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ETC (embodied technological change), etc.

The sources of labor productivity growth in the U.S. economy have been the subject of much study. Understanding these sources is important because labor productivity growth is the key to increasing our economic standard of living. For example, the difference between a productivity growth rate of 3% a year and one of 1.5% a year means the difference between doubling our standard of living in 23 years instead of 46 years!

Theory suggests four possible sources of faster productivity growth: better trained or better educated workers, a better way to organize production, more investment in capital (equipment, buildings, and so forth), and finally, improved quality of capital, that is, equipment that works faster or better in some way. The last source—quality of capital—also is called "embodied technological change," or ETC, to capture the idea that advances in technology are embodied in capital goods. Though many observers have attributed much of the recent productivity surge to ETC, its importance is controversial, in large part because of differences in approaches to measuring it.

This *Economic Letter* explains what ETC is and discusses its contribution to labor productivity growth, focusing on the challenges in measuring technological change in capital goods and assessing its importance to the growth in U.S. labor productivity.

Technological change and productivity

Technological change—or quality change—in the context of capital refers to the productivity gains resulting from the use of new capital above and beyond the gains obtainable from a comparable amount of pre-existing capital. Take, for example, the computer at your desk. Suppose that in 2000 you spent $1,500 on a PC with a Pentium III processor and wrote 20 reports, 100 memos, and 4,000 e-mails (we'll assume for your benefit that all the e-mails were work-related!). In 2001, you replaced that PC, buying a new one at the same price with exactly the same RAM, hard disk space, and so forth, but with a Pentium IV processor. Thanks to the improved performance of your PC, in 2001 you were able to generate 21 reports, 105 memos, and 4,200 e-mails in the same amount of time—an increase in your labor productivity of 5%. Finally, suppose that the annualized cost of your computer is a constant 10% of the total annual cost of doing your job (that is, capital costs plus your compensation). Since this technological change in a component that is only 10% of the costs of your job yielded a benefit of 5% higher productivity, we can say that your new PC is 50% (0.05/0.10) "better," or more productive, than your old PC. In other words, ETC is 50%.

Moreover, ETC may be even higher, depending on the calculation of the "real" or inflation-adjusted value of the 2000 and 2001 PCs. Many researchers in this field measure the real value of investment based on how much consumption was sacrificed. Therefore, nominal investment is deflated using a consumption price deflator (for example, the official price index for personal consumption expenditures). If, for example, PC prices did not change while the prices of consumption goods rose, the $1,500 you spent on the new PC in 2001 required giving up less consumption than the $1,500 you spent in 2000. So, since you got such a higher quality PC in exchange for less forgone consumption, the PC's ETC was even higher.

If ETC always were as easy to observe as it is in our PC example, then estimating ETC at the aggregate level would be simple: for every capital good in the economy, we could repeat the exercise of recording its cost change, its share of total costs, and its effect on productivity. Unfortunately, such things are not so easy to observe. So researchers have come up with a number of ways to get estimates of ETC. Their methods essentially follow one of two approaches—the price-side approach and the production-side approach.

The price-side approach

Some researchers have tried to measure ETC via the price side. To get at the technological change embodied in the new equipment, government statisticians and others often try to estimate "hedonic," also known as "characteristic," prices. In other words, they try to estimate the price of the characteristics of a good, e.g., RAM, processor speed, hard disk space, etc., rather than the price of the good itself. The price of a characteristic can be estimated by comparing the prices of different models of the same good, where the models differ only in terms of the characteristic in question. For example, one can estimate the price of a megabyte of RAM by comparing the price difference between a PC with 32 MB RAM an otherwise identical PC with 64 MB RAM. Essentially, by taking a weighted average of the prices of its characteristics, one can construct a constant-quality price index for a good.

Such a constant-quality price index can be constructed for all capital goods and aggregated to form an aggregate investment price index. Given certain assumptions, ETC can be measured by the percent decline in this investment price index relative to a consumption price index. This approach generally yields an estimate of annual ETC over the past 25 years of between 3% and 4% (see, for example, Hornstein and Krusell 1996 and Greenwood, et al., 1997).

There are two reasons to believe, however, that this number is understated. First, this approach has trouble dealing with what is known as the "new goods problem." This problem arises because measuring ETC essentially involves a comparison between similar goods over time. But what should be used as a basis for comparison when assessing the ETC of a fundamentally new good, one that did not exist in any recognizable form in the previous year? Fundamentally new goods pose serious challenges to hedonic techniques, which are no match for the kinds of radical technological changes that redefine the characteristics by which a product's performance is judged. Goods characterized by this type of technological change have a rapidly changing set of characteristics, rendering comparisons along those dimensions meaningless. Government statisticians try to handle the new goods problem through high-frequency (usually monthly) data collection, hoping that characteristics sets don't change very much within short time intervals. A second shortcoming of the price-side approach is that the detailed data required for hedonic price estimation often are unavailable for many capital goods, forcing those who measure prices to revert to more traditional techniques, which generally do not account for technological change very well.

The production-side approach

ETC also can be measured from the production side, as proposed in Sakellaris and Wilson (2001). This approach essentially formalizes the basic concepts used to measure ETC in our PC example and extends them to the entire economy. With the requisite data on productivity and current and past investment, one can imagine performing such an exercise for every business in the economy in order to estimate total ETC.

First, though, one must deal with the price deflator and the new goods problem. As in the price-side approach, where ETC is typically measured as the decline in investment prices relative to consumption prices, the production-side approach also defines ETC in consumption terms. In our PC example, we could measure output in terms of actual production units (memos, reports, and e-mails). In practice, we typically just observe revenues. By deflating current revenues as well as current and past nominal investment by a consumption price index, we can, in concept at least, properly identify ETC by the consumption units gained in productivity benefits relative to the consumption units given up for investment.

The main advantage of the production-side approach is that new goods do not pose a problem. The approach identifies technological change via changes in productivity (which one can think of as a single, universal dimension of quality), so changes in the actual characteristics of the underlying capital are irrelevant. If the new PC has a set of characteristics (e.g., a flat screen monitor or a DVD R/W) that the old PC could not have had because the technology did not exist, the production-side approach still picks up the increased technological change as long as these new characteristics generate productivity benefits.

Sakellaris and Wilson (2001) demonstrate how to apply the production-side approach to the aggregate economy with data on past and present investment and current productivity from a large cross-section of U.S. operations. We make use of the vast amount of plant-level observations on output, capital expenditures, and other productive inputs available from the U.S. Census Bureau. The data allow us to track the same plants over time since their inception to observe how productivity varies in response to having more or less new capital relative to old capital (controlling for differences in other relevant factors such as labor input, *total* capital, physical deterioration of capital, capital utilization, materials use, industry, year, etc.). We find that for the typical manufacturing plant between 1975 and 1996, ETC in equipment capital is about 12% per year. That is, the equipment purchased in a given year was on average 12% more productive than the equipment purchased the year before.

The production-side approach is not perfect, however. Though we do try to control for all factors that contribute to a plant's productivity, it is possible that unobserved factors could increase productivity (independent of investment in new technology), which in turn leads the plant to increase current investment. This could cause us to be mistaken in attributing the productivity increase to the rise in new capital relative to old capital; as a result, our estimate of ETC could have an upward bias. The true rate of ETC probably lies somewhere between that given by the production-side approach (generally 10% to15%) and that given by the price-side approach (3% to 4%). (It should also be noted that neither the price-side approach nor the production-side approach can distinguish between actual technological change in a capital good and reductions in the cost of producing the good—or, more accurately, the characteristics of the good. In practice, both end up as part of ETC.)

The importance of ETC to productivity

The implied growth rate of the capital stock and the resulting growth in labor productivity are critically dependent on the rate of ETC. Given observed patterns of aggregate investment in U.S. manufacturing over the past few decades, the difference in the average growth rate of the equipment capital stock (when quality improvements are taken into account) between that implied by an annual rate of ETC of 12% and that implied by a rate of 0% is 10%. If we make the standard assumptions that the structures stock is constant and that equipment is about one-sixth of total input costs (structures and labor accounting for the rest), then the annual contribution of equipment ETC to labor productivity growth is about 1.67 (10 times 1/6) percentage points which, given most estimates of average labor productivity growth in U.S. manufacturing (typically around 2.7%), implies that improvements in equipment account for a very large fraction of productivity growth.

A rate of ETC of 3% would imply historical equipment growth in manufacturing of 4% above and beyond that implied by zero ETC. Given the same assumptions, this implies that ETC is responsible for 0.67 percentage points, or a little less than a quarter, of total labor productivity growth. Knowing the contribution of ETC to labor productivity growth is vitally important to policymakers since policy, particularly monetary policy, is quite effective in influencing investment but is far less so in influencing the other sources of labor productivity.

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