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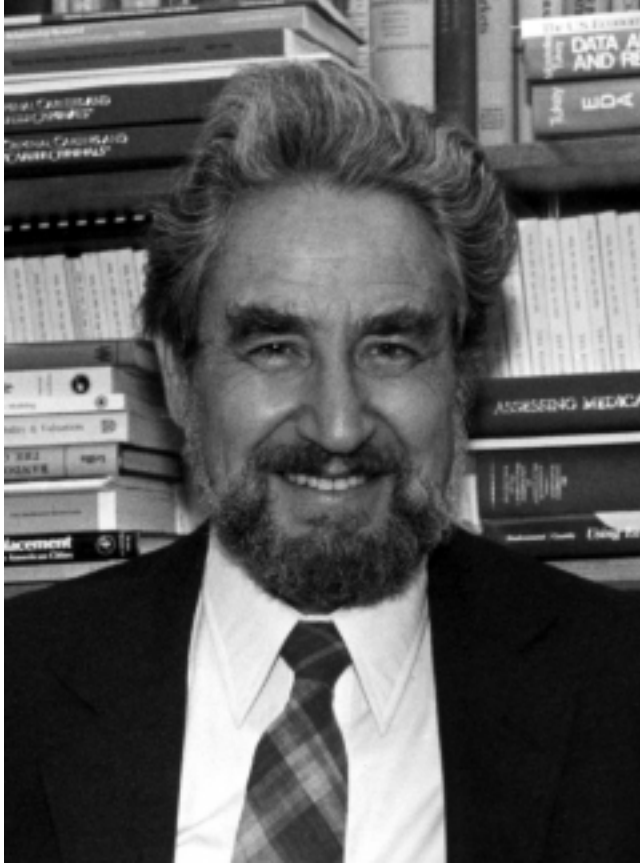
ZVI GRILICHES
1930–1999

A Biographical Memoir by
MARC NERLOVE

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ZVI GRILICHES

September 12, 1930–November 4, 1999

BY MARC NERLOVE

1. PROLOGUE

ZVI GRILICHES was born in Kaunas, Lithuania, on September 12, 1930, and died on November 4, 1999, in Cambridge, Massachusetts. The story of how he got from there to here is a long one with a harrowing beginning. It has been told by Griliches himself in a talk presented on the eve of Yom Hashoah at the Harvard-Radcliffe Hillel Foundation (1992) and in an interview given to Alan Krueger and Timothy Taylor about four months before his death (Krueger and Taylor, 2000). The beginning was harsh: In 1940 the Soviet Union annexed Lithuania and the other Baltic republics. The Nazis occupied the country in 1941. Griliches and his family were confined to the ghetto in Kaunas in August of that year. He managed to evade the periodic roundups for transport to the concentration camps until sometime during the summer of 1944. After that he was moved, often by foot, from one camp to another until he was liberated from Dachau by the American advance in May 1945. Except for a sister, he lost all his immediate family in the Holocaust. Eventually Griliches made his way via a British internment camp on Cyprus to what was then Palestine. After working on a kibbutz and participating in

the War of Independence Griliches managed to pass what we would call a high-school equivalency exam despite his lack of formal education. He spent a year studying history and languages at the Hebrew University, 1950-51. He then matriculated in the College of Agriculture at the University of California, Berkeley, where he obtained a bachelor's degree, 1953, and a master's degree, 1954, both in agricultural economics.

While most people's subsequent intellectual development, ideas, and perspective in a social science such as economics would be expected to have been affected profoundly by the horrific experiences through which Griliches lived in the decade before he emigrated to the United States, I find remarkably little evidence that his subsequent work and contributions were affected at all. As he himself once remarked, "After we came out of the Holocaust, we did not look back. We had too much trouble re-establishing some kind of life and getting going. Besides, there was no point in dwelling. People like me were a dime a dozen. Lots of people, everyone had a story. No one out there was interested in our stories" (quoted in Weinstein, 1999). He was surely not one of a "dime a dozen," but the story of his life and work I want to tell here begins in the fall of 1954 at the University of Chicago, where he received his Ph.D. degree in 1957. He joined the faculty there in 1956 and remained until 1969, when he moved to Harvard University.

The intellectual atmosphere and ferment at Chicago in the 15 years Griliches was there, first as a graduate student, 1954-56, and subsequently on the faculty, 1957-69, were heady. I have described the milieu and cast of characters in some detail in a previous paper (Nerlove, 1999) and need not repeat it here. Perhaps the greatest influence on his subsequent work was T. W. Schultz, but also important to his intellectual development were Gregg Lewis, D. Gale Johnson,

Al Harberger, and Carl Christ. Hans Theil visited, 1954-55, and his lectures provided a neat framework that Griliches adapted in his paper on specification bias in the estimation of production functions (1957). Trygve Haavelmo visited during the academic year 1957-58, and his work on the theory of investment (Haavelmo, 1960) completed that year played a pivotal role in Griliches's development of his ideas on capital heterogeneity and, more importantly, in accounting for economic growth and productivity change. I think though that it was Schultz's influence that was really formative, and a strong interaction between the two continued until Schultz's death in 1998, only a year and a half before Griliches's.

Over the years Griliches garnered many honors and awards for his work: the prestigious John Bates Clark Medal of the American Economic Association in 1965; presidencies of the Econometric Society and American Economic Association in 1975 and 1993, respectively; and an honorary degree from the Hebrew University, Jerusalem, in 1991. He was elected to fellowships in the Econometric Society, 1964; the American Academy of Arts and Sciences and the American Statistical Association, 1965; the American Association for the Advancement of Science, 1966; the American Agricultural Economics Association, 1991; and the American Economic Association, 1994. In 1975 he was elected to the National Academy of Sciences. He served on many Academy and national committees, the most notable being the so-called Boskin Commission to Study the Consumer Price Index, 1995-97, and had an important and far-ranging influence on economic statistics in the United States, a part of which I deal with in Section 3 below. Much of his contribution was through his interaction with students and research associates, particularly over the 30 years he spent at Harvard University and the National Bureau of Economic Research, and not merely through his published work. I will try to

deal with these influences *ad passim*. (One of Griliches's former students, Iain Cockburn, has put together two formidable lists of Griliches's former students, postdocs, and research associates, listing also their students and students' students in the manner of a genealogical tree. These can be accessed at http://people.bu.edu/cockburn/tree_of_zvi.html.) At the time of his death Griliches was Paul M. Warberg Professor at Harvard University and director of the program of Research on Productivity at the National Bureau of Economic Research. Many in the profession thought he should have been awarded a Nobel Prize in economics for his work. But, although the selection committee for the prize was aware that he was terminally ill, they did not choose to grant him that distinction before his death in 1999.

I knew Griliches since we were together at the University of Chicago in the years 1954-56. I followed his work closely over the years. I will share with you in this biographical memoir my appreciation and assessment, not uncritical however, of his contribution to the science of economics. Much of his work was of profound and far-reaching significance for economics. But his contributions were many and diverse and some of his work was of lesser importance and long-run significance than the more central core. In his obituary Michael Weinstein (1999) characterized Griliches as one of "the world's leading authorities on the statistical analysis of economic data" and states that he "develop[ed] techniques of statistical estimation, including methods for analyzing 'panel' data that trace the behavior of many individuals or companies over time." Indeed, much of our profession regarded Griliches as pre-eminently an econometrician. Griliches's own assessment of his contributions to econometric methodology, however, was somewhat different. He later said (Krueger and Taylor, 2000), "Much of the stuff I did was empirical. I did some econometric theory, but the

econometric theory was by and large theory I needed to develop for the problems I was working on, not because it was out there. By today's standard, I was woefully under-prepared to be an econometrician." I would say however that, although statistical and econometric methodologies were not at the central core of his contribution, he was an empirical economist in the best sense, perhaps the best his generation of economists produced. Many of the areas in econometrics that he opened up because they were relevant to the substantive work he was doing later proved to be methodologically seminal, perhaps in part because they were relevant to real economic problems. I hope that what follows provides a guide and assessment of what he accomplished, albeit a personal one, and a delineation of the central core of his contribution, which was, in my view, principally a fuller and more quantitative understanding of the process of economic growth.

Economics is an empirical science and thus is concerned with the real economic world and with understanding economic behavior and the implications of such behavior for economic policy. However, economic research, in common with research in other academic disciplines, is largely driven by its own internal logic and structure in the sense that most work is on problems that flow from previous work, rather than from any attempt to understand reality. The subdiscipline of econometrics is no exception in this respect. Griliches's contributions invariably had their origin in a serious attempt to resolve some real economic problem and to understand some real economic phenomenon, rather than to solve some outstanding methodological issue. Griliches was pre-eminently an empirical scientist and was from the beginning virtually consumed with the desire to understand and modify the real world. Such methodological conclusions of more general applicability that he may have

made draw their inspiration and strength from the substantive issues with which he was concerned. If his ideas have been held aloft, away from contact with economic reality, it is by others who have followed in his footsteps but not in his lead. It has not been his methodological contributions divorced from their substantive context that constitute Griliches's principal contribution to economic knowledge but rather his answers to the substantive questions themselves. More importantly, raising the questions themselves in the right way is his lasting legacy to our discipline.

In his presidential address to the American Economic Association (1994) Griliches wrote:

The major message that I will be trying to convey is that we often misinterpret the available data because of inadequate attention to how they are produced and that the same inattention by us to the sources of our data helps to explain why progress is so slow [in this instance in understanding the process of economic growth]. It is not just the measurement of productivity that is affected. Other fields of empirical economics are also struggling against limitations imposed by the available data. Great advances have been made in theory and in econometric techniques, but these will be wasted unless they are applied to the right data.

For most of his professional life and in the great bulk of his papers, Griliches attempted to deal with such data problems and with issues related to the appropriate ways to measure the relevant variables of economic theory. Framing the issues in this way was the key to his contribution.

Much of Griliches's substantive work dealt with the process of technological change and its interpretation as an economic phenomenon. In the introduction to a collection of early papers (1988) covering the period of his work through 1971, he wrote:

[M]easurement frameworks can be expanded to bring more aspects of technological change into the domain of "standard" economics, removing thereby some of the mystery from this range of topics. This kind of work,

however, takes much effort, is heavily data dependent, and is rarely definitive. At best it opens up new subjects rather than providing closure. It shows by example, what can be done and what it might be interesting to do more of; and often the question is as interesting as the possible answers.

The tentative and incomplete nature of much of Griliches's work is indicated by the many papers that he titled "Notes on . . . ," but this hesitancy should not blind us to the importance or significance of the contributions made. If one broadly construes econometrics as dealing with problems of appropriate measurement in addition to problems of inference, Griliches's contributions have been of immense and far-reaching significance. But, if one more narrowly interprets econometrics as concerned primarily with inference, his contributions to econometric methodology per se, derive largely from his more substantive work and his concern with measurement.

Griliches's bibliography is very large; my review of his work must, at best, be highly selective. His opera can be roughly sorted into five main categories, although some work falls in more than one category and almost all are related to the theme of appropriate measurement to a greater or lesser degree: (1) technological innovation and diffusion, R&D, and patents; (2) hedonics, including proper measurement and adjustment of input and output measures in the analysis of economic growth and productivity measurement; (3) production functions, growth accounting, and supply and derived demand; and (4) unobserved or latent variables and specification errors, including substantial substantive research on the relation among income, education or schooling, and ability, and with important implications for panel data econometrics (summarized in Nerlove, 2000). Of the four, the second and third are most central to the theme of measurement. I provide a selective bibliography at the end of this biographical memoir. Griliches, himself,

collected his most important papers in two volumes published in 1998, as well as in the earlier 1988 collection.

2. TECHNOLOGICAL INNOVATION AND DIFFUSION, R&D,
AND PATENTS

Griliches's paper (1957), arguably his best known, is essentially a summary of his Ph.D. dissertation, "Hybrid Corn: An Exploration in the Economics of Technological Change." The ideas presented in this paper foreshadow much of Griliches's subsequent work in this area. "A unifying thread that runs through . . . is the view that technological change is itself an economic phenomenon and hence also an appropriate topic for economic analysis" (1988, p. 1). But appropriate measurement of inputs and outputs is essential to this goal. Looking at the differential geographical spread of hybrid corn in the United States, Griliches (1957) sought to interpret it in terms of both the supply of the new technology in the form of specific hybrids adaptable to specific areas and the speed of adoption by farmers (i.e., their demand for the new technology). Using a logistic growth curve to summarize the spread of hybrid corn in the various states of the United States, Griliches is able to parameterize the process by three parameters: origin, slope, and ceiling. Origins are interpreted in terms of the supply of hybrid varieties by the various state experiment stations. Slopes and ceilings are interpreted in terms of farmers' incentives to adopt. But differences in ceilings are inadequately explained. The model that Griliches used is as follows:

$$P = \frac{K}{1 + e^{-(a+bt)}}$$

where P is the percentage of total corn acreage planted

with hybrid seed, K is the ceiling or equilibrium value, t is time, and b is the rate of growth coefficient; a is a location parameter. The proportional rate of growth is

$$\frac{1}{P} \frac{dP}{dt} = b \frac{P}{K}.$$

The framework Griliches developed has been the basis for many studies of technological diffusion.

Less directly, but more importantly, Griliches's interest in hybrid corn led to a concern with the other major changes that were occurring in U. S. agriculture, principally mechanization (1959) and the spectacular growth in fertilizer use (1960, collected in a 1998 volume) and thus to his concern, which I regard as central to his work, with appropriate measurement of inputs and output and thus to his pioneering resurrection of hedonic analysis. These early studies of agricultural inputs employed econometric tools sophisticated for their time and led to Griliches's papers on distributed lags and aggregation, discussion of which I omit here. I will take up hedonics in the next section and Griliches's work on production function estimation in Section 3. His concern with appropriate measurement of inputs and estimation of production functions is also reflected in his work on measurement of labor inputs and thus to that on the relation among education or schooling, ability and income as a way of adjusting labor input in studies of productivity and total factor productivity.

Much of Griliches's more recent work dealt with productivity growth in the United States, Israel, Japan, and France. To a great extent this work is related to production function estimation, but there is one very large group of papers more directly related to the source of technical change

and its explanation by economic factors, namely, those papers on R & D and patents (collected in the 1998 volume). Central to this work is the idea that technical change, and more generally knowledge, is produced. The late Jacob Schmookler pioneered in the study of patents as an indicator of inventive activity and technical change (Schmookler, 1954), but the link has proved elusive (see especially Griliches, 1990). In his presidential address to the American Economic Association (1994), Griliches characterizes patents as “a shrinking yardstick” but nonetheless valuable. Moreover, the relationship between patents and R & D is also problematic (1994). More recent work on the quality of patents rather than a simple count has demonstrated a closer relationship between inventive activity and growth at the firm level. A more rewarding direction of research has been the study of the relation between productivity growth and R & D expenditures, particularly at the level of the individual firm.

Griliches (1979) lays out the production function approach to the estimation of returns to R & D, the issues associated with output measurement in R & D intensive industries, and the problem of defining the stock of R & D capital as a factor of production. In this work he continues a leitmotiv from the part of his work on hybrid corn dealing with the supply of hybrids. One of Griliches’s most important contributions in this area was to link Census of Manufactures data on firms and industries with National Science Foundation data on R & D expenditures, no mean accomplishment in a country obsessed with privacy and maintaining confidentiality, and which required considerable managerial and administrative skill. A collaborator, Bronwyn Hall, was instrumental in these studies, as she was in the collection and collation of the patent data. In this connection mention should also be made of Griliches’s collaborators in France, Israel, and Norway: Jacques Mairesse (Institut National de

la Statistique et des Études Économiques), Tor Jakob Klette (Central Bureau of Statistics, Norway), and Haim Regev (Central Bureau of Statistics, Israel). Griliches's first collaboration, using Norwegian microdata at the firm level, was with Vidar Ringstad on production function estimation (see Section 5). Work on these data was certainly facilitated by a more open tradition of academic research in France, Israel, and Norway as contrasted to the United States. Many of Griliches's subsequent papers and those of numerous co-investigators at the National Bureau of Economic Research rest on these data. Several appear in the 1984 volume edited by Griliches. The papers in this volume deal, inter alia, with the following questions: "What is the relationship of R & D investments at the firm and industry level to subsequent performance indicators such as patents, productivity, and market value? How does one formulate and estimate such relationships? What makes them vary across different contexts and time periods? To what extent can one use patent counts as indicators of R & D output? Can one detect the output of R & D in the market valuation of the firm as a whole? What determines how much R & D is done and how many patents received?" (1984) In a paper published posthumously Klette and Griliches (2000) developed a sophisticated model of the growth of heterogeneous firms in which R & D and stochastic innovation are the engines of firm growth and applied this model to a panel of Norwegian firms. There are many innovations (nonstochastic!) in application of panel data methods in this work on micro firm data more generally. I have more to say about Griliches's contribution to panel data econometrics below in Section 5.

An important paper of Griliches is joint with D. W. Jorgenson, "The Explanation of Productivity Change" (1967). This paper has, in my view, provided a sound basis for the field of growth accounting and has been of major influence

in the study of economic development in general and of great significance in recent debates over the supposed slowdown in U. S. productivity growth. This work is foreshadowed in (1963) in some detail (indeed, the basic structure is already in place there) and earlier by Abramovitz (1950, 1956, 1962) and Denison (1962); it is more properly treated as an aspect of production function analysis in Section 4 below. For his own view of the history of this subject see Griliches (1996).

3. HEDONICS: PROPER MEASUREMENT OF PRICES AND ADJUSTMENT OF INPUT AND OUTPUT MEASURES

In 1964 (p. 382) Griliches wrote:

Economists use price series for two main purposes: (1) to deflate expenditures and receipts for the purpose of arriving at some conclusions about either changes in welfare (in the case of consumption expenditures and earning receipts) or productivity (in the case of sales receipts, wage bills, and investment expenditures); and (2) to explain and predict changes in quantities used or purchased. In either case we are likely to have a broader concept of "price" in mind than just one of the particular numbers recorded during a transaction.

Thus stated, the problem of constructing an appropriate price index for a multitude of different transactions involving different commodities of differing qualities or efficacies is basically an aggregation problem (Frisch, 1936). On the consumer side, appropriate aggregation weighting is by marginal utilities or marginal rates of substitution; on the producer side, weighting is by marginal productivities, marginal rates of transformation, or marginal rates of substitution. Under certain circumstances these marginal rates of substitution or transformation can be treated as given prices, actual or implicit. (For consumer theory Muellbauer [1974] presents several models of utility-maximizing behavior that justify such an interpretation in terms of underlying con-

sumer preferences, but he is quick to admit that his analysis neglects the other, producer, side of the market. A central problem for both consumer and producer prices is how to treat new commodities and quality changes. (Griliches's collaborations with Ernst R. Berndt on personal computers and with Iain Cockburn on pharmaceuticals should be mentioned in this connection.)

The traditional method of adjusting for quality changes over time in the measurement of prices is to "match models," that is, to use only prices for varieties of a commodity that are unchanged in specification between two adjacent periods, chaining pairs of periods over time. Difficulties arise for commodities, the varieties of which are changing rapidly over time or for totally new commodities. The hedonic technique (Waugh, 1929; Court, 1939) involves regressing unit prices for different varieties on measures of quality characteristics or attributes; if the varieties are distinguished by time periods, a simple technique for obtaining a quality-adjusted price index is to introduce dummy variables for periods in a multiple regression framework (Court, 1939). Griliches's contribution to hedonics was largely to resurrect and to promote with great vigor and effect Court's formulation. He used the technique very effectively in work on productivity growth and its sources, as described in the next section.

Although hedonic analysis for all its practical importance was not central to Griliches's work, the idea that commodities are bundles of attributes has important implications for the appropriate measurement of inputs and outputs in the analysis of changes in total factor productivity, for if the growth in quality-adjusted inputs is misestimated and/or if the growth in quality-adjusted output is likewise, total factor productivity growth will be biased. The need to adjust both inputs and outputs to measure them appropriately in this context was

recognized very early by Griliches and exploited very fully in his subsequent work, especially in his paper with Jorgenson (1967) discussed in the next section. Indeed, it set his research agenda throughout his professional career.

4. PRODUCTION FUNCTIONS, TOTAL FACTOR PRODUCTIVITY
MEASUREMENT, SUPPLY AND DERIVED DEMAND

The basic framework for growth accounting, equivalently, measurement of total factor productivity, was laid out many years ago by Abramovitz (1950, 1956, 1962); Griliches elaborated and extended this basic framework in important ways, beginning with his early paper on U. S. agriculture (1960). In 1988 (pp. 6-7) he laid the problem and the method out as follows:

A conventional measure of residual technical change (TFP) in an industry can be written as

$$\hat{t} = y - sk - (1-s)n$$

where y , k , and n are percentage rates of growth in output, capital, and labor respectively; s is the share of capital in total factor payments, and the relevant notion of capital corresponds to an aggregate of actual machine hours weighted by their respective base period (equilibrium) rentals. This procedure assumes that all the variables are measured correctly, that all the relevant variables are included, and that factor prices represent adequately the marginal productivity of the respective inputs. The last assumption is equivalent to the assumption of competitive equilibrium and constant returns to scale.

Griliches then proceeded to break $TFP = \hat{t}$, or total factor productivity, up into six components:

1. the effect of the rate of growth in the measurement error of conventional capital measures on the estimated “residual”;
2. errors in the measurement and definition of labor input;
3. errors in assessing the relative contribution of labor and capital to output growth (it would be zero if factor shares were in fact proportional to their respective production function elasticities or if all inputs were growing at the same rate; then the relative weights do not matter);
4. economies of scale, which would be zero if there were no underlying economies of scale in production or if the rate growth in the number of new firms (plants) just equaled the growth in total (weighted) input;
5. the contribution of left-out inputs (private or public);
6. various remaining errors in the measurement of output.

This decomposition is revealing in terms of Griliches’s research agenda and his progression through it: Griliches’s work on hybrid corn led him to consider two other major changes in U. S. agriculture, increasing use of chemical fertilizer (1960) and mechanization (1959), and in turn to a more general formulation of the total factor productivity problem (1960). Along the way he encountered difficulties in the measurement of fertilizer and machinery and other capital inputs. Because these measures are obtained by dividing expenditures by an index of prices, it is possible to interpret the “errors” in terms of mismeasurement of prices, and this in turn led straight to hedonics, discussed in Section 3. Much of the work on patents and R & D discussed in

Section 2 is related to the fifth component. Proper measurement of capital input requires not only attention to quality changes and prices but, in addition, to the determination of new investment, additions to the stock, and as to how such investments are translated into the relevant input variable and more recently the computer "revolution." Measurement of the "correct" labor input requires attention to the quality of the labor force, or the stock of "human capital" embodied in it; and this in turn leads to the attempt to measure the effects of education on the productivity of labor. These studies are all closely related to Griliches's work on the analysis of unobserved or latent variables; consequently, I will deal with them in detail in the next section. Griliches dealt relatively little with the mismeasurement of output per se in the context of total factor productivity and not at all, as far as I can discover, with cyclical effects on productivity, except insofar as these affect capital utilization. Finally, the fourth component, returns to scale, or more generally increasing returns, is related to Griliches's attempts to estimate production functions in a variety of contexts in order to ascertain the significance and extent of such increasing returns.

Although measurement of total factor productivity and estimation (possibly inefficiently from an econometric point of view) of a production function, not necessarily parametrically specified, are equivalent, most of Griliches's work on productivity measurement does not explicitly introduce such a function. This is also the case with his paper with Jorgenson (1967, p. 249), hereinafter G & J:

The purpose of this paper is to examine a hypothesis concerning the explanation of changes in total factor productivity. This hypothesis may be stated in two alternative and equivalent ways. In the terminology of the theory of production, if quantities of output and input are measured accurately, the growth in total output is largely explained by growth in total input, "properly

measured." Associated with the theory of production is a system of social accounts for the real product of real factor input. The rate of growth of total factor productivity is the difference between the rate of growth of real product and the rate of growth of real factor input. Within the framework of social accounting the hypothesis is that if real product and real factor input are accurately accounted for, the observed growth in total factor productivity is negligible.

G & J assume that the underlying production technology is constant returns to scale, that factors are paid their marginal products, and that the economy is in competitive equilibrium. They proceed by a series of adjustments to eliminate what they consider to be "errors" in the measurement of real output and real factor input, in order to compute average total factor productivity growth (TFP) for the period 1945-65:

1. Output = U. S. private domestic product in constant prices; input = sum of labor and capital services in constant prices, labor and capital services assumed proportional to stocks; TFP = 1.60 percent.

2. Correction for aggregation errors by weighting labor and capital services in various categories by shares in total factor payments and output by weighting by shares of consumption and investment goods in total expenditures; TFP = 1.49 percent.

3. Correction of investment goods prices using output prices on both the output and input sides, correcting the implicit deflator for producers' durables to be the same as for consumers' durables, and correcting the implicit deflator for changes in business inventories; TFP = 1.41 percent.

4. Adjustment of labor and capital for relative utilization separately, assuming the relative utilization of capital in manufacturing and nonmanufacturing is the same and adjusting by relative utilization of electric motors, correc-

tion of data on manhours for variations in labor intensity, TFP = 0.96 percent.

5. Correct aggregation of capital services by the before tax prices of various categories of investment goods (land, residential and nonresidential structures, equipment and inventories), TFP% = 0.58 percent.

6. Correct aggregation of labor services, males only by relative earnings for categories broken down by years of schooling, TFP = 0.10 percent.

There is thus remarkably little left over for the “residual,” that is the unexplained growth in output per unit of total input—too little. One suspects “overkill.” Perhaps for this reason, much of the subsequent work of both Griliches and Jorgenson was devoted to refining these adjustments. Of course, this is not an *explanation* of total factor productivity growth but rather an accounting of the sources of it.

Beginning with his early paper (1957), applying Theil’s analysis of the effects of left-out variable in OLS regression to the problem of differential managerial ability in production function estimation, Griliches published a number of papers dealing explicitly with the estimation of agricultural, manufacturing, or aggregate production functions, or the associated systems of derived demand and supply functions. In a somewhat neglected book (1971), Griliches and Ringstad estimate a number of production functions from data on a large number of individual manufacturing establishments from the 1963 Norwegian Census of Manufactures. Their particular concern is to separate economies of plant size from market size. Since their pioneering study, more such studies using individual establishment data have been attempted by others. The main contribution of (1971) was to demonstrate the feasibility of using census of manufactures data on individual establishments, an approach Griliches

was later to put to good use in his work on R & D, using the Census-National Science Foundation matched sample (1982).

5. UNOBSERVED OR LATENT VARIABLES: THE RELATION AMONG EARNINGS, EDUCATION OR SCHOOLING, AND ABILITY

As indicated in the previous section, Griliches's interest in the proper measurement of labor input led him to a series of studies relating earnings to schooling and, perforce, the unobservable variable, ability. Although, from the standpoint of Griliches's core contribution, this work may have been incidental in that it was largely related to a desire to adjust the quality of the labor input over time, I regard it as fundamental to the development of panel data econometrics (Nerlove, 2000). Disturbances in the structural equations are the best-known example of latent or unobserved variables in econometrics: "An unobservable variable is one that is measured with error. Sometimes, the error is due to inaccurate measurement in the narrow sense. More broadly, it arises whenever measurable quantities differ from their theoretical counterparts." (Goldberger, 1974, p. 193; see also 1971, 1972.) Here is a typical example from Griliches and Mason (1972): Let y_{kij} be the k th indicator of success (earnings, occupational status, etc.) of an individual j belonging to a family i ; X_{kij} are some exogenous observed factors affecting the individual or the family into which he was born; S_{ij} is schooling received; A_{ij} is an unobserved variable reflecting "ability"; u_{kij} is the usual econometric disturbance reflecting everything else (see Haavelmo, 1944) and is assumed to be independent of the disturbance for any other indicator of success and of X_{kij} , S_{ij} , and A_{ij} . A and X are also assumed to be independent. The relations we want to estimate are

$$y_{kij} = X_{kij}\alpha_k + S_{ij}\beta_k + A_{ij}\gamma_k + u_{kij},$$

one for each k . The parameter of interest is b , the effect of schooling on earnings in particular, for the adjustment of labor input in the measurement of total factor productivity. The problem is, of course, that we don't observe A_{ij} . We can assume that it is highly correlated with schooling so that just leaving it out would bias the measured effects of schooling upwards. Assume

$$s_{ij} = Z_{ij}\delta + A_{ij}\theta + w_{ij},$$

where Z_{ij} are some exogenous variables, possibly among those included in X , and w_{ij} is a disturbance independent of u_{kij} . Although we cannot observe A_{ij} , we have what Goldberger refers to as multiple indicators of it, namely schooling *and* all the success measures, which however also depend on schooling. We might have other indicators of ability not depending also on the amount of schooling received, such as IQ test scores or scores on the Armed Services Qualification test. Such "multiple indicators," as Goldberger (1974) refers to them, help to identify the coefficients in the earnings schooling relationship despite the unobservability of the latent ability variable.

In subsequent papers published in the decade Griliches (1972, 1976, 1977) and Chamberlain and Griliches (1975) further refined these methods relating them to the notion of individual-specific unobserved effects due to left-out variables. The contribution of Chamberlain and Griliches (1975) is specifically to take into account the information afforded by more than one relationship involving the *same latent variable*, that is, to confront the problem of simultaneous-equations bias head on. They write (pp. 422-423):

The usual response to the availability of data with a group structure, e.g., families and family members, firms and time, is to estimate the relationships of interest from the within-group data. In the context of estimating income and schooling relationships such calculations would “take care” of parental background differences, even though inefficiently (they ignore the between families information in the sample), but would not correct for possible bias from the individual (within family) genetic differences which may be correlated with achieved schooling levels later on. To take this explicitly into account would require the availability of direct measures of such ability, which were not available in the particular data set we were interested in analyzing. But even in their absence, if the missing variable (such as ability) affects more than one *dependent* variable, a bootstrap operation [not in the sense used today] may be possible. The basic idea for the new approach comes from the realization that such a left out variable must cause similar biases (proportional to each other) in different equations and that taking advantage of that fact may allow one to achieve identification of most of the coefficients of interest.

6. THE CENTRAL CORE

Over the years Griliches made a number of other important contributions to econometric methodology, with which I will not deal here. The central core of Griliches’s contribution to economic science consists of his contributions to our understanding of productivity growth in the context of general economic growth. His central insight was to see that “technical change,” which Abramovitz (1956) and Solow (1957) pinpointed as the principal engine of growth, is not a purely exogenous phenomenon but rather largely the result of economic activity, the main purpose of which is to generate such change. T. W. Schultz (1953), who was Griliches’s teacher at the University of Chicago, held that most of technical change in U. S. agriculture had been due to public investments in agricultural research, perhaps too extreme a view. That the rate and direction of technical change ought to be subject to the same rules as other purposeful economic activity was not particularly new or novel at the time

Griliches began his pioneering work on the spread of hybrid corn in the United States, but there was little or no quantitative evidence. Beginning with his 1957 paper Griliches systematically provided such evidence and measured its impact on growth.

Because technical change is typically measured by changes in total factor productivity, be it at the firm, industry, or economy-wide level, measurement of these factor inputs becomes crucial. But more significantly, changes in the quality of factors of production are much more than mere errors of measurement. They “embody” the sources of growth: New knowledge spreads through training and investment in new capital, which “embodies” this knowledge. Changes in education and health and other forms of human capital affect the quality of the labor input and thus its productivity. Investment in R & D is “embodied” in new equipment or in new products or in new organizational forms. Again, Griliches systematically measured these effects, and by so doing identified the sources of economic growth. I regard Griliches as the founder of modern growth accounting.

At his death Griliches was editing his Kuznets lectures, which he intended to be a definitive statement on growth and its sources. I suspect that, as he usually did, Griliches will raise a great many unanswered questions. It is sad that those of us who remain to find the answers will no longer have his wise counsel and the benefit of his extraordinary intuition and insight.

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