Federal
Reserve
Bank of
Cleveland

Economic REVIEW

1988 QUARTER 4

ECONOMIC REVIEW

1988 Quarter 4
Vol. 24, No. 4

Economic Review is published quarterly by the Research Department of the Federal Reserve Bank of Cleveland. Copies of the *Review* are available through our Public Information Department, 216/579-2157.

Coordinating Economist:
Randall W. Eberts

Editors: William G. Murmann
Robin Ratliff
Design: Michael Galka
Typesetting: Liz Hanna

ISSN 0013-0281

Do the Earnings of Manufacturing and Service Workers Grow at the Same Rate Over Their Careers?

by Randall Eberts
and Erica Groshen

Randall Eberts is an assistant vice president and economist and Erica Groshen is an economist at the Federal Reserve Bank of Cleveland.

The authors thank Ralph Day and Paula Loboda for their expert assistance, and thank Robert LaLonde for his comments.

Introduction

The U.S. labor market has undergone dramatic structural changes over the last several decades. Total employment has increased by 37 percent since 1976, but most of this growth has been concentrated disproportionately in the service-producing sectors. For instance, service employment (SICs 70 through 89) has increased 80 percent since 1976, while manufacturing employment (SICs 20 through 39) has increased only 5 percent.[1]

This uneven growth across sectors has resulted in a significant change in the industrial composition of the labor force. Twelve years ago, manufacturing claimed 24 percent of total employment while the services comprised 18 percent. Today, those roles have been completely reversed with the service sectors claiming 24 percent of total employment and manufacturing claiming 18 percent.

The transition from an economy dominated by manufacturing jobs to one with predominantly more service jobs raises the question of whether or not service jobs in general offer the same earnings potential for workers as manufacturing jobs. A popular notion is that the economic restructuring that has taken place over the last decade or so has relegated skilled production workers to jobs as hamburger flippers. Krueger and Summers (1987), for example, support the view that service jobs are lower paying by reporting that workers in service sectors such as medical, welfare, education, and personal services earn significantly less than workers in manufacturing sectors.

Wage differentials between service and manufacturing industries are even evident for workers in the same occupational categories, as shown in table 1. Within occupation, manufacturing wage premiums range from a high of 45 percent for male equipment cleaners and handlers to a low of 3 percent for female production, craft, and repair workers. Also note that the distribution of occupations employed in the two sectors is quite different. For instance, the largest occupational category for women in the service sector is professionals and specialists, while in manufacturing, machine operators and assembly occupations employ the largest number of women.

Bluestone and Harrison (1986) report some disturbing consequences of the restructuring of

■ 1 Service industries in Standard Industrial Classifications (SICs) 70 through 89 include hotels, personal services, business services, automotive and other repair, health services, educational services, social services, and engineering, accounting and related services. Manufacturing industries in SICs 20 through 39 include all durable and nondurable sectors.

TABLE 1

Average Hourly Earnings by Selected Occupation and Industry in 1987

1. Males

Selected Occupation	Manufacturing Number	Manufacturing Mean Earnings	Services Number	Services Mean Earnings
Executives, Administrators, & Managers	2,156	$16.26	2,428	$13.98
Professional & Specialists	1,964	16.38	5,162	13.20
Technical & Related Support	858	12.94	971	11.15
Sales Personnel	701	13.55	370	9.85
Administrative Support & Clerical	1,068	10.04	943	7.75
Production, Craft & Repair	4,977	11.03	1,788	8.80
Machine Operators & Assembly	5,863	8.89	486	6.79
Transportation & Material Movers	1,111	8.98	403	7.47
Handlers & Equipment Cleaners	1,311	7.64	393	5.72

2. Females

Selected Occupation	Manufacturing Number	Manufacturing Mean Earnings	Services Number	Services Mean Earnings
Executives, Administrators, & Managers	849	$11.76	2,755	$10.57
Professional & Specialists	565	12.30	9,926	10.96
Technical & Related Support	296	10.49	2,100	9.28
Sales Personnel	307	9.89	621	6.48
Administrative Support & Clerical	2,770	8.09	8,074	7.09
Production, Craft & Repair	979	7.66	164	7.51
Machine Operators & Assembly	4,391	6.20	448	5.18
Transportation & Material Movers	68	9.40	237	7.15
Handlers & Equipment Cleaners	534	6.26	96	4.60

SOURCE: Female and male wage and salary workers aged 18 to 54 working in the indicated industries and occupations in the one-quarter earnings sample drawn from all monthly *Current Population Surveys* in 1987.

employment. Their analysis shows that "...all of the employment increases experienced since 1979 have been generated by the creation of jobs which paid less than the median wage in 1973." (p. 5) They go on to add that the disproportionate expansion of the low-wage sector is found to be especially prevalent among younger entry-level workers between the ages of 16 and 34.

Although these latter results have stirred some controversy, they point to an essential question in discussing the earning potential of the great number of service jobs created in the economy. As noted earlier, several studies, including this one, have found that service workers consistently earn less than their manufacturing counterparts. The question that has not been addressed is whether or not service workers can expect the same growth rate in wages over their work life as manufacturing workers enjoy, even though they start out earning less.

To answer this question, we estimate age-earnings profiles, which approximate the growth rate of earnings of individuals over their work lives. Each profile depicts the pattern of earnings of a cross section of individuals at each age level. We then look for significant differences in age-earnings profiles between comparable workers in manufacturing and service sectors. We interpret the results of this approach to represent the earnings potential of typical service and manufacturing workers over their work lives. This interpretation rests on the assumption that the behavior of individuals and labor market conditions affecting their earnings do not vary significantly among cohorts. Although this assumption may be open to question, the approach provides a starting point for analyzing this issue.

We estimate cross-sectional age-earnings profiles using the 1987 *Current Population Survey* (CPS).[2] The year 1987 was chosen because it provides the most recent evidence. In other work not reported here, the same models were estimated for 1976 and 1986. Differences in age-earnings profiles between the two sectors were qualitatively similar in all three years. The similarity in results across years also suggests that cohort effects are probably not the driving force behind the lack of sectoral differences in age-earnings profiles.

We test for sectoral differences in age-earnings profiles at two levels of model complexity. First, we test whether earnings increase at the same rate over an individual's career for each of the two sectors by simply interacting the service-sector dummy variable with the age variables. Next, we examine whether age-earnings profiles differ between service and manufacturing sectors within relatively broad occupational categories.

Our basic finding is that only slight differences in age-earnings profiles exist between the two sectors. However, when age-earnings profiles are estimated separately for major occupational groups, the differences between sectors all but disappear. Consequently, the notion that service jobs do not offer the same earnings growth as the manufacturing jobs they are replacing is not supported by this analysis. However, since the earnings growth rates are similar between sectors, the gap between manufacturing and service wages persists throughout the individual's career.[3]

I. Age-Earnings Profiles

Why might age-earnings profiles differ across sectors and over time? The stylized relationship between earnings and age is that wages rise steeply during the first part of a worker's career, level off in the middle years, and perhaps even decline slightly in the final years. This pattern was strikingly documented by Mincer (1974) using 1960 census data. Since then, a number of studies have explored various aspects of the relationship in more detail.[4] However, no one has studied the age-earnings relationship for workers in specific industries, in particular, service and manufacturing.

Several reasons for this pattern have been advanced. The most widely cited hypothesis is the accumulation of human capital through on-the-job training (for example, Mincer [1974]). Other explanations attribute the age-earnings pattern to the knowledge an individual gains about a specific firm (Oi [1962]) or to workers' showing their commitment to a firm by accepting low pay early in their career in exchange for high pay later in their work life (Lazear [1981]). In all three cases, prolonged participation in the labor force or attachment to a firm increases the value of the worker to the firm; consequently, the worker's wages increase with age.

Differences in demand and supply characteristics can account for differences in age-earnings profiles across sectors and over time. On the demand side, for example, differences in age-earnings profiles across industries may arise because of differences in the amount of human capital accumulated during a worker's career. Workers in low skill-accumulation jobs would exhibit a shallower age-earnings profile that would probably peak at a young age. Thus, if service jobs are generally characterized as low-skill and manufacturing jobs as high-skill, then the age-earnings profiles of service jobs should be shallower than those of manufacturing jobs. However, if workers in the two sectors are comparable to begin with, total (discounted) earnings in the two sectors should equalize over the course of the workers' careers.

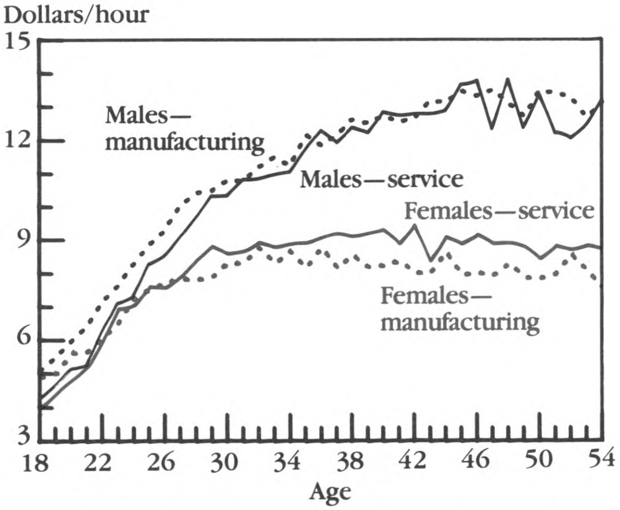
■ **2** Estimation of the relationship between earnings and age is performed using both cross-sectional and longitudinal data. For example, Freeman (1980) analyzes cross-sectional CPS data, Nakosteen and Zimmer (1987) use PSID longitudinal data, and Hanoch and Honig (1985) use panel records of the Social Security Administration. Ideally, one would follow an individual over that person's entire career in order to avoid cohort effects when estimating the age-earnings profile. Two data sets are typically used in longitudinal studies: the Panel Survey of Income Dynamics (PSID) and the National Longitudinal Survey (NLS). Cross-sectional analysis almost exclusively uses the Current Population Survey (CPS). The CPS offers a major advantage over NLS: it includes significantly more individuals. Thus, estimates based on subgroups, such as men and women in manufacturing and services, are more reliable.

■ **3** This paper addresses only the age-earnings profile question. Another equally interesting question is why service workers receive lower pay at each age level than their manufacturing counterparts. While a number of explanations for the existence of interindustry wage differentials have been advanced, none has been generally accepted. See Dickens and Katz (1987) for a summary of the state of current research on the topic.

■ **4** A recent strand of literature explores the extent to which profiles are primarily due to increases in seniority (or tenure) rather than general experience. Several studies, including Abraham and Farber (1987) and Altonji and Shakotko (1987), have challenged the empirical validity of a positive relationship between wages and tenure. Although there is support for this relationship when employer characteristics are included (Hersch and Reagan [1987]), this controversy does not directly pertain to our study since we do not distinguish between tenure and experience.

FIGURE 1

Age-Earnings Profiles, Males and Females in Manufacturing and Service Industries, 1987



SOURCE: *Current Population Survey,* one-quarter earnings sample, 1987.

The age-earnings profile may also be affected by the relative abundance of workers of various ages across industries. The effect of the supply of workers in various age groups depends upon the extent of, and variations in, the substitutability between groups among sectors. For instance, if younger service workers were imperfect substitutes for older workers in one sector, then an influx of young workers into the sector would bid down the wages of younger workers and, thus, make the profile steeper in that sector. On the other hand, if younger workers were perfect substitutes for older workers in all industries, then an influx of younger workers would leave the profile unchanged, but would reduce wages of workers of all ages. Estimates of elasticities of substitution between old and young workers generally find them to be somewhat imperfect substitutes, especially among men and the highly educated (see Freeman [1980] and Hamermesh [1986]).

II. Estimation of Age-Earnings Profiles

Our sample of workers is drawn from the one-quarter earnings sample of the 1987 CPS. We limit the sample to manufacturing (SICs 20 through 39) and service (SICs 70 through 89) workers between the ages of 18 and 54. Earnings are measured as hourly wages: weekly earnings divided by usual weekly hours. Some studies use weekly earnings and typically find little difference (except for higher variation) in compensation patterns from those derived from using hourly wages. We choose hourly earnings to minimize the problem of differences in hours worked across the various groups.

Plots of the cross-sectional patterns of mean hourly wages by age for male and female service and manufacturing workers, aged 18 to 54, in 1987 are shown in figure 1. Although these plots do not control for attributes of workers other than age, sex, and industry, they provide a starting point for this discussion. This figure and the analysis below can be viewed as a snapshot of workers frozen at various stages in their careers.[5]

First, we see the familiar shape of the age-earnings profile in both sectors, but with marked differences between the patterns of men and women. Second, we see that wages for men are lower in the service industries than in the manufacturing industries for most but not all ages. Third, although the youngest women earn more in manufacturing than do their service-sector counterparts, by the age of 28 female service workers appear to be more highly compensated. Finally, the service-sector profiles in these plots are steeper than the manufacturing profiles. The difference between manufacturing and service earnings is greatest in the earlier years and narrows with the age of workers.

To investigate age-earnings relationships while controlling for other employee characteristics, the log of hourly earnings is regressed against age and age-squared along with other worker characteristics, such as education, race, union affiliation, and full-time status. Age-earnings profiles are estimated by entering age and age-squared into the wage regression and then interacting these two variables with a service-sector dummy to distinguish between profiles for service and manufacturing jobs.[6]

■ **5** As discussed above, this approach does not control for cohort effects. That is, some cohorts — such as the baby boomers — may differ in their average characteristics from the members of other cohorts. These average differences in unnoted characteristics (say, size of cohort, health, or attitude) could affect the results reported here.

■ **6** To be consistent with other empirical studies of age-earnings profiles, we specify a quadratic relationship between age and earnings. Further exploration of this topic should consider alternative specifications.

TABLE 2

Characteristics of Manufacturing and Service Workers by Sex in 1987

Characteristic	Females	Males
Mean Hourly Earnings	$ 8.13	$10.85
Services	8.24	10.41
Manufacturing	7.82	11.21
Std. Dev. (Log Earnings)	0.517	0.545
Mean Log Earnings	1.967	2.249
Services	1.972	2.174
Manufacturing	1.952	2.309
Service Sector	74.7%	44.2%
Part Time	22.9%	7.6%
Services	27.7	13.1
Manufacturing	8.9	3.2
Union	15.0%	21.3%
Services	15.1	16.0
Manufacturing	14.5	25.4
Nonwhite	15.5%	12.7%
Services	15.1	14.2
Manufacturing	16.6	11.4
Highest Grade Completed	13.4	13.4
Services	13.8	14.3
Manufacturing	12.2	12.7
Age in Years	35.0	34.9
Services	34.9	34.1
Manufacturing	35.0	35.6
Number of Observations	42,950	36,669

SOURCE: Female and male wage and salary workers aged 18 to 54 working in manufacturing or service industries in the one-quarter earnings sample drawn from all monthly *Current Population Surveys* in 1987.

The means of these variables are displayed in table 2 by sex and industry. One interesting fact is that women's earnings are actually higher in service jobs than they are in manufacturing jobs. The apparent inconsistency of this finding with the numbers in table 1 is due to sectoral differences in occupational distribution. In general, women in the service sector are more concentrated in the highly paid occupations than are women in the manufacturing sector.

Women are much more likely to work in service-sector jobs than are men. And, it is apparent that, compared to manufacturing workers, a higher percentage of service workers are part time, especially among women. Also, male service workers are less heavily represented by unions than are male manufacturing workers.

Regression Results

The results of the earnings regressions are displayed in several tables. Table 3 presents the coefficient estimates for variables that are not part of the age-earnings profiles. These estimates determine the intercepts of the estimated profiles for each group. For example, the coefficient of the service-sector dummy variable shows that, controlling for the human capital and demographic characteristics listed, service workers' earnings are lower than manufacturing workers' earnings for both males and females. It is interesting to note that, in contrast to figure 1 and table 2 (which do not control for other characteristics), the "corrected" service-sector earnings effect (that is, the coefficient on the service dummy) for female workers is strongly negative.

The next two rows in table 3 present evidence of the wage penalty experienced by part-time workers. We see that for women the wage penalty for working part time is smaller in the service sector than it is in manufacturing. For males in manufacturing, the penalty for part-time work is larger than that for women in both sectors.

The relative attractiveness of unionism is similar between the two sectors for both sexes. For both men and women, the union wage differential is only slightly higher in services than in manufacturing.

Far more striking is the smaller racial differential in services compared to manufacturing, also found by Montgomery and Wascher (1987). For both sexes, this differential is reduced by almost half in the service sector. The importance of differences in the returns to schooling vary by sex. The results in table 3 suggest that returns to education are significantly higher for women in services, but the difference between sectors is small and statistically insignificant for men.

Age-Earnings Profiles

Age-earnings profile coefficient estimates are presented in table 4. Hourly wages exhibit typical profiles for men and women in each sector. Males appear to have a steeper, more pronounced earnings path than women in both sectors. Presumably this is due in part to more instances of nonparticipation in the labor force or preferences for part-time work among women. In addition, earnings taper off more quickly for men than for women.

In general, female service workers exhibited a steeper earnings path with greater curvature than manufacturing workers. Male service workers

TABLE 3

Coefficient Estimates of Age-Earnings Equations by Sex in 1987

Variable	Females		Males	
Intercept	-0.276	(-4.52)	-0.508	(-11.58)
Service Dummy	-0.361	(-5.21)	-0.174	(-2.82)
Part Time Dummy	-0.204	(14.14)	-0.295	(-17.38)
Part Time x Service	0.029	(1.88)	-0.083	(-4.15)
Union Member	0.140	(11.85)	0.085	(12.33)
Union x Service	0.014	(1.02)	0.007	(0.60)
Nonwhite Dummy	-0.129	(-11.69)	-0.153	(-16.67)
Nonwhite x Service	0.055	(4.27)	0.075	(5.67)
Years of School	0.082	(48.49)	0.079	(28.47)
School x Service	0.008	(4.07)	-0.002	(-1.48)
R-squared	.325		.411	

NOTE: T-statistics appear in parentheses next to coefficient estimates. The symbol "x" signifies multiplying the two variables shown, which results in an interaction term. The dependent variable is log (earnings). Other variables in the model estimated are age and age-squared interacted with the service dummy variable. Coefficients for those variables are reported in table 4.
SOURCE: Female and male wage and salary workers aged 18 to 54 working in manufacturing or service industries in the one-quarter earnings sample drawn from all monthly *Current Population Surveys* in 1987.

TABLE 4

Age-Earnings Profile Coefficient Estimates by Sex in 1987

Variable	Females		Males	
Age	0.053	(15.79)	0.070	(28.47)
Service x Age	0.010	(2.71)	-0.001	(-0.25)
$Age^2/1{,}000$	-0.604	(-13.21)	-0.713	(-21.37)
Service x $Age^2/1{,}000$	-0.136	(-2.27)	-0.024	(-0.49)
Implied Age of Peak Earnings				
Manufacturing	44		49	
Services	43		47	

NOTE: T-statistics appear in parentheses next to coefficient estimates. The symbol "x" signifies multiplying the two variables, which results in an interaction term. The dependent variable is log (earnings). Coefficients on the other variables included in the model estimated are reported in table 3.
SOURCE: Female and male wage and salary workers aged 18 to 54 working in manufacturing or service industries in the one-quarter earnings sample drawn from all monthly *Current Population Surveys* in 1987.

had earnings paths that were not significantly different from those of male manufacturing workers. However, since the age at which wage growth stops is a function of both initial slope and degree of curvature, one way to compare the various age-earnings profiles is to calculate the age at which earnings peak. The results of such calculations are shown in the lower two rows of table 4. Using the coefficient estimates in the first four rows, hourly wages peak for male service workers at age 47 while wages peak for comparable manufacturing workers at age 49. The results for women also suggest that earnings peak at an earlier age in the service sector. However, the difference between the sexes far dominates the difference between sectors.

III. Effect of Age-Earnings Profiles on Sectoral Wage Differentials

We have addressed the question of differences in age-earnings profiles between manufacturing and service workers by interacting service-sector dummy variables with age and age-squared. The next question is whether entry-level workers should expect the wage differences they initially encounter between sectors to persist, or to dissipate over their work life. Another way to ask the same question is: do the service and manufacturing jobs have the same earnings growth potential?

The earnings equation estimates reported in tables 3 and 4 allow us to calculate the earnings difference between service and manufacturing jobs (compared to manufacturing earnings) for the average 18-year-old with 12 years of education. The top two rows of table 5 report the results of that exercise for men and women in four demographic groups. The upper row is based on regressions on men's earnings; the lower row on women's earnings. For instance, the average nonwhite 18-year-old female working in a full-time, nonunion service job earns 9.8 percent less than does a comparable worker in a full-time, nonunion manufacturing job.

Note that in no case do the wages of entry-level service workers exceed those of entry-level manufacturing workers. And, the service differentials among women are sometimes larger and sometimes smaller than those found for men. Perhaps most interesting is the extent to which the service differentials vary, from a low of 6.4 percent to a high of 20.0 percent for men and from a low of 9.8 percent to a high of 14.6 percent for women. The relative disadvantage of

TABLE 5

Comparison of Entry-Level Sectoral Earnings Differentials to Lifetime Sectoral Earnings Differentials

	White Nonunion Full Time	Nonwhite Nonunion Full Time	White Union Full Time	White Nonunion Part Time
Proportional Earnings Differential of Entry-Level Service Workers Compared to Entry-Level Manufacturing Workers (Age 18)				
Males	–.131	–.064	–.125	–.200
Females	–.146	–.098	–.134	–.121
Discounted Present Value of Proportional Earnings Differential From Age 18 to Age 54				
Males	–.166	–.101	–.160	–.232
Females	–.117	–.067	–.105	–.091

NOTE: The predicted wage differential between sectors for each demographic group is converted to a proportion of manufacturing workers' earnings. Estimates of proportional discounted total earnings differentials are based on integration of the estimated earnings functions for each sector, as reported in tables 3 and 4, assuming a 3 percent real discount rate and 12 years of education.
SOURCE: Derived from estimates shown in tables 3 and 4.

service-sector employment compared to a manufacturing job varies strongly with race, sex, and part-time status.

To determine whether these differentials will persist over the workers' careers, we calculate the discounted present value of the earnings stream over the work life. The discounted present value simply adds up the annual earnings of an individual between the ages of 18 and 54. Earnings are valued at the beginning of the career and so earnings received after age 18 are discounted at a 3 percent annual rate. The present value takes into account the estimated differences between age-earnings profiles between sectors.

The lower two rows of table 5 present estimates of the service differential in the present value of earnings from a work life beginning at age 18 and lasting until age 54, using the model with varying age-earnings profiles between sectors estimated in tables 3 and 4. Results from this exercise show that the earnings differential between service and manufacturing workers is primarily due to the straight differential paid to all ages, although differences in profiles do affect these sectoral wage differentials to some extent.

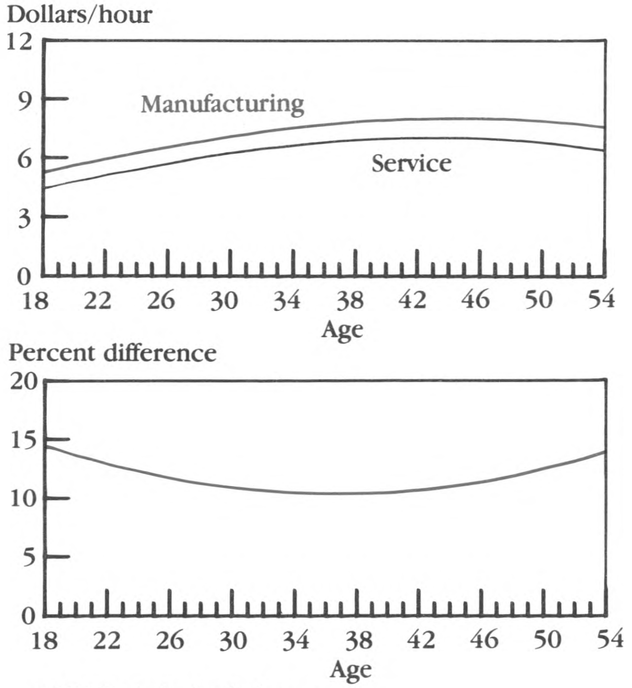
Again, all differentials suggest higher earnings in manufacturing; white nonunion women working full time experience an average difference of 11.7 percent over their work life. And the average, white, nonunion, full-time, male worker earns 16.6 percent less in a service job. For nonwhites, the service differentials are much smaller.

These earnings differences over the entire work life differ from the entry-level wage differentials because they depend on the relative shape of the age-earnings profile in each sector. In general, the lifetime sectoral differences in age-earnings profiles shown in table 5 suggest that starting wages underestimate the ultimate earnings differences for men and overestimate the lifetime pattern for women. The reason for the difference is shown in figures 2 and 3. The upper graph in figure 2 shows that for women, the percent differential increases during their middle years and then narrows during their later years. For men (shown in figure 3), the earnings gap continually increases, since service wages peak earlier and taper off more quickly than manufacturing wages.

It is interesting that the impact of service employment on males' earnings patterns appears stronger than that for females, even though the estimated service-age interaction coefficients (reported in table 4) are far larger for females than for males. This apparent anomaly stems from the offsetting nature of the age and age-squared interaction coefficients for females. For females, an increase in age increases the service differential through the service effect on the age coefficient, but reduces the service differential through the service impact on the age-squared coefficient. Among males, an increase in age is associated with a lower wage for service workers through the service impact on both the age and

FIGURE 2

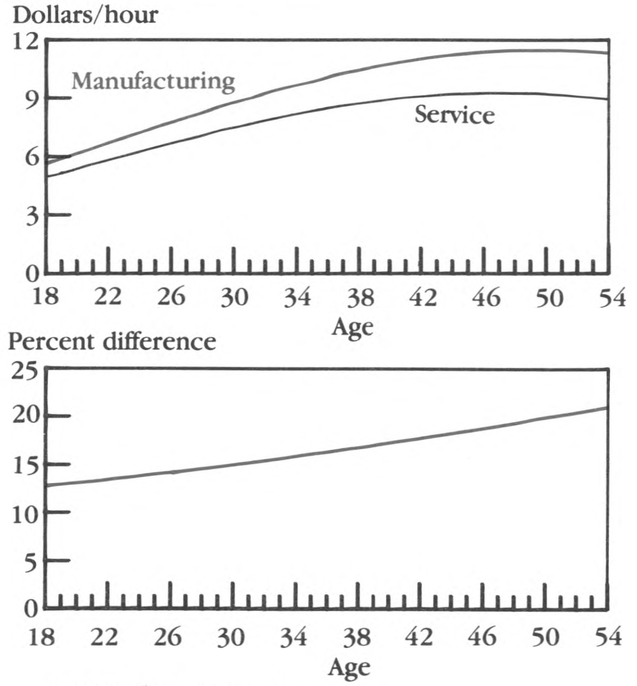
Estimated Sectoral Difference in Female Age-Earnings Profile



SOURCE: Author's calculations.

FIGURE 3

Estimated Sectoral Difference in Male Age-Earnings Profile



SOURCE: Author's calculations.

the age-squared coefficients. However, since the results for men are based on statistically insignificant sectoral differences in wage growth, any conclusion must be drawn with care.

IV. Age-Earnings Profiles Within Occupations

Implicit in the model presented above is the assumption that education and other demographic variables are good controls for human capital. Occupation provides another way to control for human capital. An alternative assumption is that sectoral differences in profiles result from occupational differences that are constant across industries. Since manufacturing and services employ a different mix of occupations, differences between the sectors may be largely a product of differences in occupations employed.

To address this issue, we estimate separately the simple wage equation with age and age-squared for various occupational categories. The sectoral differences in age-earnings profiles found earlier disappear within many of the occupations. This finding suggests that employment in the services has no independent effect on age-earnings profiles. But, it does not suggest that the changing industrial structure of employment has no impact. Rather, the impact stems from the effect of the industrial shift on the occupational distribution.

V. Summary and Conclusion

Over the last decade, service-sector employment has grown at twice the rate of total employment, while manufacturing employment has grown very little. As a result, service-sector employment now claims a larger proportion of total employment than manufacturing. This restructuring has drawn attention to concerns that service-sector jobs don't pay as much as manufacturing jobs.

To answer the question posed by the title of this paper, our findings suggest that service workers start out at a lower wage than that of comparable manufacturing workers, but then service-sector wages grow at roughly the same rate as manufacturing-sector wages.

References

Abraham, Katharine G., and Henry S. Farber. "Job Duration, Seniority, and Earnings." *American Economic Review.* 77 (June 1987): 278-297.

Altonji, Joseph G., and Robert A. Shakotko. "Do Wages Rise with Job Seniority?" *Review of Economic Studies.* 54 (July 1987): 437-459.

Bluestone, Barry, and Bennett Harrison. "The Great American Job Machine: The Proliferation of Low Wage Employment in the U.S. Economy." A Study Prepared for the Joint Economic Committee, December 1986.

Dickens, William T., and Lawrence F. Katz. "Inter-industry Wage Differences and Theories of Wage Determination." National Bureau of Economic Research Working Paper No. 2271, July 1987.

Freeman, Richard B. "The Effect of Demographic Factors on Age Earnings Profiles." *Journal of Human Resources.* 14, no. 3 (1980): 289-318.

Hamermesh, Daniel S. "The Demand for Labor in the Long Run." In Orley C. Ashenfelter and Richard Layard, eds., *Handbook of Labor Economics,* Volume 1. Amsterdam: North-Holland, 1986.

Hanoch, Giora, and Marjorie Honig. "'True' Age Profiles of Earnings: Adjusting for Censoring and for Period and Cohort Effects." *Review of Economics and Statistics.* 67, no. 3 (1985): 383-394.

Hersch, Joni, and Patricia Reagan. "Job Match, Tenure and Wages Paid by Firms." Mimeo, University of Oregon, 1987.

Krueger, Alan B., and Lawrence H. Summers. "Reflections on the Inter-Industry Wage Structure." In Kevin Lang and Jonathan S. Leonard, eds., *Unemployment and the Structure of Labor Markets.* New York: Basil Blackwell, 1987.

Lazear, Edward P. "Agency, Earnings Profiles, Productivity, and Hours Restriction." *American Economic Review.* (September 1981): 606-20.

Mincer, Jacob. *Schooling, Experience and Earnings.* New York: National Bureau of Economic Research and Columbia University Press, 1974.

Montgomery, Edward, and William Wascher. "Race and Gender Wage Inequality in Services and Manufacturing." *Industrial Relations,* 26, no. 3 (Fall 1987): 284-90.

Nakosteen, Robert A., and Michael A. Zimmer. "Marital Status and Earnings of Young Men." *The Journal of Human Resources.* 22, no. 2 (1987): 248-68.

Oi, Walter. "Labor as a Quasi-Fixed Factor." *Journal of Political Economy.* 70 (December 1962): 538-55.

Procyclical Real Wages Under Nominal-Wage Contracts With Productivity Variations

by James G. Hoehn

James G. Hoehn is an economist at the Federal Reserve Bank of Cleveland. The author gratefully acknowledges helpful discussions with Charles T. Carlstrom, William T. Gavin, and Alan C. Stockman, and acknowledges useful comments on a draft by Randall W. Eberts, Erica L. Groshen, and John B. Taylor.

Introduction

A frequent criticism directed at many macroeconomic models, especially those with wage stickiness, concerns their inability to account for the procyclical pattern of real wages. This article offers a resolution of this problem by introducing productivity factors into the determination of sticky wages. This resolution makes the resulting model more consistent with standard microeconomic theory about the determination of wages.

The problem of accounting for real-wage cyclicity arises both for sticky-wage models such as those of Keynes (1936) and Fischer (1977), and for the incomplete-information models such as those of Friedman (1968) and Lucas and Rapping (1969). Economists favoring these models have offered a wide variety of prospective solutions to the puzzle of real-wage cyclicity, including complex reinterpretation of the evidence and a variety of modifications to the models. However, none of these solutions has been widely accepted and the failure of proponents of these models to resolve the real-wage puzzle has been considered a serious shortcoming of the models.

The inability of existing sticky-wage and incomplete-information models to account for the cyclicity of the real wage has given impetus to the development of two alternative explanations of macroeconomic fluctuations. These alternatives are capable of resolving the real-wage puzzle, but have problems of their own.

First, the real-business-cycle approach explains economic fluctuations without invoking sticky wages or prices or incomplete information: employment, output, wages, and prices are determined by people's informed responses to varying productive opportunities. Real wages will generally be procyclical in such models, reflecting the variations in factor productivity that drive the real business cycle. Indeed, real-business-cycle models can easily generate implausibly high real-wage cyclicity.[1] The real-business-cycle approach also cannot account for the observed effects of money supply changes on real activity,[2] and provides no guidance for monetary policy.

Second, the real-wage puzzle has redirected many Keynesians away from wage rigidities and toward commodity price rigidities or monopolistic price-setting behavior. The sticky-price models, like the sticky-wage models, can account for

■ **1** See Christiano and Eichenbaum (1988).

■ **2** But see King and Plosser (1986), which attributes the observed relation of money and income variables to the effects of technology shocks on both variables.

the effect of policy on activity. For example, if suppliers accommodate the demand at sticky prices, and the real demand for goods depends on real-money balances, then increases in demand due to monetary expansion are met by increases in output. If the nominal wage is flexible, such an increase in output will raise the demand for labor, raising both the nominal and the real wage. Variations in demand within a sticky-price, flexible-wage model are thus able to generate procyclical variations in the real wage.

The argument here is that there is no necessity to reject the notion of a sticky wage on account of the real-wage puzzle; a more conservative solution exists in the introduction of productivity shocks into the determination of the sticky wage.

However, sticky-wage models are subject to some criticism on more theoretical lines. They have the problem of explaining why firms and workers would agree to fix wages for a period in nominal terms and then allow the quantity of employment to be determined by the firm's labor demand at that wage.[3] The objection that sticky-wage models result in nonoptimal employment determination has prompted Keynesians to endeavor to understand how constraints on the feasibility of ideal contracts, such as problems of information, contract enforcement, or transaction costs, prevent firms and workers from determining employment and output in an ideal manner. The sticky-wage model would be more explicitly consistent with microeconomic theory and might be more useful for understanding and controlling the business cycle if it made these constraints explicit.

But essentially the same issue can be raised concerning sticky-price models: what constraints would lead sellers to fix a commodity's price in nominal terms and allow quantity to be determined by the demand at that price? [4, 5]

Thus, the theoretical arguments against sticky-wage models do not compel their abandonment in favor of alternatives, returning the focus to the empirical arguments against sticky-wage models. The crucial issue separating different views about the source and policy implications of macroeconomic fluctuations is whether the real-wage puzzle can be resolved without abandoning sticky wages as part of the explanation of the business cycle. Economists have increasingly come to view the puzzle as fatally damaging to sticky-wage models. For example, Mankiw (1987, p. 105), concludes the case against them by saying "...perhaps [the] most serious...problem with the unadorned nominal wage story is that real wages do not move over the business cycle as the theory predicts...." Likewise, McCallum (1986, p. 408) claims that "[i]f wage stickiness alone was responsible for the real effects of monetary actions, with product prices adjusting flexibly, then we should observe countercyclical movements in the real wage."

This article offers a reconciliation of sticky wages with observed cyclical behavior of real wages by introducing productivity factors into nominal-wage contracts. It shows that sticky nominal wages can be consistent with the procyclical real wages of the United States—even if prices are perfectly flexible—under quite reasonable conditions: wage bargains reflect expected labor productivity, productivity variations are persistent and procyclical, and aggregate demand fluctuations are not too large relative to productivity fluctuations.

The introduction of productivity factors into the determination of nominal wages is most readily accomplished within a wage-contracting setup like Fischer's (1977), and so a modification of his approach will be used here.[6] All considered, it is worthwhile to attempt to modify sticky-wage theories to make them consistent with procyclical real wages. A successful attempt yields a model consistent with orthodox macroeconomic theory, with the important stylized facts of U.S. business cycles,[7] and with the microeconomics that links wages to productivity. Furthermore, the model is able to provide guidance to monetary policymakers about the effects of monetary policy.

■ **3** Ideally, output and employment should be determined by the condition that the marginal disutility of work equals the marginal product of labor. See Hall (1980), Hall and Lilien (1979), and Barro (1977).

■ **4** Akerlof and Yellen (1985a, 1985b, 1988) provide a partial answer to this problem, by showing how small discrepancies of individual behavior from full, explicit rationality—discrepancies associated with sticky prices and wages—can be consistent with large departures of aggregate activity from optimal levels. McCallum (1986) couples this idea that there are small private costs associated with sticky wages and prices with the notion of menu costs, or expenses incurred by changing price lists, to arrive at an economic theory of stickiness. A final and more difficult requirement of a completely explicit theory of stickiness, as playing an effective role in economic fluctuations, is a rationale for quantity determination at the sticky wage or price. This requirement is important, because economists such as Barro (1977) have conjectured that sticky prices or wages may not have any effects on allocation, but may instead be a facade for optimal quantity determination.

■ **5** A more symmetric treatment of these issues would allow for both wage and price stickiness as part of a complete model. Price stickiness can, as explained in the text, help to resolve the real-wage puzzle. The argument that sticky wages are consistent with procyclical real wages is stronger for not relying on price stickiness. If procyclical real wages can be generated in a model economy without sticky prices then, a fortiori, so much more easily can a procyclical real wage be generated when price stickiness is allowed.

I. Sticky Wages Play an Important Role in Keynesian Models

At least since the Keynesian revolution, sticky wages have played a prominent role in macroeconomic theories of the interaction between prices and quantities, providing an explanation of a number of stylized facts of the business cycle, particularly the tendency of employment to increase with inflation caused by demand stimulation, such as increases in the money supply. Keynes (1936, chapter 2) formalized the sticky-wage mechanism linking money and prices to output and employment. A decrease in the money supply lowers the price level, raising the real wage at the fixed nominal wage, forcing an employment-contracting movement along a fixed real demand for labor schedule. Keynes assumed that the real-labor-demand schedule was identical to the marginal-productivity-of-labor schedule.

More recent sticky-wage models account for the eventual adjustment of money wages to price level variations. Wages must eventually adjust one-for-one with prices, ruling out money illusion. For example, price deflation will eventually lead to lower nominal wages. Because of the unemployment caused by price deflation and the associated rise in the real wage, a firm can find workers willing to work for less than the initial money wage. But collective bargaining and other conventions concerning compensation make it difficult for money wages to decline as rapidly as prices can fall. Typically, nominal wages remain stuck until scheduled, periodic renegotiations are undertaken.

Keynes' analysis was a short-run or period analysis, in which wages were taken as historically given. Newer Keynesian sticky-wage models make the wage decisions of workers and firms respond to events and expectations of future events. Current wages in newer models are influenced by economic conditions; wages are predetermined, not exogenous.[8]

The emphasis on long-term contracts in new sticky-wage models has been accompanied by increased attention to expectation formation. As Taylor (1983, p. 63) says, "...long-term relationships do not diminish the importance of expectations in macroeconomic analysis. On the contrary, expectations of the future significantly affect the terms of contractual arrangements. They are of greater quantitative importance in contractual situations than they are in more flexible auction-market situations." Recognition of the role of forward-looking expectations about productivity thus seems well in the spirit of the new genre of wage-contracting models.

II. The Puzzle of the Procyclical Real Wage

Keynesians originally attempted to explain the fluctuations in output and employment strictly by variations in aggregate demand. This approach ruled out or abstracted from technological change, and is associated with a fixed marginal product of labor schedule. It follows that the real wage will be negatively related to employment and, in this sense, is necessarily countercyclical. In the words of Keynes (1936, p. 17), "...an increase in employment can occur only through the accompaniment of a decline in real wages. Thus, I am not disputing this vital fact

■ **6** Productivity factors could be introduced into wage determination in other models, such as the incomplete-information models mentioned. This modification could make them consistent with procyclical real wages, although this improvement would not satisfy other objections to them. Among the objections to incomplete-information models is that information lags in reality are too short to account for persistent macroeconomic fluctuations. The business fluctuations to be accounted for by a business-cycle theory have a duration of years, while delays of information available to people is at most a few months, aside from statistical revisions; money supply data are available within a few weeks. The gap in the frequencies of cause and effect is suspect. Also, in incomplete-information models that involve intertemporal substitution like those of Lucas and Barro, positive output effects of money shocks are hard to reconcile with reasonable microeconomic assumptions. Barro, Grossman and King (1984) confess that it is difficult to specify a plausible set of assumptions concerning the nature of utility functions, capital depreciation and correlations of shocks that is consistent with a positive relation in incomplete-information models; it is easier to specify assumptions that lead to no relation or a negative one! Even if Keynesian sticky-wage theory lacks the explicit individual rationality of the incomplete-information theories, it is at least capable of generating the stylized facts that increases in money generate persistent and positively related changes in inflation and in output growth.

■ **7** Stylized facts of the U.S. economy with which a successful macroeconomic model should be consistent include the following: (i) A short-run Phillips curve: Changes in aggregate demand generate a positive relation between output (and employment) and inflation. For example, large increases in the money supply, which increase aggregate demand, are associated with high inflation and high output increases. (ii) Supply shocks generate a negative relation between output and inflation. For example, an increase in the price of imported oil is associated with high inflation and below-normal output growth. (iii) Long-run vertical Phillips curve (natural-rate hypothesis): regular increases in aggregate demand and/or prices are anticipated and leave output and employment unaffected. (iv) Output and employment display persistent deviations from normal levels in the face of both demand and supply shocks. (v) Wages are institutionally sticky—more so than commodity prices. (vi) Real wages display a modest positive correlation with both output and employment. (vii) Output per worker-hour is mildly procyclical.

■ **8** McCallum (1987) argues convincingly that this represents a substantial advance.

which the classical economists have (rightly) asserted as indefeasible."[9]

Although a fixed marginal-product-of-labor schedule necessarily implies that real wages are negatively correlated with employment, it remains possible, albeit unlikely, for real wages to be positively correlated with output, if the productivity of nonlabor factors of production varies. For example, an increase in the productivity of fixed factors would increase output, lowering the price level for a given money supply, raising the real wage, and inducing a contraction of employment along the fixed marginal-product-of-labor schedule. Shocks of this kind would tend to make the real wage procyclical as measured against output, but countercyclical as measured against employment.

But while nonlabor productivity may vary, it is unlikely to do so independently of labor productivity. For example, a new wave of technology, say, low-cost personal computers, might raise the productivity of capital but ought to raise the productivity of labor simultaneously. In many empirical and theoretical studies, the production function is specified in such a way that labor and other factors are subject to equal proportional productivity shocks.

In any case, the introduction of independent variations in the productivity of nonlabor factors cannot be much relied upon to enhance the sticky-wage model's conformity with the stylized facts of the business cycle. Such variations do not provide a mechanism for a positive real-wage/employment correlation and tend to create a counterfactual negative correlation between output and employment. Hence, it seems unlikely that independent variations in nonlabor factor productivity are of great enough importance to reverse the presumption that a sticky wage and a fixed marginal-product-of-labor schedule will generate a countercyclical real wage, whether the measure of the business cycle is employment or output.

Unfortunately for Keynes' theory, real wages have not been countercyclical as predicted.[10] The literature on the behavior of real wages over the business cycle is large, controversial, and defies simple summary. The behavior of aggregate real-wage measures over the business cycle has been found to reflect changes in the composition of employed labor as well as changes in the real wage received by a representative worker. These factors are difficult to disentangle. Lucas (1970) attempted to resolve the real-wage puzzle by showing that aggregation over straight and overtime pay rates masks an underlying real-wage countercyclicity. On the other hand, aggregation of young and experienced workers has been found to bias downward the measured cyclicity of the real wage.[11] By now it is probably the consensus that, for the postwar U.S., real wages for a representative worker are mildly procyclical or at least acyclical. This unambiguously negates the Keynesian prediction; the real-wage anomaly arises even if the real wage merely fails to be countercyclical. Some of the most important recent studies leading to this conclusion are Bodkin (1969), Mitchell, et al.(1985), and Bils (1985). Rayack (1987) offers a balanced and fairly comprehensive bibliography of empirical studies on the cyclical behavior of real wages.

As the mild procyclicity or acyclicity of the real wage became regarded as a robust empirical result, economists responded with a wide range of proposed solutions to the real-wage puzzle—a range that is a monument to the inventiveness of the profession. Among the responses are monopoly or oligopoly pricing models (Keynes [1939], Modigliani [1977], and Okun [1981]); allowance for prices being stickier than wages (Blanchard [1986], and McCallum [1986]); the general disequilibrium model (Barro and Grossman [1976]); Lucasian capital dynamics or Blinder inventory dynamics (both suggested by Leiderman [1983]); retaining the sticky wage but making prices equal to a markup over wages, which makes the real wage essentially acyclical by assumption (as in Taylor [1979a, 1979b, 1980]); rejecting the notion of sticky wages as relevant to the U.S. business cycle (as have partisans of the real-business-cycle approach); or, most radically, rejecting neoclassical economics in favor of Ricardian or Marxian theory (Schor [1985]).

■ **9** Like the classical economists he criticized, Keynes never seemed to question the idea that labor was an input of fixed quality, whose productivity was determined by iron laws of technology. The concept of labor as a homogeneous physical input whose productivity is subject to rigid technological law is not taken as seriously by today's economists as it was by British economists from Malthus and Ricardo to Keynes. A better understanding of labor is a skilled attention to purposive activity, whose marginal value to an employer is influenced by innumerable social and cultural conditions, such as the weather, science, art, religion, politics, various international tensions, demographic and epidemic events, and other institutional and historical factors. The production function and the marginal product-of-labor schedule are useful analytical devices subsuming the influence of all of these factors. But it is preposterous to insist that they remain frozen and do not contribute to macroeconomic fluctuations.

■ **10** Keynes (1936) predicted, on the basis of the sticky-wage model, that changes in real wages and money wages would be negatively correlated. Dunlop (1938) and Tarshis (1939) presented contrary evidence, evoking Keynes' (1939) reply.

■ **11** See, for example, Mitchell, et al. (1985).

Many of the solutions offered, particularly those of economists favoring sticky-wage models, will appear contrived or opportunistic, disturbing an idealized conception of scientific method. Okun confesses that "[w]ith a sufficient display of ingenuity, a 'quasi-Keynesian' [sticky-wage] model can be concocted that is consistent with the cyclical facts on productivity, real wages, and factor shares....These analytical pyrotechnics really illustrate that anything goes under conditions of monopoly."[12]

However, ad hoc solutions are common and useful elements of scientific practice. "[W]ithin what Kuhn calls 'normal science'—puzzle-solving—[scientists] use the same banal and obvious methods all of us use in every human activity. They check off examples against criteria; they fudge the counter-examples enough to avoid the need for new models; they try out various guesses, formulated within the current jargon, in the hope of coming up with something which will cover the unfudgeable cases."[13] The real-wage puzzle increasingly seems to be an unfudgeable counterexample calling for some modification of the sticky-wage model. My guess of what can cover the unfudgeable case without abandoning sticky wages is formulated in the jargon of production functions and productivity shocks, recently made current in macroeconomics by real-business-cycle theorists.

It is certainly remarkable that the productivity solution to the real-wage puzzle has not, apparently, been explored before. However, a recent contribution by Leiderman (1983, p. 77) came close: "...the relationship between real wages and economic activity to be found in a given sample of data is likely to depend on the specific real and monetary shocks that affected the economy during the sample period. For example, it seems quite plausible that the specific pattern of wages/activity comovement emerging during periods of important productivity (or technology) shocks would sharply differ from that arising during monetary cycles." Leiderman found evidence that real wages declined in response to unanticipated money growth, generating a countercyclical pattern, if the oil shocks of the seventies, a kind of productivity shock, are controlled for with dummy variables. Thus, Leiderman approaches, but does not actually arrive at, an explicit recognition that shifts in the productivity of labor (other than those associated with capital or inventory responses to money surprises) could generate procyclical real wages, consistent with declining returns to labor.

Keynesians favoring sticky-wage models may have overlooked or sometimes even dismissed the productivity solution to the real-wage puzzle because of doubt that autonomous variations in labor productivity are important in the business cycle. Literature in the real-business-cycle genre has made the notion of productivity shocks appear useful in accounting for procyclicity in real wages. But this does not motivate a rejection of sticky-wage models, which can incorporate productivity shocks.

III. A Formal Wage-Contracting Model

This section reconciles the Keynesian real-wage mechanism with the stylized fact of mildly procyclical real wages by extending Fischer's (1977) model, in which nominal wages are negotiated in light of expectations of inflation. The extension involves persistent or autocorrelated shifts in the marginal-product-of-labor schedule, as plotted against the level of employment, which are taken into account in setting wages.

For example, a positive innovation in labor productivity raises expectations of future productivity because high productivity tends to persist. Firms and workers bargaining over nominal wages for the periods to come will take account of the higher expected productivity. In particular, money wages will be set at the expectation of the marginal product of labor (at a targeted employment level) times the price level. This theory is well within the spirit of Keynes' sticky-wage model, but also embodies the neoclassical notion that wages reflect expectations of productivity as well as expectations of inflation.

This amendment to the Keynesian sticky-wage mechanism can easily account for a real wage that is positively correlated with output. Consider separately the effect of demand and productivity shocks. An aggregate demand shock changes output and the real wage in opposite directions. A productivity shock changes output and real wages in the same direction. In an economy subject to both kinds of shocks, if supply shocks are important, and if wage bargainers are adroit at adjusting money wages to keep them in line with the expected marginal revenue product of labor, it is easy for an overall pattern of mildly positive correlation between output and real wages to arise.

■ **12** See Okun (1981), p. 19.

■ **13** See Rorty (1982), p. 572.

It is somewhat more difficult to generate a positive correlation between employment and the real wage. In order to do so, productivity shocks must have important positive effects on employment. This is difficult because initially, increased productivity, by raising output, reduces the price level and raises the real wage at the contract wage. The rise in the real wage reduces the incentive of a firm to expand employment. When a contract is subsequently renegotiated, the real wage can be adjusted downward (though it will remain above the level occurring prior to the productivity improvement). This downward adjustment in the real wage can provide for expanded employment and is therefore consistent with a preference among workers for more employment at a temporarily high real wage. A critical part of the mechanism for generating a positive relation between the real wage and employment under sticky wages is this desire of workers to increase expected employment under renegotiated contracts as the expected real wage under the contract rises.

In the rest of this section, a formal model is developed that is similar to Fischer's (1977), but which incorporates productivity shocks and explicit profit-maximization by firms. The supply behavior of firms implies a kind of Phillips curve (equation 13 below) in which output supply responds both to unbargained-for inflation and to productivity. The model is completed with a velocity equation (16) and a money-supply feedback policy rule (17), and solutions for output, employment, and real wages derived (18,19,20). In the next section, the model here developed is used to resolve the real-wage puzzle.

Following Fischer (1977), consider a hypothetical economy with two-period staggered, or overlapping, contracts. The economy is composed of two groups of firms, identical in all respects, except for the date at which currently effective labor contracts were signed. Firms having signed wage contracts at the end of last period ($t-1$) are referred to as group-one firms, while those that signed wage contracts at the end of the period before last ($t-2$) are referred to as group-two firms. The groups are competitive in that they take the commodity price as given. Economy-wide aggregates are simulated by taking the average of the two groups.

The firms' production function is

$$(1) \quad Y_{it} = Z_t N_{it}^{\gamma}, \; 0<\gamma<1, \; i = 1, 2,$$

where Y_{it} is the output of a firm in group i in period t, N_{it} is the labor input of a firm in group i, and Z is a global productivity shock. The marginal product of labor is

$$(2) \quad \frac{dY_{it}}{dN_{it}} = Z_t \gamma (N_{it})^{(\gamma - 1)}, \; i = 1, 2.$$

In logarithmic form, output is

$$(3) \quad y_{it} = z_t + \gamma n_{it}, \; i = 1, 2,$$

where the lowercase letters y, z, and n are natural logarithms of their uppercase counterparts. The (log of the) marginal product of labor is

$$(4) \quad ln\left(\frac{dY_{it}}{dN_{it}}\right) = z_t + ln(\gamma) + (\gamma - 1) n_{it},$$
$$i = 1, 2.$$

The demand for labor by firm i in period t, n^d_{it}, is given by the condition that the real wage equals the marginal product of labor:

$$(5) \quad (w_{it} - p_{it}) = z_t + ln(\gamma) + (\gamma - 1) n^d_{it},$$
$$i = 1, 2,$$

where w_{it} is the (log of the) wage received by group i firms' workers in period t, and p is the (log of the) price level. The notional (in the sense of Clower [1965]) supply of labor to a firm is conditioned on the real-wage rate:

$$(6) \quad n^s_{it} = \beta_0 + \beta_1 (w_{it} - p_{it}),$$
$$\beta_1 > 0, \; i = 1, 2.$$

If wages were not sticky, but varied to clear the market, they would equal w^*_{it}, the labor market clearing wage, or the wage for which labor demand equals the notional labor supply, $n^d_{it} = n^s_{it}$:

$$(7) \quad w^*_{it} = p_t + [ln(\gamma) - (1 - \gamma)\beta_0] \, J + J z_t,$$
$$\text{where } J = [1 + \beta_1 (1 - \gamma)]^{-1}.$$

The contractual wage rate is the expectation of the rate that would clear the labor market. The contract wage for group i is found by taking the expectation of (7) conditioned on information available in period $t-i$, when the contract was signed.

$$(8)\quad w^*_{it} = E_{t-i}p_t + [ln(\gamma) - (1-\gamma)\beta_0]J + JE_{t-i}z_t,$$

where E_{t-i} is the operator that conditions random variables on realizations at $t-i$ and earlier. Finally, let z_t be a first-order autoregressive process,

$$(9)\quad z_t = \rho_1 z_{t-1} + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma^2_\epsilon).$$

These elements are sufficient to specify the supply sector of the economy, under the assumption that labor input is demand-determined:

$$(10)\quad n_{it} = n^d_{it}.$$

Using (3), (5), (8), (9), and (10), it can be shown that the (log of the) output of group one is

$$(11)\quad y_{1t} = \gamma[\beta_0 + \beta_1 ln(\gamma)]J + \frac{1}{1-\gamma}\epsilon_t + (1+\beta_1)J\rho_1 z_{t-1} + \frac{\gamma}{1-\gamma}(p_t - E_{t-1}p_t),$$

and the output of group two is

$$(12)\quad y_{2t} = \gamma[\beta_0 + \beta_1 1n(\gamma)]J + \frac{1}{1-\gamma}\epsilon_t + \frac{\rho_1}{1-\gamma}\epsilon_{t-1} + (1+\beta_1)J\rho_1^2 z_{t-2} + \frac{\gamma}{1-\gamma}(p_t - E_{t-2}p_t).$$

Total output for the economy (taken as the average across firm groups) is

$$(13)\quad y_t = \gamma[\beta_0 + \beta_1 ln(\gamma)]J + \frac{1}{1-\gamma}\epsilon_t + \frac{2-\gamma J}{2(1-\gamma)}\rho_1\epsilon_{t-1} + (1+\beta_1)J\rho_1^2 z_{t-2} + \frac{\gamma}{1-\gamma}\sum_{i=1}^{2}(p_t - E_{t-i}p_t).$$

Equation (13) provides a characterization of the supply sector of the economy. It can be thought of as a kind of Phillips curve: the equation shows that output depends on inflation not expected when contracts were signed and on productivity shocks, with coefficients that depend uniquely on the elasticity of output with respect to labor input, γ, and on the elasticity of notional labor supply, β_1.

It is useful to compare and contrast the modified Fischer supply equation, (13), with the original Fischer supply equation, which was based on the assumption that wage-setters seek to stabilize the real wage. In order to see the difference clearly, rewrite (13) as

$$(14)\quad y_t = c + (a+2b)\epsilon_t + (a+b)\rho_1\epsilon_{t-1} + a\sum_{j=2}^{\infty}\rho_1^j\epsilon_{t-j} + \frac{\gamma}{1-\gamma}\sum_{i=1}^{2}(p_t - E_{t-i}p_t),$$

where $a = \dfrac{1-\gamma J}{1-\gamma}$

where $b = \dfrac{\gamma J}{2(1-\gamma)}$

where $c = \gamma[\beta_0 + \beta_1 ln(\gamma)]J$.

The parameter a shows the elasticity of the response of output to productivity variations, once wages adjust. The parameter b shows the extra output response of each group of firms that occurs prior to recontracting, reflecting the advantage employers take of productivity advances not yet reflected in wages. Both groups of firms are in a position to take such advantage in the current period of a supply shock, but group-one firms have already recontracted to reflect shocks in period $t-1$. These considerations explain why the parameter b is doubled in the ϵ_t– term, why it appears singly in the ϵ_{t-1}– term, and why it does not enter in the ϵ–terms of longer lags. Of course, productivity shocks can also influence output indirectly through their influence on price surprises.

The modified equation (14) can be compared with Fischer's original:

$$(15)\quad y_t = s_0 + \sum_{j=0}^{\infty} \rho_1^j \epsilon_{t-j} + s_1 \sum_{i=1}^{2} (p_t - E_{t-i} p_t).$$

There are two minor differences in output supply behavior implied by (14) as opposed to (15). First, the modified equation has terms for productivity shocks, the ϵs, that can be represented as an ARMA(1,2) process, while the original Fischer equation has productivity shock terms that can be represented as an AR(1) process. Second, the coefficients of (14) are determined by the taste and technology parameters, γ and β_1, and must obey special restrictions. Yet (14) has much the same qualitative implications for output and price behavior as (15). This is so, even though they have potentially different qualitative implications for the response of employment to supply shocks.

In order to complete the model, specifications of aggregate demand and monetary policy are needed. Let aggregate demand be given by the quantity theory equation, as

$$(16)\quad y_t = m_t - p_t + v_t, \quad v_t = \rho_2 v_{t-1} + \lambda_t,$$

where m is the (log of the) quantity of money and v is the (log of the) velocity of money. As indicated, velocity, v_t, is a stochastic first-order autoregression, whose innovation, λ_t, is normally distributed with variance σ_λ^2.

The money stock can be chosen by the policymaker in light of his assumed information about the state of the economy. The rule for monetary policy is specified as

$$(17)\quad m_t = \mu_0 + \mu_1 \epsilon_t + \mu_2 \epsilon_{t-1} + \mu_3 E_{t-2} z_{t-1} + \mu_4 \lambda_t + \mu_5 \lambda_{t-1} + \mu_6 E_{t-2} v_{t-1},$$

where the μ_i are choice parameters. The policy rule's arguments in $E_{t-2}\, z_{t-1}$ and $E_{t-2}\, v_{t-1}$ represent money responses to an infinite series of past innovations realized in periods $t-2$ and earlier. This specification of monetary policy is sufficient to satisfy output- or price-stabilization objectives, for example, to minimize the variance of either y or p. The policy rule parameters, μ_1, μ_2, μ_4, and μ_5 help determine output behavior; μ_3 and μ_6 do not influence output, but do influence the behavior of the price level.

The final-form solutions for economy-wide averages of output, employment, and the real-wage are

$$(18)\quad y_t = k_0 + \gamma[\beta_0 + \beta_1 ln(\gamma)]J + (1 + \gamma\mu_1)\epsilon_t + \frac{\gamma\mu_2 + \rho_1(2 - \gamma J)}{2 - \gamma}\epsilon_{t-1} + \frac{1 - \gamma J}{1 - \gamma}\sum_{j=2}^{\infty}\rho_1^j \epsilon_{t-j} + \gamma(\mu_4 + 1)\gamma_t + \frac{\gamma}{2 - \gamma}(\mu_5 + \rho_2)\lambda_{t-1},$$

$$(19)\quad n_t = [\beta_0 + \beta_1 ln(\gamma)]J + \mu_1\epsilon_t + \frac{\mu_2 + \rho_1(1 - J)}{2 - \gamma}\epsilon_{t-1} + \beta_1 J\sum_{j=2}^{\infty}\rho_1^j\epsilon_{t-j} + (1 + \mu_4)\lambda_t + \frac{\rho_2 + \mu_5}{2 - \gamma}\lambda_{t-1}, \text{ and}$$

$$(20)\quad (w_t - p_t) = [ln(\gamma) - \beta_0(1-\gamma)]J + [1-(1-\gamma)\mu_1]\epsilon_t + \frac{[1 + J(1 - \gamma)]\rho_1 - (1 - \gamma)\mu_2}{2 - \gamma}\epsilon_{t-1} + J\sum_{j=2}^{\infty}\rho_1^j\epsilon_{t-j} - (1 - \gamma)(1 + \mu_4)\lambda_t - \frac{(1 - \gamma)(\rho_2 + \mu_5)}{2 - \gamma}\lambda_{t-1},$$

where $J = [1 + \beta_1(1 - \gamma)]^{-1}$.

IV. Determinants of Real-Wage Cyclicity

Whether or not real wages are procyclical (positively correlated with output and employment) depends upon the relative size of productivity versus velocity innovations (σ_ϵ^2 versus σ_λ^2), upon their autocorrelations (ρ_1, ρ_2), upon the elasticity of notional labor supply with respect to the real wage (β_1), upon the elasticity of production with respect to labor input (γ), and upon the policy rule (the $\mu_i s$). In this section, some examples displaying the dependence of real-wage cyclicity on these elements provide a robust basis for the view that procyclical or acyclical real wages are consistent with sticky nominal wages.

Consider a simple, benchmark example in which the money supply is constant ($\mu_i = 0$, $i = 1,2...6$) and notional labor supply is inelastic ($\beta_1 = 0$). In this case, the final forms for economy-wide averages of output (y), employment (n), and the real wage ($w - p$) are (henceforth ignoring constant, or intercept terms):

$$(21)\quad y_t = \sum_{j=0}^{\infty} \rho_1^j \epsilon_{t-j} + \gamma\lambda_t + \frac{\gamma}{2-\gamma}\rho_2\lambda_{t-1},$$

$$(22)\quad n_t = \lambda_t + \frac{\rho_2}{2-\gamma}\lambda_{t-1},$$

$$(23)\quad (w_t - \mathrm{p_t}) = \sum_{j=0}^{\infty} \rho_1^j \epsilon_{t-j} - (1-\gamma)\lambda_t - \frac{1-\gamma}{2-\gamma}\rho_2\lambda_{t-1}.$$

The correlation between output and the real wage can be either positive or negative in this example, depending on the relative importance of contrary tendencies. Productivity innovations have positive effects on output and real wages, tending to create a positive correlation between them. Contrariwise, demand shocks have positive effects on output, but negative effects on real wages, tending to create a negative correlation. The benchmark example provides a plausible illustration of how sticky wages are consistent with either a positive or negative correlation between real wages and output.

The example fails to provide an illustration of how real wages and employment could be positively correlated. This is because employment, unlike output, is unaffected by the productivity shocks, as may be seen in the absence of ϵ–terms in (22). The reason productivity increases do not lead to employment increases is that productivity increases also lead to identical increases in the real wage, leaving firms' labor demand unchanged. A one-unit rise in productivity raises output by one unit at the unchanging-employment level, which—given the unitary elasticity of demand inherent in the velocity equation—leads to a one-unit fall in the price level. Thus, marginal labor productivity and the real wage both rise by one unit, leaving the profit-maximizing employment level unchanged. After old contracts expire, there will be no adjustments to make to the nominal wage, since the real wage is not driven out of equality with labor productivity by productivity shocks, and workers are satisfied with supplying the unchanged employment level (which would not be the case if notional labor supply were elastic, or $\beta_1 > 0$).

The correlation between the real wage and employment is necessarily negative in the benchmark case, reflecting the effects of demand shocks. If the real-wage puzzle is to be fully resolved, employment must respond positively to productivity shocks.

At least four modifications of the simple benchmark case can provide for positive employment effects of productivity shocks. All seem to be reasonable features of the world rather than ad hoc contrivances. These modifications allow for (1) notional labor-supply elasticity, $\beta_1 > 0$; (2) monetary policy feedback, $\mu_i \neq 0$; (3) nonunitary elasticity of demand with respect to price; and (4) less-than-complete, unilateral discretion by the firm in choosing employment levels.

First, allow for a positive notional labor-supply elasticity. This modification means that renegotiating wage contractors will aim for less increase in the real wage following a productivity innovation, in order to provide for a higher expected level of employment—one matching the higher notional labor supply induced by the higher expected real wage. This means that, while the nominal wage will be reduced under a new contract, it will not fall by as much as the price level falls. After this modification, the final-form solution for employment is

$$(24)\quad n_t = \tfrac{1}{2}\beta_1(1-\gamma)\rho_1\epsilon_{t-1} + \beta_1 J\sum_{j=2}^{\infty}\rho_1^j\epsilon_{t-j} + \lambda_t + \frac{1}{2-\gamma}\rho_2\lambda_{t-1},$$

which shows the positive delayed effect of a productivity shock on employment if $\beta_1 > 0$. The ϵ_{t-1}-term reflects positive employment responses of the first group of firms to renegotiate (reduce) nominal wages; the ϵ_{t-j}-terms for $j > 0$ reflect responses by both groups. The initial impact, $dn_t/d\epsilon_t$, remains at zero because the effect of labor supply elasticity occurs only through renegotiations of nominal wages, which occur with a lag. In spite of this delay, allowing for labor-supply elasticity produces positive employment effects of productivity shocks and thus makes possible a positive correlation between the real wage and employment.

Second, allow for monetary policy responses to shocks. The effect of this modification will depend on the kind of policy feedback introduced. The most plausible case would involve negative responses to demand, $\mu_4<0$, $\mu_5<0$, $\mu_6<0$, and positive responses to productivity, $\mu_1>0$, $\mu_2>0$, $\mu_3>0$. Such responses could be motivated by a price-stabilization objective, or by a desire to alleviate the output- and employment-distorting influence of sticky wages. The object and effect of such a policy is to offset or eliminate demand shocks from the determination of employment and output, and to encourage employment and output to expand and contract to more fully reflect positive and negative productivity shocks. Objective-seeking monetary policy thus tends to reinforce the importance of productivity relative to demand shocks and to encourage positive employment responses to productivity shocks, tipping the scales toward a positive correlation between real wages and both output and employment.

Interestingly, if policy sought to totally eliminate the effects of a sticky wage, it could do so by setting the μ_i appropriately.[14] Then, a demand shock would have no impact, the real wage would definitely be positively correlated with both employment and output (assuming $\mu_1>0$), and the economy would behave as if the sticky wage was not a problem because the labor market would always clear.

Third, allow for nonunitary elasticity of aggregate demand. This modification makes the income velocity of money vary to cushion the effect of either shock on the price level. By reducing the deflationary consequence of a positive productivity shock, the modification moderates the real-wage increase accompanying such a shock, encouraging a positive employment response during the contract interval. One way to implement the modification is to substitute the IS-LM apparatus for the simple velocity equation, but the resulting model's complexity requires a separate treatment.

Fourth, allow for the degree of discretion over employment exercised by a firm to be less than complete. Keynes and other Keynesians have built sticky-wage models that assume that an employer always chooses employment to equate real wages with marginal labor productivity. While analytically convenient, such an assumption is both extreme and unnecessary to give an important role to a sticky wage. It is extreme because it implies that employment bears no neccesary relation to its market-clearing or Pareto-optimal level. A more moderate approach is to allow employment decisions to reflect both the optimal employment level and the one-sided discretionary profit-maximizing employment level. One artifice for doing so is to let employment decisions by firms be a weighted average of the market-clearing employment level and the demand at the fixed nominal wage. Formally, replace (10) $n_{it} = n^d_{it}$ with

$$(25) \quad n_{it} = \phi n^d_{it} + (1 - \phi) n^*_{it}, \quad 0 < \phi \leq 1,$$

where n^*_{it} is the market-clearing level of employment. The lower the degree of firm discretion, ϕ, the less important are sticky wages in determining economic outcomes. Just as in the case of monetary policy feedback, this modification blunts the empirical impact of demand shocks and increases the employment and output responses to productivity shocks, increasing the correlation of the real wage with employment and output.

V. A Numerical Example of Procyclical Real Wages

A numerical simulation provides an example of procyclical real wages under nominal contracts.

The commodity supply equation is (13), preserving the traditional Keynesian assumption of equality of the real wage and marginal labor productivity. The demand equation is (16), preserving the unitary elasticity of demand with respect to price. The parameter values assigned are

■ **14** Note that by assumption (10), the real labor demand condition is always satisfied. So the monetary authority can get the labor market to clear each period by choosing a policy rule that keeps the employment-real-wage relation on the notional labor supply schedule. This policy is given by

$$\mu_1 = \beta_1 J, \ \mu_2 = \rho_1 \beta_1 J, \ \mu_4 = -1, \ \mu_5 = -\rho_2, \text{ for } J = [1+\beta_1(1-\gamma)]^{-1}$$

with μ_3 and μ_6 irrelevant. Then, assuming notional labor supply has a positive response to the real wage, the real wage is necessarily procyclical, measured against either employment or output. If policy sought to eliminate the familiar Harberger welfare-loss triangles due to sticky wages, then sticky wages would not imply countercyclical real wages. Ironically, such a policy would conceal the potential importance of the sticky wage, and thus conceal the usefulness of active policy feedback.

$$(26)\quad \gamma = .5,\ \beta_1 = .5$$

$$\sigma_\epsilon^2 = 1,\ \sigma_\lambda^2 = 5;\ \rho_1 = \rho_2 = .8.$$

In the money-supply function, (17), the particular values for the feedback parameters were one-half the values required to completely stabilize the price level. (Choice of the values that completely stabilize prices would have resulted in an implausible simulation, and one whose numerical results would have been uninteresting: the effect of demand shocks on output, employment, and the real wage would have been completely removed, resulting in a positive correlation between output, employment, and the real wage of nearly 1.) The policy parameters assumed in the simulation are

$$(27)\quad \mu_1 = .8,\ \mu_2 = .56,\ \mu_3 = .48,$$

$$\mu_4 = -.5,\ \mu_5 = -.4,\ \mu_6 = -.4.$$

The example modifies the benchmark example in two ways: notional labor supply has positive elasticity $\beta_1 = .5$, and the money-supply rule provides a positive response to a productivity shock and a negative response to a demand shock. The final-form equations for aggregate output, employment, and the real wage are

$$(28)\quad y_t = 1.50\epsilon_t + 1.07\epsilon_{t-1}$$

$$+\ 1.20 \sum_{j=2}^{\infty} (.8)^j \epsilon_{t-j} + .25\lambda_t + .13\lambda_{t-1}.$$

$$(29)\quad n_t = 1.00\epsilon_t + .53\epsilon_{t-1}$$

$$+\ .40 \sum_{j=2}^{\infty} (.8)^j \epsilon_{t-j} + .50\lambda_t + .27\lambda_{t-1}.$$

$$(30)\quad (w_t - p_t) = .50\epsilon_t + .53\epsilon_{t-1}$$

$$+\ .80 \sum_{j=2}^{\infty} (.8)^j \epsilon_{t-j} - .25\lambda_t - .13\lambda_{t-1}.$$

The two modifications to the benchmark specification are sufficient to generate positive cyclicity in the real wage: the correlation between output and the real wage is +.67; between employment and the real wage, +.15. Positive correlations arise even though the variance of the demand shock is five times as great as the variance of the productivity shock, and even though demand shocks actually account for a slightly larger portion of the variance in employment than do productivity shocks.

Incidentally, measured productivity or total productivity of labor, $y_t - n_t$, has the same cyclical behavior as the real wage, so that the procyclicity of measured productivity of the postwar U.S. economy can also be accounted for by the sticky-wage model.

The numerical simulation provides an implausibly high correlation between output and the real wage, which is ironic in view of the puzzle it was designed to resolve. The correlation can easily be reduced by changing the relative size of the disturbance variances or by other adjustments in free parameters. However, it is difficult to reduce the correlation between output and the real wage to realistic levels without making the correlation between employment and the real wage negative, unless more fundamental changes in the model are made. Addition to the model of some elements of price stickiness, partial indexation of wages to the price level, and other features of a complete macroeconomic theory might help make a sticky-wage model capable of accounting even more closely for the stylized facts of the business cycle. Such an effort, while indicated, goes beyond the scope of the present article.

VI. Conclusion

The analysis has shown that introduction of productivity factors into the determination of wages and employment permits sticky-wage models to generate positive cyclicity in the real wage. Hence, the notion of the sticky wage cannot be rejected on grounds that it is inconsistent with a procyclical real wage. By the same token, the analysis suggests that allowance for autonomous cyclical variations in labor productivity and forward-looking expectations are very useful in resolving the real-wage puzzle, and may point out the incompleteness of simple sticky-wage models lacking these features. This incompleteness can be remedied without reducing the usefulness of the sticky-wage notion. While the sticky wage cannot alone explain or account for an observed procyclical real wage, the usefulness of sticky-wage models has always been seen elsewhere, specifically in understanding the effect of nominal variables, like money and prices, on real variables, such as output and employment.

References

Akerlof, George A., and Janet L. Yellen. "A Near Rational Model of the Business Cycle, with Wage and Price Inertia." *The Quarterly Journal of Economics.* 100 (August 1985a): 823-38.

_______ . "Can Small Deviations from Missing Rationality Make Significant Differences to Economic Equilibria?" *American Economic Review.* 75 (September 1985b): 708-20.

_______ . "How Large Are the Losses From Rule of Thumb Behavior in Models of the Business Cycle?" Manuscript presented at Conference in Honor of James Tobin. May 6 and 7, 1988.

Bils, Mark J. "Real Wages Over the Business Cycle: Evidence from Panel Data." *Journal of Political Economy.* 93, no. 4 (August 1985): 666-89.

Bodkin, Ronald G. "Real Wages and Cyclical Variations in Employment: A Re-examination of the Evidence." *Canadian Journal of Economics.* 2, no. 3 (August 1969): 353-74.

Barro, Robert J., "Long-Term Contracts, Sticky Prices and Monetary Policy." *Journal of Monetary Economics.* 3, no. 3 (July 1977): 305-16.

_______ **, and Herschel I. Grossman.** *Money, Employment and Inflation.* Cambridge: Cambridge University Press 1976. p. 2.

_______ **, and Robert J. King.** "Time-Separable Preferences and Intertemporal Substitution Models of Business Cycles," *Quarterly Journal of Economics.* 99 (November 1984): 817-39.

Blanchard, Olivier J. "Empirical Structural Evidence on Wages, Prices, and Employment in the U.S." NBER Working Paper no. 2044. (October 1986).

Christiano, Lawrence J. and Eichenbaum, Martin. "Is Theory Really Ahead of Measurement? Current Real Business Cycle Theories and Aggregate Labor Market Flucuations." Unpublished paper. Federal Reserve Bank of Minneapolis, Northwestern University, and NBER, (August 1988).

Clower, R.W. "The Keynesian Counter-Revolution: A Theoretical Appraisal," in The Theory of Interest Rates, edited by F. H. Hahn and F. Brechling, International Economic Association Series, Macmillan, chapter 5 (1965): 103-25. Excerpt reprinted in Monetary Theory: Selected Readings, edited by R. W. Clower, 1969, Penguin Modern Economics Readings, selection 19, pp. 270-97.

Dunlop, John T. "The Movement of Real and Money Wage Rates." *The Economic Journal.* (September 1938): 413-34.

Fischer, Stanley. "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule." *Journal of Political Economy.* 85, no. 1 (February 1977): 191-05.

Friedman, Milton. "The Role of Monetary Policy." *American Economic Review.* 58, no. 1 (March 1968): 1-17.

Hall, Robert. "Employment Fluctuations and Wage Rigidity." *Brookings Papers on Economic Activity.* Washington, D.C. The Brookings Institution (1980).

Hall, Robert, and David M. Lilien. "Efficient Wage Bargains under Uncertain Supply and Demand." *American Economic Review.* 69, no. 5 (December 1979): 868-79.

Keynes, John Maynard. The General Theory of Employment, Interest, and Money (1936). New York, Harcourt, Brace, and World, Inc. 1964 Edition, chapter 2.

_______ . "Relative Movements of Real Wages and Output," *The Economic Journal* (March 1939): 34-51.

King, Robert, and Charles Plosser. "Money, Credit, and Prices in a Real Business Cycle." *American Economic Review.* 74 (June 1986): 363-80.

Leiderman, Leonardo. "The Response of Real Wages to Unanticipated Money Growth." *Journal of Monetary Economics.* 11, no. 1 (January 1983): 73-88.

Lucas, Robert E., Jr. "Capacity, Overtime, and Empirical Production Functions." *American Economic Review.* 60, no. 2 (May 1970): 23-27.

_______ , **and Leonard A. Rapping.** "Real Wages, Employment, and Inflation." *Journal of Political Economy.* 77, no. 5 (Sept./Oct. 1969): 721-54.

Mankiw, N. Gregory. "Comment" on Julio J. Rotemberg's "The New Keynesian Microfoundations," in NBER Macroeconomics Annual 1987, Stanley Fischer, ed. pp. 105-10.

McCallum, Bennett T. "On 'Real' and 'Sticky-Price' Theories of the Business Cycle." *Journal of Money, Credit, and Banking.* 18, no. 4 (November 1986): 397-414.

_______ . "The Development of Keynesian Macroeconomics." *American Economic Review, Papers and Proceedings.* 77, no. 2 (May 1987): 125-136.

Mitchell, Mark L., Myles S. Wallace, and John T. Warner. "Real Wages over the Business Cycle: Some Further Evidence." *Southern Economic Journal.* 51, no. 4 (April 1985): 1162-73.

Modigliani, Franco. "The Monetarist Controversy, or Should We Forsake Stabilization Policies." *American Economic Review.* 67, no. 2 (March 1977): 1-19.

Okun, Arthur M. *Prices and Quantities: A Macroeconomic Analysis.* Washington, D.C.: The Brookings Institution (1981).

Rayack, W. "Cyclical Movement in Real Wages." *Journal of Post-Keynesian Economics.* 10, no. 1 (Fall 1987): 3-21.

Rorty, Richard. "Method, Social Science, and Social Hope," Consequences of Pragmatism (Essays: 1972-1980) University of Minnesota Press, Minneapolis (1982).

Schor, Juliet B. "Changes in the Cyclical Pattern of Real Wages: Evidence from Nine Countries, 1955-80." *The Economic Journal.* 95 (June 1985): 452-68.

Tarshis, Lorie. "Changes in Real and Money Wages." *The Economic Journal.* (March 1939): 150-4.

Taylor, John B. "Staggered Wage Setting in a Macro Model." *American Economic Review: Papers and Proceedings.* (May 1979a): 108-13.

_______ . "Estimation and Control of a Macroeconomic Model with Rational Expectations." *Econometrica.* 47, no. 5 (September 1979b): 1267-86.

_______ . "Aggregate Dynamics and Staggered Contracts." *Journal of Political Economy.* 88, no. 1 (1980): 1-23.

_______ . "Rational Expectations and the Invisible Handshake," in Macroeconomics, Prices, and Quantities: Essays in Memory of Arthur M. Okun, ed. James Tobin. Washington, D.C.: Brookings Institution. (1983).

_______ . "Limit Pricing and the Banking Industry." *Journal of Money, Credit, and Banking.* 11, no. 4 (November 1979): 438-46.

Real Business Cycle Theory: a Guide, an Evaluation, and New Directions

by Alan C. Stockman

Alan C. Stockman is a professor of economics at the University of Rochester and was formerly a visiting scholar at the Federal Reserve Bank of Cleveland. The author would like to thank the Federal Reserve Bank of Cleveland for research support.

Introduction

The purpose of real business cycle (RBC) models is to explain aggregate fluctuations in business cycles without reference to monetary policy. Much of the existing RBC analysis also seeks to explain fluctuations without reference to market failures, fiscal policies, or even disturbances to preferences or demographics.

The concentration on technology shocks that characterizes most, though not all, of the current models is not in principle a defining feature of RBC analysis. This concentration indicates both the early state of research and the substantial progress that has been made by considering technology shocks.

This paper summarizes and evaluates in a mostly nontechnical way the state of RBC theory, outlines some useful directions for research in the area, and discusses the implications of this research on economic policy. For space reasons, I will regard sectoral-shift models (Lilien [1982], Abraham and Katz [1986], Loungani [1986], Davis [1987], Hamilton [1987a], and Murphy and Topel [1987]) as a separate topic that deserves its own treatment, though those models clearly form one class of RBC theory.[1]

Real business cycle analysis is important and interesting for several reasons. First, the evidence that monetary policy affects real output is much weaker than most economists had thought. Second, even if monetary policy affects real output, the evidence that it is the dominant influence on business cycles is also much weaker than previously thought. A detailed discussion of the evidence on these topics is beyond the scope of this essay; see, for example, Barro (1987), Eichenbaum and Singleton (1986), Christiano and Ljungqvist (1988), and the references cited in those works.

Third, even if monetary disturbances play a major role in many real-world business cycles, most economists believe that supply shocks and other nonmonetary disturbances, originating from sources such as oil price changes and technical progress, also play important roles in some aggregate fluctuations.

RBC analysis is designed to determine how such "real" shocks affect output, employment, hours, consumption, investment, productivity, and so on. RBC models are also designed to

■ 1 Earlier nontechnical introductory essays on RBC models include Walsh (1986) and Rush (1987). Manuelli (1986) summarizes Prescott's arguments, Summers' criticisms, and Prescott's reply. More recent summary papers include McCallum (1989) and Mankiw (1988).

TABLE 1

U.S. Business Cycle Statistics, 1954:IQ-1982:IVQ

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.8%	.82	1.00	.82
Consumption				
On services	.6	.66	.72	.61
Nondurables	1.2	.71	.76	.59
Fixed investment	5.3	.78	.89	.78
Nonresidential	5.2	.54	.79	.86
Structures	4.6	.42	.62	.70
Equipment	6.0	.56	.82	.87
Average nonfarm hours worked	1.7	.57	.85	.89
In mfg. only	1.0	.76	.85	.61
GNP/hours	1.0	.51	.34	-.04
Capital stocks:				
Nonfarm inventory	1.7	.15	.48	.68
Nonresidential structures	.4	-.20	-.03	.16
Nonresidential equipment	1.0	.03	.23	.41

NOTE: Corr. = correlation. All data were first detrended with the Hodrick-Prescott filter.
SOURCE: Prescott (1986a).

determine how disturbances at a specific time or in one sector of the economy affect the economy later and in other sectors, and to study the dynamics of the transitions.

Fourth, RBC models can be used to determine how any disturbance, even if monetary in origin, spreads through different sectors of the economy over time. While monetary policy, or monetary disturbances, may frequently set business cycles in motion, it is possible that the subsequent dynamics and characteristics of the cycles differ little from those that would have resulted from disturbances to tastes or technology. That could explain the evidence on seasonal cycles without precluding money as a major force in business cycles. Whether or not the more extreme claim that monetary policy is unimportant for business cycles turns out to be correct, RBC analysis is making important contributions for the third and fourth reasons cited above.

I. A Prototype Real Business Cycle Model

What Real Business Cycle Models Try to Explain

The characteristics of business cycles that the RBC models have been designed to explain include the sizes of the variances and covariances in table 1. Among these characteristics are the following:

1. Consumption varies less than output, which varies less than investment; the standard deviation of investment is three to five times that of output. Consumer purchases of durables vary about as much as investment, while purchases of nondurables and services vary less but remain procyclical (defined to mean positively correlated with output).
2. Hours worked are procyclical and vary about as much as output.
3. The average product of labor is procyclical and varies about half as much (in standard deviations) as output; the correlation between productivity and output is smaller than the correlation between hours and output.

Some RBC models attempt to explain other characteristics. For example, Long and Plosser (1983) have a multisector model that attempts to explain why output moves together across most sectors of the economy (including various manufacturing industries, retail and wholesale trade, services, transport, and utilities, with agriculture the main exception) as well as why temporary disturbances have longer-lived effects.

Christiano (1988) adds inventories to an RBC model to try to account for the fact that quarterly changes in inventories are about half the size of changes in GNP, even though inventories are on average only a small fraction, about 0.6 percent, of GNP. Kydland and Prescott (1988) also attempt to explain inventory behavior, particularly inventories of goods in process, through their time-to-build technology.

Real business cycle models have not yet been developed to address still other features of business cycles:

1. Nominal money and real output are highly correlated; most of this correlation is with inside, rather than outside, money (compare with Barro [1987]).
2. Prices vary less than quantities.
3. Nominal prices are acyclical.
4. Real wages are acyclical or mildly procyclical.
5. Real exports, imports, and net exports (the balance of trade surplus) are all procyclical.

Backus and Kehoe (1988) and Phillips (1988) have documented the last feature; they have shown that many of the same qualitative features found in U.S. business cycles also characterize business cycles in other countries. I will argue below that *quantitative* differences across countries in business-cycle phenomena and the cyclical behavior of international trade variables can form important new sources of evidence on RBC models. The fourth feature, the acyclical or mildly procyclical behavior of real wages, has been addressed recently by Christiano and Eichenbaum (1988), who conclude that existing models do not adequately explain this fact.

A Description of a Prototype RBC Model

Real business cycle models typically begin with assumptions such as (1) there is a representative household that maximizes the expected discounted value, over an infinite horizon, of a utility function defined over consumption and leisure, or (2) there is a constant-returns technology that transforms labor and capital into output, which may be consumed or invested to augment the capital stock in the next period.

In most RBC models, the production function is subject to random disturbances. Firms are perfectly competitive, and there are no taxes, public goods, externalities, or arbitrary restrictions on the existence of markets. The maximization problems for households and firms imply decisions for consumption, investment, the division of time between labor and leisure, and, thus, output (along with the capital stock, which is predetermined from last period). These decisions are functions of the *state variables:* the capital stock and the exogenous disturbance(s) to the production function.

Given some particular production and utility functions, an initial capital stock, and a stochastic process for the random disturbances, the model can be solved for the decision rules and, therefore, for the probability rules for all of the endogenous variables.[2] These probability rules then yield variances, covariances, and other statistical moments that can be matched against real-world data. A more technical description of a simple RBC model, in a multicountry context, is presented in section VI.

■ 2 The key technical papers on which the RBC models are based are Brock (1982) and Donaldson and Mehra (1983).

In principle, with enough freedom to choose arbitrary production and utility parameters and parameters of the stochastic process on the exogenous disturbances, one can always find variants of the model that match any given set of variances and covariances from real-world data. Lawrence Summers has criticized RBC models on this issue, claiming that it is easy to find incorrect models that match any given set of observations.

Obviously, to avoid this kind of criticism, RBC models must use some additional information to limit the arbitrary choices of utility and production parameters and exogenous stochastic processes. In the limit, it would be desirable to eliminate *all* arbitrary choices of parameters by relying solely on other information to parameterize the model, and then by showing that the model necessarily reproduces the kinds and characteristics of aggregate fluctuations that are observed in real-world data. Then there would be little controversy over Prescott's (1986a) assessment that "... it would be puzzling if the economy did not display these large fluctuations in output and employment with little associated fluctuations in the marginal product of labor."

Early RBC models, such as Long and Plosser (1983), made some of their assumptions in order to obtain analytically tractable models, so that the models would actually have closed-form solutions. The assumptions required to obtain analytic solutions to the models, however, are very stringent and, obviously, totally ad hoc. Consequently, RBC theorists have largely abandoned attempts to make their models analytically tractable and have instead turned to numerical solutions. Quantitatively accurate models are ultimately more appealing than analytically tractable models, anyway. The parameter restrictions from outside information used in RBC models are discussed in section II.

Some Variations on the Prototype Model

Kydland and Prescott (1982, 1988) include a number of additional features in their model, including time to build (so that investment cannot be installed instantly but only after a lag), variable utilization of capital, lagged effects (as well as contemporaneous effects) of leisure on utility, and imperfect information about productivity.

Hansen (1985) adds lotteries on employment (Rogerson [1984, 1988]) to the Kydland-Prescott model. People are assumed to be able to work either full time or not at all, rather than part time. If productivity conditions dictate that everyone would work part time if labor were divisible, a

Pareto-optimal allocation may involve *some* people working full time and others not working, *even though people are identical ex ante.* The choice of who works and who does not is assumed to be determined totally randomly, by an exogenous lottery.

Economies with this random allocation give everyone higher expected utility than economies without it. Hansen's application of Rogerson's theory to the Kydland-Prescott model results in a better match between the model and the data for the variability of hours worked (relative to the variance of GNP), but results in a poorer match for the average product of labor. Hansen's model also requires smaller exogenous productivity disturbances to generate the same variability of GNP.

Greenwood, Hercowitz, and Huffman (1988) investigate a model with shocks to the expected return to current investment that do not affect current output. These shocks raise investment in their model (the substitution effect dominates the wealth effect) and induce intertemporal substitution in labor supply, so that more labor is currently supplied in order to take advantage of the good investment opportunities. In addition, the utilization rate of existing capital rises to increase output and take advantage of these opportunities. The higher utilization rate of existing capital raises the marginal (and average) product of labor. This raises the opportunity cost of current leisure to households and induces them to substitute into greater current consumption. Consumption also increases because of the wealth effect associated with the technology disturbance.

In the Greenwood, et al. model, these two forces tending to raise consumption dominate the intertemporal substitution effect, which tends to reduce consumption so that households can use the goods they otherwise would have consumed in order to augment investment, which the technology shock made more productive. So consumption rises along with labor supply, output, investment, the capacity utilization rate, and the marginal and average products of labor.

It should be noted that in this model, fluctuations in current output do not result directly from assumed changes in current technology, since that technology affects only *future* output by augmenting the increase in future capital obtained from one unit of current investment. The entire increase in *current* output in the model results from economic forces responding to this productivity shock.

Kydland and Prescott (1988) also added variable utilization of capital to their earlier 1982 model by introducing an endogenous workweek of capital. In contrast to Greenwood, et al., where greater utilization raised depreciation, Kydland and Prescott assume that the cost of greater utilization (that is, a longer workweek) of capital is greater utilization (a longer workweek) of labor. They find that their model, with a variable workweek and with technology shocks measured as in Prescott (1986a), predicts essentially all of the observed variance in U.S. aggregate GNP, substantial variability for inventories (with results somewhat sensitive to the definition of inventories), and greater variation in hours worked than in their original model (but still below measured variation).

Benzivinga (1987) and Christiano (1988) examine models in which shocks to preferences play an important role. Parkin (1988), in contrast, finds little role for preference shocks in his model.

Parkin uses data on labor's share of GNP at each moment in time to obtain a time series on the corresponding parameter in the Cobb-Douglas production function. He assumes, following Solow — and in contrast to Prescott — that this function varies over time. He then uses this time-varying parameter and the production function to measure the multiplicative technology shock at each point in time (one can think of the time-varying parameter representing labor's share as a second productivity shock).

Given measured wages, labor time, consumption, and the rental price of capital (taken as the average payment to capital), Parkin then computes a time series for the utility parameters in his model and the depreciation rate. He describes this procedure as "solving the model backwards," by which he means that he calculates, given the model, what the parameters must (approximately) have been to generate observations on the time series of output, consumption, and so on. Unlike most other business-cycle models, Parkin allows some parameters to vary over time in order to fit the data (almost) exactly.

Parkin then displays these implied time series and argues that they support RBC models in the following senses: (1) none of the parameters except the productivity term varies much over time, and (2) the values of the parameters are not wildly out of line with what would have been expected, based on other information.

Parkin's assumed utility function takes the form of the expected discounted value of $(c_t^{(1-s)} l_t^{s})^f$, where c is consumption, l is leisure, and with the parameter s (the share of leisure) and the discount rate time-varying. Parkin estimates the mean of s at .828, and the percentage change in s has a mean of only .026 with a variance of .007. This parameter is therefore stable over time, implying that shocks to preferences, at least of this form, are unimportant to RBC models, and that people allocate about one-sixth of their total time to working. This estimate is smaller than the one-third value used in some other studies, but is consistent with the value cited by Eichenbaum, Hansen, and Singleton (1986) and is the value preferred by Summers (1986) in his critique of Prescott.

Parkin's estimated discount parameter varies somewhat more over time, and is somewhat higher than expected: its mean is consistent with an average real interest rate of 12 percent per year, which is too high. Labor's share is estimated to be 58 percent, as compared to the 64 percent figure used by Prescott based on historical data with the services of consumer durables included as part of output.

Finally, Parkin, after accounting for measurement error in labor and capital, examines the connection between changes in the money supply and variations over time in the parameters of the model, including productivity shocks. He finds little connection, either contemporaneously or at leads or lags, between money and the parameters of the model.

Christiano and Eichenbaum (1988) add government consumption shocks to an RBC model to induce shifts in labor *supply.* These shifts, along with shifts in the marginal product of labor due to technology shocks, might induce acyclical or mildly procyclical real wage changes, as in the data. The authors argue that government consumption is insufficiently variable to reduce (by very much) the highly procyclical movements resulting from productivity shocks. Further work with preference shocks or technology shocks, as in Greenwood, et al., may be promising in this regard.

II. Restrictions on Parameters and Functional Forms

Several sources of restrictions have been used to determine the appropriate functional forms and parameter values, aside from the behavior of the macroeconomic variables that the models seek to describe:

1. The fraction of total time spent working (and, consequently, the time spent at leisure, which enters the utility function) enters most of the models as a parameter. Some studies, such as Prescott (1986a), have used the figure of one-third, while others, such as King, Plosser, and Rebelo (1988a), have used one-fifth based on historical measurement of average weekly hours worked in the U.S. in the postwar period. Summers (1986) and Eichenbaum, et al. (1986) suggest one-sixth, which is close to the value found by Parkin (1988).

2. The psychological discount rate enters all of the models as a parameter (or a variable, as in Parkin's model). King, et al. choose this parameter at .988 per quarter to obtain an average real interest rate of 6.5 percent per year. Kydland and Prescott, Hansen, Greenwood et al., and others choose discount factors of .96 percent per year rather arbitrarily.

3. The rate of capital depreciation enters the models as a parameter. Kydland and Prescott assume a depreciation rate of 10 percent per year, on the grounds that the steady-state capital stock would then be about 2.6 times annual output if the real interest rate is 4 percent per year, and this 2.6 figure is close to the historical average in the United States. Most other models also assume 10 percent. Christiano (1988) assumes that capital depreciates at 1.83 percent per quarter, in order to try to match average U.S. data for the change in the public and private capital stock, including consumer durables, as a fraction of output. Greenwood, et al. have a variable depreciation rate depending on the utilization rate of capital. They assume that the elasticity of the depreciation rate with respect to the utilization rate is 1.42, chosen to yield a deterministic steady-state rate of depreciation in their model equal to .10 per year.

4. The marginal rate of substitution over time in consumption, which corresponds to the degree of relative risk aversion (say, r) for intertemporally separable utility functions, enters the models as a parameter. Log utility is frequently assumed, as in Kydland and Prescott (1982), implying that $r = 1$. Greenwood, et al. report results for $r = 1$ and $r = 2$, based on estimates by Hansen and Singleton (1983) and Friend and Blume (1975); Kydland and Prescott (1988) assume $r = 1.5$.

5. The marginal rate of substitution over time in leisure is an important parameter of most of the models. King, et al. (1988a) assume alternately that (a) utility is logarithmic and separable between consumption and leisure, as well as over time, giving a value of unity for the elasticity of the marginal utility of leisure with respect to leisure, or (b) the elasticity of the marginal utility of leisure is -10, based on panel data studies reviewed by Pencavel (1986), or (c) the elasticity is zero, which yields a linear utility function in leisure and so an infinite intertemporal substitutability of leisure, based on theoretical considerations of an economy with indivisible labor and lotteries, examined by Rogerson (1984, 1988) and Cho and Rogerson (1988).

The latter study examines an economy populated by families in which males are primary workers with an elasticity of intertemporal substitution close to zero, and females have the same preferences as males but, because of the fixed costs of having both parents in the labor force, females have a larger (but finite) elasticity of intertemporal substitution of labor. The authors show that, as in Rogerson's earlier work, the *aggregate* economy behaves as if the elasticity of substitution were infinite. This linear specification based on Rogerson's work is also adopted by Christiano. Greenwood, et al. choose the absolute value of the elasticity of marginal utility of labor supply with respect to labor supply to be .6, based on studies by MaCurdy (1981) and Heckman and MaCurdy (1980, 1982) that give estimates of the inverse of this number that range from .3 for males to 2.2 for females. The .6 figure chosen by Greenwood, et al. corresponds to an intertemporal elasticity of substitution of labor equal to 1.7.

6. Labor's share of total GNP is another important parameter in existing RBC models. Prescott estimates the share to be 64 percent, based on historical data with the services of consumer durables included as part of output, and this figure has been adopted in other studies as well. Without treating services of durables in this way, the historical share is higher, around 71 percent since 1950. This higher figure has been used in some other studies, such as Greenwood, et al. Christiano (1988) argues that accounting for measurement error places labor's share in the range of 57 percent to 75 percent; he assumes 66 percent.

7. The variance and autocovariances of productivity shocks play an important role in most RBC models. Prescott (1986a) estimates productivity shocks as the residuals from an aggregate Cobb-Douglas production function, with labor and capital inputs, estimated in first-difference form. He estimates that the standard deviation of these productivity shocks is 1.2 percent per quarter between 1955 and 1984, and that the technology shock is close to a random walk with drift plus serially uncorrelated measurement error. After a downward revision (that he argues is required because of measurement errors in the labor and capital inputs), Prescott ends up with an estimate of the standard deviation of .763 percent per quarter, and a first-order autoregressive coefficient of .95. Hansen also makes this assumption.

In Greenwood, et al., productivity shocks affect only future output from current investment, and not current output directly. Less serial correlation of productivity shocks is required in this model, in order to replicate the first-order autocorrelation of output in the U.S. data. The authors estimate that the first-order autocorrelation of productivity shocks is about .50 per year, while the figure of .95 per quarter would imply .81 per year.

Still other restrictions are specific to particular variations on the prototype RBC model. These include the relative wage of men and women, which appears in Cho and Rogerson and is chosen to be .6 on the basis of evidence from the Current Population Survey from 1979-84. The growth rate of the economy is another parameter that appears in some models. Prescott (1986a) sets the growth rate at zero, after using the Hodrick-Prescott filter, on the grounds that the character of fluctuations does not depend greatly on the growth rate.

The Kydland-Prescott (1988) model requires as parameters the elasticity of substitution between inventories and other factors of production, and a production-function parameter that determines whether variation in total hours occurs through a longer workweek or through more employees per hour; there is currently little evidence on which to base choices of such parameters.

As will be discussed in section VI, there are some quantitative differences between the United States, the United Kingdom, and Japan in features of business cycles. RBC models imply that some of the parameters discussed above should differ across these countries and that these differences should explain the observed differences in business cycles. There has not yet been much research devoted to determining these differences in parameters and examining whether they successfully explain cross-country differences.

III. Business Cycles and Long-Run Growth

A number of economists have recently argued that the traditional distinction between issues involving long-run secular growth on the one hand, and short-term fluctuations in GNP associated with business cycles on the other, is misplaced, and that business cycles and long-run growth are intertwined.

Nelson and Plosser (1982) argue that there is a secular or growth component to real GNP that is nonstationary, and another component that is stationary. They find that, empirically, the variance of the innovations to the nonstationary component is larger—the standard deviations are from one to six times as large—than the variance of the innovations to the stationary component. Given the assumption that monetary disturbances have only temporary effects on real output, Nelson and Plosser argue that "... real (nonmonetary) disturbances are likely to be a much more important source of output fluctua-

TABLE 2

U.S. Business Cycle Statistics, 1954:IQ-1982:IVQ Classified by Hamilton's "Normal States" and "Recession States" First-Difference Filter

	Normal States (103 observations)		Recession States (36 observations)	
Variable	Standard Deviation	Corr. with GNP	Standard Deviation	Corr. with GNP
GNP	.7%	1.00	.9	1.00
Consumption				
Total	.6	.50	.7	.45
On services	.4	.09	.5	.21
Nondurables	.7	.26	.7	.27
Fixed investment	2.3	.48	2.7	.68
Nonresidential	2.6	.28	2.4	.74
Structures	2.7	.28	2.7	.41
Equipment	3.5	.23	3.2	.76
Average nonfarm hours worked	.4	.26	.4	.12
In mfg. only	.8	.32	.8	.21
Employment	.6	.29	.7	.45
Productivity = GNP/total hours	.9	.56	1.0	.68

NOTE: Corr. = correlation. Hamilton's recession states during this period are (dates are inclusive) 1957:IQ-1958:IQ, 1960:IIQ-1960:IVQ, 1969:IIIQ-1970:IVQ, 1974:IQ-1975:IQ, 1979:IIQ-1980:IIIQ, and 1981:IIQ-1982:IVQ. Other dates in this period are normal states.
SOURCES: Hamilton (1987b) and Citibase.

tions than monetary disturbances." They also note that their conclusion "... is strengthened if monetary disturbances are viewed as only one of several sources of cyclical disturbances."

Subsequent work by Campbell and Mankiw (1987b), Clark (1987), Cochrane (1986), Evans (1986), Stock and Watson (1986), and Watson (1986) has generally corroborated the finding that real GNP has either a unit root (a nonstationary component) or a root that is close to unity (the power of the test for a unit root versus a root of .96 is small). However, measures of the relative sizes of the nonstationary (if it exists) and stationary components vary depending on the methods used. Cochrane, for example, finds that there may be a random walk component to GNP, but that its innovation variance is small relative to the variance of the transitory component. The difference between his finding and that of Nelson and Plosser results largely from his use of information from autocorrelations at long lags. Cochrane finds that the in-sample behavior of real GNP is represented well by a second-order autoregressive process around a deterministic trend.

Hamilton (1987b) estimates a simple nonlinear model of real GNP in which the economy shifts periodically from its "normal growth states" into "recession states" associated with negative average growth rates. Hamilton's model is an alternative to the assumption made in most previous work, that the first-difference of GNP is a linear stationary process (either white noise or purely deterministic). He uses a time-series model for real GNP that involves a stochastic trend: a random walk with drift in which the drift term takes one of two values, depending on the state of the economy. The state itself is a stationary Markov process. GNP is the sum of this stochastic trend component and a zero-mean ARIMA(4,1,0) process.

Hamilton's nonlinear model implies that a term is missing from an AR(4) model of the growth rate of GNP (a standard linear representation), and that addition of the extra term yields a large and significant coefficient, indicating that the nonlinear model is a better predictive model than the linear model.

He finds that, first, the dynamics of GNP during recessions are considerably different from the dynamics during normal, nonrecession periods. In particular, the economy is expected to grow at a rate of 1.2 percent per quarter during normal times and at a negative rate, –0.4 percent, during recessions. If the economy is in a normal state, there is a 90 percent chance that it will remain in the normal state next quarter; if the economy is in a recession, there is a 75 percent chance it will remain in that state next quarter. This suggests that there may be differences in the "facts" regarding business cycles across those states, and that these facts should be included in tables that RBC models seek to replicate. Table 2 shows that the main difference in correlations with GNP between normal states and recessions occurs in nonresidential investment, which is much more highly correlated with GNP during recession states.

Second, Hamilton finds that business cycles are associated with large *permanent* effects on the level of output. When the economy enters a recession, current output falls on average by 1.5 percent, while the permanent level of output falls by 3 percent. When the economy is in a normal state, a 1 percent fall in output reduces permanent output by two-thirds of 1 percent. In fact, Hamilton's results imply that most of the dynamics of GNP result from switches in the state of the economy generating the stochastic growth component rather than from the ARIMA process added to this component.

Finally, he finds that the dating of recessions estimated by the nonlinear model closely replicates the NBER dating. Hamilton's results suggest that while business cycles and long-term growth are subtly related, they are also separable in that one can study the switches between states of the economy, and characteristics of the recession states, separately from the characteristics of the normal growth state.

King, Plosser, and Rebelo (1988b) argue that it is inappropriate to study business cycles and long-term growth separately for two reasons. First, business cycles may *be* changes in the long-run growth path. Using models based on Romer (1986) and Lucas (1988), the authors construct examples of economies in which purely temporary shocks permanently affect the level of output. Similarly, permanent shocks (or policies) can change the economy's long-term rate of growth. While Hamilton's nonlinear model suggests that temporary shocks have permanent effects, it also suggests that business cycles differ substantially from "normal" changes in the long-run growth path.

Second, the authors argue that the characteristics of long-term growth—such as constancy of growth rates (although see Romer [1986]), rapidly rising consumption per capita with constant or only slowly rising leisure per capita, and the absence of a strong secular trend in the average real interest rate—imply restrictions on forms of production and utility functions and on their parameter values, and that RBC models must be made consistent with these restrictions. As McCallum (1989) argues, "... if technical change were exogenous, then there would be little necessary relation between the magnitude of growth and the extent of cycles, as they depend on two different aspects of the technical-progress process..." (that is, the mean and the short-term variations from this mean). However, even with exogenous growth, there are restrictions on the model that are required to produce steady-state growth, or large secular increases in real wages with a small reduction in hours worked, and so on.

IV. Seasonal Fluctuations and Business Cycles

Barsky and Miron (1988) have shown that deterministic seasonal fluctuations in macroeconomic variables exhibit the same characteristics (discussed above) as fluctuations at business-cycle frequencies. In addition, the seasonal fluctuations are large relative to the business-cycle fluctuations.

Using quarterly data, the authors find that deterministic seasonal fluctuations account for more than 85 percent of fluctuations in the growth rate of real GNP and over half of the fluctuations in real GNP relative to trend. Similar measures of the quantitative importance of seasonal fluctuations relative to business-cycle fluctuations apply to other macroeconomic time series, such as consumption, investment, the labor force, hours worked, and so on.

More important, they find that the *comovements* and *relative sizes* of movements in various macroeconomic variables are similar for seasonal and business-cycle fluctuations. This similarity also applies to the positive comovements of monetary aggregates and real output. As Barsky and Miron conclude, this "...suggests the possibility of a unified explanation of both business cycles and seasonal cycles." Miron (1988) has shown that the same qualitative conclusions also apply to seasonal and business-cycle fluctuations in many other countries.

If one accepts the view that business cycles and seasonal cycles have the same explanation—and are the results of the same types of disturbances as well as the same propagation mechanisms—then these results cast doubt on some popular theories of business cycles. Such theories include those based on unperceived monetary disturbances and confusion of sellers about changes in nominal and relative prices (as in Lucas [1975, 1982] and Barro [1976, 1980]) and those based on unanticipated changes in economic conditions in the face of predetermined nominal wages or prices. The seasonal changes in average weather and seasonal occurrence of holidays, such as Christmas, are clearly both perceived and anticipated.

An alternative, weaker, interpretation of the Barsky-Miron results is that business cycles and seasonal fluctuations are the results of different underlying disturbances (with the former unanticipated and the latter anticipated), but that most of the key features of business cycles are driven by the propagation of these disturbances through the economy and are largely independent of the source of the disturbance. Under this interpretation, monetary, rather than real, disturbances might play an important role in instigating business cycles. But RBC analysis would be extremely important in trying to understand the characteristics of business cycles, because the propagation mechanism studied in these models would be responsible for generating the particular comovements and relative sizes of movements of economic variables that are observed. In this sense, the focus on RBC analysis as a means of determining how disturbances affect the economy and how they spread through different sectors of the economy over time (the third and fourth reasons for RBC analysis mentioned in the introduction) would be very important.

V. Criticisms of Real Business Cycle Models

Several popular criticisms that have been levied against RBC models are presented here, along with some responses to those criticisms. For further arguments, see Summers (1986) and Prescott (1986b).

What Are These Technology Shocks?

An additional question, posed by Robert Hall (1988), is how to interpret periods in which real output actually falls: what are the negative technology shocks? Summers, having suggested that oil price changes could constitute such a shock, cites a study by Berndt (1981) which concludes that energy shocks had little role in the fall in manufacturing labor productivity from 1973 to 1977. Summers also asks, "What are the sources of technical regress? Between 1973 and 1977, for example, both mining and construction displayed negative rates of productivity growth. For smaller sectors of the economy, negative productivity growth is commonly observed."

Our inability to document the changes in technology that produced business cycles may not be important, however. We can *measure* the technical change—up to problems associated with measuring inputs—by estimating production functions. Further, much of the technical change may occur in forms not easy to understand without specialized knowledge of a particular industry, and, as Prescott stresses, the sum of many (nonindependent) technical changes is the aggregate technical change.

As for reductions in output, there are many possibilities for technical changes that *temporarily* cause reductions in measured aggregate output, and some that cause permanent reductions in *measured* output but increases in true total output (which includes unmeasured or poorly measured components, such as household production). In addition, it may be unnecessary to *explain* the sources of technical regress in an industry in order to use the *measured facts* of that regress to account for economic fluctuations. As Summers notes, for smaller sectors of the economy, negative productivity growth is commonly observed. Are all of these individual experiences of negative productivity growth to be attributed to monetary policy or macroeconomic coordination failures? Would such a traditional macroeconomic explanation of these negative productivity shocks—providing such a *quantitative* model could even be built—be a better explanation than an RBC explanation?

There Is Some Evidence that Money Affects Real Output

Christiano and Ljungqvist (1988) present simulation evidence about the failure of monetary aggregates to Granger-cause real output in systems that have been first-differenced to achieve stationarity. They find that this phenomenon results from a lack of power caused by first-differencing the data and by inducing specification error. In contrast, this Granger-causality does typically show up in systems estimated in levels or with deviations from deterministic linear trends.

These results are important because most reasonably specified models in which money affects real output imply Granger causality from money to output (though it is possible to construct examples—perhaps unrealistic ones—in which such Granger causality is absent). The estimates presented by Christiano and Ljungqvist are, as they argue, economically as well as statistically significant: about 18 percent of the conditional variance in the log of industrial production 12 months into the future is accounted for by lagged values in (the log of) M1, and this figure rises to nearly 30 percent at the 48-month horizon.

Other, less formal, evidence suggests that money affects real output, real interest rates, and other real variables in the short run. In addition, McCallum (1985, 1986) has argued that monetary policy has been implemented through interest-rate instruments and that, consequently, innovations in monetary aggregates may have no explanatory power for output once nominal interest rates are controlled for, as in Sims (1980, 1982). McCallum also contends that the explanatory power of nominal-interest-rate innovations may reflect the real effects of money on output.

A statistical association between money and output, however, does not imply that exogenous changes in money affect output, rather than vice versa (or both resulting from some other disturbance). As was noted in the introduction, the major component of the money supply that changes with real output is not high-powered money, but bank deposits.

These changes in deposits may be endogenous reponses to changes in output or may be a joint result of another underlying change. Alternatively, RBC models may not account for all fluctuations in output, but only a major part of them, with monetary disturbances accounting for the remainder. Clearly, RBC models are better equipped than monetary models to study the seasonal fluctuations in aggregate variables that mimic business-cycle behavior.

There Is Evidence that Nominal Prices Are Sluggish

The implication is that traditional, sluggish-price macroeconomic models are good models of aggregate fluctuations. But that implication does not necessarily follow. Even if nominal prices are sluggish (and there is some evidence to that effect), RBC models might explain most aggregate fluctuations for two reasons.

First, in the presence of price sluggishness, there are incentives to develop alternative allocation mechanisms, associated with long-term contracts or other devices, that bypass or supplement the use of prices in the resource allocation mechanism. The competitive equilibrium may closely approximate the solution to an RBC model if the alternative market mechanisms are sufficiently well developed.

Second, even if sluggish nominal-price adjustment affects resource allocation in important ways, it may play a subsidiary role to the features emphasized in RBCs for explaining aggregate fluctuations, either because the effects of monetary disturbances are not large relative to the effects of real disturbances or because, as discussed in the introduction, the characteristics of business cycles (once they have begun) are largely independent of the source of disturbance.

While some evidence supports nominal price sluggishness, it is largely concentrated on a few commodities such as newspapers. Moreover, much of the evidence from microeconomic data is weak because all characteristics of goods (including delivery lags, warranties, and quality control) are not held fixed. In any case, long-term contracts can involve ex-post settling up that occurs in ways that do not show up in the current price.

The Success of RBC Models Rests on Incorrect Parameter Values

Summers argues that RBC models have not explained the data as well as they seem to have, because the parameters they have chosen are incorrect. For example, he argues that the degree of intertemporal substitution is smaller than that assumed in most RBC studies. While Prescott chooses parameters to make the average real interest rate 4 percent per year, and King et al. choose them so that the rate is 6.5 percent per year, Summers argues that, based on historical data, the average real interest rate is closer to 1 percent per year. Similarly, Summers argues that Prescott's calculation of the fraction of time spent working, one-third, is much too large, and should be closer to one-sixth.

Prescott (1986b) has defended his choice (and the Kydland-Prescott choice) of parameters. He cites Rogerson's work (see above) to rationalize a high degree of intertemporal substitution in labor at the aggregate level, regardless of its magnitude at the individual level. The fraction of time spent working in his model is the fraction of time not devoted to sleep or personal care, so that the figure one-third would be close to that found from micro data. Finally, Prescott's real interest rate is intended to represent the real rate of return on capital, which can be measured approximately from GNP accounts and is about 4 percent per year, rather than a riskless real interest rate.

Technical Change Is Overstated by Prescott's Measurement

The residuals from the production functions that Prescott has estimated are not, according to this argument, correctly interpreted as mainly involving technical change.[3] There are both neglected factors and mismeasured factors.

One argument, made by Summers (1986) and McCallum (1989), involves labor-hoarding. When output is lower than normal (for example, due to a fall in aggregate demand), firms continue to employ workers who do not actually work much. The employees are measured as working, however, so the labor input is overstated when output

■ **3** Actually, Prescott calculates the production functions using a fixed value of the share parameter, rather than estimating by ordinary least squares.

is low. Similarly, it is understated when output is high. Calculation of residuals from a production function will then yield residuals that are too low when output is low, and too high when output is high. If the residuals are incorrectly interpreted as productivity shocks, these "shocks" will seem to explain the level of output, when they actually result from measurement error.

Summers cites a study by Fay and Medoff (1985) to argue that this labor-hoarding (employment of people who do not really work during recessions) is quantitatively important. McCallum points out that the growth literature following Solow (1957) typically found modifications of his procedure that would reduce the contribution of the disturbances (interpreted as technical progress in total factor productivity) to the overall growth in output. McCallum cites a study by Jorgenson and Griliches that used corrections for "aggregation errors" and changes in utilization rates of capital and labor to reduce the contribution of the residuals from nearly half of the variance of output to only 3 percent.

Prescott (1986b) notes that the Fay-Medoff study asked plant managers how many extra workers they employed in a recent downturn, rather than how many *more* extra workers they employed in the downturn than in the upturn. The latter question would be required to determine the quantitative significance of labor-hoarding. In addition, Prescott points out that labor-hoarding may *fall* in recessions: firms would be less reluctant to lay off workers in recessions because it is less likely that those workers would find alternative jobs. If so, the measurement error in the labor input would make measured technical change too small rather than, as Summers argues, too large.

Horning (1988) examines a model in which heterogeneous industries experience industry-specific as well as aggregate shocks, and shows that the number of firms hoarding labor is procyclical while the amount of labor hoarded per firm is countercyclical. Labor-hoarding will result in overstatement of the size of technology shocks only if the first effect dominates the second. Similarly, Kydland (1984) shows that measured technical change will be too small if workers are heterogeneous in skills and that highly skilled workers have less variability in weekly hours worked than do low-skilled workers. More generally, it would be desirable to have better estimates of technical change from production function studies, and these could be incorporated into RBC models.

The RBC Models Fail Formal Econometric Tests

The implication is that the RBC models should be rejected. The question is, in favor of what? Rogerson and Rupert (1988) have shown that very small measurement errors can lead to rejection of such models, even if the models are good approximations to reality.

If models are to be used for policy purposes, a formal policy decision problem should be analyzed to determine whether policymakers are better off in terms of expected utility when they make use of RBC models. The models may, for example, be wrong but give better advice than the other incorrect theories. If models are to be used for additional scientific research, then clearly the models should not be dismissed entirely when they fail, until they have been examined for the source of failure and, perhaps, changed accordingly.

The Models' Implications for Prices Fail

An example cited by Summers is the "equity premium" studied by Mehra and Prescott (1985). McCallum (1989) notes that the observed procyclical movements in real wages (see, for example, Bils [1985]) are smaller than the procyclical wage movements implied by RBC models such as that of Kydland and Prescott. Similarly, models such as the ones developed by Greenwood, Hercowitz, and Huffman presumably imply larger procyclical movements in ex ante real interest rates than those calculated from ex post data, as in Mishkin (1981) or based on survey data for inflationary expectations.

Prescott (1986b) replies that his representative-agent RBC model may be poorly designed to explain the equity premium but is well designed for aggregate fluctuations. Nevertheless, a business cycle theory that is also consistent with observations on prices would be better than having different models for different purposes.

Kydland and Prescott (1988) report implications of their model for the cyclical behavior of the real interest rate. The behavior of real interest rates is, of course, difficult to measure because inflationary expectations are not well measured. Similarly, there are notorious problems with treating measured average pecuniary compensation at a point in time as a measure of the marginal product of labor. Thus, Bils' (and the other) evidence may understate the true procyclical behavior of the marginal product of labor.

The Models Do Not Explain Involuntary Unemployment

Involuntary unemployment is generally asserted to be a "fact" of business cycles. Perhaps it is, but one can check the truth of this claim only after the term has been precisely defined. Rogerson's model with indivisible labor is promising in this regard. Because everyone is alike ex ante, yet some people find work and others do not, models like this may eventually be able to explain involuntary unemployment in the sense that a person without a job is no different in tastes, experiences, and other characteristics from someone else with a job. Alternatively, RBC models may have to be modified to include some market failures in order to account adequately for such phenomena.

There Are Large Nation-Specific Components to GNP Fluctuations

I have argued (Stockman, 1988a) that RBC models based solely on technology shocks seem unable to account for the empirical finding (documented in that paper) that there are large changes in output across all industries that occur in one country but not in another. Technology shocks would be more likely to affect a particular group of industries, irrespective of nation (at least in developed, OECD countries) than to affect a particular country, irrespective of industry. Instead, the evidence in my paper suggests that while technology shocks are important, some nation-specific disturbances play at least as large a role in output fluctuations.

Whether these nation-specific disturbances are monetary or "real" (for example, resulting from fiscal policy) remains unclear. It is possible, of course, that technology is more specific to nations than to industries, though that seems unlikely. These conclusions may also result from international transmission of aggregate disturbances. I discuss these issues briefly in the context of the formal two-country model in section VI, which illustrates one of the important reasons for developing multicountry, multisector RBC models, as outlined in that section.

It is Easy to Produce Models to Mimic Facts

Summers cites Ptolemaic astronomy as an example of how "...many theories can approximately mimic any given set of facts; that one theory can does not mean that it is even close to right." The assertion is clearly correct in general, but it is beside the point. While it is possible that many theories could replicate the facts of business cycles and meet the other criteria of being consistent with basic economic theory, the fact that a theory is consistent with the facts *raises* (and certainly does not lower) the conditional probability that it is a good and useful theory.

In any case, RBC models such as those developed by Kydland and Prescott have set a standard to which alternative models, including those with sluggish price adjustments and coordination failures, should aspire: to present a prima facie case that the model is *quantitatively* accurate. The alternative models favored by Summers and by other critics of RBC analysis may prove to be better models of aggregate fluctuations, but those models as yet have not been developed sufficiently to even enter the race against RBC models in mimicking the quantitative as well as qualitative aspects of business cycles.[4]

VI. Outline of a Stripped-Down Two-Country RBC Model

This section outlines a two-country version of a simple RBC model. It illustrates formally the setup of a prototype model, describes one method of solving the models (as in King, Plosser, and Rebelo [1988a]), and discusses the reasons for an international extension of the RBC model. Frequently, international extensions of closed-economy macroeconomic models have little motivation (except, perhaps, to turn one idea into two papers); there are better reasons for an international extension in this case.

The first reason is that RBC models have been calibrated with a single set of parameters to explain a single set of standard errors and covariances of macroeconomic variables. One way to improve on the models is to add additional variables, but this requires adding more equations and more parameters to obtain additional implications from the models.

A second way to check an RBC model is to apply the same model to a *different* set of

■ **4** The large econometric models do not qualify because they are not true structural models in the sense of the Lucas critique of econometric policy evaluation.

macroeconomic facts (standard errors, correlations, and so on), using the *same* criteria for choosing parameter values. The different sets of macroeconomic facts can be obtained by using data from different countries. Application of the models to data from other countries will therefore provide a valuable check on the models, as Rogoff (1986) also suggested. Differences in the characteristics of business cycles across countries are substantial enough to provide powerful checks on the models, as I will discuss below.

The second reason for an international extension is that the RBC models have implications, in an international setting, for additional variables such as exports, imports, and the balance of trade. RBC models with multiple sectors can also be shown to have implications for relative prices, such as the terms of trade or the relative price of nontradeables. These additional implications can be checked against the data.

In addition, the models can be used to examine issues associated with the international transmission of real disturbances, and the effects on aggregate fluctuations of various government policies toward international trade. Finally, equilibrium models of exchange rates imply that changes in real and nominal exchange rates result from "real" shocks; in this sense they are closely linked to RBC models.[5]

Also, like RBC models, equilibrium models of exchange rates are based on simple dynamic, stochastic, general-equilibrium models. But the RBC models have been quantitatively developed (in closed economies) in ways that the equilibrium models of exchange rates have not; application of the RBC models to open economies therefore has the potential of advancing the equilibrium exchange-rate models and furthering our understanding of exchange rates.

There are two categories of differences between countries: differences in parameters and differences in exogenous disturbances. To keep the issues associated with international extensions clear, consider a simple model similar to that in King, Plosser, and Rebelo with exogenous growth. There is a representative individual in each country who maximizes the expected discounted utility of consumption of two goods—one produced in each country—and leisure, $1-N$, where N is labor supply and total time is normalized to one,

$$(1) \quad U = \Sigma_{t=0}^{\infty} \beta^t u(C_{1t}, C_{2t}, 1-N_t),$$

and the foreign representative individual maximizes

$$(1^*) \quad U^* = \Sigma_{t=0}^{\infty} \beta^t u(C^*_{1t}, C^*_{2t}, 1-N^*_t).$$

Each country produces only one good, and its production is described by constant-returns-to-scale production functions

$$(2) \quad Y_t = A_t F(K_t, N_t X_t)$$

and

$$(2^*) \quad Y^*_t = A^*_t F^*(K^*_t, N^*_t X^*_t),$$

where K_t and K^*_t are chosen at date $t-1$, and investment in each country utilizes only that country's good, that is,

$$(3) \quad K_{t+1} = (1-\delta)K_t + I_t$$

and

$$(3^*) \quad K^*_{t+1} = (1-\delta^*)K^*_t + I^*_t,$$

where K and K^* are the foreign and domestic capital stocks, δ and δ^* are depreciation rates, and I and I^* are investments using domestic and foreign goods.

This model includes some assumptions that should be relaxed in further work but are made here for simplicity: that utility functions are identical across countries, that countries are completely specialized in production, and that all goods are internationally traded. Also, the production functions do not allow one good to be used as an input into the other, which precludes certain types of sectoral interactions as in the model of Long and Plosser (1983).

The resource constraints differ from those of a closed economy due to international trade:

$$(4) \quad C_{1t} + C^*_{1t} + I_t = Y_t$$

and

$$(4^*) \quad C_{2t} + C^*_{2t} + I^*_t = Y^*_t.$$

■ **5** See Stockman (1980, 1987, 1988b), Lucas (1982), Stockman and Svensson (1987), Salyer (1988), and Stockman and Dellas (1988).

Given initial conditions on the capital stock in each country and weights on domestic versus foreign utilities (which correspond to relative wealth positions in competitive equilibrium), equations (1) through (4) and nonnegativity constraints on consumption, leisure, labor supply, and capital stocks can be solved for time paths of consumption, labor, and capital for given time paths of the exogenous productivity disturbances A, A^*, X, and X^*.

Suppose we adopt the restrictions on preferences that King, Plosser, and Rebelo argue are implied by the observation of steady-state growth, and we assume that the degree of relative risk-aversion is unity. Then, for the three-argument utility function postulated here,

$$(5)\quad u(C_1, C_2, 1-N) = \log(C_1) + \log(C_2) + v(1-N),$$

where $v' > 0$ and $v'' < 0$. The production functions are assumed to be Cobb-Douglas,

$$(6)\quad Y_{1t} = A_t K_t^{1-a}(N_t X_t)^a$$

and

$$(6^*)\quad Y_{2t} = A^*_t K^{*\,1-a^*}_t(N_t X_t)^{a^*},$$

all variations in A are assumed to be temporary, and all variations in X are assumed to be permanent (explained below).

Define the transformed variables $c_1 = C_1/X$, $c^*_1 = C^*_1/X$, $c_2 = C_2/X^*$, $c^*_2 = C^*_2/X^*$, $i = I/X$, $i^* = I^*/X^*$, $k = K/X$, $k^* = K^*/X^*$, $g = X'/X$, and $g^* = X^{*\prime}/X^*$. Then a social planning problem for this economy can be expressed as

$$(7)\quad \text{Maximize } \Sigma_{t=0}^{\infty} \beta^t [w\{\log(c_{1t}) + \log(c_{2t}) + v(1-N_t)\} + (1-w)\{\log(c^*_{1t}) + \log(c^*_{2t}) + v(1-N^*_t)\}]$$

with respect to the sequence $\{c_{1t}, c_{2t}, c^*_{1t}, c^*_{2t}, k_{t+1}, k^*_{t+1}, N_t, N^*_t;\ t = 0, \ldots \infty\}$ for given utility-weight w, and subject to the sequence of constraints (with multipliers Φ and Φ^*),

$$(8a)\quad A_t K_t^{1-a} N_t^a - c_{1t} - c^*_{1t} - [g_x k_{t+1} - (1-\delta)k_t],$$

$$(8b)\quad A^*_t k^{*\,1-a^*}_t N_t^{a^*} - c_{2t} - c^*_{2t} - [g_{x^*} k^*_{t+1} - (1-\delta)k^*_t],$$

and the inequality constraints listed above.

Necessary conditions for this problem include the resource constraints (8), the inequality constraints listed above, and

$$(9a)\quad w/c_{1t} = \Phi_t = (1-w)/c^*_{1t}$$

$$(9b)\quad w/c_{2t} = \Phi^*_t = (1-w)/c^*_{2t}$$

$$(9c)\quad \beta\Phi_{t+1}[A_t(N_t/k_t)^a + (1-\delta)] = \Phi_t g_x$$

$$(9d)\quad \beta\Phi^*_{t+1}[A^*_t(N^*_t/k^*_t)^{a^*} + (1-\delta)] = \Phi^*_t g_{x^*}$$

$$(9e)\quad \Phi_t A_t k_t^{1-a} N_t^a / N_t = v'(1-N_t)$$

$$(9f)\quad \Phi^*_t A^*_t k^{*\,1-a}_t N^{*\,a}_t / N^*_t = v'(1-N^*_t)$$

$$(9g)\quad lim_{t\to\infty}\ \beta^t \Phi_t k_{t+1} = 0$$

$$(9h)\quad lim_{t\to\infty}\ \beta^t \Phi^*_t k^*_{t+1} = 0.$$

One undesirable characteristic of the solution is evident from these conditions: consumption of each good is perfectly correlated across countries. This prediction is not borne out by data. One way to modify the model would be to include nontraded goods, as in Stockman and Dellas (1988). Because numerical methods are required to solve the model anyway, it is feasible to relax the special assumption imposed in that paper that utility is separable between traded and nontraded goods.

In fact, traded goods may have to be processed in each country before they are bought and consumed by a production technology that includes nontraded goods (such as retailing, transportation to markets, and storage). This feature of traded goods has been emphasized in work by Kravis and Lipsey (1983) and explains their strong empirical finding that countries with higher wealth have higher prices of nontraded goods *and* higher prices of traded goods at the retail level. With this modification, trade would take place in intermediate goods rather than final goods, and final goods production would occur in each country with the use of a nontraded factor, as in Jones and Purvis (1983).

Next, define the operator D so that Dc_t is the log-deviation of c_t from its stationary steady-state value, c, that is $Dc_t = \log(c_t/c)$. Then take linear approximations of (9) around these stationary values,

(10a) $Dc_{1t} = Dc^*_{1t} = -D\Phi_t$

(10b) $Dc_{2t} = Dc^*_{2t} = -D\Phi^*_t$

(10c) $D\Phi_t = D\Phi_{t+1} + [1 - \beta(1-\delta)/g_x][DA_{t+1} + a(DN_{t+1} - Dk_{t+1})]$

(10d) $D\Phi^*_t = D\Phi^*_{t+1} + [1 - \beta(1-\delta)/g_{x^*}][DA^*_{t+1} + a^*(DN^*_{t+1} - Dk^*_{t+1})]$

(10e) $DA_t + (1-a)Dk_t - (1-a)DN_t + D\Phi_t = -(1-N)(v''/v')[N/(1-N)]DN_t$

(10f) $DA^*_t + (1-a^*)Dk^*_t - (1-a^*)DN^*_t + D\Phi^*_t = -(1-N^*)(v^{*\prime\prime}/v^{*\prime})[N^*/(1-N^*)]DN^*_t$

(10g) $DA_t + (1-a)Dk_t + aDN_t = s_{c1}Dc_{1t} + s_{c1^*}Dc_{*1t} + [1 - s_{c1} - s_{c^*1}][g_x/(g_x - 1 + \delta)]Dk_{t+1} + [1 - s_{c1} - s_{c^*1}][1 - g_x/(g_x - 1 + \delta)]Dk_t$

(10h) $DA^*_t + (1-a^*)Dk^*_t + a^*DN^*_t = s_{c2}Dc_{2t} + s_{c2^*}Dc_{*2t} + [1 - s_{c1} - s_{c^*1}][g_{x^*}/(g_{x^*} - 1 + \delta)]Dk^*_{t+1} + [1 - s_{c1} - s_{c^*1}][1 - g_{x^*}/(g_{x^*} - 1 + \delta)]Dk^*_t.$

Next, solve (10a), (10b), (10e), and (10f) for the optimal decisions $\{Dc_1, Dc_2, Dc^*_1, Dc^*_2, DN, DN^*\}_t$ as functions of the state variables $\{Dk_t, Dk^*_t, DA_t, DA^*_t\}$ and $\{D\Phi_t, D\Phi^*_t\}$. Then substitute these solutions into (10c), (10d), (10g), and (10h) to obtain the difference equations

$$\begin{pmatrix} Dk_{t+1} \\ D1_{t+1} \end{pmatrix} = G \begin{pmatrix} Dk_t \\ D1_t \end{pmatrix} + HDA_{t+1} + JDA$$

and

$$\begin{pmatrix} Dk^*_{t+1} \\ D1^*_{t+1} \end{pmatrix} = G^* \begin{pmatrix} Dk^*_t \\ D1^*_t \end{pmatrix} + H^*DA^*_{t+1} + J^*DA^*_t,$$

each of which is analogous to the system in King, Plosser, and Rebelo (1988a), shown there as having a solution of the form

$$\begin{pmatrix} Dk_t \\ D1_t \end{pmatrix} = G^t \begin{pmatrix} Dk_0 \\ D1_0 \end{pmatrix} + \Sigma_{j=0}^{\infty} G^jHDA_{t-j+1} + \Sigma_{j=0}^{\infty} G^jJDA_{t-j}$$

and

$$\begin{pmatrix} Dk^*_t \\ D1^*_t \end{pmatrix} = G^{*t} \begin{pmatrix} Dk^*_0 \\ D1^*_0 \end{pmatrix}$$

$$+ \Sigma_{j=0}^{\infty} G^{*j}H^*DA^*_{t-j+1}$$

$$+ \Sigma_{j=0}^{\infty} G^{*j}J^*DA^*_{t-j}.$$

Assume that certainty equivalence holds approximately and that the vector $(DA_t, DA^*_t)'$ follows a Markov process,

$$\begin{pmatrix} DA_{t+1} \\ DA^*_{t+1} \end{pmatrix} = \begin{bmatrix} p_0 & p_1 \\ p^*_1 & p^*_0 \end{bmatrix} \begin{pmatrix} DA_t \\ DA^*_t \end{pmatrix} + \begin{pmatrix} u_{At+1} \\ u_{A^*t+1} \end{pmatrix}$$

where $u = (u_A, u^*_A)$ is a random variable with mean zero and covariance matrix V_A. Then the system can be written in the form of a first-order difference equation

$$\begin{pmatrix} Dk_{t+1} \\ DA_{t+1} \\ DA^*_{t+1} \\ Dk^*_{t+1} \end{pmatrix} =$$

$$\begin{bmatrix} h_k & h_A & h^*_A & 0 \\ 0 & p_0 & p_1 & 0 \\ 0 & p^*_1 & p^*_0 & 0 \\ 0 & h^*_A & h^{**}_A & h^{**}_k \end{bmatrix} \begin{pmatrix} Dk_t \\ DA_t \\ DA^*_t \\ Dk^*_t \end{pmatrix} +$$

$$\begin{pmatrix} 0 \\ u_{At+1} \\ u^*_{At+1} \\ 0 \end{pmatrix}.$$

Let w and w^* denote (real) wage rates, let r and r^* denote real interest rates in terms of good one and good two, respectively, and let q denote the relative price of good two in terms of good one. These and the other endogenous variables $\{Dc_{1t}, Dc_{2t}, Dc^*_{1t}, Dc^*_{2t}, DN_t, DN^*_t, Dy_t, Dy^*_t, Di_t, Di^*_t, Dw_t, Dw^*_t, r_t - r, r^*_t - r^*, Dq_t\}$ can then be written as linear functions of the state vector

$$s_t = (Dk_t, DA_t, DA^*_t, Dk^*_t)'.$$

The parameters of this model are the two depreciation rates of capital; the utility-of-labor functions $v()$ and $v^*()$; the production parameters a and a^*; the utility weight w; the discount rate β; the growth rates g_x and g^*_x; the parameters of the Markov process on productivity shocks, p_0, p_1, p^*_0, p^*_1; and the covariance matrix of productivity shocks V_A. These parameters can be chosen in the ways described above to match historical observations on growth rates, labor's share of gross domestic product (GDP), and so on, and estimated parameters from microeconomic studies (such as the elasticity of the function $v()$, and to make the model reproduce some of the variances and covariances of key macroeconomic aggregates.

As noted above, the model has implications for the terms of trade, which is the only "real exchange rate" in the model and is, in real-world data, very highly correlated with the exchange rate. Consequently, the model has implications for exchange rates as in the equilibrium models referred to previously. Tables 3 through 8, described below, show roughly zero correlations between GNP and the U.S. dollar exchange rates of Japan and the United Kingdom. When U.S. GNP is controlled for, however, the partial correlation between the exchange rate and GNP in Japan and the United Kingdom rises to the range of .2 to .3.

Tables 3 through 8 display correlations between some macroeconomic aggregates and GDP for Japan and Great Britain, and the corresponding standard errors of the variables.[6] Baxter and Stockman (1988) show that these and many other similar variances and covariances are independent of the exchange-rate system, so the correlations in the tables refer to the time periods 1961:IQ-1986:IIQ for the United Kingdom and 1964:IQ-1987:IQ for Japan.

On the other hand, that research also indicated that covariances such as these are sometimes very sensitive to the method of detrending the data. The tables therefore present correlations with output after each of two types of detrending: the removal of a deterministic linear time trend and first-differencing.[7] In addition,

■ **6** The series presented have been chosen to make the tables analogous to table 1.

■ **7** Use of the Hodrick-Prescott filter always resulted, with the data used for these tables, in a correlation bounded by those presented here.

TABLE 3

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ
First-Difference Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.8%	.03	1.00	.03
Consumption	1.5	.11	.56	.01
Investment	3.2	.08	.70	.17
Government spending	7.8	-.11	.18	-.08
Real exports	4.9	-.01	.10	.02
Real imports	5.6	.05	.08	.16
Net exports	4.6	-.07	.02	-.18
Average hours worked	.8	-.01	.30	-.06
Total hours worked	1.0	.11	.29	.03
Employment	.5	.24	.09	.17
Labor force	.5	.22	.08	.11
GNP/total hours	1.8	-.04	.85	.00
GNP/worker	1.8	-.04	.97	-.02
Exchange rate	4.2	.03	-.02	-.03

NOTE: Corr. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank and International Monetary Fund.

TABLE 4

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ
Linear Trend Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	10.5%	.98	1.00	.98
Consumption	8.9	.93	.94	.93
Investment	15.6	.95	.97	.96
Government spending	11.5	.75	.78	.78
Real exports	13.9	.64	.66	.65
Real imports	21.6	.49	.53	.56
Net exports	12.3	-.12	-.19	-.26
Average hours worked	2.8	-.50	-.50	-.53
Total hours worked	3.3	-.35	-.38	-.42
Employment	1.1	.24	.19	.11
Labor force	1.0	.19	.13	.05
GNP/total hours	12.0	.94	.96	.95
GNP/worker	10.4	.98	.99	.98
Exchange rate	10.8	.10	.10	.05

NOTE: Corr. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank and International Monetary Fund.

the tables show results for the components of the foreign variables that are orthogonal to U.S. GNP, calculated by taking residuals from an OLS regression of the variables on U.S. GNP before applying the other filters.

The tables clearly indicate quantitative differences across countries in the characteristics of business cycles. The results using the Hodrick-Prescott filter are closest to those reported in the tables for the deterministic linear trend filter, so I focus on those results. The standard deviation of consumption in the United Kingdom and Japan is about equal to the standard deviation of GNP; in the United States, the standard deviation of consumption is only about three-fourths that of GNP.

In Japan, the standard deviation of investment relative to that of GNP is about half the size of that ratio in the United States or in the United Kingdom. The relative variability of the average number of hours worked per week in Japan is also much smaller than in the other two countries. The standard deviation of the average productivity of labor is about twice as large, relative to that for GNP, in Japan and the United Kingdom as in the United States. Finally, the variability of imports exceeds that of exports in all countries. Net exports, as discussed above, are countercyclical in all three countries.

The correlations with output also differ. The most striking difference is in the correlation between GNP and the average number of hours worked per week. In the U.S. data, this correlation is large and positive; for the United Kingdom and Japan, it is negative. In Japan, average hours variation dominates employment variation so that total hours worked, calculated by the product of employment and average hours, is actually countercyclical. The correlation between the average productivity of labor and GNP is much higher in Japan and the United Kingdom than in the United States.

These differences must be explained either by differences in parameters or by differences in the disturbances facing the three economies. Each

TABLE 5

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ
Filter: Linear Trend and Residuals from Projection onto U.S. GNP

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	9.2%	.96	1.00	.96
Consumption	8.5	.83	.90	.88
Investment	13.6	.92	.92	.86
Government spending	11.8	.70	.76	.77
Real exports	15.7	.69	.70	.65
Real imports	22.8	.61	.61	.56
Net exports	12.3	-.22	-.23	-.20
Average hours worked	2.7	-.56	-.59	-.61
Total hours worked	3.3	-.44	-.46	-.48
Employment	1.1	.07	.08	.05
Labor force	1.2	.01	.05	.02
GNP/total hours	9.0	.95	.99	.94
GNP/worker	9.2	.95	.99	.96
Exchange rate	11.5	.36	.32	.26

NOTE: Corr. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank, International Monetary Fund, and Citibase.

TABLE 6

British Business Cycle Statistics, 1961:IQ-1986:IIQ
First-Difference Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.7%	-.18	1.00	-.18
Consumption	1.9	-.03	.47	-.15
Investment	4.4	-.22	.31	.04
Government spending	2.2	.16	-.04	-.08
Real exports	9.7	.19	.26	-.21
Real imports	4.8	.07	.34	-.01
Net exports	9.1	.16	.10	-.22
Average hours worked	1.2	-.11	.33	.06
Total hours worked	1.5	-.14	.34	.17
Employment	6.5	-.11	.16	.22
Labor force	4.6	.06	.03	.02
GNP/total hours	1.8	-.10	-.10	-.04
GNP/worker	1.7	.00	.00	.00
Exchange rate	3.9	.13	.03	-.07
Net capital stock	0.3	.02	.07	.10
Equipment	0.3	-.02	.06	.10
Buildings	0.3	.04	.08	.10

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, and International Monetary Fund.

explanation has implications for the behavior of exports, imports, and the trade balance. The question of whether RBC models like those currently being analyzed will survive such extensions must await future research.[8]

■ 8 Other useful extensions of RBC analysis include further research integrating it with growth theory, as emphasized by King, Plosser, and Rebelo (1988b); the inclusion of private information into the analysis so that fluctuations are not unconstrained-Pareto-optimal; the inclusion of distorting government policies such as taxes and regulations (also emphasized by King, et al.); further examination of the behavior of prices, including interest rates, relative prices in multisector models, and so on; work on heterogeneity and aggregation problems; and extensions of the theory to include roles for financial intermediaries (and possibly government regulation of them), particularly since there is evidence connecting intermediation to business cycles.

VII. Policy Implications

Should any of the developments so far in RBC analysis affect current policy? Obviously, the answer involves the optimal formation of policy under uncertainty. If the standard macro models, say with sticky prices, are correct, then monetary policy can be designed to help, while if the RBC models are correct, then monetary policy will have no effects. It is clearly not correct to argue, however, that because we do not know which model is correct, we should use monetary policy as if the standard model were correct: even if it is wrong, there is little or no cost in trying it.

That argument is wrong precisely because there may be a large cost in using monetary policy if *both* the standard and the RBC models have

TABLE 7

British Business Cycle Statistics, 1961:IQ-1986:IIQ Linear Trend Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	3.5%	.88	1.00	.88
Consumption	3.6	.71	.73	.64
Investment	9.0	.81	.88	.86
Government spending	4.8	.56	.55	.55
Real exports	10.2	.38	.43	.36
Real imports	12.2	.59	.66	.67
Net exports	9.6	-.36	-.39	-.47
Average hours worked	2.2	-.29	-.27	-.33
Total hours worked	2.7	.13	.22	.22
Employment	1.9	.58	.65	.71
Labor force	1.4	-.03	-.03	-.03
GNP/total hours	3.9	.68	.73	.63
GNP/worker	2.6	.73	.83	.63
Exchange rate	11.8	-.06	-.12	-.17
Net capital stock	3.5	.78	.79	.79
Equipment	3.4	.76	.77	.77
Buildings	3.8	.79	.80	.80

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, and International Monetary Fund.

TABLE 8

British Business Cycle Statistics, 1961:IQ-1986:IIQ Filter: Linear Trend and Residuals from Projection onto U.S. GNP

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	2.5%	.76	1.00	.76
Consumption	2.5	.40	.43	.23
Investment	7.3	.52	.60	.67
Government spending	5.2	.46	.46	.38
Real exports	10.5	.37	.42	.27
Real imports	11.6	.60	.65	.60
Net exports	9.6	-.33	-.33	-.42
Average hours worked	2.2	-.18	-.15	-.20
Total hours worked	3.0	-.15	-.06	-.04
Employment	2.0	-.04	.01	.08
Labor force	1.4	-.22	-.19	-.15
GNP/total hours	4.1	.59	.67	.51
GNP/worker	3.2	.62	.77	.54
Exchange rate	12.6	.27	.27	.25
Net capital stock	3.6	.43	.46	.41
Equipment	3.2	.45	.48	.42
Buildings	3.8	.41	.45	.40

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, International Monetary Fund, and Citibase.

some explanatory power for business cycles. The cost is the *distortion* introduced into the economy if monetary policy does have real effects but is used in response to a *real* shock for which the economy is responding in an optimal way.

If policymakers want to use monetary policy for short-run stabilization rather than solely for longer-term inflation goals, they should base monetary policy on some indicators of the *source* of disturbances. If a previous change in the money supply has led to a change in output, and if there is time to reverse the money supply change to avoid the output change, then that reversal will reduce the inefficiency.

Similarly, if the economy is responding in an *inefficient* manner to some disturbance, and if monetary policy can help reduce the inefficiency, then it may be reasonable for policy to do so. But if the change in output is an optimal response to a real disturbance, then monetary policy will only introduce inefficiencies.

If policymakers could be sure of the source of disturbances, then they could use that information to formulate policy. Of course, they cannot be sure of the source. Therefore, an optimal statistical decision framework should be used for policy. This involves using existing information to try to determine, in the best way possible, the source of the disturbance, and using some estimates of the effects of money on output and of the losses from an inefficient level of output to set monetary control variables in the face of uncertainty.

The contribution of RBC theory has been to show that many aggregate fluctuations can possibly be viewed as optimal responses to external disturbances. If monetary policy is to be conducted with a goal of short-run stabilization, policymakers should use the information in RBC models to try to avoid interfering with these optimal responses.

One way to use the information would be to use a set of estimates similar to those in Christiano and Ljungqvist (1988), along with estimates of the difference between actual GNP and that predicted by RBC models, to infer the probability that the economy is responding optimally to a disturbance—as RBC models would predict—or whether it is responding, presumably inefficiently, to a monetary disturbance. The greater the likelihood that the fluctuation in GNP can be explained by the RBC model, the weaker the case for activist monetary policy, and vice versa. Of course, this presumes that the existing class of RBC models, in which the economy responds to disturbances in an optimal way, provides a good description of the response.

An alternative possibility is that disturbances are real rather than monetary in nature, but that the responses of the economy are suboptimal due to market failures of some kind.[9] This appears to place a caveat on the policy discussion here. But the caveat is not particularly strong, given the current state of knowledge, for several reasons. First, there is the question of whether government — particularly monetary policymakers — can do anything to improve welfare in suboptimal real business cycles, or to lessen the magnitude of business cycles (if that would improve welfare). Can monetary policy be of any use here, or must the government policies, if any are useful at all in this regard, be real? Second, attempts at such policies might do more harm than good in our current state of knowledge, even if they might be useful in the future. Third, there is the question of how much weight should be placed on the view that the economy responds in suboptimal ways to real disturbances. Inclusion of these features in RBC models has not been necessary to yield the degree of fit obtained so far.

Is there any reason to think that in the future RBC models will advance particularly by introducing these features, or is the tendency to include them more the result of a particular political propensity? No quantitative RBC model has yet been developed along these lines.[10]

Multicountry models such as the one outlined in section VI would be required to determine the appropriate policy response to a foreign shock. A *foreign* disturbance that induces inefficient aggregate fluctuations in that country might also induce inefficiencies in the U.S. economy and therefore warrant a domestic policy response. Alternatively, such a foreign disturbance might change opportunities only in the U.S. economy and result in efficient reactions to the inefficient foreign fluctuations, which would not warrant a domestic policy response. Further research on international transmission is required to determine the best policy response to foreign disturbances.

I do not want to minimize the difficulties in using RBC analysis, in its current state, to determine whether a policy response might be appropriate. But the existence of these difficulties neither precludes the use of the models in their current state nor warrants ignoring the evidence that, given current models, business-cycle phenomena can be quantitatively explained at least as well as an optimal response than as a suboptimal response to exogenous disturbances.

Prescott (1986a) states that the key policy implications of his research are that costly efforts at stabilization policy are likely to be counterproductive, because they may reduce the rate of technological change, and that economic fluctuations are optimal responses to uncertainty in the rate of technological change. He also contends that optimal policies should be designed to affect the long-run rate of technological change, but that the precise designs of institutions and policies requires further research on the determinants of technical progress. Given the current evidence on inflation and long-term economic growth, this conclusion supports a monetary policy geared toward low inflation and with less concern about fluctuations in real GNP.[11] Fortunately, this conclusion is consistent with the one based on stabilization considerations.

■ **9** These failures might involve externalities or inefficiencies resulting from government policies such as distorting taxation, unemployment insurance, effects of Social Security on savings, or government regulations.

■ **10** The most promising modifications in this regard may be the introduction of imperfect competition as in Hall (1988). However, in this case, it is not clear that *monetary* policy would have a role in an optimal policy response to external disturbances.

■ **11** See Gavin and Stockman (1988).

References

Abraham, Katharine G., and Lawrence F. Katz. "Cyclical Unemployment: Sectoral Shifts or Aggregate Disturbances?" *Journal of Political Economy.* 94, no. 3 (June 1986): 507-22.

Altug, Sumru. "Gestation Lags and the Business Cycle." Carnegie-Mellon University Working Paper, 1983.

Backus, David K., and Patrick J. Kehoe. "International Evidence on the Historical Properties of Business Cycles." University of Minnesota Working Paper, 1988.

Barro, Robert J. *Macroeconomics,* Second Edition. New York: John Wiley and Sons, 1987.

_______ . "A Capital Market in an Equilibrium Business Cycle Model." *Econometrica.* 48 (1980): 1393-1417.

_______ . "Rational Expectations and the Role of Monetary Policy." *Journal of Monetary Economics.* 2 (1976): 1-32.

Barsky, Robert B., and Jeffrey A. Miron. "The Seasonal Cycle and the Business Cycle." *Journal of Political Economy* (1988, forthcoming).

Baxter, Marianne, and Alan C. Stockman. "Business Cycles and the Exchange Rate Regime: Some International Evidence." Rochester Center for Economic Research Working Paper, 1988.

Benzivinga, Valerie. "An Econometric Study of Hours and Output Variation with Preference Shocks." University of Western Ontario Working Paper, 1987.

Berndt, Ernst. "Energy Price Increases and the Productivity Slowdown in U.S. Manufacturing." In *The Decline in Productivity Growth,* Conference Series No. 22. Federal Reserve Bank of Boston, 1981.

Bils, Mark J. "Real Wages over the Business Cycle: Evidence from Panel Data." *Journal of Political Economy.* 93, no. 4 (August 1985): 666-89.

Brock, William A. "Asset Prices in a Production Economy." In John J. McCall, ed., *The Economics of Information and Uncertainty.* Chicago: The University of Chicago Press, 1982.

Campbell, John Y., and N. Gregory Mankiw. "Permanent and Transitory Components in Macroeconomic Fluctuations." *American Economic Review Papers and Proceedings.* 77, no. 2 (May 1987a): 111-17.

_______ . "Are Output Fluctuations Transitory?" *Quarterly Journal of Economics.* 2 (November 1987b): 857-80.

Cho, Jang-Ok, and Richard Rogerson. "Family Labor Supply and Aggregate Fluctuations." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988): 233-46.

Christiano, Lawrence J. "Why Does Inventory Investment Fluctuate So Much?" *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988): 247-80.

_______ **, and Martin Eichenbaum.** "Is Theory Really Ahead of Measurement? Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations." National Bureau of Economic Research Working Paper No. 2700 (September 1988).

_______ **, and Lars Ljungqvist.** "Money Does Granger-Cause Output in the Bivariate Output-Money Relation." *Journal of Monetary Economics.* (1988, forthcoming).

Clark, Peter. "The Cyclical Component of U.S. Economic Activity." *Quarterly Journal of Economics.* 102, no. 4 (November 1987): 797-814.

Cochrane, John H. "How Big is the Random Walk in GNP?" University of Chicago Working Paper, 1986.

Davis, Steven J. "Fluctuations in the Pace of Labor Reallocations." Volume 27 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1987, 335-402.

Donaldson, John B., and Rajnish Mehra. "Stochastic Growth with Correlated Production Shocks." *Journal of Economic Theory.* 29, no. 2 (April 1983): 282-312.

Eichenbaum, Martin, Lars P. Hansen, and Kenneth J. Singleton. "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice Under Uncertainty." National Bureau of Economic Research Working Paper No. 1981 (July 1986).

Evans, George W. "Output and Unemployment Dynamics in the United States: 1950-1985." Stanford University Working Paper, 1986.

Fay, Jon A., and James L. Medoff. "Labor and Output Over the Business Cycle: Some Direct Evidence." *American Economic Review.* 75, no. 4 (September 1985): 638-55.

Friend, Irwin, and Marshall E. Blume. "The Demand for Risky Assets." *American Economic Review.* 65, no. 5 (December 1975): 900-22.

Gavin, William T., and Alan C. Stockman. "The Case for Zero Inflation." Federal Reserve Bank of Cleveland. *Economic Commentary,* September 15, 1988.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman. "Investment, Capacity Utilization, and the Real Business Cycle." *American Economic Review.* 78, no. 3 (June 1988): 402-17.

Hall, Robert E. "A Non-competitive, Equilibrium Model of Fluctuations." National Bureau of Economic Research Working Paper No. 2576 (May 1988).

Hamilton, James D. "A Neoclassical Model of Unemployment and the Business Cycle." University of Virginia Working Paper, 1987a.

_______ . "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle." University of Virginia Working Paper, 1987b.

_______ . "Historical Causes of Postwar Oil Shocks and Recessions." *Energy Journal.* 6 (1985): 97-116.

_______ . "Oil and the Macroeconomy Since World War II." *Journal of Political Economy.* 91, no. 2 (April 1983): 228-48.

Hansen, Gary D. "Indivisible Labor and the Business Cycle." *Journal of Monetary Economics.* 16, no. 3 (November 1985): 309-27.

Hansen, Lars P., and Kenneth J. Singleton. "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns." *Journal of Political Economy.* 91, no. 2 (April 1983): 249-65.

Heckman, James J., and Thomas E. MaCurdy. "A Life Cycle Model of Female Labour Supply." *Review of Economic Studies.* 47, no. 1 (1980): 47-74. [*Corrigendum.* 47 (October 1982): 659-60.]

Horning, Bruce C. "Labor Hoarding and the Business Cycle." Vanderbilt University Working Paper, 1988.

Jones, Ronald W., and Douglas D. Purvis. "International Differences in Response to Common External Shocks: The Role of Purchasing Power Parity." In E. Claassen and P. Salin, eds., *Recent Issues in the Theory of Flexible Exchange Rates.* Amsterdam: North-Holland Press, 1983, 33-55.

King, Robert G., Charles I. Plosser, and Sergio T. Rebelo. "Production, Growth, and Business Cycles, I: The Basic Neoclassical Model." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988a): 195-232.

_______ . "Production, Growth, and Business Cycles, II: New Directions." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988b): 309-42.

Kravis, Irving B., and Robert E. Lipsey. "Toward an Explanation of National Price Levels." Princeton Studies in International Finance, No. 52 (November 1983).

Kydland, Finn E. "Labor-Force Heterogeneity and the Business Cycle." In Karl Brunner and Allan H. Meltzer, eds., *Essays on Macroeconomic Implications of Financial and Labor Markets and Political Processes.* Volume 21 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1984, 173-208.

_______**, and Edward C. Prescott.** "The Workweek of Capital and its Cyclical Implications." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988): 343-60.

_______**, and Edward C. Prescott.** "Time to Build and Aggregate Fluctuations." *Econometrica.* 50, no. 6 (November 1982): 1345-70.

Lilien, David M. "Sectoral Shifts and Cyclical Unemployment." *Journal of Political Economy.* 90, no. 4 (August 1982): 777-93.

Long, John B. Jr., and Charles I. Plosser. "Real Business Cycles." *Journal of Political Economy.* 91, no. 1 (February 1983): 39-69.

Loungani, Prakash. "Oil Price Shocks and the Dispersion Hypothesis." *Review of Economics and Statistics.* 68, no. 3 (August 1986): 536-39.

Lucas, Robert E. Jr. "On the Mechanisms of Economic Development." *Journal of Monetary Economics.* 22 (1988): 3-42.

_______ . "Interest Rates and Currency Prices in a Two-Country World." *Journal of Monetary Economics.* 10, no. 3 (November 1982): 335-60.

_______ . "An Equilibrium Model of the Business Cycle." *Journal of Political Economy.* 83, no. 6 (December 1975): 1113-44.

MaCurdy, Thomas. "An Empirical Model of Labor Supply in a Life-Cycle Setting." *Journal of Political Economy.* 89, no. 6 (December 1981): 1059-85.

Mankiw, N. Gregory. "Real Business Cycles: A Neo-Keynesian Perspective." *Journal of Economic Perspectives.* (1988, forthcoming).

Manuelli, Rodolfo E. "Modern Business Cycle Analysis: A Guide to the Prescott-Summers Debate." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986): 3-8.

McCallum, Bennett T. "Real Business Cycle Models." In Robert J. Barro, ed., *Handbook of Modern Business Cycle Theory.* (1989, forthcoming.)

_______ . "On 'Real' and 'Sticky-Price' Theories of the Business Cycle." *Journal of Money, Credit, and Banking.* 18 (1986): 397-414.

_______ . "On Consequences and Criticisms of Monetary Targeting." *Journal of Money, Credit, and Banking.* 17, no. 4 (November 1985): 570-97.

Mehra, Rajnish, and Edward C. Prescott. "The Equity Premium: A Puzzle." *Journal of Monetary Economics.* 15, no. 2 (March 1985): 145-61.

Miron, Jeffrey. "A Cross-Country Comparison of Seasonal Cycles and Business Cycles." University of Michigan Working Paper, 1988.

Mishkin, Frederic S. "The Real Interest Rate: An Empirical Investigation." In Karl Brunner and Allan H. Meltzer, eds., *The Costs and Consequences of Inflation.* Volume 15 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1981, 151-200.

Murphy, Kevin M., and Robert H. Topel. "The Evolution of Unemployment in the United States: 1968-1985." In Stanley Fischer, ed., *National Bureau of Economic Research Macroeconomics Annual 2.* Cambridge, Mass.: The MIT Press, 1987.

Nelson, Charles R., and Charles I. Plosser. "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications." *Journal of Monetary Economics.* 10, no. 2 (September 1982): 139-62.

Parkin, Michael. "How Firm is the 'Deep Structure' of Real Business Cycle Theory?" *Carnegie-Rochester Conference Series on Public Policy.* (1988, forthcoming).

Pencavel, John. "Labor Supply of Men: A Survey." In Orley Ashenfelter and Richard Layard, eds., *Handbook of Labor Economics.* Amsterdam: North-Holland Press, 1986.

Phillips, Kerk L. "Exploring the Correlation Between Net Exports and Output." University of Rochester Working Paper, 1988.

Prescott, Edward C. "Theory Ahead of Business-Cycle Measurement." In Karl Brunner and Allan H. Meltzer, eds., *Real Business Cycles, Real Exchange Rates, and Actual Policies.* Volume 25 in the Carnegie-Rochester Conference Series on Public Policy, 1986a, 11-44.

_______ . "Response to a Skeptic." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986b): 28-32.

Rogerson, Richard. "Indivisible Labor, Lotteries, and Equilibrium." *Journal of Monetary Economics.* 21, no. 1 (January 1988): 3-16.

_______ . Topics in the Theory of Labor Economics. University of Minnesota, Ph.D. Dissertation, 1984.

_______ , and Peter Rupert. "The Effects of Measurement Error on Estimating Equilibrium Models of the Aggregate Labor Market." Stanford University Working Paper, 1988.

Rogoff, Kenneth. "'Theory Ahead of Business-Cycle Measurement,' A Comment on Prescott." In Karl Brunner and Allan H. Meltzer, eds., *Real Business Cycles, Real Exchange Rates, and Actual Policies.* Volume 25 in the Carnegie-Rochester Conference Series on Public Policy, 1986, 45-48.

Romer, Paul M. "Increasing Returns and Long-Run Growth." *Journal of Political Economy.* 94, no. 5 (October 1986): 1002-37.

Rush, Mark. "Real Business Cycles." Federal Reserve Bank of Kansas City. *Economic Review.* 72, no. 2 (February 1987): 20-32.

Salyer, Kevin D. "Exchange Rate Volatility: The Role of Real Shocks and the Velocity of Money." *Economic Inquiry.* (1988, forthcoming).

Sims, Christopher A. "Policy Analysis with Econometric Models." *Brookings Papers on Economic Activity.* (1982): 107-52.

_______ . "Macroeconomics and Reality." *Econometrica.* 48, no. 1 (January 1980): 1-48.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics.* 39 (1957): 312-20.

Stock, James H., and Mark W. Watson. "Testing for Common Trends." Harvard University Working Paper, 1986.

Stockman, Alan C. "Sectoral and National Aggregate Disturbances to Industrial Output in Seven European Countries." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988a): 387-410.

_______ . "Real Exchange Rate Variability Under Pegged and Floating Nominal Exchange Rate Systems: An Equilibrium Theory." In Karl Brunner and Allan Meltzer, eds., *Carnegie-Rochester Conference Series on Public Policy.* (1988b, forthcoming).

_______ . "The Equilibrium Approach to Exchange Rates." Federal Reserve Bank of Richmond. *Economic Review.* 73, no. 2 (March-April 1987): 12-30.

_______ . "A Theory of Exchange Rate Determination." *Journal of Political Economy.* 88, no. 4 (August 1980): 673-98.

_______ **, and Lars E.O. Svensson.** "Capital Flows, Investment, and Exchange Rates." *Journal of Monetary Economics.* 19, no. 2 (March 1987): 171-202.

_______ **, and Harris Dellas.** "International Portfolio Nondiversification and Exchange Rate Variability." *Journal of International Economics.* (1988, forthcoming).

Summers, Lawrence H. "Some Skeptical Observations on Real Business Cycle Theory." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986): 23-27.

Walsh, Carl E. "New Views of the Business Cycle: Has the Past Emphasis on Money Been Misplaced?" Federal Reserve Bank of Philadelphia. *Business Review.* (January 1986): 3-13.

Watson, Mark W. "Univariate Detrending Methods with Stochastic Trends." *Journal of Monetary Economics.* 18 (July 1986): 49-75.

Fourth Quarter Working Papers

Working Paper Notice

Current *Working Papers* of the Cleveland Federal Reserve Bank are listed in each quarterly issue of the *Economic Review*. Copies of specific papers may be requested by completing and mailing the attached form below.

Single copies of individual papers will be sent free of charge to those who request them. A mailing list service for personal subscribers, however, is not available.

Institutional subscribers, such as libraries and other organizations, will be placed on a mailing list upon request and will automatically receive *Working Papers* as they are published.

■ **8811**
Federal Grant Policies and Public Sector Scrappage Decisions
by Brian A. Cromwell

■ **8812**
The Impact of Capital Grants on Maintenance in the Local Public Sector
by Brian A. Cromwell

■ **8813**
Decomposing TFP Growth in the Presence of Cost Inefficiency, Nonconstant Returns to Scale, and Technological Progress
by Paul W. Bauer

■ **8814**
Money, Inflation, and Sectoral Shifts
by Charles T. Carlstrom and Edward N. Gamber

■ **8815**
Bankruptcy in the Life-Cycle Consumption Model
by K.J. Kowalewski

■ **8816**
Pricing Daylight Overdrafts
by E.J. Stevens

Please complete and detach the form below and mail to:

Federal Reserve Bank of Cleveland
Research Department
P.O. Box 6387
Cleveland, Ohio 44101

Check item(s) requested.

Please send the following Working Paper(s):

☐ **8811**	☐ **8813**	☐ **8815**
☐ **8812**	☐ **8814**	☐ **8816**

Send to:

Please print

Name

Address

City State Zip