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Introduction

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This volume contains papers, comments on papers, and a panel discussion that were presented at the Workshop on Price Measurements and Their Uses, held by the Conference on Research in Income and Wealth in Washington, D.C., on March 22–23, 1990. The purpose of the workshop was to review current research, to consider how the research could be applied to the programs of the federal statistical agencies—particularly the Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA)—and to identify potential avenues of new research. The workshop brought together persons actively engaged in price measurement research with economists and statisticians in government agencies who collect prices, construct the official price indexes, and use those price indexes in preparing the national economic accounts and in economic analysis.[1]

The subject matter of the conference, price indexes and how they are used to deflate the GNP and other broad aggregates, has not been of great concern to economists of late, although there have been a few notable exceptions.[2] Yet no one doubts that the practical construction of price indexes bears directly on

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1. The workshop did not attempt to provide an overview of the various types of price indexes that are produced and all the methodological issues relating to them. For that purpose, see U.S. Department of Labor (1988). For information on the preparation of constant-dollar GDP in the national economic accounts by BEA, see BEA (1987a, 1987b, 1988, 1990). In addition, Cartwright (1986), Cartwright and Smith (1988), Cole et al. (1986), and Sinclair and Catron (1990) describe the computer price indexes prepared by the two agencies.

2. In empirical work, these include Robert J. Gordon, Zvi Griliches, and Jack Triplett.

how we perceive many of the most fundamental attributes of the economy, such as how much living standards and productivity have grown over the long run, how real wages in this country compare with those abroad, and, at a time of large budget deficits, how much the nation's capital stock has increased.

The measurement of price change for high-tech products was the main focus of the workshop. Computers are now so important in the economy and their prices have fallen so much that careful measurement of their long-run price behavior is essential for the proper measurement of trends in real GNP or GDP, its investment components, and the capital stock. For example, when BEA introduced a new price index for computers in 1985, the growth rate of real GNP for the period 1982–88 was revised from 3.8 percent per year to 4.1 percent.

High-tech items were the subject of about half the workshop papers. The papers on personal computers and semiconductors break new ground with estimates of price change that differ from those from official government sources. Making use of the hedonic approach to price change—in the spirit of the 1985 IBM-BEA undertaking for the price of mainframe computers—the paper on personal computers arrives at a price decline that is much greater than the change shown by BEA for personal computers. In addition, an apparent anomaly is cleared up. It had been puzzling that, at the same time as official indexes of computer prices were showing dramatic decreases, the price index for semiconductors published by BLS was essentially flat. Any bias in the measured price of an intermediate good like semiconductors does not affect productivity growth for the entire private economy, but it does affect the allocation of productivity change among industries.

It should come as no surprise that there is still debate over the use of the hedonic approach to quality adjustment in price indexes. The issues were joined in the panel discussion that came in the closing session of the workshop, in which panelists were asked to discuss the implications of the treatment of prices of high-tech goods for the measurement of productivity change. The discussion among some of the major protagonists of a long-running controversy was enlightening, although it is doubtful that a meeting of minds between the two main camps emerged.

The papers other than those concerned with high-tech products covered a variety of topics that have been dealt with before but remain in the category of unfinished business. Two have important implications for possible biases in the measurement of consumer prices. One reports on the recent introduction of hedonic techniques to adjust for quality change in apparel. The other takes up the shift of consumer purchases away from higher-price independent food stores to lower-price chain supermarkets, a substitution that the consumer price index (CPI) has never treated as a price decline. This is not just a question concerning the 1980s, the time period that was the focus of the paper. The boom in supermarkets dates from the early post–World War II period; indeed,

food chains were already prominent in the 1920s. Readers should find BEA's treatment of military aircraft prices of interest in light of the discussion of computer prices. The paper on steel prices lends support to those who claim that price rigidity under conditions of weak demand is mainly a statistical illusion. Another paper presents the hypothesis that the Robinson-Patman Act, a law dating from 1936 that prohibits price discrimination, plays an important role in this apparent rigidity.

High-Tech Products

BLS and BEA Approaches

The papers on prices of high-tech products and the panel discussion reflect and build on recent developments in the federal statistical agencies. Because of the difficult conceptual and practical problems, BLS did not develop price indexes for computer equipment as part of the major PPI (producer price index) revision that was begun in the late 1970s and was essentially completed by 1986. In contrast to the indexes for computers, BLS has for some time produced PPIs for semiconductors using the conventional approach to quality-change adjustment described below, but outside researchers have been critical of the indexes.

BEA was aware of the rapid price declines for computers but did not have a satisfactory procedure for handling them. Until 1985, BEA used an assumption of no price change for computers in the calculation of constant-dollar GNP. This assumption became increasingly untenable as purchases of computers by business and other sectors grew rapidly and as prices of computers continued to plummet.

In 1985, following a cooperative research effort with IBM, BEA introduced a price index for computers in the U.S. national economic accounts. This development was a milestone in national economic accounting in that the use of the hedonic approach represented a distinct departure from the conventional approach to handling quality change in price measurement that had been employed by BLS and other statistical agencies in the United States and abroad.[3] Among the price indexes for capital goods in the national income and product accounts, the index for computers and peripheral equipment is unique in its very rapid and prolonged decline. In the period 1972–84 covered by the IBM-BEA study, the index declined 83 percent, or about 14 percent per year.

Under the conventional PPI approach to quality change, once BLS has determined that a specification change has occurred in an item being priced for

3. The computer price index is not the first price index in the U.S. national accounts to be based on hedonic techniques. The first was probably that for single-family houses, which was developed at the Census Bureau and introduced into the accounts in 1974.

the PPI, it follows one of several procedures. If it has no data to make a specific quality adjustment—the typical situation—two possibilities are open. If it decides that a specification change is "small"—using well-defined criteria for smallness—it ignores the change and treats any price difference from the previous month as pure price change. If the specification change is "large," and if the new model has a higher price than the old model, BLS employs a linking procedure that treats all the observed price change as an improvement in quality. If the new model has a lower price, a zero quality change is assumed, and the difference in price is counted as a price decline.[4] In those instances where specifications change and BLS obtains data from the respondent on the cost of that specification change, however, it uses cost as a measure of the quality adjustment. Cost is the appropriate theoretical measure of quality adjustment in an output price index like the PPI and the method that BLS prefers.

The hedonic approach uses a regression equation—the hedonic function—to relate the prices of individual models of a product to an array of major price-determining "characteristics" of the product. It can overcome those shortcomings of the conventional approach that assign all the observed difference in price between new and old models either to price or to quality.

In the IBM-BEA effort, the data on list prices and characteristics used were taken from publicly available sources and covered certain producers for the period 1972–84. For mainframe computer processors, the selected price-determining characteristics were main memory capacity and a summary measure of the speed with which instructions are executed. In addition, the hedonic functions were modified in order to allow for the failure of the prices of existing models to adjust promptly to the prices of new models. This was accomplished by allowing for the coexistence of two (or more) sets of prices—one for products based on an old technology (or technologies) and the other for products based on a new technology. Procedures similar to those for processors were used for disk drives, printers, and general purpose displays.

The IBM-BEA effort of 1985 did not include a price index for microcomputers (PCs), but BEA introduced such an index two years later. This index, unlike that for mainframes, was not based on hedonic techniques; it was instead a "matched-model" index. In a matched-model index, the price change associated with a new model is assumed to be the same as the price change of the continuing, that is, matched, models. The use of a matched-model index reflected partly the availability of data and partly BEA's judgment that such an index would adequately capture the full price decline in the PC market.

4. In the CPI, in contrast, when it is determined that a "large" specification change has occurred but no information is available to make a specific quality adjustment, the price change for that price quote is assumed to be the same as the price change of comparable goods. For additional detail on quality-adjustment procedures, see U.S. Department of Labor (1988).

In January 1991, BLS introduced a price index for computers within the PPI framework, following experimental presentation of the index in 1989 and 1990. Given its relatively recent origin, it was not surprising that the index received only limited attention at the workshop.[5] The BLS index differs from that prepared by BEA in that it is based on transactions prices collected from a probability sample of producers and does not rely exclusively on the hedonic approach for quality adjustments. The quality-adjustment methodology used in the BLS index is a composite of the conventional PPI approach, the hedonic approach, and the use of price change of matched models approach. Although the BLS and BEA indexes differ in implementation, the agencies view them as reflecting the same conceptual approach to price measurement, that is, the resource-cost approach.[6]

Research Issues

The workshop devoted much attention to several questions that arise in the measurement of prices of high-tech goods. One such question concerned the nature of markets for computers. Apparently, prices of old models do not promptly fall to match the performance-adjusted price of the new models. Why should this be so, and how is the phenomenon to be modeled? A second question concerned the extent to which other high-tech products display very rapid price declines. Two such products, both closely related to the mainframe computers included in the IBM-BEA study, were considered at the workshop: microcomputers (PCs) and semiconductors, an important input in the manufacture of computers. Another question was whether list prices for mainframe computers (which were used in the IBM-BEA work on computers) are suitable proxies for transactions prices. A fourth question, already alluded to, was of a different nature: Is the approach to price measurement represented by the BEA (and BLS) computer price index appropriate? Consideration of this question raises fundamental issues concerning the definition of output and capital and the purpose of productivity measurement.

Computer Prices

Stephen D. Oliner explored a relatively untapped data set on computers, namely, the asking prices for used IBM mainframe computers as compiled in the trade publication *Computer Price Guide*. He found that list prices serve as

5. A paper on how the inclusion of electronic computing equipment price indexes would affect the capital equipment component of the PPI was presented at the workshop but is not included in this volume.

6. In 1990, BEA began to use quarterly values of a weighted average of the BLS subindexes for thirty-two-bit and greater than thirty-two-bit word size computers to interpolate between annual estimates of its index for mainframe processors. BEA also began using the subindexes for sixteen-bit and thirty-two-bit word size computers in place of its matched-model index for PCs. In 1991, in the comprehensive revision of the national economic accounts, BEA introduced separate price indexes for imports and exports of computers and peripheral equipment.

reasonable proxies for transaction prices in this market. He also found that prices of old models do not promptly adjust to reflect the price declines occasioned by the introduction of new models. Oliner's results lend support to the rate of price decline for mainframe computers in the IBM-BEA study. Oliner also used the same data set to estimate the rate at which used IBM mainframe computers depreciate and analyzed data on the installed stock of IBM mainframes to derive the implied distribution of retirements.

Ernst R. Berndt and Zvi Griliches report on a hedonic study of PC prices that uses detailed data from the so-called list and discount U.S. markets for personal computers. The *list market* refers to the list prices as advertised by brand name manufacturers; the *discount market,* to prices as advertised by discount stores. An important aspect of the study is the authors' consideration of how to treat time, age, and vintage variables econometrically within a hedonic equation. This issue arises because there is an identity between the year in which the model is observed and the sum of the year in which the model was first introduced and its age in years.

Berndt and Griliches's results, which the authors characterize as preliminary, suggest a rate of price decline of about 25 percent per year from 1982 to 1988, substantially more than the 16 percent per year rate in the matched-model index for PCs used by BEA.[7] Separate regressions for the list and discount markets provide little evidence that the rate at which PC prices decline differs in the two markets. Separate regressions for new, continuing, and exiting models suggest that the price decline for continuing models may be larger than the price declines associated with the introduction of new models—the opposite experience from that observed for mainframe computers.

Semiconductors

Papers in this session addressed the question of whether it is reasonable that the PPI for semiconductors has not shown declines similar to the BEA computer price series. Papers by Ellen R. Dulberger, on the one hand, and by John R. Norsworthy and Show-Ling Jang, on the other, using different data and methodologies, conclude that semiconductor prices fell far more during the 1970s and the first part of the 1980s than did the PPI series. Using trade data (Dataquest) on memory chips and various index formulas, Dulberger constructs price series for so-called MOS memory chips. Her alternative chain price index series differ somewhat from one another, but all show considerably greater price declines than does a series she constructs to approximate the PPI fixed-based Laspeyres weighting procedures. Further, this fixed-based approximation itself falls far more rapidly than the official PPI series. Dulberger offers the hypothesis that delays in introducing new products into the PPI may be a major source of this difference. For example, she demonstrates that

7. These rates of price decline are expressed as actual rates in order to be consistent with other studies; in their paper, Berndt and Griliches present PC prices relative to the consumer price index.

the point at which dynamic random access memory (DRAM) chips (a type of MOS memory chip) are first introduced into a price index does indeed have a major effect on the price declines subsequently recorded in such an index. Finally, although lack of suitable data prevents her undertaking a careful examination of the question, Dulberger argues that, in view of the quality improvements that have occurred in chips and the complex electronic components into which they are assembled, their prices should show declines like those in the BEA deflator for computer processors.

In contrast to Dulberger's direct price index construction approach, Norsworthy and Jang investigate the extent of quality change in semiconductors by estimating a cost function and derived input demand functions for industries that use semiconductors. Their model is estimated separately using U.S. time-series data for 1968–86 for three four-digit industries: computers, telephone and telegraph apparatus, and other telecommunications equipment. Unmeasured quality change in semiconductor input for each industry is specified to be related to a quality adjustment index that is assumed to depend on two characteristics of semiconductor industry output—density of DRAM chips and bit width of microprocessor chips. The coefficients of the two included characteristics variables are found to vary by using industry. However, the authors conclude that, for all three industries, the hypothesis of no characteristics-related quality change is strongly rejected. Norsworthy and Jang's resulting quality-adjusted semiconductor prices fell even more rapidly than did the BEA computer price index.

Kenneth Flamm produces price indexes for DRAMs. He focuses on a relatively short recent period, citing evidence that, for the first time in the history of the semiconductor industry, substantial and sustained increases in the quality-adjusted price of memory chips occurred in 1987 and 1988. He uses data on actual sales contracts for DRAMs in 1985–89 to estimate an econometric model of forward pricing in DRAMs. Contract length is found to have a generally small and insignificant role as a determinant of contract pricing. Overall, his results show much smaller price differentials between American and European purchasers of DRAMs than had been indicated in published Dataquest series. He constructs quality-adjusted price indexes by weighting together chips of a given density that differ in speed and "organization." Flamm estimates that prices of 256K and 1M DRAM chips increased about 68 percent and 44 percent, respectively, from 1986 to 1988.

In his comment on the three semiconductor papers, Jack E. Triplett concludes that they all indicate that the PPI sampling mechanism has not worked for this industry. Much discussion about the problem of improving price indexes for industries experiencing rapid technological change has focused on the need to introduce new samples into the PPI more frequently. This is a problem that BLS has recognized for many years. Dulberger's finding of a significant effect of "introduction delays" on an index for DRAMs, if also true for semiconductors in general, would imply that extremely rapid introduction

of new samples is needed. Triplett suggests an alternative, not for producing indexes on a current monthly basis, but rather for producing indexes for analytic purposes. Using this approach (which is similar to a proposal by the French statistical agency), hedonic methods would be used on available industry data on list prices and characteristics of all the products produced by the industries, and the PPI sampling methodology would be reoriented to collect discounts by product class that would be used to correct the hedonic indexes.

Panel Discussion: Implications of BEA's Treatment of Computer Prices and Productivity Measurement

The panel discussion was organized for the purpose of exploring issues raised by Edward F. Denison in his 1989 book *Estimates of Productivity Change by Industry*, which was highly critical of the computer price index introduced by BEA at the end of 1985.

Denison is concerned about the size of the declines in computer prices and the effect of these declines on the measurement of real GNP for the business sector, real business investment and capital stocks, and national income, depreciation, and profits expressed in current year prices. The first part of Denison's discussion essentially reiterates his view as presented in his 1989 book. Denison prefers that capital be measured in terms of consumption forgone, advocating an approach to the measurement of capital and productivity change similar to that set forth some years ago by Thomas K. Rymes, another member of the panel. Denison did not address in detail the consumption-forgone aspect, but it was taken up more fully by Charles R. Hulten as well as by Rymes.

If capital goods are always changing in quality, how is it possible to maintain a continuous time series of capital goods prices? Aside from his fundamental preference for the consumption-forgone approach, Denison notes the availability of other options. One method is to equate different products at a common date according to their costs. Another possibility, which Denison would prefer, is to equate different products according to value to the user, that is, by the value of their marginal products. However, information of this kind is ordinarily not known, and the method is rejected on practical grounds. Denison concludes that the new method that BEA has adopted for computers is neither of these approaches. BEA compares different computers according to the main characteristics that users are interested in, namely, memory and speed. In Denison's view, this exaggerates the extent of the price decline by focusing solely on computer performance and ignoring the labor and other costs that the user must incur.

Bringing in an argument made by Triplett (1991), BEA maintains that it has not changed its method of treating quality change because, in equilibrium, marginal costs and marginal revenues are equal. In response to this issue,

Denison says that Triplett's point is not as useful as it seems. One is still faced with the problem of comparing a new model with an older one that may no longer be on the market and for which an imputation must be made. Imputations may differ according to the method used.

Denison also raises a timing issue, claiming that new products are introduced prematurely so that the price drop is accentuated. That is, BEA links the new item at too early a stage on the learning curve. Finally, Denison notes that, by using fixed price weights, BEA exaggerates the contribution of computer output to the growth of real GNP, thereby overstating GNP growth.

Griliches believes that linking computers by performance characteristics in hedonic equations is indeed the proper approach because these are the characteristics that buyers are mainly interested in. He also takes issue with Denison about the appropriate date for introducing new models. If new models have few purchasers at their very high introductory prices, that is simply a fact of the market. It means that the weight is very small, but the price drop as the new product gains acceptance and production costs fall is no less real.

Although in advocating the use of consumption forgone to measure capital Denison gives up on ever being able to deflate specific capital goods by specific goods deflators, Griliches maintains that such a lack of comparability exists as much at the consumer level as at the level of capital goods. He concedes, however, that, at the aggregate level, deflating capital by a consumer price index might be useful for welfare measurement.

Rymes, like Denison, is concerned with the proper identification of the sources of output growth. When the price of a new capital good is linked to the price of an existing capital good at a common date according to resource cost (or price)—the conventional approach—some of the technological improvement embodied in the new capital good is assigned to capital. This approach to quality adjustment keeps capital goods prices relatively low and, as a consequence, the volume of real investment and the capital stock relatively high. In Rymes's view, this is an overweighting of input quantity and results in an underweighting of productivity increase. As he sees it, such distortion can be observed as one moves from, say, final demands to intermediate industries: semiconductor inputs will be overweighted and productivity underweighted in the computer industry; likewise, ceramic inputs may be overweighted in the semiconductor industry. Rymes argues that quality-adjusted price indexes, like BEA's new computer price index, exacerbate a problem that existed before the computer revolution; indeed, they make it difficult, if not impossible, to derive a useful measure of productivity change as a component of output growth either in the aggregate or by industry.

Rymes wants to exclude from the capital stock the technological component that has traditionally kept capital goods prices relatively low and, in the case of BEA's mainframe computer index, is keeping them even lower. In his view, all that should be reflected in the capital stock is what is needed to sustain the

level of output. Rymes advocates use of an approach attributable to Roy Harrod (and implemented by Laurence Read) where distinctions between capital and technological change are more clearly maintained.

Although Hulten was not the last speaker, his remarks provide a clarification of the Rymes-Denison consumption-forgone approach versus the conventional (capital goods deflation) approach. The conventional way of measuring capital stock is as the sum of past investment adjusted for the using up of capital. In Rymes's view, since with the passage of time technological change makes it possible to lessen the amount of resources needed to reproduce a given stock of capital, factor input should be limited to the amount of saving (consumption forgone) required to reproduce such a stock.

Hulten's analysis concludes that, whereas the controversy had previously been viewed as a debate over the appropriate definitions of output and capital for growth analysis, it really boils down to a difference in objectives for productivity analysis. In the Rymes-Denison view, the conventional measure of capital includes a component that is more properly classified as technical change. Their preferred measure of total factor productivity would exclude this component from capital. In Hulten's opinion, both approaches are correct for answering different questions. The approach that uses the conventional definition of capital and total factor productivity answers the question of how much the production function has shifted relative to a given capital-labor ratio. The Denison-Rymes approach answers the question of how much more output growth there is because of technical change, that is, the initial rise in output associated with the improved technology and, in addition, all subsequent increases in output that follow in its wake.

In the discussion that followed, most of the panelists expressed agreement with Hulten's proposition that there are two approaches to productivity measurement and that they answer different questions. Griliches, in particular, prefers to measure productivity change in terms of observed prices and quantities in an industry and to be able to relate it to such factors as research and development in the "industry." He would prefer to deal with the effect of the additional capital that is induced by technological change in a subsequent stage of analysis. Rymes disagreed with Griliches with respect to which approach is most relevant in considering the effects of technical progress.

Thus, much of the discussion focused on the first of Denison's two points (the consumption-forgone standard). To the extent that Denison's second point was discussed, none of the other panelists agreed with him that the BEA computer price is inappropriate, although the measurement of prices of computers and other high-tech goods is not a closed matter. There was general agreement on the distorting effect of the interaction of the computer price index and BEA's use of fixed price weights in calculating real GNP. This particular problem has been recognized by BEA; in early 1992, the Bureau introduced alternative measures of GDP in which the weights are changed at more or less frequent intervals.

Quality-Change Issues in Consumer Prices

The papers in this section deal with two aspects of the treatment of quality change that may lead to bias in consumer price measures if not taken into account. The first is the widely discussed problem that arises when products disappear and are replaced with new versions. The second concerns changes in quality that may be associated with shifts among types of retail outlets. Presently, all price-level differences between outlets are implicitly assumed in the CPI to correspond to quality differences, but, to the extent that that is not the case, there will be an upward bias in the index.

Paul R. Liegey, Jr., reported on research to adjust apparel commodities in the CPI for quality change. Many apparel commodities are marketed on a seasonal basis, with one or more markdowns from the introductory price during the course of the season. For these commodities, price increases by and large occur only at the time of introduction. Standard CPI linking procedures would not work if applied to this market, and there was concern that the special procedures used by BLS might have led to an understatement of price changes.

Liegey reports on the experimental use of hedonic techniques for introducing replacement items for two types of apparel—women's coats and jackets and women's suits. For women's coats and jackets, the use of the hedonic technique gives an annual price change from October 1988 to October 1989 almost 4 percentage points larger than that in the published CPI, suggesting a downward bias in the index. For women's suits, the hedonic technique results in an annual change over half a percentage point less than the published index. Liegey suggests that this difference in outcome for women's suits may reflect a differential rate of success among the apparel components in excluding quality change from the published price change. Liegey also reports that BLS began to use hedonic techniques in the CPI in January 1991 for about twenty types of apparel.

Marshall Reinsdorf considers whether the CPI accurately reflects the shift of purchases away from full-price and high-price stores to chains and other lower-price retail outlets. Although Denison raised this issue some thirty years ago as a potential source of upward bias in retail price measures, it is only very recently that economists have begun to pay attention to it again. The theoretical problem is in some ways analogous to the bias in a cost-of-living index with fixed weights when consumers shift their purchases as relative prices change. Comparing prices at outlets linked into the CPI with those at the outlets they replaced, Reinsdorf finds a potential for an upward bias in the food-at-home component of the CPI (about 0.25 percent per year, assuming that everything else is comparable). In another part of the paper, he presents some comparisons of food items as carried in the CPI, on the one hand, and as shown by BLS in the "average price" series for specific food items paid by urban consumers. From January 1980 to January 1990, with few exceptions,

the prices of the food items in the CPI went up about 2 percent per year more than the corresponding items in the "average price" series. In Reinsdorf's view, this may reflect a lower quality of services offered by the lower-price outlets, but the differences are sufficiently striking to warrant continued investigation.

Transactions Prices

The PPI is designed to measure changes in transactions prices of producers; the official definition is "changes in net revenues received by producers." Thomas Betsock and Irwin B. Gerduk of BLS describe the difficulties that the Bureau experienced in obtaining transactions prices from steel producers, who had typically reported list prices for the PPI. In 1985, actual market prices for sheet steel were far below list prices. For BLS, reporting difficulties reached crisis proportions in the fall of that year, when producers finally reduced list prices to reflect actual market prices more accurately but at the same time curtailed buyers' discounts and thus raised their actual realized prices over immediately preceding market levels. For PPI purposes, BLS chose to take the level correction at the cost of missing a month-to-month price rise. Although major producers continued to report list prices through the 1980s, there is reason to believe that the steel industry had a change of heart in 1990 and is now showing much more genuine cooperation with BLS. Since the end of 1989, one cannot help but be impressed by the differences in the paths traced by transactions prices for sheet steel, on the one hand, and list prices, on the other.

Murray F. Foss's paper deals with the same problem of obtaining accurate transactions prices from business for the PPI. He hypothesizes that the existence of the Robinson-Patman Act, which makes price discrimination illegal except under certain conditions, inhibits many businessmen from reporting transactions prices because they may be making price concessions that either are or might be viewed as being in violation of the law. In the fieldwork for their 1970 study of industrial prices, Stigler and Kindahl found that businessmen were reticent about reporting selling prices because of the Robinson-Patman Act. Although government enforcement of Robinson-Patman over the last several years has been greatly reduced, the threat of private suits remains. Foss believes that BLS might be able to enlist better reporting by business for the PPI if it encouraged producers to report averages (of several transactions) to a greater extent, such as is now being done with steel producers.

Price Indexes for Defense

Richard C. Ziemer and Pamela A. Kelly give a very detailed description of the complex procedures used by BEA to deflate defense purchases in the GNP. As an aid in exposition, they set up a numerical "model" involving hypothet-

ical aircraft that describes how improvements in various types of aircraft are treated. Quality is said to change if there is a physical change in an aircraft type that permits the aircraft to fulfill its mission better in the opinion of the Defense Department. Adjustments are made on the basis of costs; that is, the value of a quality improvement is measured by the cost of the improvement. The authors also describe how BEA deals with the "learning-curve" phenomenon, that is, the decline in costs as production of a new defense item increases.

Arthur J. Alexander criticizes the use of cost as a measure of quality change for defense goods because improved products can be made at costs that are lower than those of older products. This has been a commonly voiced criticism of BLS's and BEA's treatment of quality change of capital goods. Drawing on his own research, Alexander cites examples of improved aircraft engines that were introduced at lower costs than the costs of the engines that were replaced. The improvements, which took the form of greater reliability and reduced maintenance costs, were the result of increased experience on the part of the engine manufacturer and substantial expenditures of research and development funds supplied by the Department of Defense.

Directions for Future Research

What was presented and commented on at the workshop suggests the importance of additional research on these topics. This is especially true of the high-tech field, where the development of price indexes of high-tech products that adequately account for quality change moves ahead at a slow pace while such products are proliferating. Continued investigation of quality adjustment procedures for items where technical change is rapid is extremely important. In addition, research is needed on alternative practical methods for data collection in these cases, such as suggested by Triplett.

If the proper measurement of prices of computer products is a contemporary concern, it is fair to ask how important high-tech products were treated in official price indexes in the past. Erwin Diewert raised this point in his paper at the fiftieth anniversary conference in 1988 (see Diewert 1990). Automobiles were not introduced into the CPI until 1935, when total passenger car registrations in the United States exceeded 22 million. The nature of the price index was doubtless a major consideration because the CPI of its day covered only urban wage earners and clerical workers, who typically did not purchase new passenger cars. Checking the historical record in this regard could have important implications for measuring the growth of real output and productivity in the early part of the twentieth century.

The workshop raised questions about the proper treatment of military goods such as aircraft. The present BEA procedure apparently ignores maintenance aspects of quality that must be important to the military. In addition, Robert Gordon has recently published price indexes for commercial aircraft that be-

have quite differently from the BEA prices for military aircraft (see Gordon 1990).

Several areas apart from high-tech products merit further investigation. The experience with steel sheet prices is probably not unique, and the reporting of list prices is probably not uncommon. There is a large body of price data on purchases of common civilian items by the U.S. General Services Administration that could be used to compare with revised PPI data since the late 1970s, especially during recessions. Research by Reinsdorf has shown the possibility of a large seller substitution bias for food at home and for gasoline; further work, using hedonic methods, is needed to develop point estimates. In addition, studies of seller substitution bias for other goods would be important.

Research on a broad range of price measurement issues and development of new or improved price series would benefit from both increased availability of data from private-sector sources and increased use of micro data within the statistical agencies. Studies of particular industries are needed, such as that being carried out by Berndt, Griliches, and Rosett (1992) for pharmaceuticals using data provided by several firms within the industry. More cooperative undertakings, such as that employed in the IBM-BEA computer project, might be a helpful approach. For increased use of government-collected micro data to be possible, improved support for longitudinal micro data files is needed.

Some issues in the price measurement field that were not addressed at the workshop are of major importance for future research. Development of consumer price measures for the flow of services from durable goods is one example. Another is the choice of alternative functional forms for price indexes, the practical importance of which has been clearly demonstrated, especially for investment goods (Young 1992; Triplett 1992). Theoretical work on defining the output of service-sector industries is a necessary first step in development of price indexes or in improvement of existing indexes for services; this topic was the focus of a separate National Bureau of Economic Research/Conference on Research in Income and Wealth conference also held in 1990 (see Griliches 1992). The appropriate treatment in price indexes of government-mandated pollution and safety equipment is still debated. For some purposes, measures of well-being more general than real personal consumption or real gross domestic product may be of interest, and these would require development of corresponding price measures. It should be obvious that price research is a field where much remains to be done.

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