PRODUCTIVITY AND THE BUSINESS CYCLE

ROBERT E. HALL*

Hoover Institution and Department of Economics,

Stanford University

and

National Bureau of Economic Research

INTRODUCTION

Hardly any fact about the United States economy is better established than the procyclical behavior of productivity. All measures agree that productivity accelerates in booms and stalls or even regresses in slumps. But macroeconomists are in deep disagreement about the causal relation between output fluctuations and productivity growth. Some--members of the real business-cycle school--view productivity growth as a prime moving force for the entire economy. They see a surge of GNP as the natural outcome of improved ability to produce output. Others conclude that causality runs in the opposite direction--labor and other factors are able to produce more per unit of input when demand is strong than when it is weak. My plan is not to try to settle this debate, but rather to draw out the implications of the two views in parallel and to show that entirely different views of fluctuations are consistent with the facts. I will make use of the powerful method of productivity measurement devised by Robert Solow (1957), which isolates true production function shifts under rather general conditions without making parametric assumptions about the technology. I will also make use of recent work of my own, which considers the problem of productivity measurement in a framework where markets are not necessarily competitive. The examination will make use of a 9-sector breakdown of private GNP from the U.S. National Income and Product Accounts.

The results are the following: first, under the assumption of competition, productivity shifts are large and highly procyclical. Over three-quarters of the shifts emanate from the manufacturing and trade sectors, which account for only half of private GNP. Productivity shifts explain about 78 percent of the total variation in the growth of real private GNP and a substantial fraction of the variation in the growth of employment as well.

Instrumental estimates reveal some market power in most of the industries and substantial market power in some of them. In that respect, the competitive real business-cycle model is rejected. However, the productivity shifts measured taking market power into account are still quite cyclical. The same basic story about the shifts still holds. They are concentrated in manufacturing and trade, and they have substantial explanatory power for fluctuations in real output and employment. A non-competitive real business cycle is not at all refuted by the data. The findings on this point are not definitive because relatively small variations in the estimates of market power have large implications for the explanatory power of the resulting productivity shifts.

I. TOTAL FACTOR PRODUCTIVITY

Solow's (1957) derivation of the index of total factor productivity is well-known, but it is so simple that I will repeat it here. A production function relates output, Q, to capital, K, and employment, N; the function shifts over time according to a Hicks-neutral index, θ_t:

$$Q = \theta_t \ F(K,N) \tag{1}$$

Let θ, q, k, and n be the rates of growth of θ, Q, K, and N, and let M_K and M_N be the marginal products of capital and labor. Then, taking the derivative of Q with respect to time and doing a little algebraic manipulation yields:

$$\dot{q} = \theta + \frac{M_K K}{Q} k + \frac{M_N N}{Q} \dot{n} \tag{2}$$

To measure the rate of productivity growth, θ, one simply takes the rate of growth of output and subtracts first the rate of growth of capital input, k, weighted by its elasticity, $M_K K/Q$, and second the rate of growth of

labor input, n, weighted by its elasticity, $M_N N/Q$. If there were additional factors of production such as materials and energy, each would contribute another similar term. In order to use this formula to measure productivity growth, we need to have observable measures of the marginal products of the factors. Solow made two suggestions. First, he noted that under competitive conditions in product and labor markets, the product wage measures the marginal product of labor. He replaced M_N by w/p, in which case the elasticity is

$$\alpha = \frac{M_N N}{Q} = \frac{wN}{pQ} \tag{3}$$

which is simply labor's share in total revenue. Solow's second suggestion was to assume constant returns to scale, in which case the capital elasticity can be taken to be $1-\alpha$. It is important to understand that the first suggestion is logically distinct from the assumption of constant returns. For example, Solow's procedure gives exactly the right answer for a competitive firm with a fixed capital stock (or no capital) and diminishing returns to labor, whether or not the technology has constant returns.

In practice, computation of productivity growth by Solow's total factor productivity method uses finite differences in the logs of the variables. With Δq, Δk, and Δn being the differences in the logs and α being labor's share on the average over an interval, the formula for θ is

$$\theta = \Delta q - \alpha \, \Delta n - (1 - \alpha) \, \Delta k \tag{4}$$

Star and Hall (1976) show that the use of finite differences is unlikely to have any significant error even when the differences span decades.

It is convenient at this point to redefine Δq as the difference between the rate of growth of output and the rate of growth of the capital stock, and Δn as the difference between the rate of growth of labor input and the rate of growth of the capital stock, so that equation 4 has the simpler form,

$$\theta = \Delta q - \alpha \, \Delta n \tag{5}$$

A. PRODUCTIVITY MEASUREMENT IN THE PRESENCE OF MARKET POWER

For a noncompetitive firm whose price exceeds its marginal cost, Solow's method is biased. In that case, the product wage understates the marginal product of labor. Thus, α understates the elasticity of output with respect to labor and θ is overstated in any episode when Δn is positive. In particular, productivity growth is overstated in a cyclical expansion, when employment typically grows quite a bit faster than does the capital stock, and productivity growth is understated in a slump, when employment falls or grows less than does capital. Thus,

Proposition: In the presence of market power, measured total factor productivity (based on the assumption of competition) is spuriously procyclical.

If the degree of market power is known, it is a simple matter to adjust total factor productivity to offset the bias. Suppose the elasticity of the demand function perceived by the firm is ε. Then the ratio of price to marginal cost is

$$\mu = \frac{1}{1-1/\epsilon} \tag{6}$$

The proper measure of the marginal product of labor is the ratio of the wage to marginal cost, so the proper measure of the elasticity of output with respect to employment is $\mu\alpha$. The proper measure of total factor productivity is

$$\theta = \Delta q - \mu\alpha \, \Delta n \tag{7}$$

However, this measure is useful only when reliable outside measures of market power, μ, are available. My earlier work (Hall (1986a)) looks at this relationship from the opposite point of view. It considers the equation,

$$\Delta q = \mu\alpha \, \Delta n + \theta \tag{8}$$

as a structural equation containing an unknown parameter, μ, and uses standard econometric techniques to estimate the markup ratio, μ. I treat θ as a constant plus an unobserved random element which is the disturbance in this equation.

The key econometric issue is the characterization of the random productivity shift. Plainly, the shift for a given industry is an important determinant of the levels of employment and output in that industry. Hence, estimation by regression is precluded; an instrumental variable is essential. According to real business-cycle theory, productivity shifts have a common element across industries and this common element is one of the important driving forces in the business cycle. Under that view, endogenous aggregate variables cannot serve as instruments for individual industries. Only truly exogenous variables are suitable instruments.

Under the alternative view that there is no common element across industries, an aggregate variable can serve as an instrument, at least for an industry that is an insignificant fraction of the total economy. My earlier work assumed the latter. It uses the change in total real GNP as an instrument to estimate the markup ratio μ. In effect, the value of μ is inferred by comparing the amount that output increases in a given industry when there is an aggregate boom to the amount that employment increases, weighted by its share, α. In those industries where the ratio is high, that is, where a large increase in output requires only a small increase in weighted labor input, the process yields an estimate of a high markup. The inference is that the actual marginal product of labor has been understated by the product wage as a result of the upward distortion in the price associated with market power.

In this paper, I will present estimates of the markup ratio, μ, based on both types of instruments. Those estimates obtained with arguably truly exogenous variables--military spending and world oil prices--do not rely on an identifying assumption that is inconsistent with the real business-cycle view, but the estimates have a good deal of sampling error. The estimates based on the assumption that the growth of total real GNP is uncorrelated with productivity growth in each sector have less sampling variation but are biased if a common pattern of productivity shifts is an important driving force for total GNP. Moreover, the results based on the exogenous variables suggest that such a bias does indeed exist.

II. A FRAMEWORK FOR STUDYING PRODUCTIVITY ACROSS INDUSTRIES

The data that are the inputs for the proposed calculations are real

value added, q_i, the corresponding price deflator, p_i, labor input, n_i, wage, w_i and capital stock, k_i. The first step is to define a measure of aggregate output that is a complement to the Solow productivity measure. The natural aggregate is the Divisia index, defined as

$$\Delta q = \Sigma \ \beta_i \ \Delta \ q_i \tag{9}$$

where Δq is the rate of growth of the aggregate, β_i is the share of the value of output of industry i in the total value of output ($\beta_i = p_i q_i / \Sigma p_j \ q_j$), and $\Delta \ q_i$ is the rate of growth of output of industry i. I will treat the β_is as constants over time (estimated as the mean over the sample), even though they actually change slightly over time. I will be studying the time series of productivity residuals, r_i, defined by

$$r_i = \Delta \ q_i - \alpha_i \ \Delta n_i \tag{10}$$

The aggregate productivity residual is just

$$r = \Sigma \ \beta_i \ r_i \tag{11}$$

Note that r could also be calculated by applying Solow's method to aggregate output, provided that workers paid different wages were treated as separate inputs to production.

The basic questions considered in this paper deal with the common element of productivity growth across industries. I use two different approaches to measuring the common element; one of the important conclusions of the paper is that both approaches give essentially the same answer. One approach associates the common element with the aggregate productivity residual: it asks how closely related is productivity growth in a particular industry to aggregate growth. The other approach associates the common element with aggregate output growth: it asks how closely related productivity growth in a particular industry is to the business cycle as measured by aggregate output growth. The measures I will use also have properties that partition total productivity fluctuations into components arising from each industry.

To measure the association of industry i's residual with aggregate productivity growth, I define

$$\lambda_i = \text{regression coefficient of } r_i \text{ on } r \tag{12}$$

λ_i is the elasticity of the industry's productivity with respect to aggregate productivity, in the sense that a one-percent increase in aggregate productivity is typically associated with a λ_i-percent increase in productivity in industry i.

A related measure,

$$\gamma_i = \beta_i \lambda_i \tag{13}$$

measures the contribution of industry i to fluctuations in aggregate productivity. γ_i is just the product of the relative importance of the industry and its association with total productivity growth. The γ_is partition total fluctuations by industry in the sense that the sum of the γ_is across all industries is equal to one by construction.

To measure the association of industry i's productivity growth with output growth, I start by defining

$$\psi = \text{coefficient of regression of aggregate productivity}$$
$$\text{growth on aggregate output growth} \tag{14}$$

Then I define

$$\delta_i = \text{coefficient of regression of industry i's productivity}$$
$$\text{residual on aggregate output growth, divided by } \psi, \text{ the}$$
$$\text{aggregate coefficient} \tag{15}$$

The δ_i is comparable to λ_i; it measures the elasticity of industry i's productivity growth to total productivity growth. However, it considers only the productivity growth associated with aggregate output growth. δ_i is effectively an instrumental estimate of the elasticity, with aggregate output growth as the instrument.

The δ_is can also be weighted by the output shares in order to partition total productivity growth into components arising from each industry:

$$\omega_i = \beta_i \delta_i \tag{16}$$

ω_i is the fraction arising from industry i of the total amount of productivity growth that is associated with aggregate output growth. Again, the ω_i sum to one across all the industries.

III. DATA

The data are annual and are taken from the United States National Income and Product Accounts. The series are:

Q: Real value added

K: Net real capital stock

p: Implicit deflator with indirect business taxes removed (ratio of nominal value added less IBT to real value added)

N: Hours of work of all employees

w: Total compensation divided by N

As instrumental variables, I consider

Rate of growth of world oil price in dollars, current year and lagged

Rate of growth of real military purchases of goods and services

Rate of growth of awards of federal defense contracts in real terms

Rate of growth of military employment

A dummy variable taking the value of one in each Republican administration and zero in other years

The data are available for the period 1953-1978.

IV. INSTRUMENTAL ESTIMATES OF THE MARKUP RATIO BY INDUSTRY

Table 1 gives estimates of the markup ratio for each industry for five different sets of instruments. In all cases, the estimates are obtained by applying instrumental variables to equation 8. The first four columns use various combinations of the arguably exogenous variables as instruments, and the last column uses only the rate of growth of real GNP, which is not an exogenous variable in any theory but is eligible to serve as an instrument under the hypothesis that productivity shifts in a given sector are neither a contributor to nor the result of the aggregate business cycle.

Instrument set (2) is the cleanest; it contains only variables that measure the impact of wars on the economy, and the claim of exogeneity

Table 1

Instrumental Estimates of Markup Ratio

Industry	Instrument Set					Selected
	(1)	(2)	(3)	(4)	(5)	
Services	1.26	1.40	1.31	1.41	2.04	1.26
	(0.17)	(0.21)	(0.16)	(0.21)	(0.92)	
Finance, insurance, real estate	4.33 (1.08)	8.98 (9.42)	3.91 (0.84)	5.27 (3.17)	-10.05 (95.22)	3.91
Manufacturing durables	1.21 (0.28)	0.56 (1.12)	1.27 (0.26)	1.40 (0.41)	1.63 (0.1)	1.21
Manufacturing nondurables	1.78 (0.31)	-0.79 (4.3)	1.74 (0.31)	0.94 (1.44)	1.64 (0.18)	1.78
Trade	2.85	2.05	2.36	1.68	4.80	2.36
	(1.01)	(0.81)	(0.82)	(0.74)	(3.74)	
Construction	1.64	0.36	1.63	0.65	1.10	1.54
	(0.41)	(1.61)	(0.41)	(1.02)	(0.33)	
Transportation, utilities	1.41 (0.43)	2.50 (1.02)	1.53 (0.39)	2.21 (0.61)	2.15 (0.26)	1.41
Mining	0.02	1.32	0.15	1.38	3.56	1.20
	(0.6)	(0.6)	(0.55)	(0.6)	(1.22)	
Agriculture	2.34	2.94	1.84	2.06	-154.72	1.00
	(1.55)	(1.75)	(1.39)	(1.46)	(3319.96)	

Instruments:
(1)   Oil, oil lagged, and three military variables.
(2)   Three military variables
(3)   Oil, military, and political dummy
(4)   Military variables and political dummy
(5)   Change in real GNP

rests only on the proposition that the business cycle is not a cause of fluctuations in military spending. However, the military variables deliver a usable estimate of the markup ratio only in the service sector, where the markup is estimated to be 1.40 with a standard error of 0.21.

Instrument set (1) adds the rate of change of the dollar price of oil to the military variables. Before discussing these results, I need to indicate why the price of oil might be a reasonable instrument. In the first place, its use rests on the notion that the sharp increase in oil prices in 1974 and other smaller fluctuations were not caused by events that drove the United Sates business cycle, but were exogenous. To the extent that political events in the Middle East are the result of the ups and downs of the United States economy, this hypothesis is incorrect. Second, and probably more important, use of the oil price as an instrument rests on the hypothesis that exogenous shifts in the price do not cause shifts in productivity. This hypothesis is controversial. Indeed, some authors have attributed the productivity slowdown of the 1970s to higher energy prices. The argument in favor of the hypothesis is very simple: factor prices do not shift production functions. Total factor productivity calculations should isolate shifts in the production function from other shifts, such as shifts in factor intensities that result in changes in the output/labor ratio.

When the rate of change of the oil price is added as an instrument, a number of additional industries appear to have market power that is measured with sufficient precision to reject the hypothesis of competition. The facts underlying this finding are the following: when oil prices rise, both output and employment fall. The decline in labor cost associated with the decline in employment, calculated as a ratio to the decline in output, is the measure of marginal cost that I compare to the price in order to estimate the markup ratio, μ. The decline in employment in some of the industries is small in comparison to the decline in output, meaning that marginal cost is low in comparison to price. The industries in which the hypothesis of competition is rejected unambiguously in favor of market power are finance-insurance-real estate (FIRE) and manufacturing nondurables. The hypothesis is rejected at a less convincing level of significance in services, trade, and construction. There is little evidence against competition in durables, transportation, mining, and agriculture.

Instrument set (3) adds another variable to the list of instruments--a dummy for the party of the President. Growth of output has generally been

substantially higher under Democrats than under Republicans, so this added instrument improves the precision of the estimates of μ. The claim that the political dummy is exogenous would have to rest on the belief that election outcomes are not significantly related to economic events or that the differences in actual economic policies are accidental and unforeseen.

Instrument set (4) asks if the political dummy has enough explanatory power so that the oil variable need not be used. The results are generally reasonable, but the standard errors of μ are too large for informative estimates in most industries.

Instrument set (5) contains just one variable, the rate of growth of real private GNP. The results are similar to those in my earlier paper (Hall (1986a)). Competition is strongly rejected in manufacturing durables, nondurables, transportation, and mining. The results are completely uninformative in FIRE and agriculture and subject to high-sampling variation in services and trade. The hypothesis of competition is accepted in construction, with a reasonably small standard error. These results are interesting and meaningful only under the strong identifying hypothesis that the aggregate cycle neither causes nor is caused by productivity fluctuations.

The last column of Table 1 shows the value for μ that I use in the subsequent calculations. In most instances, I use the estimate from the first column, with the oil and military instruments. For two industries, I use values based on prior beliefs, because all of the instrumental estimates have large sampling errors: mining, where I took μ to be 1.2, and agriculture, which I assumed is competitive with μ equal to 1.

A. Substantive Findings in Table 1

The basic message of Table 1 is the following: when an outside event causes output to rise, the added labor needed to produce that output costs substantially less than the price the firm is able command for the added output. The conclusion is reached by taking the ratio of the covariance of the growth of output and the instrument to the covariance of the growth of labor input and the instrument, adjusted by the labor share, α, which incorporates the ratio of the price to the wage. If price and marginal cost were equal, the ratio of the covariances (the markup ratio) would be unity. Under noncompetitive conditions, the ratio exceeds unity.

For a profit-maximizing firm, the markup ratio, μ, is related to the elasticity of demand perceived by the firm, ε, by $\mu = \varepsilon/(\varepsilon-1)$. Hence, if the firm perceives an elasticity of demand that is stable over time, its

markup ratio should also be stable over time. In that case, the econometric procedure used here will provide an estimate of the underlying markup ratio. If the elasticity changes over time (for example, if it is growing because of increasing foreign competition), then the estimate will provide information about the average value of the markup ratio over time.

A full discussion of the impact of various sources of specification errors appears in my earlier paper (Hall (1986a)). Much of the most important potential source of bias is cyclical measurement error in work effort. In an industry where workers put in more intense effort when output is high, but are not paid more than usual during such periods, the method I have developed will overstate the markup ratio. The numerator of the estimate of μ will be correct because output is correctly measured. But the denominator will be too small because fluctuations in labor input are understated. However, the earlier paper shows that unmeasured, uncompensated variations in work effort would have to be quite large to explain all of the findings of markups in excess of one. It also shows that essentially none of the supposed fluctuations in effort are compensated on a current basis. In view of the substantial fraction of the workforce that is compensated partly or fully on piece rate or commission bases, this finding casts further doubt on the importance of unmeasured fluctuations in work effort.

Existing research on market power has largely confined its attention to manufacturing, so it is difficult to compare the findings of Table 1 to those of research. However, recent work by Domowitz, Hubbard, and Petersen (1987), within the general framework of this and my earlier paper, has confirmed that markups estimated by my method are positively associated with traditional measures such as concentration ratios.

Is there a relation between market power and profit? On the one hand, with a constant-returns technology, firms with market power should be correspondingly profitable. On the other, it would be paradoxical if firms were chronically profitable in the absence of barriers to entry. My research on this point (Hall (1986b)) reaches the conclusion that fixed cost, minimum scales, or other failures of constant returns are sufficiently important in the industries with market power so that an equilibrium exists with close to zero pure profit for prospective entrants but continuing market power for the incumbents. Basically, this finding is nothing more than an interpretation of measures of excess profits that takes proper account of the full economic costs associated with ownership of capital.

V. BEHAVIOR OF PRODUCTIVITY

I have obtained results under the hypothesis of competition (markup ratio, μ, equal to one by assumption) and for the case of possible market power (μ estimated by instrumental variables).

A. COMPETITION

Table 2 decomposes total productivity for the case of competition. The first column gives the value share, β_i, for each industry. The second column shows the elasticity of the productivity residual in the industry to the aggregate productivity change, λ_i. The elasticities are low in services, in FIRE, negative in agriculture, and between .6 and 2.3 in durables, nondurables, trade, construction, mining, and transportation. The third column shows the decomposition of the total variation in aggregate productivity growth obtained by weighting the elasticities by the shares. It is clear that the great bulk of total productivity variation comes from durables (44 percent), nondurables (15 percent), and trade (19 percent). The three sectors, which account for 48 percent of private GNP, contribute 79 percent of total productivity variation.

The last two columns decompose the part of productivity variation that is associated with the business cycle. The decomposition gives essentially the same story as the decomposition of total productivity variation for a very simple reason: under the assumption of competition, most productivity variation, both in the aggregate and in each industry, is cyclical. Again, the elasticity is close to zero in services and FIRE, negative in agriculture, and above one in most of the rest of the industries. The only important differences between the total elasticities and the elasticities associated with the business cycle are that the elasticity for construction is smaller in the second case and the elasticity for agriculture is even more negative in the second case. The concentration of productivity variation in manufacturing and trade is even more extreme when only the cyclical component of the variation is considered--85 percent of the total arises in those three industries.

Table 3 repeats the decomposition of total productivity growth by industry for productivity growth computations that take account of market power. The story about the sources of total productivity growth is very similar to the one in Table 2. Over 40 percent of the variation in total productivity growth comes from durables; 75 percent comes from manufacturing and trade combined. The part of productivity growth that is

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Table 2

Decompositions of Productivity Growth by Industry, Competitive Case

Industry	Value Share	Elas. w.r.t. agg. prod.	Contri- bution	Elas. w.r.t. agg. out.	Contri- bution
Services	13.3	0.23	3.1	0.38	5.1
Fin., ins., real est.	14.6	0.16	2.3	.00	0.1
Durables	18.9	2.33	44.2	2.70	51.2
Nondurables	12.1	1.26	15.3	1.22	14.7
Trade	17.6	1.09	19.1	1.08	18.9
Construction	6.1	1.39	8.5	0.27	1.6
Transp. and utilities	10.1	0.85	8.6	1.02	10.3
Mining	2.7	0.67	1.8	1.44	3.9
Agriculture	4.5	−0.64	−2.9	−1.29	−5.8

Notes:

Value share is the proportion of the value of private GNP arising from the industry.

The elasticity with respect to aggregate productivity is the regression coefficient of the industry's total factor productivity growth on aggregate total factor productivity growth.

The contribution is the product of the elasticity and the value share.

The elasticity with respect to aggregate output is the ratio of the regression coefficient of the industry's total factor productivity growth on aggregate output growth, divided by the regression coefficient of aggregate total factor productivity growth on aggregate output growth.

Table 3

Decomposition of Productivity Growth by Industry, Market-Power Case

Industry	Value Share	Elas. w.r.t. agg. prod.	Contri-bution	Elas. w.r.t. agg. out.	Contri-bution
Services	13.3	0.01	0.1	0.61	8.2
Fin., ins., real est.	14.6	0.25	3.7	-0.7	-1.0
Durables	18.9	2.17	41.1	3.79	71.7
Nondurables	12.1	0.92	11.1	-0.30	-3.7
Trade	17.6	1.32	23.2	1.60	28.0
Construction	6.1	1.62	9.8	-1.76	-10.7
Transp. and Util.	10.1	0.91	9.3	1.16	11.8
Mining	2.7	0.91	2.5	2.65	7.2
Agriculture	4.5	-0.18	-0.8	-2.57	-11.6

Notes:

Value share is the proportion of the value of private GNP arising from the industry.

The elasticity with respect to aggregate productivity is the regression coefficient of the industry's total factor productivity growth on aggregate total factor productivity growth.

The contribution is the product of the elasticity and the value share.

The elasticity with respect to aggregate output is the ratio of the regression coefficient of the industry's total factor productivity growth on aggregate output growth, divided by the regression coefficient of aggregate total factor productivity growth on aggregate output growth.

associated with movements in total output is even more sharply concentrated in durables, which accounts for almost three-quarters of that variation by itself. It is important to note that aggregate productivity is much less procyclical when the adjustment for market power is made. The estimates of the regression coefficient of aggregate productivity growth on aggregate output growth are:

Under competition:	0.375
	(.064)
With market power:	0.188
	(.072)

That is, the last column of Table 3 decomposes a total amount of cyclical movement of productivity that is only half as large as in the competitive case of Table 2.

The estimates of the markup coefficient, μ, in Table 1 have a close connection to the differences between Tables 2 and 3 with respect to the decomposition in the last column. The estimates of the markup coefficient in the last column of Table 1 are, by definition, the ones that make productivity in the industry completely noncyclical. For industries with procyclical employment and output, a markup coefficient less than the one in the last column of Table 1 makes measured productivity procyclical and vice versa. In nondurables, the estimate of μ that I choose from Table 1 is 1.78, a little above the value of 1.64 in column 5. Hence, the regression coefficient reported in the next-to-last column of Table 3 for nondurables is slightly negative. On the other hand, my value for durables, 1.21, is well below the level that would make productivity noncyclical; consequently, it is quite procyclical. The durables industry emerges as the dominant source of cyclical productivity because it is highly cyclical to begin with, and the adjustment for market power does less in durables than in any other cyclical industry to reduce cyclicality.

To summarize the findings of Table 3: first, adjustment for market power has a dramatic impact on the total amount of cyclical movement in productivity, cutting it roughly in half. Second, the durables sector, which was the single biggest source of aggregate productivity variation when productivity is measured under the assumption of competition, becomes completely dominant when the adjustment is made.

These conclusions are far from robust. In particular, they rest very

sensitively on the fairly low estimate of the markup ratio, μ, durables. The estimate is 1.21 with a standard error of 0.28. Raising by one standard error to 1.49 would eliminate much of the cyclic movements of productivity in durables and knock out large amounts of t cyclical movements of total productivity growth as well.

B. EXPLANATORY POWER OF PRODUCTIVITY SHIFTS FOR OUTPUT

Real business-cycle theory considers productivity shifts as importan sources of fluctuations in total output; see Long and Plosser (1983), Prescott (1986), Eichenbaum and Singleton (1986), and many other papers cited in the latter. Consequently, it is interesting to ask if the measured productivity residuals from this paper are good explanatory variables for output by industry and for total output. Before I discuss the evidence on this point, I should make two remarks about what can be learned from the evidence:

1. Low explanatory power of productivity residuals for output would not refute the real business-cycle model. The model considers many other sources of fluctuations such as shifts in preferences, changes in the terms of trade, and perception errors about real interest rates. A finding of a small role for shifts in production functions would only cast doubt on the version of the real business-cycle model that stresses those shifts. The examination of the explanatory power of the shifts is suggested by the prominence of technology shifts in recent real business-cycle discussions.

2. A finding of high explanatory power for productivity residuals is not fatal for alternative models of fluctuations. Any sensible model of fluctuations gives some role to shifts in technology. Further, the apparent explanatory power may be spurious because the true driving forces are correlated with the measured productivity shifts.

The reduced form for any model for output can be approximated as a linear system relating the rate of growth of output (aggregate or by industry) to the observed driving forces, including the productivity residuals. The disturbances in the reduced-form equations measure the influences of unobserved determinants of output growth. If the disturbances are taken to be uncorrelated with the productivity measures and other observed determinants, then the reduced form can be estimated by regression. The result is a three-way breakdown of the overall variance in output growth: part attributable to productivity shifts, part attributable to other observed variables, and part to an unexplained residual. The breakdown between the first two components will be unambiguous only if the

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productivity measures are uncorrelated with the other observed variables. If all of the other variables have been used as instruments in estimating the productivity equation, then the lack of correlation is guaranteed. Otherwise, upper and lower bounds are available by assigning the common element first to productivity shifts and second to the other variables.

Table 4 shows that both sets of productivity residuals have high explanatory power for output. The upper part of the table refers to the productivity measures based on competition. The first column shows the fraction of the total variance of output growth in an industry explained by the best linear combination of the productivity residuals in that and all other industries. This usually provides an upper bound on the explanatory power of the productivity shifts (the exception is FIRE, where the other variables are complementary rather than competing explainers of output). In all industries except FIRE, at least two-thirds of the variance of output growth is associated with the productivity residuals. The second column shows the lower bound; this is the increment to the R^2 of the regression when the productivity residuals are added in the presence of the other variables. Measured productivity explains about 60 percent of output growth in total and in most individual industries.

The third column shows the upper bound to the explanatory power of the other variables. The variables included are all of the instruments listed in Section III: rate of change of oil price, current ad lagged, three military variables, and a political dummy. At most, the other variables explain about half of the variation in output. The fraction of total output variation explained is about a third. The fourth column is the lower bound to their explanatory power; it differs from the third column by the same common element that separates the first and second columns. Finally, the fifth column gives the fraction of the variance of the growth of output not explained by either the productivity shifts or the observed variables. The unexplained fraction is unambiguous because, by assumption, the unexplained driving forces are uncorrelated with the productivity shifts and the other variables.

The bottom part of Table 4 repeats the breakdown of the sources of output growth for the productivity measures based on the estimates of market power. What is remarkable is the similarity of the two parts of the table. Because most of the productivity measures used in the bottom part are obtained by an econometric procedure that makes them orthogonal to some or all of the exogenous variables, the amount of ambiguity in the allocation of explanatory power is smaller than for the results based on

Table 4

Sources of Variation in Output Growth
Productivity Measures Based on Competition

| Industry | Fraction of variance of output growth associated with | | | | |
| | Productivity | | Other Variables | | |
	Including Common Element	Excluding Common Element	Including Common Element	Excluding Common Element	Unexplained
Services	0.666	0.430	0.482	0.246	0.088
Fin., ins. real est	0.172	0.582	0.316	0.726	0.102
Durables	0.802	0.686	0.246	0.130	0.068
Nondurables	0.867	0.597	0.361	0.091	0.042
Trade	0.871	0.621	0.332	0.082	0.047
Construction	0.702	0.369	0.565	0.232	0.066
Transp. and util.	0.785	0.604	0.265	0.084	0.131
Mining	0.706	0.558	0.204	0.056	0.238
Agriculture	0.874	0.707	0.204	0.037	0.089
Total	0.780	0.610	0.326	0.156	0.064

Productivity measures based on market power

| Industry | Fraction of variance of output growth associated with | | | | |
| | Productivity | | Other Variables | | |
	Including Common Element	Excluding Common Element	Including Common Element	Excluding Common Element	Unexplained
Services	0.659	0.464	0.482	0.287	0.054
Fin., ins. real est	0.410	0.573	0.316	0.479	0.111
Durables	0.843	0.706	0.246	0.109	0.048
Nondurables	0.728	0.589	0.361	0.222	0.050
Trade	0.748	0.570	0.332	0.154	0.098
Construction	0.384	0.352	0.565	0.533	0.083
Transp. and util.	0.843	0.646	0.265	0.068	0.089
Mining	0.786	0.622	0.204	0.040	0.174
Agriculture	0.879	0.724	0.204	0.049	0.072
Total	0.774	0.627	0.326	0.179	0.047

Notes:

Including common element is the R-squared for a regression containing only the one set of variables.

Excluding common element is the increase in R-squared when the set of variables is added to a regression containing the other set of variables.

Unexplained is 1 minus the R-squared of the regression containing both sets of variables.

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competition. But the basic story is very much the same: the set of measured productivity shifts has high explanatory power for total output fluctuations and fluctuations in each industry.

Table 4 suggests that productivity shifts could well be major driving forces for output fluctuations, as proposed by the real business-cycle model. The evidence is not definitive unless the further hypothesis is adopted that the unobserved driving forces—shifts in preferences, changes in terms of trade other than oil, and changes in government policies other than military spending and those associated with the political party of the President—are uncorrelated with the shifts in productivity.

There is a second, more important reason that the bottom part of Table 4 is not definitive evidence in favor of the view that productivity shifts are an important determinant of output fluctuations. Much of the explanatory power comes from the productivity measure for durables. Recall that the competitive productivity measure for durables is highly correlated with the growth of private real GNP. Table 1 shows that it would take a markup ratio of 1.63 to remove the cycle from measured productivity in durables. The markup ratio for durables used in Table 4 and the other results based on market power is only 1.21. Hence, the productivity residual taking account of market power in durables is highly correlated with the aggregate business cycle. The bottom part of Table 4 would look very different if a markup ratio around 1.6 were forced on durables. Or, to take the point to its logical extreme, if the estimates of the markup ratio from the last column of Table 1 were adopted in all industries, the explanatory power of the productivity measures for aggregate output would be literally zero. That property underlies the method of estimation used in that last column.

The procedure used in Table 4 for appraising the explanatory power of productivity shifts appears to be biased in favor of high power. Random errors in the estimates of the markup coefficients can make the productivity measures more cyclical than they should be. As long as one industry winds up with a highly cyclical measure, it will appear that output in all sectors is being driven by the productivity shift in that one sector.

The solution to this problem is to use more information about the coefficients of the reduced form. Table 5 shows certain of the estimated reduced-form coefficients for the regressions underlying Table 4. The coefficients are for the productivity shift in the industry itself and the productivity shift for durables. The two dependent variables considered

Table 5

Reduced-form Coefficients, Market Power Estimates

Industry	Elasticity of Output Growth with Respect to	
	Own Prod. Growth	Durables Prod. Growth
Services	0.821	0.07
	(0.366)	(0.127)
Fin., ins., real est.	0.246	0.079
	(0.227)	(0.09)
Durables	2.019	2.019
	(0.373)	(0.373)
Nondurables	0.165	0.641
	(0.274)	(0.233)
Trade	0.316	0.435
	(0.218)	(0.156)
Construction	0.474	0.626
	(0.285)	(0.469)
Transp. and util.	0.748	0.358
	(0.28)	(0.131)
Mining	0.555	0.318
	(0.188)	(0.195)
Agriculture	0.921	0.266
	(0.109)	(0.122)

are output growth and the growth of labor input. Not surprisingly, in all industries, output responds positively to productivity growth in that industry. The response is sufficiently strong so that the response of labor input to productivity growth is also positive. In the standard interpretation, this means that the stimulus to demand for output from lower price overcomes the negative impact of higher productivity on labor demand.

More troublesome is the uniformly positive response of output to productivity growth in durables. With productivity growth held constant in every other industry, a spurt of productivity growth in durables (19 percent of the total economy) stimulates output growth in nondurables, trade, construction, transportation, and mining, all of which have elasticities with respect to durables productivity growth of 0.3 or higher. The durables boom does not draw resources from other sectors at all, nor does the durables industry release resources for use in other sectors. Instead, the effect of higher productivity in durables is to draw resources into productive activities.

These findings merely underscore the point that a real business-cycle model requires an explanation for the fact that the net aggregate effect of a favorable burst of productivity growth is to increase employment. Intertemporal substitution in labor supply is almost certainly an important element of a complete equilibrium model of fluctuations. The growth in economy-wide employment associated with productivity growth in durables must be stimulated by the labor-supply response to higher real interest rates. Real wages must fall in all sectors with unchanging productivity and higher output.

VI. CONCLUSIONS

Total factor productivity, calculated under the assumption of competition, is highly cyclical in a number of industries. This well-known fact can be turned around to say that the productivity shifts of a set of industries have high explanatory power for output fluctuations when considered as exogenous variables in a regression. The fact remains when other arguably exogenous variables appear in the regression as well.

Total factor productivity is biased toward being procyclical when there is market power. Given estimates of the degree of market power, as measured by the markup coefficient, it is possible to compute alternative

measures of total factor productivity. Estimation requires the use of instrumental variables, which are neither causes of shifts in productivity nor are their fluctuations caused by those shifts. Estimates based on a plausible list of instruments reveal considerable market power in some industries. However, the modified measure of total factor productivity is still quite procyclical in some industries, notably durables. Hence, the explanatory power of the productivity measures for output fluctuations is virtually as high as for the measures based on competition.

Though these findings are basically favorable to versions of the real business-cycle model that stresses shifts in technology as driving forces, the evidence is far from definitive. The real business-cycle model must explain why output and employment in all sectors of the economy respond so strongly and positively to productivity shifts in the durables sector.

The resolution of the important questions about the driving forces for economic fluctuations is of the first order of importance for stabilization policy. In an economy operating according to the principles of the sticky-price disequilibrium model, where occasional short falls of demand cause inefficient periods of depressed resource utilization, a countercyclical demand policy has important social dividends. In an economy at the other pole, where fluctuations in productivity bring efficient fluctuations in output, demand management is perverse and possibly costly. This paper has not settled the issue and does not even point in a particular direction. It does show that shifts in production functions are highly correlated with fluctuations in output. It casts doubt on the proposition that the correlation arises because shifts in output caused by exogenous forces induce corresponding shifts in productivity. However, the evidence is completely compatible with the hypothesis that events such as financial disturbances account for both output and productivity declines. In sum, research of the type presented here is making a little progress in settling the scientific issues underlying the debate between policy activists and their opponents. What may emerge is a consensus that the government has control over some of the disturbances--notably financial ones--that contribute both to fluctuations in output and in productivity. The type of model that is likely to emerge is one in which the response to disturbances is described as an economic equilibrium, not as a competitive equilibrium.

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