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Context and Prologue

Introduction

Ernst R. Berndt and Charles R. Hulten

If the data were perfect, collected from well-designed randomized experiments, there would be hardly room for a separate field of econometrics. Given that it is the "badness" of the data that provides us with our living, perhaps it is not all that surprising that we have shown little interest in improving it.
—Zvi Griliches (1986, 1466)

Great advances have been made in theory and in econometric techniques, but these will be wasted unless they are applied to the right data.
—Zvi Griliches (1994, 2)

My father would never eat "cutlets" (minced meat patties) in the old country. He would not eat them in restaurants because he didn't know what they were made of and he wouldn't eat them at home because he did.
—Zvi Griliches (an old family story, 1986, 1472)

Empirical economists have over generations adopted the attitude that having bad data is better than having no data at all,

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> that their task is to learn as much as is possible about how the world works from the unquestionably lousy data at hand.
> —Zvi Griliches (1986, 1508)

> Why are the data not better? . . . Why does it feel as if the glass is still half-empty? . . . The metaphor of the glass half-empty is also misleading. As we fill it, the glass keeps growing. A major aspect of learning is that the unknown keeps expanding as we learn. This should be looked at positively. It is much better this way—especially for those of us who are engaged in research!
> —Zvi Griliches (1994, 14, 17, 18)

Overview

More than fifty years ago, Oskar Morgenstern (1950) pointedly asked whether economic data were sufficiently accurate for the purposes for which economists, econometricians, and economic policymakers were using them. Morgenstern raised serious doubts concerning the quality of many economic data series and implicitly about the foundations of a large number of econometric and economic policy analyses. In 1986, more than thirty-five years later, in the final remarks section of his *Handbook of Econometrics* chapter entitled "Economic Data Issues," Zvi Griliches commented with sadness on Morgenstern's important observations and criticisms, stating, "Years have passed and there has been very little coherent response to his criticisms" (1986, 1507).

The absence of a coherent response cannot be laid at Griliches's feet. His entire career can be viewed as an attempt to advance the cause of accuracy in economic measurement. His interest in the causes and consequences of technical progress led to his pathbreaking work on price hedonics, now the principal analytical technique available to account for changes in product quality. It also led him to investigate the issue of how research and development (R&D) investment is linked to the growth of real output. His research on human capital and its relation to the production function led him to formulate a measure of human capital-*cum*-labor quality. This approach to measuring the contribution of labor (and capital) to economic growth was one of Griliches's main contributions to the pioneering work on total factor productivity with Dale Jorgenson. The Jorgenson-Griliches collaboration was especially notable because of its insistence that accurate measurement was inextricably linked to economic theory: the theory of production implied an internally consistent accounting framework for the data, the theory outlined specific measurement methods, and price and quantity data that did not conform to this framework could lead to biased and uninterpretable results. This insight is at the heart of current efforts to improve the U.S. National Income and Product Accounts.

The study of multifactor productivity led Griliches to the question of the accuracy of service-sector output. Aggregate productivity growth had slowed in the 1970s, and one explanation was the shift in the composition of output toward service-producing industries where output growth measures are problematic and likely biased downward. The 1992 NBER Conference on Research in Income and Wealth (CRIW) volume that he edited (Griliches 1992) was the most comprehensive summary of measurement problems in these "hard-to-measure" sectors of its time. Moreover, his 1994 article (Griliches 1994), which coined the terms *measurable* and *unmeasurable* sectors (the latter including construction, trade, finance, other services, and government) focused attention on the breadth of the problem and challenged the view that each service industry was a special problem to be dealt with on its own. While improvements in the accuracy of service-sector outputs must recognize the unique characteristics of each sector's products, there is a unity to the problem: in all cases, the problem emanates from the fact that the units of measurement of the underlying product are very difficult to define (what is the "output" of a bank, a lawyer, a consultant, or a college professor?). In other words, one must know what "it" is before trying to measure "it."

Griliches's emphasis on the difficulties in measuring outputs and prices in the service sectors is not just an academic issue but also has substantive policy implications. For example, in his 1998 address at the annual meetings of the American Economic Association and the American Finance Association in Chicago, Federal Reserve Board Chairman Alan Greenspan stated:

> Of mounting importance is a deeper understanding of the economic characteristics of sustained price stability. We central bankers need also to better judge how to assess our performance in achieving and maintaining that objective in light of the uncertainties surrounding the accuracy of our measured price indexes. . . . The published price data indicate that the level of output per hour in a number of service-producing industries has been falling for more than two decades. It is simply not credible that firms in these industries have been becoming less and less efficient for more than twenty years. Much more reasonable is the view that prices have been mismeasured, and that the true quality-adjusted prices have been rising more slowly than the published price indexes. Properly measured, output and productivity trends in these service industries are doubtless considerably stronger than suggested by the published data. (Greenspan 1998)

Many goods and services are easy to measure badly but difficult to measure well, and the units-of-measurement problem is by no means restricted to intangible service-sector outputs. Similar issues arise with tangible outputs and inputs where there is important product variety: different technological vintages of capital goods, workers with varying amounts of human capital, alternative qualities of automobiles. Treating all investment in

computing equipment or all worker hours as a homogeneous input with an implicit common unit of measurement, or treating real aggregate expenditure for medical goods and services as a homogeneous output, runs the risk of misstating the true growth of the economy as well as the rate of price inflation.

Some of the consequences of such a misstatement were highlighted in earlier remarks by Greenspan in 1995, who indicated to the Senate Finance Committee that he believed the U.S. Consumer Price Index (CPI) overstated true inflation by between 0.5 and 1.5 percent per year. A bias of this potential was particularly important to monetary policymakers in an environment of low measured inflation in the 1990s. (It is even more critical today, as macroeconomists consider the possibility of low measured inflation actually implying a deflationary environment due to continued failure fully to capture the price index consequences of quality improvements embodied in new goods.) It was also of great importance to fiscal and income security policy as the CPI is widely used for cost-of-living adjustments. A commission was established to study the problem, chaired by Michael Boskin, of which Griliches was a member; this commission concluded that in 1995 the best estimate of the bias in the CPI was about 1.1 percent per year (see Boskin et al. 1996) and that a bias of this magnitude would cost the federal government around $1 trillion over the succeeding twelve years.

Debates over the existence of a "new economy" also depend critically on the accuracy of statistics on real output and input. Based on his study of the history of lighting, one prominent academic researcher, William Nordhaus (1997), was led to observe that "The bottom line is simple: traditional price indexes of lighting vastly overstate the increase in lighting prices over the last two centuries, and the true rise in living standards in this sector has consequently been vastly understated" (Nordhaus 1997, 30). The high-tech meltdown of 2000 underscores the need for accurate statistics on the prices and quantities in an era of rapid technological change. This means that the measurement problems of the hard-to-measure outputs (and inputs) must be confronted head-on. This was the central theme of the conference held to honor the memory of Zvi Griliches.

The CRIW Conferences in Honor of Zvi Griliches

In recognition of Zvi Griliches's contributions to the cause of economic measurement and to identify and build on ways in which further progress can be made in improving the quality of our economic statistics, the CRIW sponsored a conference held in the Washington, D.C. area on September 19–20, 2003. This conference focused primarily on economic measurement issues in the areas of productivity, price hedonics, capital measurement, diffusion of new technologies, and output and price measurement in hard-to-measure sectors of the economy. An earlier conference was held on Au-

gust 25–27, 2003, in Paris, France; it focused on other legacies of Griliches, such as returns to R&D, international diffusion of new technologies, econometric tools for dealing with measurement errors of various types, and the economics of intellectual property rights. For the most part, though not exclusively, papers presented at the Paris conference comprise a volume edited by Jacques Mairesse (ENSEE) and Manuel Trajtenberg (Tel Aviv University), assisted by Ernst R. Berndt and Charles R. Hulten, under the title of Zvi Griliches's last book, *R&D, Education and Economic Growth,* while those presented at the Washington conference appear in this volume.

Summary of Papers at the Conference on the Hard-to-Measure Sectors of the Economy

The chapters included in this tribute to Zvi Griliches encompass a series of topics in economic measurement to which he contributed directly, exhibited an abiding interest, or supported indirectly through his role as director of the NBER Program on Technological Change and Productivity Measurement. The chapters are linked by the theme of hard-to-measure goods and services and range over themes mentioned earlier: the measurement of service sector outputs, the measurement of capital and labor inputs, issues in the consistent measurement of input quantities and productivity growth, measurement error, the diffusion of new technologies, and the challenges posed by the definition and measurement of output in the new economy.

We begin and end this volume with chapters that focus specifically on Zvi Griliches's contributions to economic measurement. In chapter 1, "Theory and Measurement: An Essay in Honor of Zvi Griliches," Charles R. Hulten provides an initial overview of Zvi's contributions to the cause of economic measurement in the context of how the field of economics (and its general attitude to measurement issues) evolved during the period spanned by his career. In order to appreciate fully the magnitude of Griliches's contributions to measurement, Hulten argues that it must be recognized that the whole was greater than the sum of its parts. Hulten's chapter also examines the link between data and theory in the context of Koopmans' (1947) famous injunction to avoid "measurement without theory." One of the great achievements of Griliches's career was to demonstrate how this injunction could be implemented. Hulten then looks to the future of the Koopmans' injunction and argues for the need to account for possible feedback effects arising from the impact of mismeasurement on the behavior of economic agents, and the associated need to take into consideration the political economy context of measurement bias.

The final chapter in this volume, chapter 19—"Zvi Griliches's Contributions to Economic Measurement," is based on a luncheon address at the

conference by Jack E. Triplett. Triplett reviews the measurement problems on which Griliches worked, those on which he did not work directly but on which he had a significant influence, and those that will likely continue to be important in the future. He also discusses in greater detail Griliches's interactions with government economists and statisticians in the various statistical agencies. Triplett emphasizes that Zvi Griliches's impact on measurement extended far beyond his immediate research, including that on his many students and colleagues (and their students and colleagues), as well as from his leadership in the measurement community as a whole.

In between these two chapters focusing specifically on Zvi Griliches's lasting contributions, are sections devoted to issues involving the role of information technology in productivity growth (chapters 2 through 5), specific issues involving the measurement of capital and labor inputs within a consistent framework (chapters 6 through 9), various aspects of price measurement (chapters 10 through 15), analyses of data sets old and new (chapters 16 and 17), and a surprising update of Griliches's classic paper on the diffusion of hybrid corn (chapter 18).

Classic Input Measurement Issues Revisited

The next set of four chapters deal with an issue to which Griliches made one of his most important contributions: the accurate measurement of capital and labor inputs and the associated hypothesis, with Dale Jorgenson, that much of what is recorded as total factor productivity is actually measurement error. The first chapter in this section, chapter 2—"Production Function and Wage Equation Estimation with Heterogeneous Labor: Evidence from a New Matched Employer-Employee Data Set," by Judith Hellerstein and David Neumark deals with labor rather than capital measurement. Hellerstein and Neumark report on efforts underway to link hours worked to labor force characteristics, an innovation that promises to increase the accuracy of the labor input measures used in various analyses of productivity. This is a subject pioneered by Griliches in his early efforts to incorporate human capital in the structure of production. Here Hellerstein and Neumark use cross-sectional data to derive direct estimates of the impact of human capital on output. These findings are then compared to the conventional productivity approach that assumes wages are a satisfactory proxy for the direct effect.

In chapter 3, "Where Does The Time Go? Concepts and Measurement in the American Time Use Survey," Harley Frazis and Jay Stewart report on a newly introduced Bureau of Labor Statistics survey that eventually will provide time series data on the use of household time, both market and nonmarket. Initial results reported in this chapter indicate that the value of nonmarket household time (i.e., household production) amounted to more than $3 trillion in 2003, or about 30 percent of current gross domestic

product (GDP). In addition to providing information of great value to labor economists, this new data series will be useful for gaining insight into the widely noted divergence between the estimates of employment and wages obtained from the household-based Current Population Survey and the establishment-based Current Employment Statistics program.

In chapter 4, "Technology and the Theory of Vintage Aggregation," Michael J. Harper reexamines a well-known and conceptually difficult aspect of the vintage asset problem: the aggregation of different technological vintages of capital. Harper explores several of the salient theoretical issues and provides an important reminder that much of the empirical literature on the sources of economic growth rest on simplifying assumptions that may not be true. A related set of capital measurement issues is addressed in chapter 5, "Why Do Computers Depreciate?," by Valerie Ramey, Matthew Shapiro, and Michael Geske. These authors focus on another difficult capital measurement problem—measuring the economic depreciation of computers using the "vintage" price of used computers and separately identifying and measuring the obsolescence and deterioration components of economic depreciation. This separation reveals that the decline in the price of a computer as it ages is largely due to obsolescence and a decline in replacement cost, with only a negligible effect attributed to physical deterioration.

Quality Adjustment and Price Measurement Issues: Recent Developments

Price measurement was a prominent subject of Zvi Griliches's research. In this section of the volume, five chapters are devoted to various issues in price measurement. Over the years, numerous researchers, as well as several commissions, have concluded that the CPI overstates true inflation, particularly when one takes into account quality changes embodied in new goods. Robert J. Gordon has long hypothesized that this CPI upward bias phenomenon may not be true for the most important component of the CPI—rental shelter—and that in this case the bias might in fact be downward, not upward. In chapter 6, "Downward Bias in the Most Important CPI Component: The Case of Rental Shelter, 1914–2003," Robert J. Gordon and Todd vanGoethem assess and find strong support for the hypothesis that the CPI has been biased downward for its entire history since 1914. The bias appears to have been particularly large, on the order of –1.0 percent annually, prior to the methodological improvements in the CPI that date from the mid-1980s.

The next three chapters in this section on price measurement focus on more disaggregated price measures in product markets undergoing rapid technological change. In chapter 7, "Pricing at the On-Ramp to the Internet: Price Indexes for ISPs during the 1990s," Greg Stranger and Shane Greenstein estimate hedonic price indexes for dial-up Internet service pro-

viders (ISPs) in the United States from November 1993 to January 1999. Not taking into account quality changes, Stranger and Greenstein find that ISP price indexes are flat. However, hedonic price indexes reveal a decline of about 20 percent in price per unit of ISP quality between late 1996 and early 1999.

In chapter 8, "Different Approaches to Estimating Hedonic Indexes," Saeed Heravi and Mick Silver review and then compare empirically three general approaches to constructing hedonic price indexes: hedonic imputation, dummy time hedonic indexes, and fixed effects model indexes, with each variant also measured as weighted versus unweighted, chained and fixed base, and arithmetic and geometric mean aggregators. These differing methods are applied to 1998–1999 U.K. scanner data for washing machines, dishwashers, and vacuum cleaners. Heravi and Silver summarize their numerous findings on different methods by reporting results of a meta-analysis.

In chapter 9, "Price Indexes for Microsoft's Personal Computer Software Products," Jaison R. Abel, Ernst R. Berndt, and Alan G. White report on research based on the universe of Microsoft's PC-based software transactions in the United States over the July 1993 through June 2001 time period. While previous literature has typically focused on retail prices (mail order in particular), their data encompass the relatively much larger volume licensing and original equipment manufacturer channels. Using matched model methods (as their data are only from one manufacturer, the number of distinct models is too small for hedonic estimation), they take into account product changes, such as upgrades, and the transformation from stand-alone to integrated productivity suites. Although there are differences over time periods and across products, they find that the prices of Microsoft's desktop operating systems and applications have generally been falling over this time period.

Finally, Zvi Griliches had a lifelong interest in assessing the contributions of R&D to economic growth. Over the years he devoted considerable efforts in constructing price indexes for R&D that could be used to deflate R&D expenditures into real or quantity measures of R&D. In order to make international comparisons of the contribution of R&D to economic growth, R&D purchasing power parities (PPPs) relative to the United States have been employed; to date, these R&D PPPs have been assumed to be the same as GDP PPPs. In the final chapter of this section, chapter 10—"International Comparisons of R&D Expenditures: Does an R&D PPP Make a Difference?," Sean M. Dougherty, Robert Inklaar, Robert H. McGuckin, and Bart van Ark develop PPPs for R&D expenditures in nineteen manufacturing industries and six countries (United States, France, Germany, Japan, the Netherlands, and the United Kingdom) for 1987 and 1997, based on separate R&D input prices for various cost categories, particularly labor and materials. They then examine the robustness of various

R&D PPP measures and argue for a preferred PPP that differs considerably from the current norm.

Information Technology and the Acceleration of Productivity Growth

Chapter 11, "Information Technology and the G7 Economies," by Dale Jorgenson describes the growth accounting model developed in his collaboration with Griliches and the elaboration and applications that have followed from it, in this case, international comparisons based on harmonized prices for information technology equipment and software. While the seminal Jorgenson and Griliches (1967) study highlighted the importance of disaggregating investment and capital stocks into their equipment and structures components, here Jorgenson focuses on disaggregating equipment into its information technology (IT) and non-IT components. Jorgenson finds that a powerful surge in investment in IT after 1995 characterizes all of the G7 economies. These IT investments accounted for a large portion of the resurgence in U.S. economic growth and a substantial but smaller portion in the remaining G7 economies. More generally, Jorgenson finds that investment in tangible assets was the most important source of economic growth in the G7 nations and, in particular, that the contribution of capital input exceeded that of productivity growth for all countries in all periods.

The next two chapters focus more specifically on microprocessors and IT equipment. In chapter 12, "The Role of Semiconductor Inputs in IT Hardware Price Declines: Computers versus Communications," Ana Aizcorbe, Kenneth Flamm, and Anjum Khurshid calculate industry-specific semiconductor input price indexes and then assess the relative impact of changes in this high technology input price on the prices and quality improvement in two high-tech downstream industries—PCs and communications equipment. They find that between 1997 and 1998, changes in semiconductor input prices appear to account for 20–30 percent of price declines in both consumer electronics and local area network (LAN) equipment and for 40–60 percent of price declines in computers. They conclude that differences in the composition of semiconductor input bundles, coupled with significant differences in the relative importance of semiconductor inputs in cost, potentially account for the entire difference between output price declines in the computer and communications equipment producing industries.

In chapter 13, "Computer Investment, Computer Networks, and Productivity," B. K. Atrostic and Sang Nguyen contribute to the debate over how the IT revolution affects economic growth. Atrostic and Nguyen specifically focus on how computers are used, not just how many there are. They hypothesize that the productivity of a single computer is enhanced when it is connected to other computers. Using data from the new Com-

puter Network Use Supplement (CNUS) data base, Atrostic and Nguyen assess empirically the magnitude of this network effect on productivity growth. They find that the impact of networks is statistically large in "new" plants and may be as important as investment in computers itself as a source of growth in output per worker.

Measuring and Modeling Productivity, Consumption, and Diffusion

In chapter 14, "Services Productivity in the United States: Griliches's Services Volume Revisited," Barry Bosworth and Jack E. Triplett examine problems associated with measuring output in the service industries of the economy, one of the most prominent hard-to-measure sectors. Bosworth and Triplett begin by summarizing what has been learned from a number of the service-sector conferences held at the Brookings Institution over the last few years. These conferences ranged over issues in finance, insurance and banking, health and education, transportation, and trade. These are all sectors in which conventional measures of output are widely viewed as problematic and which Griliches (1994) dubbed as "unmeasurable" sectors. Bosworth and Triplett provide a brief assessment of current procedures for measuring the output of these sectors and then present estimates of the contribution of the service industries to the recent growth (and pick up) in overall productivity, which they find to be substantial (in apparent contrast to earlier time periods). Information technology investments play an important role in the productivity growth of the service sectors.

In chapter 15, "A Consistent Accounting of U.S. Productivity Growth," Eric J. Bartelsman and Joseph Beaulieu outline and develop a framework for integrating economic statistics from a variety of sources into a unified and internally consistent database. The goal is to present the data in such a way that users can easily change assumptions regarding the way the data are organized and classified so that users can efficiently assess the robustness of their estimates to variations in methodology. The authors illustrate the usefulness of this framework by applying it to productivity measurement in light of the Y2K problem and the possible acceleration of capital retirement during the rush to invest in Y2K-compliant IT capital. When they correct for this effect, the growth rate of multifactor productivity in the nonfarm business sector is found to be larger in the period 1995–1999 and smaller for subsequent years 2000 and 2001. The contribution of capital is correspondingly smaller in the first period and larger in the second. This pattern is of potential importance for the literature on the role of IT investment in the widely discussed post-1995 productivity pick-up.

In the following paper, chapter 16—"Should Exact Index Numbers Have Standard Errors? Theory and Application to Asian Growth," Robert C. Feenstra and Marshall B. Reinsdorf examine the relatively neglected issue of estimating sample variance in the context of constructing exact

index numbers. Published index numbers are rarely accompanied by an indicator of variability, and it is thus difficult to assess whether a new estimate is significantly different from the previous one. This chapter contributes not only to the technical literature on the subject, but also applies the analysis to the specific case of total factor productivity (TFP) indexes and examines the question of whether TFP growth in Singapore has been negative or positive, which has become an issue of considerable controversy. The authors' application illustrates both the relevance of the problem and the nature of the solution.

The next chapter in this volume focuses very specifically on U.S. government data sets—one on measurement error in the venerable Consumer Expenditure Survey (CES) and the other on household time allocation as measured in the just recently introduced American Time Use Survey (ATUS). Much of Zvi Griliches's research dealt with measurement error and with issues in the measurement of human capital, including the value of time. In chapter 17, "What Really Happened to Consumption Inequality in the United States?," Orazio Attanasio, Erich Battistin, and Hidehiko Ichimura consider data quality issues for the analysis of consumption inequality exploiting two complementary data sets from the CES—one known as the Interview sample and the other as the Diary sample. The authors develop a methodology that extracts and combines the most reliable information from each sample to derive a correction for the measurement error affecting observed measures of consumption inequality in the two surveys. They conclude that consumption inequality, as measured by the standard deviation of the log of nondurable consumption, has increased by roughly 5 percent during the 1990s.

Griliches's classic 1957 study of hybrid corn emphasized the importance of economic incentives and profitability in the adoption and diffusion of a new technology. In the final paper in this section, chapter 18—"Technology Adoption from Hybrid Corn to Beta-Blockers," Jonathan Skinner and Douglas Staiger return to a forty-year-old debate between Griliches and sociologists who emphasized the structure of organizations, informal networks, and "change agents" as forces affecting the diffusion of hybrid corn. Skinner and Staiger consider state-level factors associated with the adoption of a variety of technological innovations over the last seventy-five years: hybrid corn and farm tractors in the first half of the twentieth century, computers in the 1990s, and treatment following heart attacks with beta-blockers during the last decade. They find first that some states consistently adopted new effective technology, whether it be hybrid corn, farm tractors, or effective treatments for prevention of recurrent heart attacks, such as the beta-blockers. Second, the adoption of these new highly effective technologies was closely associated with social capital and state-level 1928 high school graduation rates, but not per capita income, population density, or (in the case of beta-blockers) expenditures on heart attack pa-

tients. Skinner and Staiger therefore reopen old debates and suggest new reasons for why medical practice varies geographically. They conjecture that economic models may be useful in identifying why some regions are more likely to adopt early, but sociological barriers—perhaps related to lack of social capital or informational networks—can potentially explain why other regions lag far behind. Future research on factors affecting new technologies—be they agricultural or medical innovations—will undoubtedly continue to assess empirically issues raised by Zvi Griliches in his pathbreaking PhD dissertation.

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