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3. What has happened to price measurement since the Boskin Report? The U.S. Experience

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Introduction

The report by the U.S. Advisory Commission to Study the Consumer Price Index (known more commonly as the Boskin Report) issued on December 4, 1996 addressed the broad conceptual question of whether a price index should aim to be a cost-of-living measure or simply a cost-of-goods (COGI) measure and focused attention on three key problems inherent in the calculation of consumer price indexes: consumer substitution, quality change, and new goods. These issues received further attention in the 2002 report by the National Academy of Sciences on Conceptualizing and Measuring Cost-of-Living and Price Indexes (known as the CNSTAT Report). Subsequent to the Boskin Report, the U.S. Bureau of Labor Statistics (BLS) reaffirmed its cost-of-living conceptual framework and, building on prior research, introduced methodological changes that have addressed the substitution, quality, and new goods issues. These include: 1) The introduction of the geometric means formula to account for lower-level substitution. 2) The introduction of the Chained Consumer Price Index for All Urban Consumers (C-CPI-U) to provide an index that accounts for upper level substitution. 3) Expansion of the use of hedonic models to improve the measurement of quality change. And 4) The institution of procedures to introduce new goods into the index more quickly by more frequent updates to the item samples. This paper details these methodological changes and provides some estimates of their quantitative impact.

Conceptual Basis of the CPI

Decisions about particular CPI issues are rooted in the fundamental conceptual goals of the CPI. The CPI remains committed to using a cost-of living index (COLI) as its theoretical goal. The current *BLS Handbook of Methods* asserts

> As it pertains to the CPI, the COLI for the current month is based on the answer to the following question: *"What is the cost, at this month's market prices, of achieving the standard of living actually attained in the base period?"* This cost is a hypothetical expenditure—the lowest expenditure level necessary at this month's prices to achieve the base-period's living standard. The ratio of this hypothetical cost to the actual cost of the base-period consumption basket in the base period is the COLI. Unfortunately, because the cost of achieving a living standard cannot be observed directly, in operational terms a COLI can only be approximated. Although the CPI cannot be said to equal a cost-of-living index, the concept of the COLI provides the CPI's measurement objective and the standard by which we define any bias in the CPI. BLS long has said that it operates within a cost-of-living framework in producing the CPI. That framework has guided, and will continue to guide, operational decisions about the construction of the index.[1]

This approach is explicitly endorsed by the Boskin Report and affirmed by the CNSTAT report, and indeed this approach dates to the 1961 Stigler Report, an important predecessor to the Boskin Report. (Triplett and Reinsdorf, 2005) This choice arises because of the way the CPI is used in practice. In the U.S., the CPI is extensively used

both by government and private economic actors to make cost-of-living adjustments, so this argues for a COLI framework. Such a framework necessarily involves complications as measuring a concept as broad as the cost-of-living in a dynamic economy and using only price data is theoretically and operationally difficult, but the COGI concept would have difficulties of its own and lead to an index that was possibly unsuitable for the way it was used. A cost-of-goods-index would surely yield different decisions about quality adjustments, substitution, and other CPI issues. The CNSTAT panel mentioned, however, that "for many (perhaps even most) purposes, the distinctions are less important than they might seem."

The Boskin Report in Context

While the Boskin Report generated tremendous attention, it is best understood as one chapter in a long history of evaluation of the conceptual foundations and methodologies of the CPI and price indexes in general, a history chronicled in Reinsdorf and Triplett (2005). This history includes both the development of price index theory and the occasional review of the U.S. CPI specifically.

Bias in the CPI

The Boskin Report asserted an upward bias in the CPI of 1.1% arising mostly from biases related to substitution, new goods, and quality change. This estimate was consistent with widespread perception and most other estimates of the time.[2] While there have been substantial changes in CPI methodology since, other recent studies and comments indicate a wide belief that an upward bias still exists. Lebow and Rudd (2003) estimate the upward bias at 0.6% after a careful analysis, with most of the bias coming from new goods and quality change. In an update to their report, the members of the Boskin commission estimated the bias at 0.8% as of 1999.

On the other hand, dissenting voices are heard arguing that the CPI understates inflation, partly as the result of recent changes to address quality and substitution issues. Hulten (1997) argues that the quality change bias may be negative, even so negative as to more than offset the other positive biases. Outside of the academic community there is some perception that the CPI understates inflation; this view has been articulated recently by some in the finance community including Stephen Roach, Joe Carson, and Bill Gross.[3] Additionally, Robert Gordon, one of the members of the Boskin commission, has two recent papers suggesting a downward bias in the CPI due to rent and apparel.

Substitution Bias

Substitution bias arises in a fixed-weight CPI if consumers change their purchasing behavior in response to relative price changes. Conceptually, substitution can be divided into "Upper Level" and "Lower Level" substitution. This distinction between upper and lower level bias corresponds to the two stage process involved in calculating the U.S. CPI. The CPI is broken down into 211 item categories and 38 areas, which are cities or groups of cities where prices are collected. This classification forms a matrix of 8018

cells. Basic indexes are calculated for each cell; this is the first stage of calculation and substitution within each of these 8018 cells is characterized as lower level substitution. The basic indexes are then aggregated into composite indexes, culminating with the aggregate of all basic indexes, the All items index. Substitution among the 8018 different cells must be addressed differently and is termed upper level substitution. Substituting between Swiss and cheddar cheese would be an example of lower level substitution, as these would be in the same cell. Beef and chicken are in different cells, so substituting between them would be an example of upper level substitution.

Until 1999, the CPI was a modified Laspeyres index[4], using a modified Laspeyres formula for both creating the basic indexes and aggregation to upper level indexes. This formula effectively assumes zero substitution as the initial quantities used in the formula are assumed to stay fixed after their introduction until the next update. That is, the modified Laspeyres or "Lowe" formula assumes an elasticity of substitution of zero. It is well known that a Laspeyres index is an upper bound to a cost of living index. To the extent that consumers can and do change their purchasing behavior in response to relative price changes, a Laspeyres formula will result in an upward bias in the index and overstate the cost of living.[5]

The Boskin Report estimated biases for both upper and lower level substitution: 0.15% per year for Upper Level bias and 0.25% per year for Lower for a total bias of 0.4%. Substitution bias has been a concern in the CPI and other price indexes even before the Boskin Report, and the BLS has addressed both upper level and lower level bias in the index in the years since the report.

In 1999, the CPI converted to a geometric means formula for item strata within which substitution is realistic, about 61% of the index.[6] The strata that remained Laspeyres are mostly from housing and medical care; in fact excluding rent and owners' equivalent rent only one-seventh of the weight in the CPI still uses a Laspeyes formula to calculate basic indexes. The geometric mean formula effectively assumes constant relative expenditure on a given item rather than constant quantity; as the relative price increases the assumed quantity proportionally decreases. This formula thus implicitly assumes a unitary elasticity of substitution. This geometric means formula is used in averaging of prices to create basic indexes, not in the aggregation of those indexes, so it only addresses lower level bias.[7]

In 2002, the CPI started producing an additional index, the Chained Consumer Price Index for All Urban Consumers (C-CPI-U).[8] This index uses a Tornqvist formula and expenditure data from both the base and current period in the upper level aggregation to calculate the indexes. Thus the final versions of the C-CPI-U indexes are based on actual consumer behavior rather than assumptions about substitution behavior. However, since expenditure data is only available with a time lag, a geometric means formula is used to estimate the indexes initially and then the figures are revised when the final expenditure data are available. It should also be emphasized that the C-CPI-U is a distinct index from the standard CPI-U, rather than a change to CPI-U methodology. However, the C-CPI-U provides an approximation of the quantitative impact of Upper Level Substitution.

Table 1 summarizes the effects of Upper and Lower Level Substitution.[9]

Table 1

Annualized % changes 12/99-12/04

	CPI-U-XL	CPI-U	C-CPI-U	Lower	Upper	Total
All items	2.77	2.49	2.09	0.28	0.40	0.68
CPI major groups:						
Food and beverages	2.9	2.6	2.3	0.3	0.3	0.6
Housing	3.0	3.0	2.8	0.0	0.2	0.2
Apparel	-0.3	-1.8	-2.2	1.5	0.4	1.9
Transportation	2.4	2.1	1.8	0.3	0.3	0.6
Medical care	4.5	4.4	4.3	0.1	0.1	0.2
Recreation	1.8	1.2	0.7	0.6	0.5	1.1
Educ/communication	2.5	1.9	0.0	0.6	1.9	2.5
Education	6.5	6.3	6.5	0.2	-0.2	0
Communication	-1.4	-2.3	-4.8	0.9	2.5	3.4
Other G&S	3.5	3.2	2.8	0.3	0.4	0.7
Special aggregates:						
Food	2.9	2.6	2.3	0.3	0.3	0.6
Energy	6.8	6.5	6.1	0.3	0.4	0.7
All items less food & energy	2.4	2.1	1.7	0.3	0.4	0.7
C&S:						
Commodities	1.8	1.3	0.6	0.5	0.7	1.2
Services	3.5	3.3	3.2	0.2	0.1	0.3

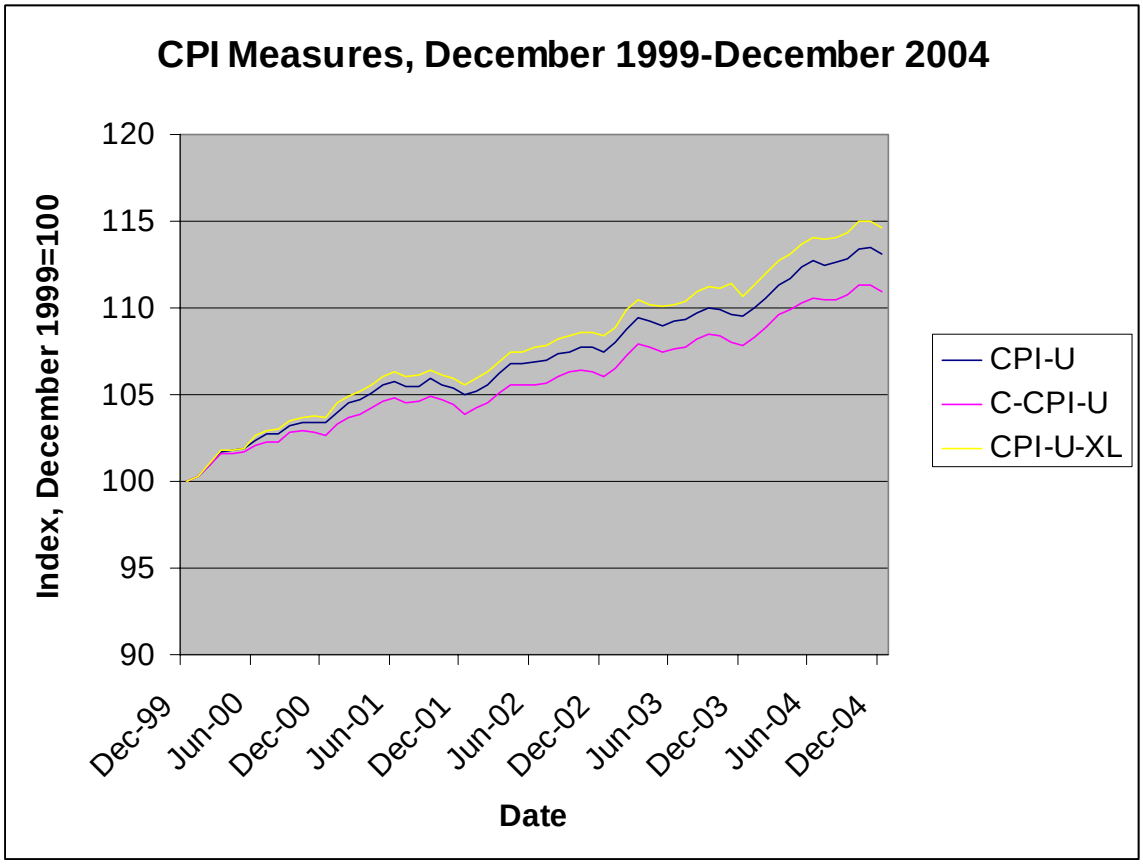
The far right columns show the effects of lower level substitution, upper level substitution, and total substitution. The lower level substitution estimate is derived by comparing the standard CPI-U, which now uses a geometric means formula to calculate basic indexes, to the CPI-U-XL which has retained a Laspeyres formula at all levels.[10] The Upper Level Substitution estimate is the difference between the CPI-U and the C-CPI-U. All data are from December 1999 through December 2004.

The chart also shows differences broken down by major group and for special categories. Many of the results are intuitive. For example, Apparel, a group of goods among which substitution is relatively easy for consumers, has a large lower level effect. Housing and medical care both have many strata that are still Laspeyres, since substitution in these areas may be difficult, so the Lower Level effects are small. Commodities have a larger effect than services. For Lower Level bias many of these results correspond closely to

earlier BLS estimates. Before the change to geometric means was instituted-indeed before the Boskin Report-the BLS created an experimental measure called the CPI-U-XG to study the effects of a possible change to geometric means. The difference between the XG and the CPI-U-XL averaged .27% per year from December 1994 to December 1996.[11]

Upper level bias, as measured by the difference between the CPI-U and C-CPI-U, has proved to be larger than expected. BLS simulations before the C-CPI-U was first published resulted in an initial estimate of 0.15%, later revised to 0.22%. As seen above the average annual difference from 1999-2004 has been 0.4%. However, it is useful to examine the data year-by-year:

Chart 1



All Items percent changes, CPI-U XL, CPI-U, C-CPI-U, 2000-2004:

Table 2

Year	CPI-U-XL	CPI-U	C-CPI-U	Lower	Upper	Total
2000	3.70	3.40	2.60	0.30	0.80	1.10
2001	1.83	1.55	1.27	0.28	0.28	0.56
2002	2.65	2.38	2.02	0.27	0.36	0.63
2003	2.12	1.86	1.69	0.26	0.17	0.43
2004	3.52	3.29	2.88[12]	0.23	0.41	0.64

From Table 2 it is evident that the high upper level figure is largely the result of the anomalously high 0.80% effect in 2000.[13] The size of this effect was a result of unusually great price dispersion and the weights for the CPI-U being relatively old then.[14] From 2001-2004, the effect is fairly consistent and more modest, about 0.3%.

It should be emphasized that while the geometric means formula used to address Lower Level Substitution is in the standard CPI-U, Upper Level Substitution bias is not addressed in the current CPI-U but only in the C-CPI-U. Thus if one believes that conceptually a COLI should account for upper level substitution then the C-CPI-U may represent a preferable measure.

While the geometric mean formula corrects for the lower level substitution bias, recent BLS research suggests that this estimate introduces a finite sample bias for cells with small samples. Since the finite sample estimate for the geometric mean formula is given by $\exp(\Sigma \ln(P_t/P_{t-1}) + \text{error})$, the exp(error) becomes a positive multiplier, and hence, the finite sample estimate is higher than the population mean. BLS research has documented the fact that an insufficient sample in these basic cells will yield an upward bias in the estimator of 0.1 percentage point or more per year (McClelland and Reinsdorf (1999), and Bradley (2004)). In fact, this small sample bias could decrease the estimate of the upper level substitution bias shown above (Bradley (2004)).

New Goods and Quality Change Bias

Perhaps the most fundamental problem in creating a price index is that the actual market basket available to and purchased by consumers changes continuously, while the market basket of goods that are priced in a survey cannot realistically change as quickly. A price index must have methods to account for new goods entering the economy and changes in the quality of existing goods. In this discussion, quality change occurs when a good in the CPI sample is replaced by a new item of different quality, while a new good is a good that enters the economy but is not in the CPI sample and would not enter it through item replacement or sample rotation.[15]

Since the CPI seeks to approximate a COLI, conceptually the goal is for the CPI to be a constant-quality index. Thus when the quality of goods and services in the market basket change, it is inevitable that the CPI must make some estimate of the quantitative value of such changes. This has been and surely will continue to be a source of disagreement and controversy in the CPI, since consumers have widely varying preferences and disagreement over the valuation of changes in goods and services is to be expected. Arguments about a quality bias in the CPI have come from both sides and with different levels of sophistication. It is widely perceived, or perhaps was widely perceived, that much quality change goes undetected, resulting in an upward bias in the CPI. The Boskin Report, while noting BLS efforts to account for quality change, asserted an upward bias of 0.6%, larger than the upper and lower level substitution bias combined. Indeed the Report went through a category-by-category analysis of quality bias, though some of their estimates seemed to be conjectural. Gordon (1999) conceded this estimate

might have been too high by a tenth of a percent. Lebow and Rudd (2003) also assert a smaller upward bias of 0.3%, about half of that coming from the medical care category.

More recently some have argued that there may actually be a downward quality change bias. Hulten (1997) estimates a downward bias of 0.71%-0.97% per year from what he terms "link bias" and "quality cost bias." "Link bias" refers to a potential downward bias that could occur if manufacturers time real price increases to coincide with the introduction of new models or redesigned products. "Quality cost bias" is the bias that would result if the assumption of cost-elasticity of one, implicit in CPI quality adjustment procedures, does not hold. Hobijn (2003) also argues for at least the possibility of a downward bias. Comments by Gross (2004) are symptomatic of widespread belief that new BLS methods have a downward bias. BLS has maintained that the evidence on quality bias and its direction are much less clear than for substitution bias.[16]

It is certainly true that the CPI, and indeed virtually any price index, faces difficulties both conceptually and operationally in dealing with quality change, and economists of different persuasions have disagreed, and will continue to disagree, on the merits of different approaches. However, it should be emphasized that:

-The question isn't whether to adjust for quality but how.
-The CPI has several methods it uses to address quality change.
-Shifts from one method to another for several types of goods, while conceptually important, seem to have very minor quantitative impact on the All Items index.

Operationally the CPI deals with quality change in several different ways. For any given item being priced, the CPI economic assistant in the field must make a decision if the item has changed in any way, that is to say has been replaced with a new version. If the original and new versions are essentially the same she may deem them directly comparable and use the price comparison as if no change had occurred. If the versions are substantially different then some sort of quality adjustment procedures must be used. These procedures can be categorized either as imputation or direct quality adjustment.

There are two distinct methods of imputation in the CPI. *Cell-relative imputation*, sometimes called "linking," imputes the price change for the noncomparable versions by the price change of all the other similar items in the same geographic area. Thus the price change for that quote is estimated as being the same percent change as the price change for the cell for that item strata and index area. *Class-mean imputation* is used when price change is closely associated with introduction of new lines or models, such as in the New Vehicles category. With class-mean imputation the price change is estimated from the other observations going through replacement at the same time and that were quality adjusted directly or judged directly comparable.[17]

Quality Adjustment and Hedonics

Direct quality adjustment refers to the analyst making an estimate of the quantitative value of a quality change. This is done either based on manufacturers cost data or on

estimates of the value to consumers of particular features of the good in question. Often these values are estimated using hedonic models and this technique is referred to as Hedonics. Hedonics is widely considered the most promising technique for direct quality adjustment[18] and the CPI has employed it for an increasing number of categories of goods. In practice, the hedonic approach gives BLS analysts another tool to consider when confronted with the problem of quality change.

This table summarizes implementation of hedonic methods in the CPI:

Table 3: **Hedonics in the CPI by Date of Introduction**

Date	Item	Code	Weight[19]
February 1989	Rent	HA01	6.133
	Owner's Equivalent Rent	HC01	23.158
January 1989	Apparel	AA01	0.186
		AA03	0.223
		AA04	0.168
		AC01	0.111
		AC02	0.175
		AC03	0.730
		AE01	0.235
		AE03	0.362
January 1998	Computers[20]	EE01	0.192
January 1999	Televisions	RA01	0.132
January 2000	Audio equipment (12 items)	RA05	0.104
	Video Cameras	RA03	0.043
April 2000	VCRs	RA03	
	DVD players	RA03	
July 2000	Refrigerator/freezers	HK01	0.165
	Microwave ovens	HK01	
	College textbooks	EA01	0.217
October 2000	Washers	HK01	
	Dryers	HK01	
Total			32.334
Total excluding housing			3.043
Total excluding housing and apparel			0.853

The Hedonics in the Housing categories are small adjustments based on the aging of the housing units sampled. The remaining hedonic adjustments are for categories which together make up a fairly modest portion of the total weight in the CPI, about 3.04%. It is clear that hedonics has become an important tool for dealing with quality change in certain categories, increasing the ability to make quality adjustments. In 1999, in item category RA03, which includes VCRs and DVD players, imputation was used 267 times and direct quality adjustment only once. In 2001 after a hedonic model was developed for this category, imputation was used 92 times and direct quality adjustment 260 times. In HK01, major appliances, imputation was used 80 times in 1999 with no direct quality adjustment; in 2001 imputation was used 40 times while 80 quotes were directly quality adjusted.

While hedonics is an important technique for particular categories, it bears emphasizing that is used for only a small part of the total index. Moreover, research from the CPI-U Research Series shows that its impact on indexes has been often modest and of uncertain direction. The Research Series was created to provide a methodologically consistent index; to this end estimates were made of the quantitative index of methodological changes in the CPI since 1978 (see Reed and Stewart (1999)). These included changes to quality adjustment procedures. The estimates in the research series are taken from simulations described in the research for each item category for which hedonics was implemented.

Estimated Impact of Hedonic Quality Adjustment vs. Previous Methods for CPI categories where Hedonics was introduced since 1998

Table 4

Item	**Code**	**Yearly effect %**
Computers	EE01	-3.81[21]
Televisions	RA01	-0.11
Audio Equipment	RA05	1.52
VCR	RA03	1.89
Camcorders	RA03	0.15
Refrigerators	HK01	0.02
Washers	HK01	-0.78
Dryers	HK01	0.06
Microwave	HK01	-0.17
College Textbooks	EA01	-2.53

In this table a negative sign indicates that the change to hedonic adjustment has caused the index to rise more slowly (or decline more rapidly) than it would have using previous quality adjustment procedures. The inconsistency of the effect is exemplified by the fact that the impacts for washers and dryers have the opposite sign. While the switch to hedonic adjustment had a significant index on several of the individual item categories, it is important to note that the net effect on the All items index was negligible. This is because the direction of these effects varied and the items in question had such a small weight (the total relative importance of items for which hedonics have been implemented since 1998 is 0.853%). Indeed the net effect of hedonics from 1999 onward (which

excludes personal computers, but includes televisions and all later categories) on the All items index is estimated to be less than one hundredth of one percent per year, specifically +0.005%. This contrasts sharply with the perception that the recent increased use of hedonics has had a substantial downward effect on the index.

To the extent that hedonic methods were used prior to 1998, they tended to make the CPI slightly *higher*. The CPI implemented hedonic methods for many Apparel categories in 1989. Apparel is different from technology goods in that changes in quality are not as likely to be consistently positive. The estimated net affect on Apparel of using hedonic adjustment is positive; hedonics makes the relevant apparel indexes higher by an estimated +0.39% per year. Also in 1989, the CPI implemented a hedonic approach to quality adjust housing for the aging of the housing stock. This adjustment is estimated to have an effect of +0.31% per year.[22]

Note that these figures are estimates of the effect of switching to hedonic methods from other quality adjustment procedures. Another study looked at the effects of hedonics compared to completely omitting any quotes where there was a quality change for the Video and Audio Equipment categories (basically a matched model approach): This study used data from December 2002 to February 2005.

Table 5: Annualized percentages with and without quality adjustment

	Annualized percent change	Annualized percent change without substitutes[23]	Difference
Audio and Video (Dec 2002 – Feb 2005)			
Audio and Video (RA)	0.46	0.68	-0.22
Televisions (RA01)	-12.86	-10.92	-1.94
Other video equipment (RA03)	-13.52	-13.43	-0.10
Audio equipment (RA05)	-6.66	-6.26	-0.41
Women's dresses (Dec 2002 – Feb 2005)	-3.83	-3.99	+.16
Computers and peripheral equipment (March 2004 – Sept 2004)	-9.78	-6.60	-3.18

As would be expected, this produces quantitative differences more substantial than the comparison to previous methods, but only for televisions and computers is the effect truly large.

Table 5 also illustrates the differences due to quality adjustments for women's dresses and computers. As suggested above, the quality adjustment used for women's dresses causes the index to rise (or fall less rapidly). Quality adjustments for computers,

however, have the same affect on the index as for televisions – these adjustments cause the index to fall more rapidly.

In the past year, BLS has moved away from using hedonics to value the quality changes resulting from substitutions in computers. From January 1998 to September 2003 the CPI program used hedonic regressions, developed in a cooperative effort with the other price programs, as a basis to determine appropriate quality adjustments amounts for personal computers. Due to the rapid and content change in PC configurations, the CPI began to move towards an approach that uses attribute values available on the Internet to determine quality as a basis to determine appropriate quality adjustments amounts for personal computers. By September 2003, a process of attribute cost adjustment was fully implemented. The attribute cost adjustment process has a database of 250 to 300 variables/items which are updated monthly. This alternative method for quality adjustments allows for more adjustments to be calculated as many of the items that change in a PC are not specifically covered in a hedonic model.

A recent study compared the quality adjustments arising from the current attribute method to those that would arise from the hedonic method. This study compared 6 months of adjustments (April 2004 – September 2004). As compared to the original hedonic method, the new attribute method results in a slightly larger decline in the index (an annualized rate of -9.78% compared to -8.58% for the hedonic method).

Updating the Market Basket

Along with quality adjustment of goods in the sample, there is the issue of goods entering the economy that are not in the sample. Given the COLI concept, it is crucial that the CPI get new goods into the sample quickly, in order to have a market basket that accurately reflects consumer purchases. Additionally, it allows the CPI to capture some of the consumer surplus when new goods enter the economy and decline steadily in price, as sometimes happen with new technology goods; failure to capture this surplus has been seen as a possible source of bias.

The CPI has taken several steps in recent years to keep the market basket up-to date. Since 2002 updated expenditure weights based upon consumer expenditure surveys have been introduced every two years (as opposed to roughly every ten years in the past). Additionally, the lag time from survey to implementation is shorter, and the survey is completed in a shorter time. The result of this is that weights used in the CPI reflect much more recent consumer behavior than in years past. This probably results in a smaller increase in the index; for 2004 the increase in the index was 0.06% lower than it would have been had the old weights been in place.

Additionally, the CPI has changed its sample and outlet rotation procedures. In 1998, the CPI went from rotating 20% of the outlet sample per year to 25%, so that the entire sample is rotated every four years instead of every five. Additionally, some items in selected categories that tend to change rapidly are rotated every two years. Thus the market basket of the CPI is considerably more up-to-date than it used to be, particularly

in terms of high tech goods. For example, the new procedures have resulted in greater representation in the sample for technology items like flat panel televisions and digital video recorders.

One final recommendation of the Boskin Report was for the BLS to improve its mechanism for bringing in outside information, research, and expertise. In 2000 the Federal Economic Statistics Advisory Committee (FESAC) was created. This group meets periodically with BLS representatives and provides a nexus between BLS and the academic research community. FESAC has allowed the CPI to exchange ideas with the academic and research community more efficiently acting as a tool for the CPI both to transmit its latest research and methodology to the academic sector and receive new research relevant to the CPI.

Conclusion

The Boskin Report focused attention on the CPI and some particular sources of possible bias in the index, but improving the CPI is an ongoing process. Since the 1996 report there have been important changes to improve the index. The implementation of the geometric means formula to calculate basic indexes addressed lower level substitution bias, and the creation of the C-CPI-U provides a measure that accounts for upper level substitution. While the case for quality change bias is much less clear cut, the expanded use of hedonic models to directly quality adjust has given BLS analysts another sophisticated option to address this issue. However, in contrast to the new methods used to address consumer substitution and in contrast to widespread perception, these changes have not had an important quantitative effect on the All Items index. More frequent weight updates and sample rotation mean that the market basket used in calculating the CPI is more up-to-date and reflective of current consumer behavior than it ever has been. The CPI will continue to constantly evaluate and improve its methodologies to produce the most accurate index possible.

[1] The COLI approach in the U.S. CPI is placed in historical context in Greenlees (2001)
[2] The following table summarizes the state of estimates on CPI bias up through the Boskin Report:

Recent Estimates of Bias in the U.S. Consumer Price Index		
Author(s)	**Point Estimate**	**Interval Estimate**
Advisory Commission to Study the CPI (1995)	1.0	0.7 - 2.0
Michael Boskin (1995)	1.5	1.0 - 2.0
Congressional Budget Office (1995)	----	0.2 - 0.8
Michael R. Darby (1995)	1.5	0.5 - 2.5
W. Erwin Diewert (1995b)	----	1.3 - 1.7
Robert J. Gordon (1995)	1.7	----
Alan Greenspan (1995)	----	0.5 - 1.5
Zvi Griliches (1995)	1.0	0.4 - 1.6
Dale W. Jorgenson (1995)	1.0	0.5 - 1.5
Jim Klumpner (1996)	----	0.3 - 0.5
Lebow, Roberts, and Stockton (1994)	----	0.4 - 1.5
Ariel Pakes (1995)	0.8	----
Shapiro and Wilcox (1996)	1.1	0.7 - 1.6
Wynne and Sigalla (1994)	less than 1.0	----

This table is adapted from Moulton (1996)

[3] Roach and Carson have been particularly critical of the CPI's housing measures; see http://www.wwwmsdw.ro/GEFdata/digests/19970320-thu.html for Roach's criticisms and http://quote.bloomberg.com/apps/news?pid=10000039&refer=columnist_baum&sid=aa49I53YXUPw for Carson's. Gross has focused on quality adjustment, particularly hedonics; see http://www.pimco.com/LeftNav/Late+Breaking+Commentary/IO/2004/IO_Oct_2004.htm.

[4] Technically, the CPI is a Lowe price index, not a Laspeyres index. See Balk and Diewert (2004) for more on this distinction.

[5] The modified Laspeyres or "Lowe" does not have the property in general of being an upper bound to a cost-of-living index. This follows since the comparisons of intermediate values of a Laspeyres index subsequent to the base period do not have this property.

[6] This table shows the indexes which are still calculated using a Laspeyres formula, taken from the BLS Handbook of Methods:

Table 3. Item categories using the Laspeyres formula:

1. Selected shelter services (Rent of primary residence; Owners' equivalent rent of primary residence; and Housing at school, excluding board)

2. Selected utilities and government charges (electricity; residential water and sewerage maintenance; land-line telephone services, local charges; Utility (piped) gas service; State and local registration, license, and motor vehicle property tax)

3. Selected medical care services (physicians' services; hospital services; dental services; services by other medical professionals; and nursing homes and adult daycare.)

[7] Reinsdorf and Triplett suggest other reasons beyond substitution to use the geometric mean estimator.
[8] For a detailed discussion of this index see Cage, Greenlees, and Jackman (2003)
[9] Unlike the CPI-U and CPI-U-XL, major group and other sub-aggregate C-CPI-U indexes are not independent. For example, the Food and Beverage C-CPI-U index reflects average price change among food and beverage items, but because relative price change for items in other major groups (e.g. Housing, Transportation, etc.) may impact the level of expenditure on food items, the Food and Beverage C-CPI-U index is conditional upon price-change in other major groups. Moreover, C-CPI-U indexes are not precisely consistent in aggregation, though in practice they are very close. That is, an expenditure weighted average of the sub-indexes may not yield the exact estimate of All items price change as the official All items index. Additionally, the difference between the C-CPI-U and published CPI-U is being used as a measure of upper level substitution even though the published CPI-U is technically a "Lowe" index. So, while this chart does give an idea of the relative magnitude of the substitution effects, it should be interpreted with caution for the major groups and other sub-aggregates. Note that BLS research on upper-level substitution bias , which had preceded the development of the C-CPI-U and had been provided to the Boskin Commission, however, was based on the comparison of a true-Laspeyres index with Fisher and Tornqvist superlative indexes.
[10] The CPI-U-XL is an unofficial index that has been maintained which uses a Laspeyres formula to average the prices within basic item area cells, as well as aggregating those indexes. Recent CPI-U-XL data is not published but is available upon request.
[11] Data from which this is derived is available at http://www.bls.gov/cpi/cpigmtab.htm
[12] This is the figure from interim data; the final version is not yet available.
[13] Cage, et al. (2003) estimate that the size of the difference is only 0.6% if the biennial weights are used in the construction of the CPI-U. In addition, this large difference is also apparent in the difference between the PCE chain-weight and fixed-weight indexes for 2000.
[14] Weights for the final version of the C-CPI-U are from contemporaneous expenditure data and so the CPI-U weights are always, in a sense, older than those of the C-CPI-U. However, since the CPI-U weights are updated every two years, the time gap between the weights of the two indexes varies over time.
[15] This follows the distinction in National Research Council (2002).
[16] This is made particularly clear in Moulton (1996) and Greenlees (1997).
[17] This discussion follows that in the *BLS Handbook of Methods*.
[18] See National Research Council (2002) p. 122.
[19] "Weight" represents the Relative importance of components in the Consumer Price Indexes: U.S. city average, December 2004; Listed on BLS at
ftp://ftp.bls.gov/pub/special.requests/cpi/cpiri_2004.txt
[20] Computer quality adjustment is now done using an *attribute pricing* approach using specific manufacturer's cost information to estimate values for features of the good.
[21] This effect was for the Expenditure category Information Processing Equipment, of which computers was a portion. The effect on computers alone is about -6.5%.
[22] In the past 3 years, the average adjustment has fallen to +0.26% per year..
[23] The phrase "without substitution" is vague; this briefly describes the actual procedures used in this simulation:
For audio and video equipment, the simulation removed quality adjustments and imputed the price change for those quotes, while directly compared substitutions were left alone. For women's dresses,

the simulation removed quality adjustments and either directly compared or imputed the price change for those quotes, while the directly compared subs were left alone. For personal computers , the experiment removed all substitutions regardless of whether there was actual quality change present or not.

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