July 12, 2001

IT, Hedonic Price Indexes, and Productivity

Jack E. Triplett
Brookings Institution
Washington, D.C. USA

Prepared for IAOS Satellite Conference
Tokyo, August 30-31, 2001

National accounts deflators for computers and IT (information technology) equipment differ enormously. Computer equipment deflators in the national accounts of OECD countries recorded changes that ranged from +80% to –72% for the decade of the 1980s (Wyckoff, 1995). As these are internationally traded commodities, it is not plausible that internal market conditions in developed countries can create differences of this magnitude. A Eurostat task force (Eurostat, 1999) found a smaller dispersion among European countries' IT deflators for the early 1990s. But still, price declines recorded by national computer deflators in Europe ranged from -10% to -47%. Again, such variations within a common market are too large to be caused by differences in national distribution systems and market conditions.

Different methodologies for producing quality-adjusted computer price indexes are employed for IT products across OECD countries. Significantly, the largest declines found by Wyckoff (1995) and by Eurostat (1999) were recorded in countries that used hedonic price indexes for computers—the US in the former study, France in the latter. Conventional price index methodologies for adjusting for quality change in IT equipment generally yielded smaller price declines, and a great amount of dispersion; in some countries, conventional methodologies have even produced rising IT price indexes in the past. Both studies concluded that the dispersion in measured IT price trends across OECD countries reflects statistical methodologies, not true international differences in computer prices.

Real, or constant price, investment in IT is estimated by deflation. With price indexes that differ internationally to the extent recorded in the Wyckoff and Eurostat studies, international differences in real investment in IT are mostly artifacts of deflation methodologies. Thus, data deficiencies make it nearly impossible to analyze the impact of IT across the economies of OECD countries.

This paper reviews briefly the contribution of IT to recent economic growth and productivity in the U.S., describes hedonic price indexes, and compares them with conventional methods used by most of the world's statistical agencies. It also summarizes a new research effort that is intended to produce internationally comparable deflators for IT equipment, to facilitate international comparisons of productivity and of the impact of IT on economic growth.

I. Contribution of IT to Recent U.S. Economic Growth and Productivity. Research on the acceleration of U.S. economic growth after 1995 is reviewed in Bosworth and Triplett (2001), on which this section is based. Around a third of the post-1995 acceleration in growth was associated with an increased stock of capital, most of it increased IT capital. As the result of substantial IT investment in the U.S., these products make up a larger share of the U.S. capital stock than they once did, and so they now contribute a larger share of capital services than in the past. Indeed the services of IT capital provide all

of the acceleration in the growth of capital services in the U.S. economy after 1995. Non-IT capital grew but did not accelerate in the 1990s.

U.S. labor productivity (LP) increased from around 1.4 percent per year before 1995 to about 1.8 percent per year after 1995. Around a quarter to a third of the acceleration in U.S. LP came from increased growth in capital services per worker (capital deepening), and two-thirds or more came from more rapidly growing multifactor productivity (MFP). IT capital is responsible for all of the acceleration in the capital contribution to LP. Additionally, a major part of the acceleration in U.S. MFP occurred in the machinery producing manufacturing industries that contain computer and other IT industries and the semiconductor industry. Thus, IT contributed mightily to recent U.S. economic growth, both because of its contribution as an investment good and from the productivity spurt within the IT producing industries.

The substantial contributions of IT to recent U.S. economic growth can be estimated and analyzed because the U.S. has a well-established (but by no means fully adequate) system of deflators for IT equipment that allow for the very rapid technological advances in these products. The U.S. deflator system began with a collaboration between the Bureau of Economic Analysis and economists at the IBM Corporation on price indexes for computers and peripheral equipment that resulted in the first introduction of hedonic computer price indexes into the national accounts of any country (Cole, et al., 1986; Cartwright, 1986). This work was probably the most far-reaching innovation world wide in national accounts in the decade of the 1980s. The innovation has now been extended in the U.S. to price indexes for semiconductors and to other IT equipment, but by no means all of IT. Indeed, measures of U.S. telecommunications equipment prices are probably still in need of improvement (Jorgenson, 2001).

Because IT has been so important a contributor to recent U.S. economic growth, economists want to determine the contribution of IT in other economies. Analyzing the contributions of IT in other economies is far more difficult because the basic analytic statistics on IT are not always adequate, mainly because of inadequate IT deflators. Some other countries measure IT prices using hedonic indexes: France, Sweden, Canada and Japan produce their own hedonic computer price indexes, and Australia and Denmark use U.S. indexes, exchange rate adjusted, as investment deflators in their own national accounts. But it is not possible to assure that measures of IT investment for all OECD countries are compatible.

A number of recent studies (Schreyer, 1999, Daveri, 2001, Oulton, 2001) employ U.S. price indexes for IT equipment as proxies for groups of OECD countries. The great and implausible international variations documented in Wyckoff (1995) and Eurostat (1999) have convinced scholars that extrapolation of U.S. price indexes is better than accepting the measures that are now published for many OECD countries. Their decision is supported by fragmentary research that exists which suggests substantial corrolations among hedonic price indexes estimated for different countries. For example, a preliminary study of German computer prices (Moch, 1999) suggests that German personal computer prices are declining as rapidly as those in the United States, which is comparable to a similar finding some time ago for France by Moreau (1996), and also to a computer price index for Taiwan (Jang, et al., 1996).

It must clearly be the case, however, that use of country B's price index in country A is inferior to the one that accurately measures prices in country A.

I**I. Hedonic Indexes and Conventional Statistical Agency Methods for Adjusting for Quality Change**. Why is measuring price change for IT so hard? The issues that arise in measuring price indexes for computers are sometimes viewed as a bit arcane, but the matter is of great importance for developing data for analyzing the economic impact of IT.

Generally, price index compilers count on matching the same observation (the same product from the same seller) from period to period as a methodology to hold constant all of the elements of a transaction other than the "pure price change." Quality change is widely recognized as one of the most difficult problems in the construction of price indexes, because when the quality of the item in the price index sample changes, any price difference between the new item and the old one will reflect the value of the quality change in addition to the pure price change. The challenge is to find a "quality adjustment" that measures the value of the quality change.

When statistical agencies do not have available hedonic quality adjustments (which are described below), they implement a variety of procedures that together constitute the "conventional method," often also called the "matched model" method. Broadly, these procedures may be grouped into explicit and implicit quality adjustments.

Explicit quality adjustments include simple judgment (some portion of the difference in price between the faster new and the slower old computers is judged to be the value of increased speed) and production cost estimates obtained from manufacturers. New model computers are often cheaper than the ones they replace, so these conventional explicit quality adjustments do not work because they imply negative quality adjustments, when it is clear that computer quality has improved. Subtracting "option prices" from the purchase price is also used (the addition of a sound card to the standard specification for a computer might be valued by the price of the card when it was only offered as an extra-cost option).

Implicit quality adjustments arise from a number of "linking" procedures that are commonly used when quality changes are encountered in price indexes. The exact linking method differs from country to country and to an extent from circumstance to circumstance. Linking out of the old models and linking in of the new amounts to dropping the changed computers from the index and calculating the price index from only the computers that have not changed. A major problem with this approach is that computer models change very rapidly; many statistical agencies have reported that the overlap of the same, unchanged computer models might be so short that severe sample attrition is experienced, If so, the price index constructed from only the models that do not change is not representative of the computer market.

Chapter II of the draft OECD handbook on IT price indexes (Triplett, 2000) presents more information on the quality adjustment procedures used in statistical agencies, including "flow charts" that indicate how agencies decide which detailed procedure to employ. It also discusses the probable biases to price indexes from the employment of the several linking methodologies that are used.

An alternative way of estimating constant-quality price indexes is called a *hedonic price index*. A hedonic price index is one that makes use of a *hedonic function*.

A hedonic function is a regression involving the price of some product (such as computers) and the characteristics of that product (for computers, processor speed, memory size, presence of sound cards and other features, designated as "X" in the following equation):

[1] $\ln P = a_0 + a_1 \ln (\text{speed}) + a_2 \ln (\text{memory}) + a_x X + e$

The regression is usually, but not necessarily, logarithmic, as shown in equation [1].

Most statistical agencies that implement hedonic price indexes for computers use equation [1] to impute prices for new or exiting computers, or to make an explicit quality adjustment for changes in the levels of characteristics (faster speed, for example) in new models of computers. Thus, if a new computer is faster than the older one, equation [1] can be used to value the increased speed of the new computer, and make an adjustment for it, so constant-performance price comparisons can be made between the new and old computers (yielding quality-adjusted price indexes). The hedonic quality adjustment is thus a statistical estimate of an explicit quality adjustment, which can be used instead of the more informal

explicit quality adjustments commonly employed (judgment, or manufacturers' cost), or which permits an explicit quality adjustment instead of the implicit adjustments implied by conventional "matched model" methods. For more information about hedonic functions and their use to construct hedonic price indexes, see the draft hedonic handbook prepared for the OECD (Triplett, 2000). A survey of hedonic research on computers and peripheral equipment is Triplett (1989).

The price index literature contains a good deal of speculation about whether hedonic indexes should or should not give the same result as matched model indexes with conventional quality adjustments. Although part of this speculation is motivated by the need to think through the conditions under which one might wish to change from conventional quality adjustments to hedonic adjustments, in a real sense whether the two methods give similar results is an empirical question that is best answered by research studies, and not by theory or speculation. Most existing studies have shown that hedonic indexes for IT equipment decline more rapidly, and in some cases much more rapidly, than matched model indexes using conventional linking methods to deal with changed computers—though to be sure the number of relevant studies is small.

A question yielding more insight is to ask under what conditions do the two methodologies differ. The answer to this question provides information that is relevant to determining whether the advantages gained from estimating hedonic indexes are worth their sometimes substantial cost.

Growing interest in hedonic indexes is apparent in many countries. One recent example of this interest is the valuable "Symposium on Hedonic Methods in Price Statistics," sponsored by the German statistical agency, the Statistisches Bundesamt, and the German Central Bank, the Deutsche Bundesbank. Information on the agenda for this Symposium and its papers may be obtained from: marco.schwickerath@statistik-bund.de.

III. Reseach on Internationally Comparable Hedonic Price Indexes for IT Equipment. The cost of hedonic indexes is a great barrier to their more widespread adoption for IT deflators. They require collecting a great amount of data on prices and characteristics of computers, a substantial amount of econometric modeling to estimate hedonic functions (of a type of activity that is not commonly carried out in price compiling agencies), and some broad experience in interpreting regression coefficients and applying the regression results to price changes collected for the index.

A research project is just getting underway to explore cost-effective solutions to the substantial problems that arise in computing quality-adjusted price indexes for IT products. This project involves an international collaboration between the OECD, the European Hedonic Center at Eurostat, Statistics Canada and the Australian Bureau of Statistics, and it will therefore cover countries in a number of quite different markets, including at the present writing, Europe, North America and Australia.

The project has several parts. First, it will explore whether computer hedonic functions are similar internationally. If a function like equation [1] prevails across a group of countries, then it might be possible to estimate and maintain the computer hedonic function in some central location (such as the European Hedonic Center), and make the results available to individual countries to use in making quality adjustments in their own computer price indexes. Second, an important by-product of the project is the capability for estimating PPP (purchasing power parities) for computer purchases in different countries, which could suggest methodological improvements to international comparisons projects. Third, it will determine whether there is evidence that *comparable* international price indexes for computers and IT have dispersions as great as exist currently in the national accounts of various countries, or whether international price movements in IT are as similar as existing research seems to suggest. Finally, it will compare hedonic and conventional matched model indexes for computers, to determine why and under

what conditions they give different results; this information will therefore permit an assessment of the gains from the more expensive hedonic price indexes for IT products.

An initial report on this research project, with very preliminary results for two countries, is Moch and Triplett (2001).

References

Bosworth, Barry and Jack E. Triplett. 2001. "What's New About the New Economy? IT, Economic Growth, and Productivity." International Productivity Monitor Number Two, Spring: 19-30.

Cartwright, David W. 1986. "Improved Deflation of Purchases of Computers." Survey of Current Business 66(3): 7-9, March.

Cole, Rosanne, Y.C. Chen, Joan A. Barquin-Stolleman, Ellen Dulberger, Nurhan Helvacian, and James H. Hodge. 1986. "Quality-Adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment." Survey of Current Business 66(1): 41-50, January.

Daveri, Francesco. 2001. "Is Growth an Information Technology Story in Europe Too?" Paper presented at the ZEW Conference on the Economics of Information and Communication Technologies, Mannheim, Germany, June 18-19, 2001.

Eurostat Task Force. 1999. "Volume Measures for Computers and Software." Report of the Eurostat Task Force on Volume Measures for Computers and Software, June.

Jang, Show-Ling, Bih-Jane Liu, and Sheng-Zhang Yang. 1996. "Constructing a Quality-Adjusted Price Index for Computers in Taiwan." Taiwan Economic Review 24(4): 557-577.

Jorgenson, Dale W. 2001. "Information Technology and the U.S. Economy." American Economic Review 91(1), March 2001, 1-32.

Moch, Dietmar. 1999. "Price Indices for Information and Communication Technology Industries: An Application to the German PC Market." Working Paper for the Center for European Economic Research (ZEW), Mannheim, Germany, August.

Moch, Dietmar and Jack E. Triplett. 2001. "International Comparisons of Hedonic Price Indexes for Computers: A Preliminary Examination." Paper presented at the Summer Institute, National Bureau of Economic Research (NBER), July.

Moreau, Antoine. 1996. "Methodology of the Price Index for Microcomputers and Printers in France." In OECD Proceedings: Industry Productivity, International Comparison and Measurement Issues. Paris: Organisation for Economic Co-operation and Development.

Oulton, Nicholas. 2001. "ICT and Productivity Growth in the UK." Bank of England Working Paper, May.

Schreyer, Paul. 2000. "The Contribution of Information and Communication Technology to Output Growth: A Study of the G-7 Countries." Directorate for Science, Technology and Industry, Statistical Working Papers 2000/2 [DSTI/DOC(2000)2]. Paris: Organization for Economic Cooperation and Development, March.

Triplett, Jack E. 1989. "Price and Technological Change in a Capital Good: A Survey of Research on Computers." In Dale W. Jorgenson and Ralph Landau, eds. Technology and Capital Formation. MIT Press, Cambridge, Massachusetts, USA and London, England.

Triplett, Jack E. 2000. "Handbook on Quality Adjustment of Price Indexes for Information and Communication Technology Products." Directorate for Science, Technology, and Industry, Working Party on Statistics, DSTI/EAS/IND/SWP(2000)2. Paris: Organization for Economic Cooperation and Development, November.

Wyckoff, Andrew W. 1995. "The Impact of Computer Prices on International Comparisons of Labour Productivity." Economics of Innovation and New Technology 3: 277-93.