ARE CYCLICAL FLUCTUATIONS
IN PRODUCTIVITY DUE MORE
TO SUPPLY SHOCKS
OR DEMAND SHOCKS?

Matthew D. Shapiro

Are Cyclical Fluctuations in Productivity
Due More to Supply Shocks or Demand Shocks?

ABSTRACT

Measured productivity is strongly procyclical. Real business cycle theories
suggest that actual fluctuations in productivity are the source of
fluctuations in aggregate output. Keynesian theories maintain that
fluctuations in aggregate output come from shocks to aggregate demand.
Keynesian theories appeal to labor hoarding or off the production function
behavior to explain the procyclicality of productivity. If observed
productivity shocks are true productivity shocks, a function of factor
prices should covary exactly with productivity. In annual data for U.S.
industries, that function of factor prices and conventionally-measured
productivity move together very closely. Moreover, their difference is
uncorrelated with aggregate output.

Matthew D. Shapiro
NBER
1050 Massachusetts Avenue
Cambridge, MA 02138

Productivity plays a central role in the business cycle. Measured productivity varies positively with output. The procyclicality of productivity is a focus of recent debates over the sources of economic fluctuations. Real business cycle theories take shocks in productivity as a source of business cycles.[1] (See Kydland and Prescott (1982), Long and Plosser (1983), Prescott (1986), and Shapiro (1986)). These theories explain the joint movement of output and measured productivity virtually by definition.

Keynesian theories, on the other hand, attribute the business cycle to demand shocks. Such shocks include changes in fiscal policy, taste, velocity, and autonomous investment or animal spirits. Keynesian theories must explain the procyclical fluctuation in productivity. The sticky wage version of the Keynesian model found in the General Theory and more recently in models of overlapping contracts (see Fischer (1977) for example) do not explain procyclical productivity. In these models, firms are always on their demand for labor schedules. Hence, shocks to output demand would reduce the marginal product of labor and lead to counter-cyclical productivity. The counter-cyclicality of productivity in sticky wage models is the dual of the counter-cyclicality of real wages. That unsatisfactory feature of the sticky wage model has been widely discussed since the Dunlop-Tarshis-Keynes debate.

The Keynesian explanation for procyclical productivity is that firms do not adjust their labor input in light of short run fluctuation in demand because it is too costly to do so. This leads to "labor hoarding" or short run "off the production function" behavior. Such behavior on the part of

firms need not be irrational, but can be motivated by complications in the production technology (costs of adjustment, overhead labor) not captured in standard short run production functions. Such behavior also provides part of the theoretical underpinnings of Okun's Law. (See Dornbusch and Fischer (1981, pp. 368-371) for a Keynesian account of procyclical productivity.)

Hall, in an important series of papers (1986a, b, c), reinterprets the finding that productivity is procyclical. If a demand shock can lead to an increase in output with little increase in input, then marginal cost must be low. Competitive firms with the ability to increase output with little increase in input would cut price. Demand would increase and hence attenuate the procyclicality of measured productivity. Hence, Hall interprets the procyclicality of productivity as evidence that firms behave monopolistically and that they have consistent excess capacity. Hall's explanation is within the standard Keynesian tradition discussed in the previous paragraph, although it is important and distinct in its implications for market structure. Yet in either Hall's or the textbook Keynesian model, cyclical fluctuations in productivity arise from shocks to aggregate demand rather than shocks to true productivity.

In this paper, I attempt to test whether observed fluctuations in productivity are more from supply (real business cycles) or from demand (the Keynesian theory). To do so, I appeal to data on product and factor prices. Prices should provide an independent indication of the source of the productivity fluctuations. Implementations of real business cycle models have been criticized for neglecting their predictions about factor prices despite their strong implications for them (see Summers (1986)). In this

paper, I ask whether the observed fluctuations in factor prices are consistent with hypothesis that measured productivity shocks are true productivity shocks. Further, I ask whether departures from the predicted joint movement of measured productivity and factor prices are consistent with Keynesian alternatives.

I. Productivity and Prices

Productivity is measured here as the percent change of the residual in the value-added production function. Consider a constant returns to scale production function with Hicks-neutral technological progress. Output, Y_t, is a function of labor, N_t, and capital, K_t:

$$(1) \qquad Y_t = f(N_t, K_t) E_t^* .$$

The level of the true productivity shock is denoted E_t^*. Solow (1957) shows that the percent change in the shock E_t^* (denoted $\Delta \varepsilon_t$) can be measured from observed data. Taking logarithmic time derivatives of (1), setting the marginal product of labor equal to the real wage, and applying Euler's Law for linearly homogenous functions yields Solow's famous residual

$$(2) \qquad \Delta \varepsilon_t = (\Delta y_t - \Delta k_t) - \alpha_t (\Delta n_t - \Delta k_t) .$$

The $\alpha_t = W_t N_t / P_t Y_t$ is the share of labor income in nominal output (W_t is the wage and P_t the price level) and the time derivative of the logarithm of a variable Z_t is denoted Δz_t. In the empirical work, these are approximated

as logarithmic differences. Solow's residual is a measure of the percent change in total factor productivity for any constant returns to scale technology; for it to be a valid measure, only labor need be paid its marginal product.

The aim of this paper is to evaluate whether the measured Solow residual is a true shift in the production function or whether it has a demand component as Keynesian theories suggest. In the next section, I outline how data on prices help distinguish between these competing hypotheses. Before considering the precise implications of the competing hypotheses, it is worthwhile to examine the basic co-movements of prices and measured productivity.

Table 1 gives the correlation of the Solow residual with rates of change of aggregate GNP, of prices, and of wages for industries in the U.S. economy.[2] The first column gives the correlation of the Solow residual with aggregate GNP growth, the second column gives the correlation with the growth in the industry price divided by the GNP deflator, and the third column gives the correlation with growth in the real wage (compensation per manhour divided by industry price). The first column indicates that measured productivity growth varies positively with aggregate output growth. The procyclicality is particularly strong in aggregate and in manufacturing. Construction is an interesting exception. Even though its output moves strongly with aggregate output, its productivity is acyclical.

For virtually every industry, and for the aggregate economy, the changes in measured productivity are negatively correlated with real price growth. This finding is closely related to Houthakker's (1979) that price

growth and output growth are negatively correlated in industry data. The
negative correlation of price growth and the Solow residual provides some
evidence that the industry level shocks to productivity are shocks to
supply. Nonetheless, this evidence is only suggestive. Keynesian models
with sticky prices have no restriction in general on the price-productivity
correlation. Moreover, it is difficult to interpret the correlation if
there are aggregate shocks to true productivity. If a productivity shock
hits all industries equally, it may not change relative output prices.
Hence, the price-productivity correlations, although they suggest that
idiosyncratic supply shocks are important, are not helpful in studying the
sources of cyclical fluctuation in industry productivity.

Fluctuations in the real (product) wage should, on the other hand, shed
light on whether there are aggregate shocks to productivity. Specifically,
real wages should increase if productivity increases either
idiosyncratically or in aggregate. In Table 1, the correlation of real wage
growth and the Solow residual is almost always positive. Hence, the data
admit the possibility that the observed fluctuations in productivity are
indeed from supply. In the next section, I outline a dual approach to
measuring factor productivity that uses the factor price data. There is a
price-based measure of productivity that should be identical to the Solow
residual if the measured Solow residual is a true shock to the production
function. In the subsequent section, I apply these measurements to the data
to see whether movements in the two measures are similar. I also study
whether their deviations are cyclical as Keynesian alternatives suggest.

II. Dual Measurement of Productivity

Under almost the same conditions that Solow uses to derive his famous residual, it is possible to derive an alternative one based on factor prices.

If a firm has a constant returns to scale technology such as that given in equation (1), it will have a cost function $C(\cdot)$ of the following form:

$$(3) \qquad C(Y_t, W_t, R_t) = g(W_t, R_t) \, Y_t \, / \, E_t^*.$$

Here, R_t is the rental rate of capital. The function $g(\cdot)$ is, of course, linearly homogenous. Shephard's lemma gives conditional factor demand equation. Defining marginal cost as X_t,

$$(4) \qquad X_t = C_Y(Y_t, W_t, R_t) = g(W_t, R_t) \, / \, E_t^*.$$

To derive an expression for the productivity shock in terms of the dual, we follow identical steps as with the production function. Logarithmic differentiation of (4) yields

$$(5) \qquad \Delta x_t = \frac{g_W(W_t, R_t)\frac{dW}{dt}}{g(W_t, R_t)} + \frac{g_R(W_t, R_t)\frac{dR}{dt}}{g(W_t, R_t)} - \Delta \varepsilon_t^*$$

where Δx_t is the percent change in the marginal cost. Shephard's lemma implies that

$$(6) \qquad g_W(\cdot) = L_t \, E_t^* \, / \, Y_t \quad \text{and}$$

(7) $\qquad g_R(\cdot) = K_t E_t^* / Y_t$.

Using Euler's Law, substituting into equation (5), and setting price equal to marginal cost yields the standard pricing equation. Denote the percent change in the wage as Δw_t and the percent change in the rental cost of capital as Δr_t. Under competition, the price growth (Δp_t) is given by

(8) $\qquad \Delta p_t = \alpha_t \Delta w_t + (1-\alpha_t) \Delta r_t - \Delta \varepsilon_t^*$

where $\Delta \varepsilon_t^*$ is total factor productivity growth. Rearranging yields

(9) $\qquad \Delta \varepsilon_t^P = \alpha_t (\Delta w_t - \Delta p_t) + (1-\alpha_t) (\Delta r_t - \Delta p_t)$

where the price-based measurement of the productivity shock is labeled $\Delta \varepsilon_t^P$ to distinguish it from the Solow residual $\Delta \varepsilon_t$ defined in (2).

This productivity residual is derived under almost as general assumptions as is Solow's. The only extra assumption made is that capital is paid its marginal product within the period. This assumption is clearly unrealistic because of costs of adjustment and time to build. It can be relaxed at some cost in generality. Suppose that changes in capital must be decided at least one period in advance. Then marginal cost becomes simply

(10) $\qquad X_t = w_t \dfrac{\partial N_t}{\partial Y_t}$.

The derivative of labor with respect to output will be a function of the capital stock, the level of output, and the productivity shock. Equation (10) can be logarithmically differentiated and an expression similar to (9) can be derived. Unfortunately, to obtain an analytic expression, it is necessary to parameterize the production function. The ensuing result is not as general as (9). Suppose that the production function is constant elasticity of substitution (CES) so

$$(11) \qquad Y_t = [(1-\alpha)K_t^\rho + \alpha N_t^\rho]^{1/\rho} E_t^*$$

where α is a distribution parameter and ρ is a parameter such that $1/(1-\rho)$ is the elasticity of substitution between capital and labor. For the Cobb-Douglas case ($\rho=0$), the dual measure of productivity growth becomes

$$(12) \qquad \Delta\varepsilon_t^p = \alpha \ (\Delta w_t - \Delta p_t) + (1-\alpha) \ (\Delta y_t - \Delta k_t) \ .$$

In the general CES case, it is

$$(13) \qquad \Delta\varepsilon_t^p = [\alpha_t(\Delta w_t - \Delta p_t) + (1-\alpha_t)(1-\rho)(\Delta y_t - \Delta k_t)]/(1-\rho(1-\alpha_t)) \ .$$

These expressions are similar to (9). They are still importantly dependent on the real wage. Instead of the term in the cost of capital, they have terms that reflects the marginal product of capital in terms of quantities. These capture the short run increasing marginal cost due to the fixity of capital. Kydland and Prescott (1982) assume that the change in the capital

stock is pre-determined and that the production function is Cobb-Douglas, so it seems appropriate to consider that case here.[3]

II. Primal versus Dual Productivity: Empirical Findings

There are two ways to measure productivity change: the standard, output-based measure and the dual, price-based measure. Under the null hypothesis that the measured changes in productivity are true changes in productivity, these measures should be identical except for measurement errors or specification errors from incorrect parameterization of the production function. In this section, I compare these two measures. Moreover, I study whether the two measures depart from each other in a way that would be predicted by a Keynesian alternative. Under such an alternative, the Solow residual moves independently with aggregate demand. Cyclical fluctuations in quantity-based productivity occur because firms hoard labor or are off their production functions. Under the Keynesian alternative, the cyclical fluctuations in the quantity-based measure of productivity have nothing to do with the true productivity of the factors of production, so factor prices should not move in response to these cyclical fluctuations. Hence, the deviation of the quantity-based and price-based measures should be cyclical under the Keynesian alternative.

Consider first a regression of the Solow residual $\Delta\varepsilon_t$ on the dual residual $\Delta\varepsilon_t^p$ and a constant. Under the null hypothesis that the two productivity measurements are equal, the slope coefficient and the R^2 should both equal one. For aggregate manufacturing, using the unrealistic

specification that capital is flexible (equation (9)), the estimates are as follows[4]:

(14) $\quad \Delta\varepsilon_t - 0.03 + 0.79 \ \Delta\varepsilon_t^p$, s.e.e.$=3.01$, D.W.$=1.95$, $R^2=0.13$
$\quad\quad\quad\quad\quad (0.95) \ (0.35)$

Even in this specification, the hypothesis that the slope coefficient is one cannot be rejected although the fraction of variance explained is very low. Ignoring the short run fixity of capital understates the variability of marginal cost. In the Cobb-Douglas specification (equation (12)), the results are as follows[5]:

(15) $\quad \Delta\varepsilon_t = -0.31 + 1.10 \ \Delta\varepsilon_t^p$, s.e.e.$=1.58$, D.W.$=2.03$, $R^2=0.76$
$\quad\quad\quad\quad\quad (0.34) \ (0.11)$

The slope coefficient is close to one and fairly tightly estimated. Moveover, variation in the factor prices explains about three-fourth the variance in the quantity-based measure. Finally, in a CES specification with ρ constrained to equal -1 (elasticity of substitution equal to 0.5), the estimates are:

(16) $\quad \Delta\varepsilon_t = 0.54 + 0.88 \ \Delta\varepsilon_t^p$, s.e.e.$=1.23$, D.W.$=1.98$, $R^2=0.86$
$\quad\quad\quad\quad\quad (0.22) \ (0.07)$

Again the slope coefficient is precisely estimated to be close to one and the R^2 is very high. Therefore, in the specifications where the short run

fixity of capital is taken into account, the two measures of productivity appear to be very similar.

Now consider the prediction of a Keynesian alternative where movements in measured Solow residuals are accounted for by movements in demand. This alternative can be tested directly by including a measure of demand, say the growth rate of aggregate GNP. We know from Table 1 that a regression of GNP growth alone on manufacturing productivity explains about half of the variance of measured productivity. Because the Cobb-Douglas and the case with lower elasticity of substitution yield similar results, only the results for Cobb-Douglas are presented. They are as follows:

(17) $\quad \Delta\varepsilon_t = -0.63 + 0.92 \ \Delta\varepsilon_t^P + 0.21 \ \Delta GNP_t$, s.e.e.$=1.57$, D.W.$=1.86$, $R^2=0.77$
$\qquad\qquad\quad (0.42) \ (0.18) \qquad\quad (0.17)$

The addition of GNP growth adds almost nothing to the explanatory power of the equation. Moreover, the null hypothesis that the coefficient on $\Delta\varepsilon_t^P$ is one and the coefficient on ΔGNP_t is zero cannot be rejected (the $F(2,33) = 1.25$ statistic has marginal significance 0.30).

In the Cobb-Douglas case, the difference of $\Delta\varepsilon_t$ and $\Delta\varepsilon_t^P$ is simply $\alpha[(\Delta y_t - \Delta n_t) - (\Delta w_t - \Delta p_t)]$. Hence, imposing the restriction that the slope coefficient in equation (17) is one yields a regression of the difference of labor productivity and real wage growth on aggregate output growth. This difference, as equation (17) indicates, is not cyclical. When the restriction is imposed on equation (17), the coefficient of aggregate GNP growth remains insignificant and the equation has a R^2 of only 0.07.

Table 2 gives similar results for all the industries studied. The first column reports the estimated slope coefficient for equation (15), that is a regression of the Solow residual on the Cobb-Douglas dual residual. Many of the point estimates are close to one and precisely estimated. In about a quarter of the estimates, it is possible to reject the null hypothesis. The final two columns give the fraction of variance in $\Delta \varepsilon_t$ explained by either $\Delta \varepsilon_t^p$ or by ΔGNP_t.[6] In general, a much higher fraction is explained by the prices than by aggregate output. The result reported in equation (17) of the text holds for many industries: the deviation of the two productivity measures is acyclical.

III. Discussion

Productivity can be measured by either prices or quantities. If measured productivity is equal to true productivity, these two measures should be identical. Indeed, the two measures are very closely related: for the aggregate and for most industries, the coefficient of the dual measure in a regression of the primal is precisely estimated to be one; the fraction of variance explained by dual measure is high. Of course, the estimated R^2 is not exactly unity as the theory predicts, but the deviations from that value can easily be attributed to specification and measurement errors.

More importantly, the deviation of the two measures is not cyclical. Under the hypothesis that the coefficient of $\Delta \varepsilon_t^p$ is one in equation (17), which cannot be rejected for two-thirds of the industries, equation (17) can be interpreted as a regression of the difference of labor productivity and real wage growth rates on aggregate output growth. Keynesian theories of

labor hoarding or of monopolistic excess capacity predict that measured labor productivity is procyclical. Output can increase autonomously from an increase in inputs when demand increases. Because true productivity is not increasing, there is no reason to expect an equal increase in the product wage. In the absence of a Keynesian theory that has the real wage as a better proxy for demand shocks than is aggregate GNP growth, it seems very hard to reconcile the findings in this paper with theories that make changes in conventionally measured productivity a consequence of fluctuations in aggregate demand. A possible Keynesian explanation of procyclical productivity is monopolistic theories with rent sharing arrangements. Such theories would require marginal cost to rise precisely with the rise in observed labor productivity.

The results need to be somewhat qualified. The two measures of productivity are not exactly the same. In a few industries, the supply shock story fails importantly. More importantly, the data used in this paper are annual. Perhaps rigidities such as sticky prices and labor hoarding are confined to operate within the year. Further tests are needed on data of higher frequency. Nonetheless, if these Keynesian phenomena are indeed confined to operate over a horizon of a year, the supply shock model has explained much of the conventionally-defined business cycle.

Table 1

Correlations with Solow Residual

Correlation of $\Delta\varepsilon$
with change in:

	aggregate GNP	real price	real wage
Private Industry	0.79	-0.18	0.27
Agriculture	-0.31	-0.27	0.22
Mining	0.62	-0.51	0.48
Construction	0.06	-0.84	0.78
Manufacturing	0.77	-0.46	0.31
Durables	0.76	-0.37	0.23
Lumber	0.10	-0.53	0.53
Furniture	0.37	-0.73	0.73
Stone,Clay,Glass	0.49	0.02	-0.07
Primary Metals	0.72	-0.24	0.45
Fabricated Metals	0.57	-0.61	0.51
Machinery	0.46	-0.71	0.78
Electric Eq.	0.48	-0.44	0.37
Motor Vehicles	0.49	-0.06	0.27
Other Trans. Eq.	-0.13	-0.40	0.47
Instruments	0.38	-0.41	0.32
Misc. Mfging.	0.17	-0.67	0.56
Nondurables	0.45	0.55	0.40
Food	0.05	-0.63	0.61
Tobacco	0.28	-0.58	0.58
Textiles	0.08	-0.68	0.76
Apparel	0.34	-0.69	0.57
Paper	0.46	-0.72	0.76
Printing	0.18	-0.58	0.64
Chemicals	0.43	-0.60	0.50
Petroleum	0.37	-0.18	0.06
Rubber	0.54	-0.37	0.38
Leather	0.30	-0.61	0.57
Transportation	0.68	-0.57	0.59
Railroads	0.71	-0.54	0.60
Local Transport	0.14	-0.78	0.76
Trucking	0.52	-0.80	0.91
Water Transport	0.39	-0.79	0.82
Air Transport	0.61	-0.45	0.55
Communications	0.21	-0.11	0.55
Electricity, Gas	0.37	-0.36	0.41
Wholesale Trade	0.36	-0.49	0.56
Retail Trade	0.47	-0.63	0.68
Finance	0.27	0.13	-0.20
Services	0.15	-0.49	0.50

Table 2

Regression of the Solow Residual:
Cobb-Douglas Case

	slope coefficient in regression equation (15)	fraction of variance in $\Delta\varepsilon$ [equation (17)] explained by:	
		$\Delta\varepsilon^P$	ΔGNP
Private Industry	0.98	0.83	0.00
Agriculture	1.02	0.93	0.01
Mining	0.69*	0.74	0.02
Construction	1.01	0.90	0.00
Manufacturing	1.10	0.76	0.01
Durables	1.16	0.71	0.03
Lumber	0.84	0.71	0.06
Furniture	0.85	0.75	0.02
Stone,Clay,Glass	1.33	0.64	0.00
Primary Metals	1.34*	0.84	0.01
Fabricated Metals	0.78*	0.64	0.06
Machinery	1.07	0.89	0.00
Electric Eq.	1.10	0.57	0.01
Motor Vehicles	1.33*	0.84	0.01
Other Trans. Eq.	1.05	0.35	0.04
Instruments	0.97	0.51	0.03
Misc. Mfging.	1.13	0.66	0.00
Nondurables	0.97	0.72	0.01
Food	0.70*	0.65	0.02
Tobacco	0.98	0.98	0.00
Textiles	0.99	0.78	0.01
Apparel	0.63*	0.45	0.00
Paper	1.11	0.87	0.01
Printing	1.03	0.71	0.01
Chemicals	1.23*	0.84	0.01
Petroleum	0.64*	0.41	0.07
Rubber	0.97	0.57	0.06
Leather	0.74	0.48	0.01
Transportation	1.05	0.82	0.02
Railroads	1.11	0.74	0.04
Local Transport	0.72*	0.79	0.01
Trucking	0.94	0.94	0.00
Water Transport	0.98	0.83	0.00
Air Transport	0.99	0.72	0.11
Communications	0.79	0.58	0.04
Electricity, Gas	1.05	0.82	0.00
Wholesale Trade	1.08	0.76	0.03
Retail Trade	0.86	0.82	0.00
Finance	1.09*	0.95	0.00
Services	0.84	0.76	0.03

Note: * denotes significantly different from one at the five percent level. See text for definitions of equations (15) and (17).

REFERENCES

Campbell, John Y. and Mankiw, N. Gregory, "Permanent and Transitory Components in Macroeconomic Fluctuations," <u>American Economic Review Papers and Proceedings</u>, this number.

Dornbusch, Rudiger, and Fischer, Stanley, <u>Macroeconomics</u>, 2nd. ed. New York: McGraw-Hill, 1981.

Fischer, Stanley, "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," <u>Journal of Political Economy</u>, February 1977, <u>88</u>, 191-205.

Hall, Robert E., "The Relation Between Price and Marginal Cost in U.S. Industry," unpublished paper, Hoover Institution, Stanford, CA, 1986 (a).

Hall, Robert E., "Market Structure and Macro Fluctuation," <u>Brookings Papers on Economic Activity</u>, forthcoming, 1986 (b).

Hall, Robert E., "Chronic Excess Capacity in U.S. Industry," National Bureau of Economic Research Working Paper No. 1973, Cambridge, MA, 1986 (c).

Houthakker, Hendrik S., "Growth and Inflation: Analysis by Industry," <u>Brookings Paper on Economic Activity</u>, 1:1979, 241-56.

Kydland, Finn E. and Prescott, Edward C., "Time to Build and Aggregate Fluctuations," <u>Econometrica</u>, November 1982, <u>50</u>, 1345-1370.

Long, John B., Jr. and Plosser, Charles I., "Real Business Cycles," <u>Journal of Political Economy</u>, February 1983, <u>91</u>, 39-69.

Prescott, Edward C., "Theory Ahead of Business Cycle Measurement," <u>Carnegie-Rochester Conference Series on Public Policy</u>, forthcoming, 1986.

Shapiro, Matthew D., "Investment, Output, and the Cost of Capital,"

   Brookings Papers on Economics Activity, 1:1986, 111-152.

Shapiro, Matthew D., "How Monopolistically Competitive Is U.S. Industry?"

   unpublished, National Bureau of Economic Research, Cambridge, MA, 1987.

Solow, Robert M., "Technical Change and the Aggregate Production Function,"

   Review of Economics and Statistics, August 1957, 39, 312-320.

Summers, Lawrence H., "Some Skeptical Observations on Real Business Cycle

   Theory," unpublished, Harvard University, 1986.

FOOTNOTES

[1]Given the finding that most of the variance of output changes is explained by a permanent component (see Campbell and Mankiw (1987)), it is necessary to clarify what is meant by the business <u>cycle</u>. Here, a variable is said to be <u>cyclical</u> if it moves positively with innovations in aggregate output.

[2]The data are from the annual U.S. National Income and Product Accounts from 1950 to 1985; they are revised as of July 1986. Data on output, deflators, wages, and hours are taken from section six of the NIPA (see <u>Survey of Current Business</u>, July 1986, for example). The capital stock are from the revised industry level data (see <u>Survey of Current Business</u>, August 1986). See Shapiro (1987) for details about the data.

[3]They also consider inventories, which are ignored here.

[4]The rental price of capital is calculated as

$$R_t = (\delta + v_t)q_t(1 - z_t \tau_t - \omega_t)/(1 - \tau_t)$$

where δ is the average depreciation rate (0.125 for manufacturing), v_t is the required rate of return (measured by the dividend-price ratio on the Standard and Poor's Composite), z_t in the present discounted value of depreciation allowances, ω_t is the investment tax credit rate, and τ_t is the corporate profits tax rate. The variables z_t and ω_t are computed by DRI. Note that if this measure of profits were found in the national accounts, which of course it is not, equation (14) would be tautologous. As Hall (1986c) stresses, tests of the model that factors earn their marginal products depend critically on the measurement of profits.

[5]In the Cobb-Douglas estimates of $\Delta\varepsilon_t^p$, α is estimated as its average value.

[6]The decomposition attributes the covariance of $\Delta\varepsilon_t^p$ and ΔGNP_t to $\Delta\varepsilon_t^p$, which is appropriate given the difficulty rejecting the hypothesis that growth in aggregate output does not enter (17).