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Procyclical Real Wages Under Nominal-Wage Contracts With Productivity Variations

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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 Akedof 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 anive 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 pice. 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-laborschedule.

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 fured 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-informationmodels 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 fured 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 fured 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 fured 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 [19861, 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

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

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

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

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:

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

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, $n_{it}^d = n_{it}^s$:

$$(7) \quad w_{it}^* = p_t + [\ln(\gamma) - (1 - \gamma)\beta_0] J + J z_t,$$

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

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(I) process. Second, the coefficients of (14) are determined by the taste and technology parameters, y 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, A,, is normally distributed with variance a): .

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

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

where the μ_i are choice parameters. The policy rule's arguments in $E_{t-2}\, z_{t-1}$ and $E_{t-2}\, v_{t-}$, 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):

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

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

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

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) $n_{it} = n^d_i$, 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) $\gamma = .5,\ \beta_1 = .5$

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

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

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

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

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

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

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

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

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

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.

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