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Commentary

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The content of Charles R. Hulten's article, "Quality Change in the CPI: The Neglected Cost Dimension," has two main components. First, it presents an overview of the methods and problems associated with quality measurement in the consumer price index (CPI). Second, the article discusses two "new" biases, one that involves the "cost side" of producing new goods, and one that focuses on the specific practice of "linking" and the possibility that linking may overstate the extent of quality increases. My discussion focuses on the new biases and on some general issues about quality change that are of particular interest to macroeconomists.

THE LINK BIAS

The link method is the "least informed" method. It relies on price comparisons among goods that are not close substitutes to the given good. Hulten points out that, in practice, linking leads to large quality adjustments: Of the total price increases for these goods, 86 percent are assigned to quality improvements in 1984. In contrast, goods for which better adjustment methods are available only have 22 percent of their total price increases assigned to quality improvements. This difference is striking, and I agree with Hulten's suspicion. He estimates the magnitude of this bias by hypothetically reducing the quality component of the price change in these link-method items from 86 percent to 22 percent. The implied bias is –0.73 of a percentage point for the aggregate CPI. This is a useful exercise, but more work is clearly needed to obtain sharper estimates. For example, the reason better methods may have not been used for many of the link-method items is precisely that these items have embodied substantial quality change. Hence, Hulten's bias estimate should perhaps be interpreted as more of an upper bound than as a point estimate.

When large differences in quality adjustments occur across groups of goods, then relatively small changes in the composition of goods—in this case, say, a change in the relative size of the group of goods for which linking is used—may lead to large changes in the overall price index. Such changes could occur because of accounting practices (the assignment of goods to the different methods of price measurement) or simply because goods with substantial quality change are increasing in importance in the economy. As I will argue, this phenomenon could lead to significant changes in measured aggregate productivity growth.

THE COST SIDE

New qualities are usually produced at a cost, and Hulten explains how a second new bias might arise as a result. This cost could take the form of more expensive materials or resources associated with developing the new product and that appear as a markup. A parameter μ in Hulten's article captures the fraction of the percentage quality increase in the product that has a corresponding cost increase. (If the quality goes up by 1 percent, the cost of producing it goes up by μ percent.) Hulten calls for an *upward* adjustment of quality in inverse proportion to μ (i.e., for a downward price adjustment). Given this view, he suggests a revision of the official price index that is based on estimation of μ in another article (Hulten 1996).

A simple example should clarify the issues. Suppose computers are identified with one characteristic—speed of computation—and computers of different speeds are perfect substitutes (and divisible). For simplicity, suppose also that there is no "pure price" change (the dollar price of the same good stays the same over time, if the good is traded). Now imagine that from one year to the next a new computer (Y) is developed. The new computer is better (faster) than the old, baseline computer (X) by a factor θ. Denote the price of the new computer at t+1 by $P_Y(t+1)$, and let the baseline computer in year t have been priced at $P_X(t)$. Hulten states that $P_Y(t+1) = (1+\mu\theta)\, P_X(t)$, where μ is the fraction of the percentage increase in quality that also increases costs. The $\mu=0$ case would correspond to the new technology being "manna from heaven": When there is no pure price inflation, the price of Y at t+1 is the same as that for the inferior product X at t. The μ=1 case would mean that the new model delivers no net gain for consumers.

The overlap method of quality measurement identifies quality difference between two goods currently sold by their relative price.[1] If X is sold at t+1, $P_Y(t+1)/P_X(t+1)$ would therefore be a measure of relative quality, assuming that the relative price captures the consumers' marginal rates of substitution (MRS) between the two goods. However, if μ<1, product X could not be sold at t+1 (or would not be produced), assuming that consumers are well-informed and rational, because this good provides fewer quality units for the same resource cost. Therefore, with these assumptions, if a good is indeed sold at t, μ=1.

Hulten points to a possible downward bias in the quality differential between the two goods—when $P_Y(t+1)/P_X(t+1)$ is used to measure the differential and when μ<1. The logic of this must be that consumers systematically underevaluate the quality of new goods, relative to old goods. Hulten refers to "information lags or other market frictions" as reasons why good X might still be sold on the market (so that $P_X(t+1)$ could be recorded) despite its disadvantage in providing quality per dollar. Alternatively, it is possible that the prices $P_X(t+1)$—observed by Bureau of Labor Statistics (BLS) agents—are not prices at which trade takes place but historical prices.

In general, it seems hazardous to treat similar goods' relative prices as systematically misrepresenting quality differentials. It is true that the assumptions of perfect information and perfect competition are stylized, but alternative pricing theory is either not well developed or not generally agreed on. Until such theory is set, why assume that systematic biases exist and that they have a certain sign? What if consumers instead systematically overestimate (e.g., because of frictions) the quality of new products? Then, Hulten's suggested change in the CPI would go in the opposite direction. Although I find merit in Hulten's point of view, my preliminary conclusion is that the BLS methods should maintain the assumption that consumers are correct on average. Hence, no CPI adjustment is needed in this particular case.

MORE MOTIVATION FOR LOOKING AT QUALITY CHANGE

In the public debate, the potential CPI adjustments have received considerable attention mainly because the CPI is used to index many government spending programs and part of the tax code. Here, I would like to emphasize some other aspects of price index revisions that are of concern to macroeconomists: These revisions may be crucial for assessing our past productivity performance and for understanding how the welfare of various societal groups has been affected during the postwar period.

During the past 50 years, some important trends have characterized the data both in the U.S. and in most other developed economies: Important changes have taken place in the sectorial composition of output and in relative prices. The "unmeasurable" sector, to use Griliches's (1994) terminology, has steadily grown in importance, with the service sector playing a key role. Among the noteworthy relative price changes are a steady fall in durable consumption goods and equipment prices

[1] As Hulten points out, hedonic pricing analysis would lead to parallel results. I therefore focus on the overlap method.

and a (suspicious) rise in services' prices. Finally, the past 15 years to 20 years have witnessed a sharp rise in skilled workers' relative wages. Many of these facts may be intimately connected with quality change.

Postwar declines in the relative prices of durable consumption goods and of producer equipment have been substantial. These facts were established in Gordon's (1990) careful work on adjusting durable goods prices for quality. A number of researchers have recently used and further analyzed Gordon's findings. Hulten's (1992) paper and my own work with Greenwood and Hercowitz (1997) interpret the fall in the relative price of equipment measured in quality units as reflecting investment-specific technological change. We also assess the importance of this fall for aggregate output growth. Thus, Gordon's quality adjustments of the equipment price data led to new conclusions in growth accounting. By our estimate, technological change in equipment goods has accounted for more than half of aggregate postwar growth in the United States.

Relatedly, the past 20 years have witnessed phenomenal growth in information technology (IT). It, together with other improvements in equipment technology, suggests that the rate of technological change in durables increased during this period. For example, McHugh and Lane (1987) study sectorial data and find that vintage capital effects were more important determinants of productivity after the mid 1970s than earlier.[2] The increase in the growth rate of durable goods technology may have had important macroeconomic effects beyond the direct effects on productivity. First, to the extent various worker groups benefit differently from the new technologies because of their skill compositions, the distribution of income may become more unequal. Indeed, in the late 1970s, wage inequality rose sharply and continued rising in a permanent fashion. If there are capital-skill complementarities in production, this relative wage development is a natural consequence of the increase in the rate of technology growth. Second, substantial, economy-wide learning has most likely occurred in response to the introduction of the new technologies. Such learning would typically lead to drops both in measures of output and of productivity. The possibility of a connection between the productivity slowdown and a period of rapid technological change is suggestive in this context.

Furthermore, when we try to assess the welfare consequences of technological change and of the introduction of new goods, it may be important to take into account how the nature of the advances affect various consumer groups differently. When the new goods are subject to mismeasured (presumably overestimated) prices, then groups that use the new goods have enjoyed higher consumption than the unadjusted data suggest; whereas groups that do not use the new goods have experienced consumption growth that is appropriately captured by the unadjusted data. Therefore, quality adjustments in principle have differential effects. In the particular case of the recent IT developments, it seems plausible that something like a quality-skill-complementarity effect occurs in consumption as well. In particular, if the new IT products are especially appreciated by highly skilled groups (e.g., the highly educated), then the quality increases in the consumption bundles of these groups have allowed their effective consumption to grow more quickly than that of less "sophisticated" consumers. The effective rise in inequality may have therefore been worse than that suggested by wage and earnings data alone.

For the present purposes, my main point is that the rate of technological change is likely a key determinant of the extent of quality improvement and hence of price increases. By implication, careful adjustments of outputs for quality are crucial components in studies of technological change and are therefore highly relevant for understanding the determinants of aggregate output and productivity growth, labor market outcomes, and the dynamics of inequality. As such,

[2] See Greenwood and Yorukoglu (1996); Hornstein and Krusell (1996); and Krusell, Ohanian, Ríos-Rull, et al. (1996) for detailed discussions of this phenomenon.

they are of great importance to macroeconomists.

WHAT TO DO?

I have argued that there are many reasons (in addition to those recently receiving public attention) why quality change is an important phenomenon in macroeconomics. Hulten provides an excellent survey of current methods for measuring quality change. He clarifies both how far we are from an accurate assessment of quality's role and how difficult the measurement problem is. Hulten teaches us why we should prioritize the development of new methods for improving quality measurement and why we should allocate more resources to applying those methods already available for a broader range of goods. As an example of the latter, Gordon's (1990) quality adjustments to durable goods, which have proven very valuable in many studies, ended in 1983. Why not adopt the methods he used and extend these time series to the present?

Until significantly better data are available, is there no hope for new insights into the extent and role of quality improvements? One answer is: Follow Einstein/Prescott, and there might be hope. In other words, use theory, while waiting and looking for data. In fact, several recent studies do just that and, because theorizing sometimes leads to practical insights, such efforts may be worthwhile.

Perhaps the most innovative of the attempts to use theory to shed light on the role of mismeasured quality is the most recent of them all: Peter Klenow's discussion of Jack E. Triplett's conference paper (in this issue on pp. 43-46). Klenow, quite like Solow (1957) 40 years ago, uses price theory to induce what the quality movements in services must have been to make sense of the choices people made regarding their recorded expenditures on services vs. other goods. If the preferences for services and other consumption goods have remained constant (and are "reasonably" calibrated), Klenow argues, then the official data on relative prices and quantities of services and other consumption goods are not (even approximately) consistent with the consumers' first-order conditions for expenditure shares during this period.

One way to measure the discrepancy is to back out a residual, interpreted either as a preference shifter or as unmeasured quality change, from any two consecutive first-order conditions. The "Klenow residual" is thus a preference counterpart of the "Solow residual," and it showed a marked increase throughout the sample. Therefore, given the increase in the official price of services and the observed expenditure shares, either a drastic increase in the preference for services or an overstatement of the price increase (or a combination of both) must have occurred. And as for the Solow residual, it is important to understand its origins: How much comes from measurement error (in inputs or service quality)? How much represents structural change (changes in technology or preferences)? For example, it should be possible to examine, by studying a cross section of households, whether the increase in female work force participation may have triggered an increase in demand for market-provided services. Presumably, this effect could be quantified and thus explain part of the Klenow residual. In sum, this theoretical exercise yields an estimate of the measurement error due to changes in the quality of services.

Other researchers have recently discussed quality change in the context of growth models. First, Howitt's (1995) paper considers a knowledge-driven growth model in which new goods are introduced over time. The quality mismeasurement in that setting naturally has to do with measuring the new goods. Second, in my own recent work (Hornstein and Krusell, 1996), we model quality of a different kind. We assume that any good has a quantity and a quality component and that firms can choose any mix between the two, subject to respective technologies for producing quantity and quality. This mix can therefore change over time and can be interpreted as the "service," or production accuracy, associated with a given product.[3]

The point of both these papers is that changes in macroeconomic variables will imply changes in the amount of quality chosen. Therefore, the observed macroeconomic time series could be fed into the models to generate an artificial historical time series for quality. In each case, these experiments involve more structure than does the calculation of the Klenow residual, which is what makes the latter relatively powerful. These papers also make structural assumptions about the production of services, whereas the Klenow residual derives from structural assumptions on preferences and consumption behavior.

By following any of these modeling strategies, it seems possible not only to generate artificial series on the quality components of output, but also to obtain artificial series for *measured* output and *measured* productivity. Parts of the productivity slowdown could perhaps be understood by studying the behavior of macroeconomic aggregates in conjunction with specific structural assumptions. For example, if there has been a movement toward a higher "quality share" of total output because of the kind of technological change and changes in product mix that we have experienced, then a measured productivity slowdown would have been a natural consequence.

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[3] More precisely, the traded joint output of quantity, Y, and quality, Q, is denoted y and satisfies $y = Y \times Q$, with production of the two latter determined by $Y = (k_Y^{\alpha_Y} l_Y^{1-\alpha_Y})^{\beta}$ and $Q = (k_Q^{\alpha_Q} l_Q^{1-\alpha_Q})^{1-\beta}$ where the k's and l's are the capital and labor inputs in each respective activity and β is the "technology share" of quality. This structure is constant-returns-to-scale in total inputs. A technological increase in the importance of services over time would be modeled by an increase in β in this framework. The hypothesis that the IT revolution would have carried with it an increase in the relative importance of quality could thus be given this formal representation.