DISCUSSION

Mark Bils*

Hall (1987) wrote, "Hardly any fact about the United States economy is better established than the procyclical behavior of productivity." But in Basu and Kimball (1997), Basu, Fernald, and Kimball (1998), and in this paper, Basu and his coauthors (from here on Basu) argue that, correctly measured, *technology shocks* are not procyclical. They are very negatively correlated with inputs, including hours of work, and largely uncorrelated with output.

A key element of Basu's papers is to instrument for cyclical fluctuations using variables arguably orthogonal to technology shocks. Papers by Gali (1998) and Kiley (1997) also conclude that technology shocks are very negatively correlated with inputs. But those authors identify technology shocks very differently, using structural restrictions on a VAR. It is interesting that these two sets of papers, with very different approaches, have similar results. Both sets of papers stress output-price stickiness as key to understanding the strong negative relationship between technology shocks and inputs.

I first review Basu's exercise, asking whether it perhaps adjusts too much for procyclical factor utilization. My primary objective, however, is to test the conclusions of Basu, Gali, and Kiley that the negative correlation they find between inputs and their technology shocks is support for sticky prices.

COUNTERCYCLICAL TECHNOLOGY SHOCKS

At least since Jorgenson and Griliches (1967), procyclical unmeasured utilization of factors has been viewed as part of the explanation for

*Associate Professor of Economics, University of Rochester.

Table 1
Correlations of TFP Growth and Productivity Growth with Growth in Output and Hours, Aggregate Data

	ΔLn(Y)	ΔLn(N)
ΔLn(TFP)	.81	.40
ΔLn(Y/N)	.56	.04

Note: Data are for the total private U.S. economy, annually for 1948 to 1994.
Source: U.S. Bureau of Labor Statistics.

procyclical productivity. Basu allows for procyclical capital utilization and procyclical labor effort. Most writers, including Jorgenson and Griliches (1967) and Shapiro (1993), have focused on capital utilization. Suppose, for the moment, that firms add to production by extending the workweek, say, by adding a sixth weekly workday on Saturday. This would seem to increase worker hours, utilized capital, and output all by one-fifth. Output per hour worked is unaffected. If we take this as a reference point, it suggests looking at output per hour worked (labor productivity) as a simple alternative measure of technology shocks.

Table 1 compares the cyclical behavior of total factor productivity (TFP) to that for labor productivity. The table gives correlations of TFP and labor productivity first with output, then with hours. The series are annual growth rates for aggregate (private sector) U.S. data for 1948 to 1994. Adopting labor productivity as a measure of technology eliminates the positive correlation of technology shocks with hours, but a strong positive correlation remains with output.

In addition to cyclical factor utilization, Basu also generalizes TFP accounting to allow for imperfect competition. His estimate of the gross markup, however, is essentially one (perfect competition), so the impact of imperfect competition is nil. Basu also employs disaggregated data to reduce biases from aggregating. Table 2 repeats the correlations reported in Table 1, but this time calculated for annual data from 1958 to 1994 for

Table 2
Correlations of TFP Growth and Productivity Growth with Growth in Output and Hours, 4-digit Manufacturing Data

	ΔLn(Y)	ΔLn(N)
ΔLn(TFP)	.61	.27
ΔLn(Y/N)	.63	−.05

Note: Data are for 450 U.S. manufacturing industries, annually for 1958 to 1994. As a result of calculating inventory accumulation and first differencing, observations are for 1960 to 1994.
Source: *NBER Productivity Database.*

450 4-digit manufacturing industries. These data are taken from the *NBER Productivity Database* and largely reflect information in the *Annual Surveys of Manufactures*. (Basu employs 2-digit data and incorporates information beyond manufacturing.) Comparing Tables 1 and 2, the correlation between output and labor productivity drops from .40 to .27, but remains very significantly positive. The correlation between hours and labor productivity is now negative (−.05), but much less so than for Basu's technology shock. I would conclude that Basu's most important adjustments to TFP reflect the allowances for procyclical factor utilization.

My reference point supposes that utilized capital moves one-for-one with hours. By assuming that production is Cobb-Douglas in materials as well as capital and labor, Basu treats capital input as moving like the cost of materials (subtracting movements in capital's shadow price). Materials costs vary much more cyclically than do labor costs. As a result, I believe Basu's series for utilized capital is considerably more procyclical than hours worked.

Also departing from my reference point, Basu has quality of labor input varying because of procyclical effort. How the quality of labor input varies cyclically is an open question. Bils and Cho (1994) and Basu cite evidence contained in Schor (1987) that effort measures for piece-rate workers in England vary positively with hours per worker. But these variations are relatively small. On the other hand, there is considerable evidence that the workers who are added to the work force in an expansion are considerably lower-paid (for example, from Solon, Barsky, and Parker 1994, by more than 30 percent), and presumably of lower quality. I would expect the effect of adding less able workers in booms to dominate any variations in effort, making quality of effort countercyclical.

Basu's series is based on a formal model, identifying assumptions, and estimation. So to attack Basu's results, ultimately one must confront his identification. Basu instruments for cyclical fluctuations using government spending, oil prices, and monetary variables. This maps out a predicted relationship between outputs and inputs under the presumption of a constant technology. Deviations from that relationship are then interpreted as technology shocks. I interpret Basu's findings as follows: Productivity is actually more positively correlated with instrumented changes in inputs than with all changes in inputs. This implies that Basu's residual measure of technology shocks must be negatively correlated with inputs. Basu interprets this as true technology shocks creating, given sticky prices, a fall in inputs.

But suppose that at a cyclical frequency technology shocks are fairly unimportant. Then movements in TFP largely reflect variations in the utilization or quality of inputs. If the variations in these inputs are more procyclical for the instrumented expansions than for expansions in hours more generally, this is sufficient to qualitatively generate Basu's findings.

Why might factor utilization vary more for some fluctuations, more exactly Basu's instrumented fluctuations, than for others? The instruments Basu uses, oil shocks and the like, are relatively transitory shocks. We would expect greater use of increased factor utilization for more transitory shocks. Furthermore, transitory fluctuations lead to smaller employment increases relative to hours per worker, and therefore less of a reduction in the average quality of worker.[1]

Second, Basu assumes a constant relation between effort and hours. Similarly, in Bils and Cho (1994) preferences are such that workers will simultaneously adjust leisure at home and leisure at work, resulting in a perfect correlation between hours per worker and effort per hour. But central to that result is a labor market in which wages are perfectly flexible, or firms and workers behave as though wages are perfectly flexible. Bils and Chang (1998) show that if wages are sticky, then effort goes up with hours for some shocks, but down for others. For example, a positive shock to government spending (one of Basu's instruments) should, under market clearing, result in a fall in the real wage. If rigidities prevent the real wage from falling, then effort rises to clear the market simultaneously with an increase in hours. By contrast, for a technology shock the market-clearing real wage should rise. If wage rigidity prevents this, then effort actually falls to clear the labor market simultaneously with an increase in hours.

Finally, and perhaps most important, if inputs are measured with error in the disaggregate data, then it is possible to find a stronger impact of inputs on output when one instruments with variables orthogonal to technology shocks, *even if true technology shocks are positively correlated with inputs*. This result is in fact expected if technology shocks are relatively unimportant.

Inventories and the Response of Hours to Technology Shocks

Why might inputs be negatively correlated with technology shocks? One possibility is that product demands are inelastic, at least in the short run. By contrast, Basu, as well as Gali (1998), Kiley (1997), and Basu, Fernald, and Kimball (1998), focus on sticky prices. The reasoning is straightforward. With a predetermined (sticky) price, sales are given. For given sales and output, a rise in productivity must reduce inputs.

Generally speaking, sales do not equal production. If firms produce

[1] Basu and Kimball (1997) attempt to correct for worker quality by using a quality-of-worker index constructed by Dale Jorgenson. But this index only adjusts for the observable traits of sex, education, and experience. It rationalizes only a small portion of the differences in earnings across workers found by Solon, Barsky, and Parker (1994) and others.

Table 3
Response of Hours to Labor Productivity

	ΔLn(N)	
ΔLn(Y/N)	−.096 (.0089)	−.267 (.047)
$\frac{\bar{I}}{\bar{S}}$		−.047 (.012)
$\left(\frac{\bar{I}}{\bar{S}}\right)\Delta Ln(Y/N)$		1.009 (.129)

Note: Data are for 450 U.S. manufacturing industries, 1958–1994; see Table 2.
Standard errors are in parentheses.
Regressions include time dummies.
Source: See Table 2.

to stock or hold nontrivial working inventories, then, in response to a favorable cost shock, firms can expand output relative to sales. They would do so to exploit any transitory nature of a productivity increase and also to increase inventory stocks up to higher anticipated levels of production and sales (for example, Kahn 1987). This suggests examining the response of inputs to technology shocks for industries where inventories are important separately from those where they are less important. Even under flexible prices we expect inputs to respond more to cost shocks if firms can inventory their output (for example, West 1991). But the role of inventories will be particularly important if prices are sticky.

Table 3 presents the response of labor hours to labor productivity. The variables again are in terms of annual growth rates and the data are for the 450 industries in the *NBER Productivity Database*. (The regression includes dummies for each of the time periods.) Looking at Column 1, an increase of 1 percentage point in labor productivity is associated with a fall in hours of about 0.10 percent, with a standard error of 0.0089 percent. (By comparison, a 1 percentage point increase in TFP is associated with an increase in hours of 0.37 percent, with a standard error of 0.012 percent.)

The second column of Table 3 adds two additional variables: the average ratio of inventories to sales for the industry for the period 1958 to 1994, and this ratio interacted with the growth rate in labor productivity. As predicted, labor hours are much less likely to decline for inventories that hold significant inventories. The interaction variable has a coefficient of 1.009 with a standard error of 0.129. For an industry with an inventory-sales ratio of 0.16, which is the mean across industries, this implies that hours fall by 0.105 percent for each percentage point increase in labor productivity. By contrast, for an industry with an inventory-sales

Table 4
Response of Prices to Labor Productivity

	ΔLn(P)	
ΔLn(Y/N)	−.199 (.0044)	−.238 (.011)
$\frac{\bar{I}}{\bar{S}}$		.0097 (.0061)
$\left(\frac{\bar{I}}{\bar{S}}\right)\Delta Ln(Y/N)$		.232 (.064)

Note: Data are for 450 U.S. manufacturing industries, 1958–1994; see Table 2.
Standard errors are in parentheses.
Regressions include time dummies.
Source: See Table 2.

ratio of 0.30, equaling two standard deviations above the mean, hours would actually rise slightly, by 0.033 percent.

As discussed just above, however, we should expect inventory holding to be associated with a more positive response of hours even if prices are completely flexible. So it is useful to examine price behavior more directly.

Evidence on Sticky Prices

As I have stated, Basu in this paper, Basu, Fernald, and Kimball (1998), Gali (1998), and Kiley (1997) all attribute a negative correlation between technology shocks and inputs to sticky prices. Nevertheless, these papers do not directly examine how prices respond to their constructed technology shocks. Here I take a look at price responses for my simple measure of technology shocks, labor productivity.

The first column of Table 4 relates industry price changes, again for the *NBER Productivity Database*, to industry growth in labor productivity. The regression includes time dummies, so fluctuations in variables are judged relative to movements in manufacturing as a whole. A 1 percentage point increase in productivity is associated with a very significant fall in price of 0.20 percent (standard error 0.0044). For comparison, a 1 percentage point increase in measured TFP in an industry is associated with a price decrease of 0.40 percent (standard error 0.0057 percent). So prices do respond rather dramatically to these measures of productivity movements.

The second column of Table 4 again interacts growth in labor productivity with the industry's average ratio of inventories to sales. Flexible price models would suggest that firms cut price less in response

Table 5
Response of Prices to Productivity

	$\Delta Ln(P_t)$	
$\Delta Ln(TFP_t)$	−.408 (.0059)	
$\Delta Ln(TFP_{t-1})$	−.038 (.0059)	
$\Delta Ln(Y_t/N_t)$		−.205 (.0045)
$\Delta Ln(Y_{t-1}/N_{t-1})$		−.031 (.0046)

Note: Data are for 450 U.S. manufacturing industries, 1958–1994; see Table 2.
Standard errors are in parentheses.
Regressions include time dummies.
Source: See Table 2.

to a technology shock if they can produce for inventory. By the reasoning in the previous section, the firm that produces to inventory exhibits a larger output response to the technology shock. If short-run marginal cost is upward-sloping, this leads to a higher marginal cost and a higher price. In fact, the interaction is significantly positive (coefficient of 0.232 with a standard error of 0.064), providing some support for the joint hypothesis of upward-sloping marginal cost and price flexibility.

Finally, Table 5 presents the industry relative price response to both this year's and last year's productivity growth. If prices are sticky, we should expect lagged productivity growth to enter significantly, as productivity shifts are clearly persistent. The first column measures productivity shifts by growth in TFP. The previous year's growth in TFP does enter statistically very significantly in reducing this year's price increase. The magnitude of the effect is not large, however, being a full order of magnitude smaller than the negative impact of current TFP growth. The second column measures productivity shifts by labor productivity, with results similar to those for TFP. Last year's growth in labor productivity does reduce this year's price increase, but the impact is less than one-sixth of that for current growth in labor productivity.

In Conclusion

To my knowledge, no one has shown that technology shocks, correcting in some reasonable manner for utilization, are positively correlated with inputs. On the other hand, we have no reason, outside of some questionable parameter choices by calibrators, to expect a priori that output will increase more than proportionately to a favorable technology shock. So I do not see it as puzzling that inputs might be negatively affected by improvements in technology.

Basu's clever efforts lead him to conclude not only that inputs are negatively correlated with technology shocks, but that the magnitude of this relation is *very large*. The magnitude is so large, in fact, that output is not positively correlated with technology shocks. I am more than willing to recognize a zero correlation between output and technology innovations as a startling puzzle. To calm myself (if not others) I have offered some reasons why Basu's approach might overly correct for procyclical factor utilization, thereby hiding a strong positive correlation between technology shocks and output.

I have also presented some tentative evidence on price rigidities, which Basu suggests may be the source of a weak relation between shocks to technology and output. I find that labor responds considerably more positively to productivity improvements if firms hold considerable inventories. This is potentially consistent with price rigidities. But more important, in my view, is the fact that industry prices fall substantially when productivity increases, suggesting a fairly limited role for sticky prices.

References

Basu, Susanto and Miles S. Kimball. 1997. "Cyclical Productivity with Unobserved Input Variation." Manuscript.

Basu, Susanto, John G. Fernald, and Miles S. Kimball. 1998. "Are Technology Improvements Contractionary?" Manuscript.

Bils, Mark and Yongsung Chang. 1998. "Wages and the Allocation of Hours and Effort." Manuscript.

Bils, Mark and Jang-Ok Cho. 1994. "Cyclical Factor Utilization." *Journal of Monetary Economics* 33 (April), pp. 319–54.

Gali, Jordi. 1998. "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" Forthcoming, *The American Economic Review.*

Hall, Robert E. 1987. "Productivity and the Business Cycle." *Carnegie-Rochester Conference Series on Public Policy* 27, pp. 421–44.

Jorgenson, Dale W. and Zvi Griliches. 1967. "The Explanation of Productivity Change." *Review of Economic Studies* 34, pp. 249–83.

Kahn, James A. 1987. "Inventories and the Volatility of Production." *The American Economic Review* 77, pp. 667–79.

Kiley, Michael. 1997. "Labor Productivity in U.S. Manufacturing: Does Sectoral Comovement Reflect Technology Shocks?" Manuscript.

Schor, Juliet B. 1987. "Does Work Intensity Respond to Macroeconomic Variables? Evidence from British Manufacturing, 1970–1986." Manuscript.

Shapiro, Matthew D. 1993. "Cyclical Productivity and the Workweek of Capital." *The American Economic Review* 83 (May), pp. 229–33.

Solon, Gary, Robert Barsky, and Jonathan Parker. 1994. "Measuring the Cyclicality of Real Wages: How Important Is Compositional Bias?" *Quarterly Journal of Economics* 109, pp. 1–25.

West, Kenneth. 1991. "The Sources of Fluctuations in Aggregate Inventories and GNP." *Quarterly Journal of Economics* 106, pp. 939–72.