Discussion

Thomas F. Cooley*

In a much-cited paper, Edward C. Prescott (1986) argued that "technology shocks account for more than half the fluctuations (in real output) in the post-war period, with a best point estimate near 75%." This claim was based on simulating a very simple model economy founded on the Solow growth model but perturbed by shocks to technology whose properties mimic Solow residuals. Since that time, many authors have tried to refine this estimate by looking at more fully articulated dynamic general equilibrium models and at models with different features of the economic environment. Some have argued, on the basis of both empirical and quantitative evidence, that the Prescott claim overstates the contribution of technology shocks. Susanto Basu in this paper and a number of earlier papers has been working on a direct approach to measuring the true technology change in the Solow residuals. This is an ambitious agenda and Basu's results are interesting and a bit puzzling.

A useful way to think about the conventional wisdom on the importance of technology shocks is described in a paper by Rao Aiyagari (1994). He proposed a model-independent way to measure the contribution of technology shocks. It requires a standard specification of technology, then three critical assumptions: 1) perfect competition; 2) no external economies; 3) no measurement error. Under these assumptions, technology shocks should be able to account for three facts that characterize U.S. business cycles: 1) The correlation between productivity and the labor input is approximately zero. 2) The variability of the labor input relative to output is 0.86. 3) Labor's share of output is about 0.64. Given these assumptions, Aiyagari shows that *either* the contribution of technology

*Professor of Economics, University of Rochester.

shocks to fluctuations in output must be about 78 percent *or* some of these facts must be violated.

What happens when we alter the basic set of assumptions? We know the following:

- Introducing monopolistic competition lowers the contribution of technology shocks.
- Introducing economies of scale lowers the contribution of technology shocks.
- Introducing wage premiums can, but need not, lower the contribution of technology shocks.
- Introducing measurement error can lower the contribution of technology shocks.

To know how much these things matter for the contribution of technology shocks, we have to know something more about a number of elasticities and about measurement error. Absent compelling evidence that these things are important, Prescott's estimate seems pretty good.

Basu in this paper tries to address some of these issues directly by getting an empirical estimate of the size of technology shocks. He constructs a new series of aggregate technology change that controls for the following:

- imperfect competition,
- variable utilization of capital and labor, and
- aggregation bias.

Given this series, he investigates how well current business-cycle models can explain movements in business-cycle variables following an improvement in technology as measured by his technology change series, and how much they can explain historical output fluctuations. Lastly, he compares the performance of two business-cycle models, a standard real business cycle (RBC) model with variable factor utilization and a sticky-price model with variable factor utilization.

The empirical finding of the paper is quite striking. It suggests that technology changes have contractionary effects in the short run. This conclusion derives from the fact that the correlation between his corrected series of technological change and output growth is *low*, and from the finding that the correlation between his corrected series of technological change and input growth is *negative*.

Basu uses this series to show, via a quantitative exercise, that an RBC model with variable capital utilization cannot explain these findings. He also uses it to argue in favor of a sticky-price view of the world by showing that a model with sticky prices and variable capital utilization does a slightly better job.

The Economic Environment

The basic assumption is that there are cost-minimizing firms with access to the production technology

$$Y = F(\tilde{K}, \tilde{L}, M, T), \qquad \underbrace{\tilde{L}}_{\text{labor services}} = EHN, \qquad \underbrace{\tilde{K}}_{\text{capital services}} = ZK \tag{1}$$

- K and N are quasi-fixed, but H, E, and Z can vary in the short run.
- M represents intermediate inputs and energy.
- T indexes technology.
- F is (locally) homogeneous of arbitrary degree γ.

$$\gamma = \frac{F_1\tilde{K}}{Y} + \frac{F_2\tilde{L}}{Y} + \frac{F_3M}{Y} \tag{2}$$

This setup, with a bit of work, leads to the following estimating equation for the markup, based on totally differentiating the production function:

$$\begin{aligned} dy &= \mu[s_K(dk + dz) + s_L(dn + dh + de) + s_m dm] + dt \\ &= \mu[s_K dk + s_L(dn + dh) + s_M dm] + \mu[s_K dz + s_L de] + dt \\ &= \mu \underbrace{dx}_{\substack{\text{share-weighted} \\ \text{average of observed input growth}}} + \mu du + dt \end{aligned} \tag{3}$$

The problem in estimating this is to find some suitable proxies for the utilization term du. Here Basu exploits the results of several of his other papers. Basu and Kimball (1997) use the basic insight that a cost-minimizing firm operates on all margins simultaneously, both observed and unobserved, to show that increases in observed inputs can proxy for unobserved changes in utilization. Basu and Fernald (1997) argue that under a variety of conditions—for example, different industries having different degrees of market power—inputs may have different marginal products in different uses. Aggregate productivity growth depends on which sectors change input use over the business cycle. To get the "right" aggregate technology index, one should correct sectoral Solow residuals and then aggregate across sectors.

Why does an RBC model with variable capital utilization do a poor job? There are several reasons for procyclical productivity:

- procyclical technology,
- imperfect competition and increasing returns,
- cyclical factor utilization, and
- cyclical reallocation of resources with different marginal products.

Basu controls for these three nontechnological components of measured productivity and derives technology as a residual. Empirically, we know from his work and the work of others that increasing returns and imperfect competition are not likely to be important and that cyclical factor utilization and cyclical reallocation seem to be the most important factors generating the negative correlation between technology and inputs.

Basu argues that a sticky-price model seems to be more consistent with these findings, and the intuition is fairly simple. Suppose the quantity theory governs the demand for money. In the short run, if the supply of money is fixed and prices cannot adjust, real balances and output are fixed. In this setup, a positive technology shock will lead to *less* employment and hours, since firms need less labor to produce the fixed output, leading to the negative relationship between technology change and factor inputs.

How should we think about the findings of the paper? In discussing this I want to emphasize two issues. The first is whether we should be concerned about the apparent reduced importance of the technology shocks and the negative contemporaneous correlation with inputs. The second is whether this should lead you naturally to think about sticky price models.

First, I think we have moved a long way from the original real business cycle view of the world that relied on large, very volatile and persistent aggregate technology shocks to produce output fluctuations at the business cycle frequency. Burnside, Eichenbaum, and Rebelo (1995) and Burnside and Eichenbaum (1996) have shown that cyclical factor utilization is an important propagation mechanism for business cycle shocks. Other work models firm heterogeneity and firm financial decisions and finds these to be important and powerful sources of propagation for business cycle shocks (Cooley and Quadrini 1997; Bernanke, Gertler, and Gilchrist 1998). All of these things suggest that the size and persistence of technology shocks needed to generate fluctuations are greatly reduced. This does not address the finding that the technology residual is only weakly correlated with output, but that finding is very sensitive to the choice of instruments and to the identifying assumptions that the paper uses.

Should these findings lead you to think of this as evidence for sticky prices? As indicated above, the findings do fit the sticky-price framework to some extent, but there is no direct evidence to support this. Moreover, theory makes no clear prediction about whether labor or capital is likely to work more or less in response to technology improvements. Examples are abundant of improvements in technology due to changes in organization or work rules where output remains unchanged and inputs fall. Clearly, the nature of industry equilibrium, whether final demand is elastic or inelastic, may be important for this. The nature of the technology is also important. If technology is embodied in capital—a vintage capital world—improvements in technology can lead to reallocation of labor from older to newer vintages and employment can fall in the short run. This is a feature of the model in Campbell (1998).

I would be led in the direction of thinking that these results suggest that we may have the wrong model and that investment-specific technological change may be important. For example, Greenwood, Hercowitz, and Krusell (1998) simulate an economy where the only shock to the economy is investment-specific technology change of the form

$$k = (1 - \delta(h)k + iq.$$

Here depreciation is related to utilization; the term iq captures the technical change. They calibrate q using Gordon's (1990) price series. Unlike in standard RBC models, the technology shock here does not directly affect the production function in the current period. The current output is affected by the decline in marginal utilization cost of capital. Although equipment investment is only 7 percent of GNP, this transmission mechanism turns out to be important. Their findings suggest that this form of technological change is a source of about 30 percent of output fluctuations.

Considerations like this would imply a mis-specification in the empirical part of the analysis. It may be that, absent direct evidence of price rigidity, we should think about the implications of a vintage capital world. In vintage capital models, depreciation is typically economic rather than physical. If that is the case, then there is a danger of overstating the consequences of cyclical factor utilization. Moreover, in a vintage capital world with learning-by-doing, as in Cooley, Greenwood, and Yorukoglu (1997) or Greenwood and Yorukoglu (1996), technological change can be associated with contemporaneous output declines.

These are all reasons why I would be slow to argue that this evidence suggests technology shocks have little to do with business cycles. What is the alternative? Nevertheless, I think this is interesting work. It forces us to think hard about the nature of technology shocks; it adds to the body of persuasive evidence that suggests that increasing returns are not an important feature of the data and that cyclical factor utilization is important.

References

Aiyagari, S. Rao. 1994. "On the Contribution of Technology Shocks to Business Cycles." *Quarterly Review*, Federal Reserve Bank of Minneapolis, Winter, pp. 22–34.

Basu, Susanto and John Fernald. 1997. "Aggregate Productivity and Aggregate Technology." International Finance Discussion Paper 593, Board of Governors of the Federal Reserve System.

Basu, Susanto and Miles Kimball. 1997. "Cyclical Productivity with Unobserved Input Variation." NBER Working Paper No. 5915.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. 1998. "The Financial Accelerator in a Quantitative Business Cycle Framework." NBER Working Paper No. 6455, *Handbook of Macroeconomics,* forthcoming.

Burnside, Craig and Martin Eichenbaum. 1996. "Factor Hoarding and the Propagation of Business Shocks." *The American Economic Review, 86,* pp. 1154–74.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo. 1995. "Capital Utilization and Returns to Scale." In B. Bernanke and J. Rotemberg, eds. *NBER Macroeconomics Annual 1995.* Cambridge, MA: The MIT Press.

Campbell, Jeffrey R. 1998. "Entry, Exit, Embodied Technology, and Business Cycles." *Review of Economic Dynamics, 1, No. 2,* pp. 371–408.

Cooley, Thomas F., Jeremy Greenwood, and Mehmet Yorukoglu. 1997. "The Replacement Problem." *Journal of Monetary Economics, 40, 3,* pp. 435–56.

Cooley, Thomas F. and Vincenzo Quadrini. 1997. "Monetary Policy and the Financial Decisions of Firms." Working Paper, University of Rochester.

Gordon, R. 1990. *The Measurement of Durable Goods Prices.* Chicago: University of Chicago Press.

Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell. 1998. "The Role of Investment-Specific Technological Change in the Business Cycle." *European Economic Review,* forthcoming.

Greenwood, Jeremy and Mehmet Yorukoglu. 1997. "1974." *Carnegie-Rochester Series on Public Policy, 46,* pp. 49–95.

Prescott, Edward C. 1986. "Theory Ahead of Business Cycle Measurement." *Quarterly Review,* Federal Reserve Bank of Minneapolis, Fall, pp. 9–22.