procedures for accounting for quality change (including the bias from changing outlets) overestimate the rise in the cost of living by 0.7 percentage points annually. Of this total, about half occurs in six categories, as follows: professional medical services (3.0 percentage points per year), hospital and related services (3.0), household appliances (5.6), apparel (1.0), cars (0.8), and entertainment goods (2.0).

The report relies heavily on a few well-documented estimates of quality change, particularly those in computers and consumer durable equipment. For example,

Gordon (1990) conducted a landmark study of quality change in consumer durable equipment and found 3.2 percentage points per year upward bias for appliances and 5.9 percentage points upward bias for radios and televisions. The most daunting quality-change issues arise in the health care sector. Here, prices are almost universally measured as input rather than output prices; that is, the price of an office visit or hospital stay is measured rather than the price of a treatment or of attaining a certain health status. Cutler et al. (1996) estimated that a true price index for treatment of heart attacks declined 5.5 percentage points per year relative to the corresponding component of the CPI. Studies of pharmaceuticals have uncovered an upward bias of around 3 percentage points per year (Griliches and Cockburn, 1994).

Other Issues: Tectonic Shifts and More

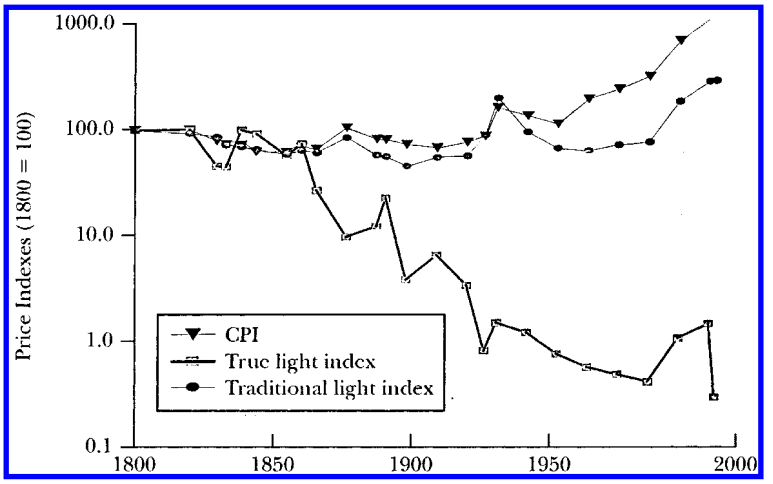
The Boskin Commission reviewed evidence on quality change in the conventionally measured CPI. I will discuss some of the more difficult issues omitted from current discussions of measuring changes in the cost of living: tectonic shifts in technology, public goods, health care, and quality deterioration. I also show how self-assessment of economic welfare can shed light on this question.

Tectonic Shifts: The Price of Lighting

Turn next to really revolutionary technological changes. Ponder the tectonic shifts in the economy that occurred as railroads replaced muddy cow paths, as telegraph replaced Pony Express, as telephone replaced correspondence, as air conditioning made the deserts habitable, as television replaced dark and lonely nights, as antibiotics eradicated terrible plagues, e-mail replaces other forms of communication, and as artificial intelligence through computers gradually invades all aspects of modern society. How well are revolutionary new technologies captured in price and output indexes? Ironically, the most revolutionary breakthroughs are most often missed. The reason, as noted above, is that conventional price indexes ignore the impact of revolutionary new products on the cost of living by linking them into the price index, which implicitly assumes that they offer no additional enhancement of economic welfare.

Lighting provides a useful example because it is a relatively simple technology that has undergone revolutionary technological changes over the last two centuries. The true price of light is conceptually simple because there are objective measures of output, specifically, lumen-hours. It is thus possible to compare the ''true'' price of the characteristic service of lighting, measured in lumen-hours, with the conventional consumer price index for light. To derive a conventional estimate of the price of light, I pieced together price indexes for lighting back to 1800 from a variety of sources and combined these with the official CPI since 1920. The traditional price of light comprises either consumer or wholesale price indexes for ''lighting'' or for the fuels that go into lighting, such as candles, town gas, kerosene,

Figure 1
Traditional and True Price of Light



Source: Nordhaus (1997).

and electricity (Nordhaus, 1997). The true price of light is derived from a wide variety of studies of the efficiency of lighting devices and of fuel prices.

The result of this calculation is astonishing. Figure 1 compares conventional and true price indexes of light along with the overall consumer price index. The true price of light bears no resemblance to the conventional index. As can be seen in Figure 1, *the conventional price of light has risen by a factor of about 1000 relative to the true price.* The average annual bias over the 1800–1992 period, that is, the rise in the conventional price relative to the true price, is 3.6 percentage points per year. Lighting is at present the only case in which we can compare the characteristic service price across the tectonic shifts of major technological revolutions. If similar biases are found elsewhere, this would indicate significant upward growth biases in price indexes and downward growth biases in measures of real output.

Public Goods

A rising fraction of consumption is provided by firms or governments. We might want to consider the cost of a broader measure of consumption, which I call an ''augmented cost-of-living index,'' or ACOLI. The purpose of constructing an ACOLI is to recognize that consumers enjoy certain goods and services that are ''paid for'' by firms in wage-lowering fringe benefits or by governments through indirect taxes. These raise conceptual problems because these price-raising costs get into the CPI while the value of the consumption is not counted in consumer expenditures or market incomes.

Consider for example a bridge built by the government and financed by gasoline taxes. The gasoline tax will raise prices and the CPI, and this will be counted as a decline in real wages or real incomes. However, if the incremental benefits of

the bridge just equal the incremental costs, then the apparently lower post-bridge real income will attain just the same level of economic well-being as the higher pre-bridge real income.

An ACOLI might adjust for: 1) employer-provided fringe benefits, particularly for health care, which raise prices but provide corresponding benefits; 2) social insurance taxes, which are benefit taxes earmarked for health care or retirement programs; and 3) social regulation, in which price-raising regulations convey benefits in terms of improved health and safety. Each expenditure raises the prices of conventional consumer goods and services, but there is also a corresponding improvement in the quantity or quality of goods and services not purchased by consumers.

We have today only rudimentary measures of the bias that arises from omitting augmented consumption. For illustrative purposes, I calculated an ACOLI for the 1960–94 period by subtracting the costs of fringe benefits, benefit taxes, and regulation from the CPI, assuming that these were prices paid for increased services. The result was to lower the increase in the cost of living over this period by 15 percent, or about 0.40 percentage points per year (Nordhaus, 1996).

Health

One of the most daunting issues in the measurement of price indexes and real income involves changes in health status. A significant increase in life expectancy with the same flow of consumption each year would generally be reckoned as an improved level of economic welfare. Universal inoculations, improved automobile-safety equipment, new treatments for heart attacks, and declining air pollution are a few examples of how new public and private goods have produced dramatic improvements in health status.

Should we adjust price indexes to reflect the (literal) decline in the cost of living? This approach is adopted by the Boskin Commission and is the thrust of current research on health economics. A more radical approach would be to consider medical expenses as an input and treat health status as the output. Under this approach, we would subtract health care expenditures from consumption expenditures, treating it as an intermediate input, and adjust real income to reflect the hedonic value of the improvement of health status.

An example will illustrate the health-status output approach. The population-weighted mortality rate declined from 1036 per 100,000 in 1970 to 788 per 100,000 in 1990. We can estimate the value of this increase in life expectancy using conventional estimates of the value of fatalities prevented of about $3 million in 1992 prices and 1990 income levels (Viscusi, 1993). Over the 1970 to 1990 period, conventionally measured real per capita personal consumption expenditures grew at an average annual rate of 2.2 percent. After subtracting medical expenditures and adjusting for the rise in life expectancy, real per capita consumption grew at 3.5 percent per annum. Hence, an adjustment for the value of higher life expectancy would increase real consumption growth by 1.3 percentage points per year!

This adjustment raises as many questions as it answers. The estimate of the value of life is controversial and, some believe, implausibly high. A substantial part

of the improvement in health status probably reflects public goods (such as improved sanitation) and nonmarket activities (such as wearing seat belts), neither of which is included in consumption expenditures. It raises difficult questions about the proper boundaries for measuring economic welfare—quite analogous to the issues raised in asking whether our national product accounts should be extended to reflect nonmarket activities such as home-cooked meals, leisure, pollution, and global warming. Notwithstanding these problems, this calculation suggests that health status is yet another area where our conventional measures of the cost of living are seriously defective.

Quality Deterioration

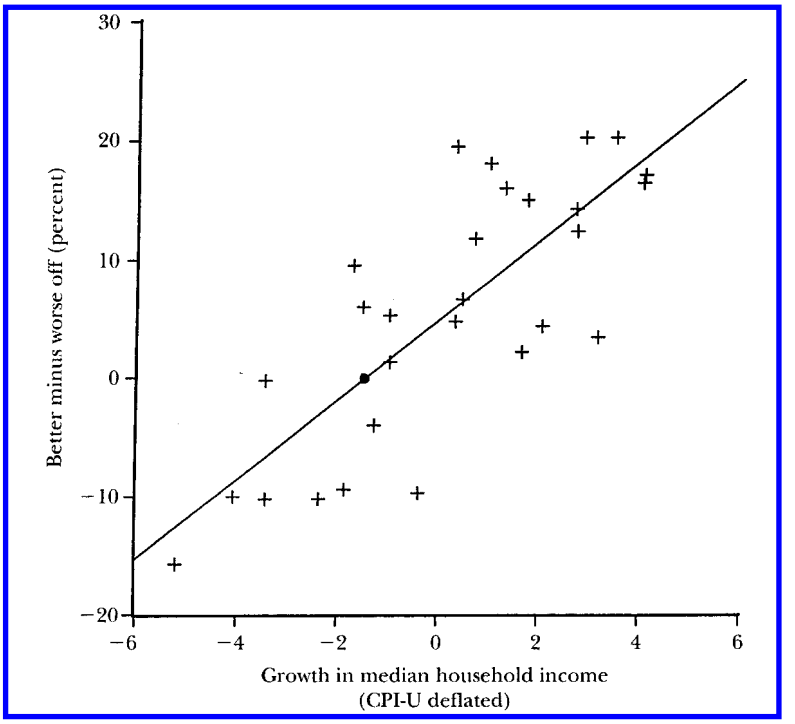
Many people have complained that the Boskin Commission was equipped with rose-colored glasses along with its impressive spreadsheets—overlooking deteriorating quality change. In considering the issue of quality deterioration, I will focus only on quality deterioration of existing products, which is the exact counterpart of the appearance of new products. The downside of the automobile and air-travel revolution is the deterioration in rail service; typewriters are perfectly adequate for many tasks but have largely disappeared from stores; as software programs are upgraded, they become so complicated that their use seems to require an advanced degree; many electronic devices have daunting instructions; the self-service revolution has led to the demise of many service-oriented retail businesses; the house calls of the family doctor are a fond memory; and so forth. Because new products do not usually dominate old ones along every characteristic of service provided, there are difficult issues of measurement here. When a commodity disappears—as occurred for the 27,304 products in the 1993 BLS sample—its price in effect rises sharply. To calculate the economic loss from these disappearing products is just as daunting as finding the gains from new products.

Self-Appraised Economic Status and the CPI

One way to address the question of CPI bias is to use survey data on how people see their own economic welfare compared with changes in their actual real incomes. To study this, I used measured median household income collected by the Bureau of the Census and deflated by the Consumer Price Index (CPI-U). I then compared this with the survey of consumer behavior done by the Survey Research Center at the University of Michigan, in which people were asked how their financial condition changed over the last year.

The data for the years from 1968 to 1994 are shown in Figure 2. The horizontal axis shows the growth in CPI-deflated median income each year. The vertical axis shows the algebraic difference between those reporting themselves better off and those reporting themselves worse off for a year. I assume that *correctly measured* median real income is unchanged when equal numbers of people report themselves better and worse off. The point at which the regression line intersects the zero line on the vertical axis is an estimate of the bias of the measure of real income. The regression line reveals that, on average, an equal number of people reported themselves better off as worse off when CPI-deflated income was declin-

Figure 2
Growth in Measured Median Income and Self-Assessed Economic Status



Source: University of Michigan, Survey Research Center and Bureau of the Census.

ing at 1.5 percent per year. Statistically, this approach estimates that the CPI bias is 1.5 percentage points per year with a coefficient standard error of 0.48. Alternative specifications, including different measures and a Gallup survey with the same question about economic well-being, give biases from 1.0 to 1.5 percentage points per year.[1]

This calculation offers a completely independent estimate of the bias in the CPI based on people's perceptions of their own financial condition. Interestingly, the magnitude of the estimate is consistent with the Boskin Commission's estimates (1.3 percentage points per year over the historical period). Before taking this as the final nail in the CPI coffin, however, further research is needed on this approach. It is likely that changes in the distribution of income of life-cycle effects might account for some of the apparent bias. Moreover, we know that people's self-assessment of their financial condition contains many features

[1] The regression is (percent better off minus percent worse off) $= \alpha \times$ [(percent change in median income) minus β]. Using non-linear least squares, I estimate β and its standard error as 1.5 and 0.48, respectively.

other than their measured real incomes, so this little regression can hardly be conclusive.[2]

Conclusions

What should we conclude about the issue of quality change in the CPI? My personal reading is that the Boskin Commission's case on quality change is persuasive but not conclusive. The case is persuasive because of the sheer weight of cases in which the procedures of the Bureau of Labor Statistics appear to give an upward bias along with the evidence that the BLS does little direct quality adjustment. Moreover, omissions in such areas as new products, public goods, and health status are further evidence of an upward bias in the cost of living. Finally, none of the existing studies estimate the impact of major tectonic shifts, like those in lighting discussed above.

But the case is not conclusive because of reservations about the estimates of quality-change bias. Careful quality-change estimates have been made for only a small fraction of consumer purchases, and we cannot assess the selection bias in the choice of sectors studied. We have careful studies of televisions, computers, and pharmaceuticals, but none for bananas, haircuts, and church sermons. The task of judging the actual amount of quality change—which is difficult enough for individual commodities—is overwhelming for the totality of products because the CPI deals with an enormous population of commodities. Tens of thousands of items disappear from BLS's view each year, and we do not really know how much quality change is already included in the BLS estimates. The CPI is so complex an organism that, like a Star Wars computer code, few can understand its exact functioning.

The implications of the bias debate are far-reaching. To a first approximation, an upward bias in consumer prices will be reflected in a similar downward bias in the growth of real consumption. Hence, if consumer price measures have an upward bias of 1.1 percentage points a year, then real U.S. wages from 1960 to 1995 grew by 61 percent rather than the conventionally measured 10 percent. To take another example, consider the impact on total factor productivity for the U.S. private economy, which is estimated to have grown at 0.6 percent per year from 1973 to 1995. If the Boskin Commission estimates carry over to the entire private economy, then total factor productivity growth has been almost triple the conventional estimate.

How should we proceed beyond today's disputes about particular commodities or sectors? This war of the anecdotes is likely to be a war of attrition because the number of products involved far outnumbers the number of interested and competent economists and statisticians. We need a different strategy to resolve the un-

[2] Using a similar methodology, Krueger and Siskind (1997) examine longitudinal data on individuals and conclude that there is no bias.

certainties about quality change. One promising approach would be to take an appropriately stratified sample of commodities in the CPI and do a thorough estimate of the ''true'' price of the service delivered by those items (in the spirit of the lighting example discussed above). It might require a dozen teams of economists a half-dozen years to estimate the bias for a few dozen products. But this process would produce better estimates of unmeasured quality change along with estimates of reliability. It is hard to think of a more exciting and worthwhile topic in applied economics.

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References

Armknecht, Paul, Walter F. Lane, and Kenneth J. Steward, ''New Products and the U.S. Consumer Price Index.'' In Timothy F. Bresnahan and Robert J. Gordon, eds. *The Economics of New Goods*. Chicago: University of Chicago Press, 1997, 375–91.

Boskin, Michael, et al., ''Toward a More Accurate Measure of the Cost of Living: The Final Report of the Advisory Commission to Study the Consumer Price Index,'' December 4, 1996 (updated version).

Cutler, David, Mark B. McClellan, Joseph Newhouse, and Dahlia Remler, ''Are Medical Care Prices Declining?'' mimeo, Harvard University, 1996.

Gordon, Robert J., *The Measurement of Durable Goods Prices*. Chicago: University of Chicago Press, 1990.

Griliches, Zvi, and Iain Cockburn, ''Generics and New Goods in Pharmaceutical Price Indexes,'' *American Economic Review*, December 1994, *84*:5, December 1994, 1213–32.

Krueger, Alan B., and Aaron Siskind, ''Assessing Bias in the Consumer Price Index,'' mimeo, October 11, 1997.

Moulton, Brent R., and Karin E. Moses, ''Addressing the Quality Change Issue in the Consumer Price Index,'' *Brookings Papers on Economic Activity*, 1997, *1*, 305–49.

Nordhaus, William D., ''Beyond the CPI: An Augmented Cost of Living Index (ACOLI),'' *Business Economics*, July 1997, *32*:3, 48–54.

Nordhaus, William D., ''Do Real-Output and Real-Wage Measure Capture Reality? The History of Lighting Suggests Not.'' In Timothy F. Bresnahan and Robert J. Gordon, eds. *The Economics of New Goods*. Chicago: University of Chicago Press, 1997, 29–66.

Viscusi, W. Kip, ''The Value of Risks to Life and Health,'' *Journal of Economic Literature*, December 1993, *31*:4, 1912–46.

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2. Daniel Kahneman, Alan B. Krueger. 2006. Developments in the Measurement of Subjective Well-Being. *Journal of Economic Perspectives* **20**:1, 3-24. [Abstract] [View PDF article] [PDF with links]
3. David E. Lebow, Jeremy B. Rudd. 2003. Measurement Error in the Consumer Price Index: Where Do We Stand?. *Journal of Economic Literature* **41**:1, 159-201. [Abstract] [View PDF article] [PDF with links]
4. Bruce W. Hamilton. 2001. Using Engel's Law to Estimate CPI Bias. *American Economic Review* **91**:3, 619-630. [Citation] [View PDF article] [PDF with links]