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ARE PRODUCTIVITY FLUCTUATIONS DUE TO REAL SUPPLY SHOCKS?

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Shapiro (1987) draws support for real business cycle theories from the behavior of cost-based and output-based measures of productivity. This evidence is examined and shown to rely on spurious correlations.

1. Introduction

Equilibrium real business cycle models focus on exogenous shifts in productivity as the source of business fluctuations. The 'Keynesian alternative' argues that most of the procyclical movement in productivity represents labor hoarding by firms; that is, in the face of negative demand shocks, firms pay for more worker-hours than is necessary for the production accomplished. [1] Shapiro (1987) argues that if movements in the quantity-based measure of productivity are true productivity shocks, then they should be closely related to movements in the price-based dual productivity measure. If, on the other hand, labor hoarding is prevalent, the quantity-based measure of productivity should be correlated with demand. In this note, the empirical implementation of this test by Shapiro (1987) is criticized. Shapiro uses a special form of the price-based productivity measure that is spuriously correlated with the quantity-based measure; thus, he finds little residual productivity movement that must be explained by demand shocks. The next section outlines Shapiro's analysis and establishes notation, and section 3 provides empirical results.

2. Two measures of productivity

Consider a production function,

$$Y_t = f(N_t, K_t) E_t^Q, \tag{1}$$

where Y_t and N_t are the real flows of output and labor services, while K_t is the stock of capital, and E_t^Q is the productivity level during period t. Assume that firms face competitive markets and are efficient in production; inputs are then paid the value of their marginal product,

$$\frac{\partial Y_t}{\partial N_t} = \frac{W_t}{P_t}, \qquad \frac{\partial Y_t}{\partial K_t} = \frac{R_t}{P_t}, \tag{2}$$

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[1] See the overviews by McCallum (1988) and Fay and Medoff (1985).

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where P_t, R_t, W_t are the price of output, the rental rate of capital, and the wage rate of labor services. Let Δz_t represent the time derivative of the logarithm of a variable Z_t; then logarithmic differentiation of (1) and substitution from (2) obtains

$$\Delta e_t^{\mathrm{Q}} = \Delta y_t - \alpha_t \, \Delta n_t - \beta_t \, \Delta k_t, \tag{3}$$

where $\alpha_t = W_t N_t / P_t Y_t$ and $\beta_t = R_t K_t / P_t Y_t$ are the income shares of labor and capital. Under constant returns to scale in production, $\alpha_t + \beta_t = 1$, and the Solow (1957) residual can be calculated as

$$\Delta e_t^{\mathrm{Q}} = \Delta y_t - \alpha_t \, \Delta n_t - (1 - \alpha_t) \, \Delta k_t \tag{4}$$

(and the assumption that capital is paid its marginal product is not strictly necessary). These changes in productivity are interpreted by real business cycle proponents are true shifts of the production function. Under the alternative of labor hoarding, cyclical variations in productivity are simply the result of firms operating 'off' of a short-run production function – holding more labor, for example, than is strictly necessary for the output produced.

Another definition of productivity changes is based on the discrepancy between movements in output price and in share-weighted factor prices. Under constant returns to scale, the cost function has the form

$$C_t = g(W_t, R_t) Y_t / E_t^{\mathrm{P}}, \tag{5}$$

where C_t is the minimum cost of producing output Y_t, given W_t, R_t, and productivity level E_t^{P}. Under constant returns to scale and assuming that labor and capital are paid their marginal product, $P_t Y_t = R_t K_t + W_t N_t = C_t$, logarithmic differentiation of (5) and application of Shephard's lemma yields

$$\Delta e_t^{\mathrm{P}} = -\Delta p_t + \alpha_t \, \Delta w_t + (1 - \alpha_t) \, \Delta r_t, \tag{6}$$

so that any increase in costs not recouped in price must reflect an increase in productivity.

Shapiro (1987) argues that the nature of the deviation between these two measured indicates the source of the quantity-based productivity fluctuations, in particular, whether these fluctuations represent true technical changes or are simply labor hoarding by firms in response to changes in demand. If the output-based measure reflects true technical productivity change, then it should be identical to the price-based measure. On the other hand, under the Keynesian alternative, quantity-based productivity fluctuations occur because firms hoard labor in off-the-production-function behavior, and the quantity-based measure has little to do with the true productivity of the factors of production. The actual production function and underlying productivity have not shifted, so there is no reason for factor prices to adjust. Cyclical labor hoarding will be reflected in the quantity-based measure but not in the price-based measure.

3. Empirical relationship between primal and dual productivity

Under the null hypothesis that productivity fluctuations are technical changes, a regression of Δe_t^{Q} on Δe_t^{P} should yield a slope coefficient of one and an R^2 of one. Of course, in practice, specification and measurement errors exist, so this relationship will not be exact. However, in a regression of Δe_t^{Q}

on Δe_t^P and a cyclical measure of demand, say changes in aggregate real GNP, the demand variable should have a coefficient close to zero. If the demand variable were significant, it would indicate a demand-driven component in the discrepancy between the two productivity measures and support the Keynesian alternative that fluctuations in the quantity measure result from movements in demand. All regressions use annual data from 1950 through 1985 with variables defined exactlly as in Shapiro (1987). [2]

For aggregate manufacturing, using the productivity definitions given in eqs. (4) and (6), estimates of the productivity regressions (with standard errors in parentheses) are [3]

$$\Delta e_t^Q = \underset{(0.63)}{2.27} - \underset{(0.26)}{0.23}\,\Delta e_t^P, \qquad \bar{R}^2 = 0.0, \quad DW = 1.68, \tag{7}$$

$$\Delta e_t^Q = \underset{(0.57)}{-0.86} - \underset{(0.16)}{0.31}\,\Delta e_t^P + \underset{(0.13)}{0.95}\,\Delta GNP_t, \qquad \bar{R}^2 = 0.62, \qquad DW = 1.32. \tag{8}$$

There is little evidence that the quantity-based and price-based productivity measures move together [eq. (7)], and strong evidence that their difference is related to demand [eq. (8)].

Shapiro notes, however, that these results assume that the firm can adjust its capital stock quickly enough during the year to attain an optimal level. If the marginal productivity of the capital stock does not equal the real cost of capital, then the derivation of the price-based measure, Δe_t^P, is invalid. His solution is to reformulate Δe_t^P assuming a Cobb–Douglas production function and the requirement that changes in the capital stock must be decided at least one year in advance. Under such assumptions, the cost of capital measurments of captital input in the price-based measure are replaced by quantity measurements, and a mongrel price/quantity measure of productivity is obtained:

$$\Delta e_t^{CD} = \alpha(-\Delta p_t + \Delta w_t) + (1-\alpha)(\Delta y_t - \Delta k_t), \tag{9}$$

where α is the Cobb–Douglas share parameter. (The estimate of α used is the average of the α_t.) Shapiro replaces Δe_t^P with Δe_t^{CD} and runs these regressions: [4]

$$\Delta e_t^Q = \underset{(0.37)}{-0.40} + \underset{(0.11)}{1.13}\,\Delta e_t^{CD}, \qquad \bar{R}^2 = 0.75, \quad DW = 2.03, \tag{10}$$

$$\Delta e_t^Q = \underset{(0.44)}{0.76} + \underset{(0.18)}{0.92}\,\Delta e_t^{CD} + \underset{(0.17)}{0.24}\,\Delta GNP_t, \qquad \bar{R}^2 = 0.76, \quad DW = 1.81. \tag{11}$$

These results appear much more favorable to the real supply shock argument; the coefficient of Δe_t^{CD} is close to one, and cyclical changes in GNP have very little residual explanatory power (note the negligible increase in $\bar{R}^2$). It is on these results that Shapiro bases his conclusions. However, these conclusions are only justified if Δe_t^{CD} represents a legitimate price-based measure of productivity. Shapiro asserts that it is 'importantly dependent upon the real wage', but given that Δy_t and Δk_t are common components to both Δe_t^Q and Δe_t^{CD}, the correlation between these two measures of

[2] A listing of the data and further regression results can be found in the working paper version of this paper, Rudebusch (1987).

[3] The coefficients of eq. (7) should be identical to those of eq. (14) in Shapiro (1987, p. 122); however, his regression results are in error owing to an incorrect calculation of the price-based productivity measure.

[4] These are equivalent to eqs. (15) and (17) in Shapiro (1987, p. 122).

productivity may be artificially inflated. The degree of this spurious correlation can be assessed by splitting Δe_t^{CD} into its price and quantity components. Two regressions of Δe_t^{Q} on the separate components of Δe_t^{CD} provide an indication of the marginal explanatory power of the price variables:

$$\Delta e_t^{\mathrm{Q}} = \underset{(1.2)}{0.13} + \underset{(0.49)}{0.92}\left[\alpha(-\Delta p_t + \Delta w_t)\right], \qquad \bar{R}^2 = 0.07, \quad DW = 1.92, \tag{12}$$

$$\Delta e_t^{\mathrm{Q}} = \underset{(0.37)}{1.95} \underset{(0.16)}{-0.02}\left[\alpha(-\Delta p_t + \Delta w_t)\right] + \underset{(0.09)}{1.60}\left[(1-\alpha)(\Delta y_t - \Delta k_t)\right],$$
$$\bar{R}^2 = 0.91, \qquad DW = 1.79. \tag{13}$$

Changes in the real wage have almost no explanatory power for changes in quantity-measured productivity, and as an element of Δe_t^{CD}, the real wage contributes nothing to the correlation with Δe_t^{Q}. The fact that Δe_t^{Q} is correlated with elements of itself should hardly be construed as evidence in support of supply-side fluctuations in productivity.

Finally, I provide another empirical test of the importance of technical change in productivity fluctuations built upon the framework outlined in section 2. Rather than measuring the capital input as a stock and being forced to adjust Δe_t^{P}, one can use the product of capacity utilization and the capital stock as a measure of capital input to construct a Δe_t^{Q} consistent with fluctuations in prices, where R_t is defined as the rental rate of capital services. The assumption that capital services are paid the value of their marginal product is far more tenable than the assumption, discarded at the beginning of this section, that the capital stock is paid its marginal product. A correction for utilization is common in the literature on productivity analysis and is made, for example, in Solow's (1957) original work and in Jorgenson and Griliches (1972).

The Federal Reserve's capacity utilization index, U_t, is used to construct a capital input, $K_t^* = U_t K_t$, for the capital services Solow residual, $\Delta e_t^{\mathrm{Q}*}$, in eq. (4). The productivity regression for aggregate manufacturing yields

$$\Delta e_t^{\mathrm{Q}*} = \underset{(0.37)}{2.11} \underset{(0.15)}{-0.26}\,\Delta e_t^{\mathrm{P}}, \qquad \bar{R}^2 = 0.05, \quad DW = 1.43, \tag{14}$$

$$\Delta_t^{Q*} = \underset{(0.49)}{0.95} \underset{(0.13)}{-0.28}\,\Delta e_t^{\mathrm{P}} + \underset{(0.11)}{0.35}\,\Delta GNP_t, \qquad \bar{R}^2 = 0.27, \quad DW = 1.36. \tag{15}$$

There is no evidence that changes in output productivity are reflected in prices or that they are true technical changes. Furthermore, the productivity fluctuations are highly correlated with demand, as they should be under labor hoarding.

4. Conclusion

The above results indicate that the swings in (quantity-based) productivity are not reflected in prices and cannot be accounted for as technical change. Instead, productivity movements, even after subtracting the technical changes reflected in prices, appear to be closely related to demand fluctuations.

References

Fay, Jon A. and James L. Medoff, 1985, Labor and output over the business cycle: Some direct evidence, American Economic Review 75, no. 4, Sept., 638–655.

Jorgenson, D.W. and Z. Griliches, 1972, The explanation of productivity change, Survey of Current Business 52, May, 3–36.

McCallum, Bennett T., 1988, Real business cycle models, in: Robert J. Barro, ed., Handbook of modern business cycle theory, forthcoming.

Rudebusch, Glenn, 1987, Are productivity fluctuations due to real supply shocks?, Economic Activity working paper no. 76 (Federal Reserve Board, Washington, DC).

Shapiro, Matthew D., 1987, Are cyclical fluctuations in productivity due more to supply shocks or demand shocks?, American Economic Review, Proceedings 77, May, 118–124.

Solow, Robert M., 1957, Technical change and the aggregate production function, The Review of Economics and Statistics 39, Aug., 312–320.