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Estimated Tradeoffs Between Unemployment and Inflation

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An important question in macroeconomics is the size of the tradeoff between unemployment and inflation. I have been asked by the organizers of this symposium to consider this question, and so this is yet another paper on the tradeoff issue. Given an econometric model of price and wage behavior, it is straightforward to compute the tradeoff. The key problem is finding the model that best approximates the unknown structure, and this problem is the focus of this paper.

Three models of price and wage behavior are considered. The first, Model 1, is the one contained in my macroeconomic model of the United States (Fair, 1984). The second, Model 2, is one that is closer to what might be considered the standard model in the literature. The third, Model 3, is one in which there is no long-run tradeoff between unemployment and inflation. Model 3 is Model 2 with a certain restriction on the coefficients.

The paper is organized as follows. Some methodological issues are discussed first. The models are then presented, estimated, and tested. The unemployment-inflation tradeoffs implied by each model are then presented, and the final section contains a general evaluation of the results and a discussion of their consequences for macroeconomic policy and research.

Some methodology

It will be useful to present a few of my views about macroeconomic research before launching into the specification of the equations. The first issue concerns how much information one expects to get out of macro time series data. Consider, for example, the question of which demand variable to use in a price or wage equation. My experience is that macro data are not capable of discriminating among many different measures of demand. Similar results are obtained using such variables as the overall unemployment rate, the unemployment rate of married men, various weighted unemployment rates, various output gaps, and various nonlinear functions of these variables.[1] It is also difficult to discriminate among alternative lag distributions for the explanatory variables, a point made by Griliches (1968) many years ago and one that still seems valid.

If one feels, as I do, that macro data contain a fairly limited amount of information, the obvious procedure to follow in econometric work is to keep the specifications simple. If the data cannot discriminate among alternative detailed specifications, there is no sense in making detailed specifications in the first place. One should also avoid making strong inferences from results that are sensitive to alternative specifications among which the data may not be able to discriminate. This is an obvious point, but it is perhaps worth emphasizing. In particular, note that one should be wary about making strong conclusions regarding the validity of a model's long-run properties. This is because long-run properties are likely to be sensitive to alternative lag distributions, which are in turn likely to be difficult to discriminate among.

The approach of keeping macro specifications fairly simple is at odds with the approach of Robert Gordon and George Perry, two of the leading figures in the field of price and wage behavior. Gordon's specifications are characterized by the use of high-order polynomial distributed lags with long lag lengths, the use of detailed dummy variables, and considerable work in the construction of many of the explanatory variables. One reason that Gordon's specifications change so much from year to year is probably that they are too detailed to be supported by the data. New data seem to imply a change in specification when in fact no specification for a given year is really supported.[2] Perry's specifications are also usually somewhat involved, especially with respect to the choice of the demand variable and the use of dummy variables.[3] It will be clear in what follows that my specifications are simpler than those of Gordon and Perry, and one should keep in mind my reason for this difference.

Another view I have about macroeconomic research is that there have been too few attempts to test one model against another. One reason there

1. See, for example, the discussion in Fair (1978), pp. 176-80, and in Fair (1984), p. 128-29.

2. A minor but illustrative example of Gordon's changing specifications concerns the use of dummy variables for the Nixon control period. In Gordon (1980) one dummy variable is used, which is 0.67 for 1971:III-1972:IV, −1.0 for 1974:II-1975:I, and 0.0 otherwise. In Gordon and King (1982) two variables are used. One is 0.8 for 1971:III-1972:II and 0.0 otherwise, and the other is 0.4 for 1974:II and 1975:I, 1.6 for 1974:III and 1974:IV, and 0.0 otherwise.

3. See, for example, the specifications in Perry (1980).

is currently so much disagreement in macroeconomics is probably that there has been so little testing of alternative specifications. I developed a few years ago a method for testing alternative models (Fair [1980]), and this is the method that I have used in this paper to compare the three models of price and wage behavior. One of the premises upon which this method is based is that all models are at least somewhat misspecified. An important feature of the method is that it accounts for the effects of misspecification in making the comparisons across models.

Finally, my approach in examining macroeconomic issues is to specify and estimate structural equations. A few years ago this was standard operating procedure, but it is now somewhat out of fashion. Some have turned to vector autoregressive equations, while others have turned to reduced form equations. In his recent work, for example, Gordon has switched to estimating reduced form price equations.[4] The reduced form approach ignores potentially important restrictions on the reduced form coefficients, and in this sense it is inefficient. Also, it is not possible in Gordon's recent work to know whether a variable that is added to the reduced form price equation belongs in the structural price equation, in the structural wage equation, or in both. Important questions about the wage-price process are simply left unanswered when only reduced form equations are estimated. For example, one important question with respect to a particular set of structural wage and price equations is whether the implied behavior of the real wage is sensible, and this question cannot be answered by the reduced form approach. Real wage behavior is considered below.

The three models

Model 1

Model 1 is the model of price and wage behavior in my U.S. model. The following is a brief discussion of it. A more complete discussion is contained in Fair (1984). Firms in the theoretical model are assumed to set prices and wages in a profit-maximizing context. They have some monopoly power in the short run in their price- and wage-setting behavior. Raising their prices above prices charged by other firms does not result in an immediate loss of all their customers, and lowering their prices below prices charged by other firms does not result in an immediate gain of everyone else's customers. There is, however, a tendency for high-price firms to lose customers over time and for low-price firms to gain customers. Similar statements hold for wages. Firms expect that the future prices and wages

4. See, for example, Gordon (1980) and Gordon and King (1982).

of other firms are in part a function of their own past prices and wages. Since a firm's market share is a function of its price relative to the prices of other firms, its optimal price strategy depends on this relationship. Expectations of firms are in some cases determined in fairly sophisticated ways, but none of the expectations are rational in the Muth sense. Firms do not know the complete model, and their expectations can turn out to be incorrect.

There are five main decision variables of a firm in the theoretical model. In addition to the firm's price level and wage rate, the variables are the firm's production, investment, and demand for employment. These decision variables are determined by solving a multiperiod maximization problem. The predetermined variables that affect the solution to this problem include (1) the initial stocks of excess capital, excess labor, and inventories, (2) the current and expected future values of the interest rate, (3) the current and expected future demand schedules for the firm's output, (4) the current and expected future supply schedules of labor facing the firm, and (5) expectations of other firms' future price and wage decisions.

The transition in macroeconomics from theoretical models to econometric specifications is usually difficult, and the present case is no exception. The aim of the econometric work is to try to approximate the decision equations of the firms that result from the solutions of the maximization problems. The empirical work for the price and wage equations consisted of trying the variables listed above, directly or indirectly, as explanatory variables. Observed variables were used directly, and unobserved variables were used indirectly by trying observed variables that seemed likely to affect the unobserved variables. The main unobserved variables are expectations.

I will not review here the work that led to the final estimated equations; this is discussed in Fair (1984, pp. 126-31). The final estimated equations are presented in Table 1. The equations are in log form. The explanatory variables in the price equation include the price level lagged once, the wage rate inclusive of employer Social Security taxes, the price of imports, and the unemployment rate lagged once. The unemployment rate is taken to be a proxy for the current and expected future demand schedules for the firms' output. For the work in Fair (1984) an alternative measure of demand was used, which was a measure of the real output gap. As noted above, a variety of demand variables work about equally well. The unemployment rate was used in this paper in order to make the tradeoff calculations below somewhat simpler. The other three variables in the price equation are taken to be proxies for expectations of other firms' price decisions. Increases in the lagged price level, the wage rate, and the price of

TABLE 1
The Price and Wage Models
Sample Period is 1954:I–1984:I (121 observations)

Explanatory Variables

Model 1

Dependent Variable $\log P_t$	*const.*	$\log P_{t-1}$	$\log W_t(1+d_t)$	$\log PIM_t$	UR_{t-1}	*SE*	*DW*
2SLS	.159	.937	.0268	.0335	−.205	.00377	1.75
	(7.32)	(107.01)	(6.33)	(11.05)	(6.19)		
3SLS	.160	.936	.0271	.0336	−.205	.00377	1.74
	(7.42)	(107.99)	(6.43)	(11.24)	(6.26)		
3SLS[a]	.164	.934	.0279	.0340	−.201	.00377	1.74
	(7.66)	(109.60)	(6.68)	(11.53)	(6.15)		

$\log W_t$	*const.*	$\log W_{t-1}$	$\log P_t$	$\log P_{t-1}$	t	UR_t	*SE*	*DW*
2SLS	−.477	.921	.503	−.456	.000754	−.0753	.00578	1.99
	(1.69)	(20.13)	(3.47)	(3.49)	(1.93)	(1.22)		
3SLS	−.293	.951	.514	−.485	.000493	−.0716	.00581	2.04
	(1.08)	(21.77)	(3.64)	(3.80)	(1.32)	(1.18)		
3SLS[a]	−.291	.951	.515	−.485	.000479	−.0799	.00581	2.04
	(2.73)	(52.50)		(5.35)	(3.61)	(1.62)		

Models 2 and 3

$\log P_t - \log P_{t-1}$	*const.*	$\log P_{t-1} - \log P_{t-2}$	$\log W_{t-1}(1+d_{t-1}) - \log W_{t-5}(1+d_{t-5})$	$\log PIM_{t-1} - \log PIM_{t-3}$	*SE*	*DW*
Model 2: OLS	−.00260	.293	.146	.0582	.00404	2.04
	(2.07)	(3.73)	(5.27)	(5.78)		
Model 2: 3SLS	−.00264	.292	.147	.0578	.00404	2.04
	(2.11)	(3.72)	(5.31)	(5.74)		
Model 3: 3SLS[b]	−.00536	.323	.191	.0461	.00415	2.04
	(5.48)	(4.14)	(7.77)	(4.87)		

$\log W_t - \log W_{t-1}$	*const.*	$\log P_{t-1} - \log P_{t-5}$	UR_t	*SE*	*DW*
Model 2: 2SLS	.0142	.175	−.114	.00565	1.96
	(7.48)	(8.69)	(3.27)		
Model 2: 3SLS	.0142	.175	−.116	.00565	1.96
	(7.52)	(8.68)	(3.30)		
Model 3: 3SLS[b]	.0144	.221	−.151	.00578	1.87
	(7.60)		(4.50)		

Notes: t-statistics in absolute value are in parentheses.

[a]Coefficient constraint (4) in text imposed on the equations.

[b]Coefficient constraint (10) in text imposed on the equations.

OLS = ordinary least squares

2SLS = two stage least squares

3SLS = three stage least squares

First stage regressors:

A = second basic set of variables in Fair (1984), Table 6-1, p. 228.

Model 1, 2SLS, $\log P_t$ eq.	:	A minus ZZ_{t-1} plus $\log(1+d_t)$. (ZZ is a demand pressure variable.)
Model 1, 2SLS, $\log W_t$ eq.	:	A plus $\log PX_{t-1}$. (PX is a price deflator.)
Model 1, 3SLS	:	A plus $\log(1+d_t)$ plus $\log PX_{t-1}$.
Model 2, 2SLS	:	A plus $\log PX_{t-1}$ plus $\log P_{t-1} - \log P_{t-5}$.
Models 2 and 3, 3SLS	:	A plus $\log(1+d_t)$ plus $\log PX_{t-1}$ plus $\log P_{t-1} - \log P_{t-5}$ plus $\log PIM_{t-1} - \log PIM_{t-3}$ plus $\log W_{t-1}(1+d_{t-1}) - \log W_{t-5}(1+d_{t-5})$ plus $\log P_{t-1} - \log P_{t-2}$

Variable	*Notation in Fair (1984)*	*Description*
d_t	$d_{5g} + d_{5s}$	Employer social security tax rate
P_t	P_f	Price deflator for private nonfarm output
PIM_t	PIM	Price deflator for imports
UR_t	UR	Civilian unemployment rate
W_t	W_f	Average hourly earnings excluding overtime of workers in the private sector

imports are assumed to lead to expectations of future price increases, which in the theoretical model lead to an increase in current prices.

The explanatory variables in the wage equation include the wage lagged once, the current price level, the price level lagged once, a time trend, and the unemployment rate. The unemployment rate is taken to be a proxy for the current and expected future supply schedules of labor facing the firms. The lagged wage variable and the current and lagged price variables are taken to be proxies for expectations of other firms' wage decisions. Increases in these variables are assumed to lead to expectations of future wage increases, which in the theoretical model lead to an increase in current wages. The time trend was added to account for trend changes in the wage rate relative to the price level. The inclusion of the time trend is important, since it helps identify the price equation. Aside from the different lags for the unemployment rate, the time trend and the lagged wage rate are the only two variables not included in the price equation that are included in the wage equation.[5]

Before discussing the estimates, a constraint that was imposed on the real wage rate needs to be explained. It does not seem sensible for the real wage rate (W_t/P_t) to be a function of either W_t or P_t separately, and in order to ensure that this not be true, a constraint on the coefficients of the price and wage equations must be imposed. The relevant parts of the two equations are

$$(1) \quad \log P_t = \beta_1 \log P_{t-1} + \beta_2 \log W_t + \ldots$$

$$(2) \quad \log W_t = \gamma_1 \log W_{t-1} + \gamma_2 \log P_t + \gamma_3 \log P_{t-1} + \ldots .$$

From these two equations, the equation for the real wage is

$$(3) \quad \log W_t - \log P_t = \frac{1}{1 - \beta_2\gamma_2}\gamma_1(1 - \beta_2) \log W_{t-1} - \frac{1}{1 - \beta_2\gamma_2}[\beta_1(1 - \gamma_2) - \gamma_3(1 - \beta_2)]\log P_{t-1} + \ldots .$$

5. There is one slight difference between the wage equation here and the one in Fair (1984). The same price deflator is used in both equations here (the private nonfarm deflator), whereas a different price deflator is used in the wage equation in Fair (1984) (the private deflator, both farm and nonfarm). This difference is not important in the sense that the data cannot discriminate between the two, and the simpler specification was used here for ease of interpretation.

In order for the real wage not to be a function of the wage and price levels, the coefficient of log W_{t-1} in (3) must equal the negative of the coefficient of log P_{t-1}. This requires that

$$(4) \quad 0 = (\gamma_1 + \gamma_3)(1 - \beta_2) - \beta_1(1 - \gamma_2).$$

Three sets of estimates of Model 1 are presented in Table 1. The estimation technique for the first set is two-stage least squares (2SLS), and the estimation technique for the second and third sets is three-stage least squares (3SLS).[6] Restriction (4) is imposed for the third set, but not for the first and second. The endogenous variables in the price equation are log P_t and log W_t, and the endogenous variables in the wage equation are log W_t, log P_t, and UR_t. UR_t is taken to be an endogenous variable even though no equation is specified for it in this paper. It is an endogenous variable in my U.S. model. The first-stage regressors that were used for the estimates are discussed in the notes to Table 1. The basic set of variables referred to in the notes consists of 34 variables. These are the main predetermined variables in my U.S. model. The 2SLS estimated residuals were used for the estimation of the covariance matrix of the error terms that is needed for the 3SLS estimates. The correlation coefficient for the error terms in the two equations was −0.299.

The data base used in Fair (1984) was updated through 1984:I for the results in this paper. The estimation period for all the equations in Table 1 is 1954:I-1984:I, which is a total of 121 observations.

The three sets of estimates of Model 1 are quite close, and there is little to choose among them. The coefficient restriction (4) is clearly supported by the data. The value of the 3SLS objective function was −96.471 for the unrestricted estimates and −96.567 for the restricted estimates, for a difference of only 0.096. This difference is asymptotically distributed as χ^2 with one degree of freedom, and the 0.096 value is far below the critical χ^2 value at the 95 percent confidence level of 3.84.

Model 1 differs from traditional models of wage and price behavior in a number of ways, and it will be useful to discuss two of these differences. First, most price and wage equations are specified in terms of rates of change of prices and wages rather than in terms of levels. Given the theory behind Model 1, the natural decision variables seemed to be the levels of

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6. All calculations for this paper, except for those in the section on properties of the models, were done using the Fair-Parke program. The Parke (1982) algorithm was used to compute the 3SLS estimates.

prices and wages rather than the rates of change, and so this was the specification used. For example, the market share equations in the theoretical model have a firm's market share as a function of the ratio of the firm's price to the average price of other firms. These prices are all price levels, and the objective of the firm is to choose the price level path (along with the paths of the other decision variables) that maximizes the multiperiod objective function. A firm decides what its price level should be relative to the price levels of other firms. The use of levels instead of rates of change has important consequences for the long-run properties of the model. This is discussed below.

Second, most price equations are postulated to be markup equations, where little or no demand effects are expected. Wage equations are postulated to be the ones where demand effects are most likely to exist. Model 1 is to some extent the reverse of this. The unemployment rate has a larger coefficient estimate (in absolute value) and is more significant in the price equation than in the wage equation. Also, the coefficient estimate of the wage rate in the price equation is too small to be interpreted as a markup coefficient. The theory behind the price and wage equations is not a markup theory, and so there is no reason to expect the estimated equations to have properties of markup equations. The equations do not appear to have such properties.

Model 2

As just noted, price and wage equations are typically specified in terms of rates of change of prices and wages rather than in terms of levels, and price equations are typically specified to be markup equations. This specification has been used for Model 2. I tried a number of equations that seemed consistent with this specification. The final equations are presented in Table 1.

The equations for Model 2 are in log form. The quarterly change in price is a function of the quarterly change in price lagged once, the four-quarter change in the wage rate lagged once, and the two-quarter change in the import price deflator lagged once. The quarterly change in the wage is a function of the four-quarter change in the price level lagged once, and of the unemployment rate. These equations are consistent with the interpretation of the price equation as a markup equation and of the wage equation as the one in which demand effects appear. The unemployment rate appears in the wage equation but not in the price equation. It was of the wrong sign and not significant when included in the price equation (both the current rate and the rate lagged one quarter were separately tried). The following is a discussion of some of the experimentation behind the choice of the final equations.

The data seemed to support the use of the four-quarter change in the wage lagged once in the price equation. When the four one-quarter changes, $\log W_{t-i}(1 + d_{t-i}) - \log W_{t-i-1}(1 + d_{t-i-1}), i = 1, 2, 3, 4$, were used in place of the four-quarter change, the coefficient estimates and t-statistics were: 0.139 (2.33), 0.144 (2.41), 0.181 (3.00), and 0.120 (1.97). These coefficients seemed close enough to warrant simply using the four-quarter change. When the one-quarter change unlagged was included with the other four one-quarter changes, it was not significant (coefficient estimate of 0.071, with t-statistic of 1.17). Similarly when the one-quarter change lagged five quarters was included with the other four, it was not significant (coefficient estimate of −0.001, with t-statistic of −0.02). The data seemed to support the use of the two-quarter change in the price of imports lagged once. When the one-quarter changes lagged once and twice were used in place of the two-quarter change, the coefficient esimtates and t-statistics were 0.0674 (3.20) and 0.0477 (2.03).

The quarterly change in the wage rate lagged once was not significant when added to the wage equation. The t-statistic was only −0.49. The use of the four-quarter change in the price in the wage equation was supported less than was the use of the four-quarter change in the wage in the price equation, but the four-quarter change in the price was used in the wage equation anyway. When the four one-quarter changes were used in place of the four-quarter change, the coefficient estimates and t-statistics were 0.249 (2.22), 0.126 (1.07), −0.017 (−0.14), and 0.352 (2.94). When the one-quarter change unlagged was included with the other four one-quarter changes, it was not significant (coefficient estimate of 0.110, with t-statistic of 0.72). Similarly, when the one-quarter change lagged five quarters was included with the other four, it was not significant (coefficient estimate of −0.120, with t-statistic of −1.05). When the one-quarter changes lagged five and six quarters were included with the other four, the coefficient estimates and t-statistics were −0.099 (0.84) and −0.079 (0.72). There is thus no evidence that price changes lagged more than four quarters belong in the wage equation.

Two sets of estimates of Model 2 are presented in Table 1. The estimation techniques for the first set are ordinary least squares for the price equation and 2SLS for the wage equation. The estimation technique for the second set is 3SLS. There are no endogenous explanatory variables in the price equation. The unemployment rate in the wage equation was taken to be an endogenous variable. The two sets of estimates are very close. The correlation coefficient for the error terms in the two equations was only 0.030, and so very little was gained by using 3SLS. Comparing the single-equation fits with those for Model 1, the price equation has a larger standard error (0.00404 versus 0.00377) and the wage equation has a smaller standard error (0.00565 versus 0.00581).

Model 3

As will be seen in a later section, there is a tradeoff between the unemployment rate and inflation implicit in Model 2.[7] There is, however, a restriction that can be placed on the coefficients of Model 2 that implies no long-run tradeoff. Model 3 is Model 2 with this restriction imposed. The restriction is as follows. Let $\dot{p}_{t-i} = \log P_{t-i} - \log P_{t-i-1}$ and $\dot{w}_{t-i} = \log W_{t-i} - \log W_{t-i-1}$, $i = 0, 1, \ldots, 4$. Write the price and wage equations of Model 2 as

$$(5) \quad \dot{p}_t = Z_t + \beta_1\dot{p}_{t-1} + \beta_2(\dot{w}_{t-1} + \dot{w}_{t-2} + \dot{w}_{t-3} + \dot{w}_{t-4}),$$

$$(6) \quad \dot{w}_t = \gamma_0 + \gamma_1(\dot{p}_{t-1} + \dot{p}_{t-2} + \dot{p}_{t-3} + \dot{p}_{t-4}) + \gamma_2 UR_t,$$

where $Z_t = \beta_0 + \beta_2[\log(1 + d_{t-1}) - \log(1 + d_{t-5})] + \beta_3(\log PIM_{t-1} - \log PIM_{t-3})$. Consider now a steady state where $\dot{p} = \dot{p}_t = \dot{p}_{t-1} = \ldots$, $\dot{w} = \dot{w}_t = \dot{w}_{t-1} = \ldots$, $Z = Z_t = Z_{t-1} = \ldots$, and $UR = UR_t = UR_{t-1} \ldots$. In this case (5) and (6) can be written

$$(7) \quad \dot{p} = Z + \beta_1\dot{p} + 4\beta_2\dot{w},$$

$$(8) \quad \dot{w} = \gamma_0 + 4\gamma_1\dot{p} + \gamma_2 UR.$$

Substituting (8) into (7) and rearranging terms yields

$$(9) \quad (1 - \beta_1 - 16\beta_2\gamma_1)\,\dot{p} = Z + 4\beta_2\gamma_0 + 4\beta_2\gamma_2 UR.$$

7. There is a tradeoff in the sense that given the two estimated equations of Model 2, a change in the unemployment rate leads to a finite long-run change in the rate of inflation. This assumes that the structure of the wage and price equations is stable over time. For example, part of what the equations are picking up are effects of expectations of future wage and price behavior on current behavior. If the expectation mechanism that is approximated by the equations changes, for whatever reason, the stability assumption is violated. Sargent (1971) has stressed the fact that estimated coefficients of lagged dependent variables in wage and price equations are picking up both the effects of lagged values on expected future values and the effects of expected future values on current values. Without extra assumptions, it is not possible to separate the two kinds of effects. For present purposes it is unnecessary to do this if one is willing to make the above stability assumption, as is done here.

If

$$(10) \quad 1 - \beta_1 - 16\beta_2\gamma_1 = 0.$$

there is no long-run tradeoff, and this is the restriction that was imposed on Model 3.

The estimates with this restriction imposed are presented in Table 1. The equations were estimated by 3SLS, where UR_t was treated as an endogenous variable. The value of the 3SLS objective function was − 116.669 for the unrestricted estimates and − 128.525 for the restricted estimates, for a difference of 11.856. Again, this difference is asymptotically distributed as χ^2 with one degree of freedom. The 11.856 value is considerably above the critical χ^2 value at the 95 percent confidence level of 3.84, and so the restriction is not supported by the data. The single equation fits for the price and wage equations are 0.00415 and 0.00578 for the restricted estimates, which compare to 0.00404 and 0.00565 for the unrestricted estimates.

Given the coefficient estimates of Model 3 and given an assumption about the long-run value of Z, one can compute the value of the unemployment rate (say UR*) for which inflation neither accelerates nor decelerates. Under the assumption that the long-run growth rate of d_t is zero and that the long-run growth rate of the import price deflator is 7.0 percent at an annual rate, the value of UR* is 6.25 percent. This value is simply computed by solving the equation $0 = Z + 4\beta_2\gamma_0 + 4\beta_2\gamma_2 UR$ for UR. The long-run rate of change of the price level that corresponds to this value of UR is 3.39 percent at an annual rate. The corresponding growth rate for the nominal wage is 5.06 percent, and the corresponding growth rate for the real wage is 1.62 percent.

A comparison of the models

Although the single equation fits are available from Table 1, these fits are not the appropriate criterion for comparing the models. Among other things, they do not test for the dynamic accuracy of the models, and they do not account in an explicit way for the possible misspecification of the models. The method in Fair (1980) can be used to compare models, and this method is used in this section to compare the three models.

The method accounts for the four main sources of uncertainty of a forecast: uncertainty due to 1) the error terms, 2) the coefficient estimates, 3) the exogenous variables, and 4) the possible misspecification of the model. Because it accounts for these four sources, it can be used to make comparisons across models. In other words, it puts each model on an equal footing for purposes of comparison. Exogenous variable uncertainty is not a problem in the present case because each model has the same exogenous variables, namely d_t and PIM_t. Therefore, exogenous variable uncertainty has not been taken into account: both d_t and PIM_t have been assumed to be known with certainty. The following is a brief outline of the method except for the part pertaining to exogenous variable uncertainty.

The method

Assume that the model has m stochastic equations, p unrestricted coefficients to estimate, and T observations for the estimation. The model can be nonlinear, simultaneous, and dynamic. Let S denote the covariance matrix of the error terms, and let V denote the covariance matrix of the coefficient estimates. S is m × m and V is p × p. An estimate of S, say $\hat{S}$, is $(1/T)\hat{U}\hat{U}'$, where $\hat{U}$ is an m × T matrix of estimated errors. The estimate of V, say $\hat{V}$, depends on the estimation technique used. Let $\hat{\alpha}$ denote a p-component vector of the coefficient estimates, and let u_t denote an m-component vector of the error terms for period t.

Uncertainty from the error terms and coefficient estimates can be estimated in a straightforward way by means of stochastic simulation. Given assumptions about the distributions of the error terms and coefficient estimates, one can draw values of both error terms and coefficients. For each set of values the model can be solved for the period of interest. Given, say, J trials, the estimated forecast mean and estimated variance of the forecast error for each endogenous variable for each period can be computed. Let $\tilde{\tilde{y}}_{itk}$ denote the estimated mean of the k-period-ahead forecast of variable i, where t is the first period of the forecast, and let $\tilde{\sigma}^2_{itk}$ denote the estimated variance of the forecast error. $\tilde{\tilde{y}}_{itk}$ is simply the average of the J predicted values from the J trials, and $\tilde{\sigma}^2_{itk}$ is the sum of squared deviations of the predicted values from the estimated mean divided by J.

It is usually assumed that the distributions of the error terms and coefficient estimates are normal, although the stochastic-simulation procedure does not require the normality assumption. The normality assumption has been used for the results in this paper. Let u^*_t be a particular draw of the error terms for period t, and let α^* be a particular draw of the coefficients. The distribution of u^*_t is assumed to be $N(0,\hat{S})$, and the distribution of α^* is assumed to be $N(\hat{\alpha},\hat{V})$.

Estimating the uncertainty from the possible misspecification of the model is the most difficult and costly part of the method. It requires successive reestimation and stochastic simulation of the model. It is based on a comparison of estimated variances computed by means of stochastic simulation with estimated variances computed from outside-sample (i.e., outside the estimation period) forecast errors. Assuming no stochastic-simulation error, the expected value of the difference between the two estimated variances for a given variable and period is zero for a correctly specified model. The expected value is not in general zero for a misspecified model, and this fact is used to try to account for misspecification.

Without going into details, the basic procedure is to estimate the model over a number of different estimation periods and for each set of estimates to compute the difference between the two estimated variances for each variable and length ahead of the forecast. The average of these differences for each variable and length ahead provides an estimate of the expected value. Let $\bar{d}_{ik}$ denote this average for variable i and length ahead k. Given $\bar{d}_{ik}$, the final step is to add it to $\tilde{\sigma}^2_{itk}$. This sum, which will be denoted $\hat{\sigma}^2_{itk}$, is the final estimated variance. Another way of looking at $\bar{d}_{ik}$ is that it is the part of the forecast-error variance not accounted for by the stochastic-simulation estimate.[8]

The results

Table 2 contains the results. The values in the a rows are stochastic-simulation estimates of the forecast standard errors based on draws of error terms only. The values in the b rows are based on draws of both error terms and coefficients. The results are based on 500 trials for each of the two stochastic simulations.[9] The simulation period is 1982:II-1984:I. In terms of the above notation, the b-row values are values of $\tilde{\sigma}^2_{itk}$. Each model consists of three equations: the price equation, the wage equation, and an identity determining the real wage, W/P.

For the misspecification results, each model was estimated and stochastically simulated 37 times.[10] For the first set, the estimation period ended

8. *Strictly speaking,* $\bar{d}_{ik}$, *is not a measure of the misspecification of the model (for the k-period-ahead forecast of variable i).* Misspecification can affect the stochastic simulation estimate of the variance, ($\tilde{\sigma}^2_{itk}$), and $\bar{d}_{ik}$ is merely the effect of misspecification on the total variance not reflected in $\tilde{\sigma}^2_{itk}$. For purposes of comparing the models, it does not matter how much of the misspecification is in $\tilde{\sigma}^2_{itk}$. The variance that is used for comparison is the total variance, $\hat{\sigma}^2_{itk}$.

9. The 3SLS estimates of each model were used for these simulations, including the 3SLS estimates of S and V. The errors in Table 2 are in units of percent of the forecast mean. See the discussion in Chapter 8 in Fair (1984) for the exact way in which the percentage errors are computed.

10. Because the OLS-2SLS and 3SLS estimates of Model 2 were so close for the results in Table 2, the OLS-2SLS techniques were used for the successive reestimation for Model 2. Estimating a model 37 times by 3SLS is expensive, and for Model 2 it seemed unnecessary to do this. The estimate of V for the OLS-2SLS techniques was assumed to be block diagonal for purposes of the stochastic simulation draws. Both Models 1 and 3 were estimated 37 times by 3SLS.

TABLE 2
Estimated Standard Errors of Forecasts for 1982:II–1984:I for the Three Models

	1982 II	1982 III	1982 IV	1983 I	1983 II	1983 III	1983 IV	1984 I
Price level (P)								
Model 1: a	.37	.51	.61	.69	.75	.78	.83	.86
b	.37	.54	.67	.79	.87	.98	1.03	1.15
d	.50	.83	1.11	1.47	1.84	2.21	2.55	2.94
Model 2: a	.41	.66	.88	1.11	1.38	1.62	1.90	2.17
b	.39	.68	.93	1.21	1.51	1.79	2.09	2.42
d	.53	.99	1.45	1.99	2.59	3.18	3.80	4.51
Model 3: a	.41	.70	.98	1.27	1.59	1.94	2.33	2.75
b	.43	.73	1.00	1.31	1.71	2.10	2.54	3.05
d	.49	.85	1.17	1.59	2.13	2.65	3.09	3.67
Nominal wage (W)								
Model 1: a	.54	.78	.96	1.06	1.17	1.26	1.32	1.40
b	.57	.78	.98	1.18	1.40	1.51	1.64	1.82
d	.52	.72	.87	1.00	1.24	1.47	1.77	2.10
Model 2: a	.54	.76	.98	1.20	1.41	1.68	1.90	2.15
b	.56	.83	1.10	1.38	1.72	2.07	2.41	2.72
d	.54	.80	.99	1.21	1.61	2.16	2.54	2.95
Model 3: a	.57	.82	1.05	1.30	1.60	1.93	2.25	2.65
b	.60	.87	1.13	1.41	1.76	2.14	2.57	2.98
d	.66	1.08	1.41	1.71	2.13	2.63	2.99	3.28
Real wage (W/P)								
Model 1: a	.62	.90	1.10	1.19	1.30	1.38	1.45	1.52
b	.66	.94	1.15	1.29	1.49	1.63	1.74	1.89
d	.70	.92	1.07	1.14	1.35	1.55	1.82	2.22
Model 2: a	.67	.88	1.04	1.15	1.20	1.27	1.31	1.40
b	.68	.97	1.13	1.27	1.39	1.47	1.54	1.59
d	.73	1.01	1.22	1.45	1.60	1.69	1.84	1.97
Model 3: a	.66	.93	1.08	1.10	1.14	1.20	1.26	1.36
b	.71	1.01	1.20	1.25	1.33	1.35	1.39	1.46
d	.78	1.06	1.28	1.47	1.58	1.64	1.81	1.96

Notes: a = Uncertainty due to error terms.
b = Uncertainty due to error terms and coefficient estimates.
c = Uncertainty due to error terms, coefficient estimates, and the possible misspecification of the model.
Errors are in percentage points.

in 1974:IV and the simulation period began in 1975:I. For the second set, the estimation period ended in 1975:I and the simulation period began in 1975:II. For the final set, the estimation period ended in 1983:IV and the simulation period began in 1984:I. The beginning quarter was 1954:I for all estimation periods. The length of the first 30 simulation periods was eight quarters. Since the data set ended in 1984:I, the length of the 31st simulation period, which began in 1982:III, was only seven quarters. Similarly, the length of the 32nd period was six, and so on through the length of the 37th period, which was only one quarter. For each of the 37 sets of estimates, new estimates of

V and S were obtained. Each of the 37 stochastic simulations was based on 200 trials.

The results produced for the one-quarter-ahead forecast for each of the three endogenous variables 37 values of the difference between the estimated forecast-error variance based on outside-sample errors (i.e., the squared forecast errors) and the estimated forecast-error variance based on stochastic simulation. The average of these 37 values was taken for each variable. In terms of the above notation, this average is $\bar{d}_{i1}$, where i refers to variable i and the 1 refers to the one-quarter-ahead forecast. The total variance for the one-quarter-ahead forecast of variable i is $\tilde{\sigma}^2_{it1} + \bar{d}_{i1}$, which in terms of the above notation is $\hat{\sigma}^2_{it1}$. For the results in Table 2, t is 1982:II, and the d-row value for 1982:II for each variable is the square root of $\hat{\sigma}^2_{it1}$. The calculations for the two-quarter-ahead forecasts are the same except that there are only 36 values of the difference between the two estimated variances for each variable. Similarly, there are only 35 values for the three-quarter-ahead forecast, and so on.

The d-row values in Table 2 can be compared across models. For both the price level and the nominal wage, Model 1 is the clear winner. It has the lowest standard errors for all the periods except for the one-quarter-ahead forecast of the price level, where the standard error is 0.50 for Model 1 and 0.49 for Model 3. By the end of the eight-quarter horizon, the differences in the standard errors are fairly large. For the price level, the eight-quarter standard errors are 2.94 for Model 1, 4.51 for Model 2, and 3.67 for Model 3. For the nominal wage, the errors are 2.10 for Model 1, 2.95 for Model 2, and 3.28 for Model 3. With respect to Model 2 versus Model 3, Model 3 does better for prices and Model 2 does better for wages.

The results for the real wage are closer. Model 1 is the best for the first six quarters, the models essentially tie for the seventh quarter, and Models 2 and 3 are better than Model 1 for the eighth quarter. In general the results are fairly close, and there is no clearcut winner.

Properties of the models

For each model, it is straightforward to compute the tradeoff between the unemployment rate and inflation. A simulation is first run using a particular value of the unemployment rate, and then another simulation is run using another value. The differences in the predicted values from the two simulations are the estimated tradeoffs. Before doing this, however, it will be useful to consider some issues regarding the behavior of the real wage.

Real wage issues

There appear to be constraints on the long-run behavior of the real wage that are not necessarily captured by equations like those for Models 1, 2, and 3. Consider, for example, a profit share variable, denoted SHRπ, which is defined to be the ratio of after-tax profits of the firm sector to the wage bill of the firm sector net of employer Social Security taxes.[11] The mean of this variable for the 1954:I-1984:I period is 0.109, with a maximum value of 0.136 in 1979:III and a minimum value of 0.066 in 1983:I. The variable has essentially no trend throughout this period. A regression of SHRπ on a constant term and time trend for this period yields a coefficient estimate of the time trend of −0.000084, with a t-statistic of −1.91. This coefficient multiplied by 121, the number of observations, yields −0.010, which is the estimated trend change in SHRπ. This is a fairly small change over the 30-year period.

Now, a fall in the level of the real wage of 1 percent leads to a rise in SHRπ of approximately 0.0075. If a given experiment with the price and wage equations results in a large change in the long-run level of the real wage, this may imply values of SHRπ that are considerably beyond the historical range. If so, this may call into question the long-run properties, since there may be forces at work (not captured by the equations) keeping SHRπ at roughly a constant level in the long run. It is thus important when examining the following results to look carefully at the long-run behavior of the real wage.

Unemployment-inflation tradeoffs

Results for the first set of experiments are presented in Table 3. The first simulation for each model began in 1984:II, which means that the initial conditions through 1984:I were used. The simulation was allowed to run for 140 quarters. An unemployment rate of 7.8 percent was used for all future periods. The annual rate of growth of the import price deflator was taken to be 7.0 percent. The rate of growth of the employer Social Security tax rate (d_t) was taken to be zero throughout the period. The second simulation for each model differed from the first only in the unemployment rate that was used. Unemployment was lowered to 6.8 percent for all future periods for this simulation. The results in Table 3 are the differences between the two simulations.

As can be seen, the models have quite different long-run properties. For Model 1, the 1 percentage point drop in the unemployment rate leads to an eventual rise in the price level of 5.15 percent and in the wage level of 4.81

11. SHRπ is a variable in my U.S. model. See Fair (1984) for the precise definition of it.

TABLE 3
Response of Prices and Wages to a One Percentage Point Fall in the Unemployment Rate

	Model 1						Model 2						Model 3					
Quarters Ahead	$\frac{P^b}{P^a}$	$\dot{p}^b - \dot{p}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^b}{W^a/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$	$\frac{P^b}{P^a}$	$\dot{p}^b - \dot{p}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^b}{W^a/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$	$\frac{P^b}{P^a}$	$\dot{p}^b - \dot{p}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^b}{W^a/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$
1	1.0000	0.01	1.0008	0.35	1.0008	0.32	1.0000	0.0	1.0012	0.48	1.0012	0.48	1.0000	0.0	1.0015	0.63	1.0015	0.61
2	1.0021	0.88	1.0026	0.79	1.0005	−0.10	1.0002	0.07	1.0023	0.48	1.0022	0.40	1.0003	0.12	1.0030	0.63	1.0027	0.49
3	1.0041	0.84	1.0044	0.76	1.0003	−0.10	1.0006	0.16	1.0035	0.50	1.0030	0.32	1.0010	0.28	1.0046	0.65	1.0036	0.36
4	1.0060	0.80	1.0061	0.73	1.0001	−0.09	1.0012	0.26	1.0048	0.52	1.0036	0.25	1.0021	0.45	1.0063	0.71	1.0043	0.25
5	1.0079	0.77	1.0077	0.70	0.9999	−0.08	1.0021	0.37	1.0062	0.57	1.0041	0.20	1.0036	0.64	1.0083	0.82	1.0047	0.16
6	1.0096	0.74	1.0093	0.67	0.9997	−0.08	1.0031	0.41	1.0077	0.64	1.0046	0.22	1.0054	0.73	1.0106	0.96	1.0052	0.21
7	1.0113	0.71	1.0108	0.64	0.9995	−0.07	1.0041	0.44	1.0094	0.70	1.0052	0.24	1.0075	0.83	1.0133	1.10	1.0058	0.25
8	1.0130	0.68	1.0123	0.62	0.9993	−0.07	1.0053	0.48	1.0112	0.75	1.0058	0.25	1.0098	0.94	1.0163	1.22	1.0064	0.26
9	1.0145	0.65	1.0137	0.59	0.9992	−0.06	1.0066	0.53	1.0131	0.79	1.0064	0.25	1.0124	1.08	1.0196	1.33	1.0070	0.23
10	1.0160	0.62	1.0150	0.57	0.9990	−0.06	1.0080	0.57	1.0151	0.82	1.0070	0.23	1.0155	1.21	1.0231	1.43	1.0075	0.19
11	1.0175	0.60	1.0163	0.55	0.9989	−0.06	1.0095	0.61	1.0171	0.85	1.0076	0.22	1.0188	1.35	1.0269	1.53	1.0079	0.16
12	1.0188	0.57	1.0176	0.53	0.9988	−0.05	1.0110	0.64	1.0192	0.88	1.0081	0.22	1.0225	1.47	1.0310	1.65	1.0083	0.15
13	1.0202	0.55	1.0188	0.51	0.9986	−0.05	1.0127	0.67	1.0214	0.90	1.0086	0.22	1.0265	1.59	1.0354	1.77	1.0087	0.15
14	1.0214	0.53	1.0199	0.49	0.9985	−0.05	1.0144	0.70	1.0237	0.93	1.0092	0.22	1.0308	1.71	1.0401	1.88	1.0090	0.14
15	1.0226	0.51	1.0210	0.47	0.9984	−0.04	1.0162	0.72	1.0260	0.95	1.0097	0.21	1.0355	1.83	1.0452	1.99	1.0093	0.13
16	1.0238	0.48	1.0221	0.45	0.9983	−0.04	1.0180	0.74	1.0284	0.97	1.0102	0.21	1.0405	1.96	1.0505	2.10	1.0096	0.11
17	1.0249	0.46	1.0231	0.43	0.9982	−0.04	1.0198	0.76	1.0308	0.99	1.0108	0.21	1.0459	2.08	1.0562	2.21	1.0098	0.09
18	1.0260	0.45	1.0241	0.41	0.9981	−0.04	1.0218	0.78	1.0333	1.00	1.0113	0.21	1.0516	2.21	1.0621	2.32	1.0100	0.08
19	1.0270	0.43	1.0250	0.40	0.9980	−0.03	1.0237	0.80	1.0358	1.02	1.0118	0.21	1.0577	2.33	1.0685	2.43	1.0102	0.06
20	1.0280	0.41	1.0259	0.38	0.9980	−0.03	1.0257	0.81	1.0383	1.03	1.0123	0.20	1.0641	2.45	1.0751	2.54	1.0103	0.05
30	1.0360	0.27	1.0333	0.26	0.9974	−0.02	1.0474	0.90	1.0655	1.11	1.0173	0.20	1.1504	3.66	1.1613	3.62	1.0095	−0.10
40	1.0412	0.18	1.0382	0.17	0.9971	−0.01	1.0709	0.93	1.0947	1.14	1.0222	0.19	1.2829	4.83	1.2895	4.68	1.0052	−0.24
60	1.0470	0.08	1.0438	0.08	0.9969	−0.00	1.1209	0.95	1.1566	1.16	1.0318	0.19	1.7514	7.09	1.7267	6.73	0.9859	−0.53
80	1.0496	0.03	1.0462	0.03	0.9968	−0.00	1.1736	0.95	1.2224	1.16	1.0416	0.19	2.7077	9.23	2.5812	8.68	0.9533	−0.83
100	1.0508	0.02	1.0474	0.02	0.9968	−0.00	1.2289	0.95	1.2921	1.16	1.0514	0.19	4.7408	11.25	4.3077	10.54	0.9086	−1.13
120	1.0513	0.01	1.0479	0.01	0.9968	−0.00	1.2868	0.95	1.3657	1.16	1.0613	0.19	9.3999	13.17	8.0258	12.32	0.8538	−1.42
140	1.0515	0.00	1.0481	0.00	0.9968	−0.00	1.3474	0.95	1.4435	1.16	1.0714	0.19	21.1064	14.98	16.6934	14.00	0.7909	−1.72

Notes: [a]Predicted value for a sustained unemployment rate of 7.8 percent.
[b]Predicted value for a sustained unemployment rate of 6.8 percent.
˙Percentage change at an annual rate.

Initial conditions were the actual values through 1984 I.
The import price deflator was assumed to grow at an annual rate of 7.0 percent throughout the period.
The rate of growth of d_t was assumed to be zero throughout the period.

percent. The real wage falls slightly (by 0.32 percent). At the end of the first year the price level is 0.60 percent higher; at the end of the second year it is 1.30 percent higher; and at the end of the fourth year it is 2.38 percent higher, which is about halfway to the final increase of 5.15 percent. Not counting the first quarter, the increase in the rate of growth of the price level falls from 0.88 in the second quarter, to 0.80 in the fourth quarter, to 0.68 in the eighth quarter, to 0.48 in the sixteenth quarter, and to zero after 140 quarters. A similar pattern holds for the nominal wage.

For Model 2, the 1 percentage point drop in the unemployment rate leads to an eventual increase in the rate of change of the price level of 0.95 percent. The eventual increase in the rate of change of the nominal wage is 1.16 percent, and the eventual increase in the rate of change of the real wage is 0.19 percent. The price and wage levels are, of course, ever-increasing. After 140 quarters the price level is 34.74 percent higher, the nominal wage is 44.35 percent higher, and the real wage is 7.14 percent higher. At somewhere between 30 and 40 quarters, the price level becomes 5.15 percent higher, which is the long-run total for Model 1.

It is interesting to compare the first few quarters for Models 1 and 2. The rate of inflation is initially much larger for Model 1 than for Model 2. After eight quarters the price level is 1.30 percent higher for Model 1, compared to 0.53 percent higher for Model 2. The rate of inflation for Model 1 falls from 0.88 in the second quarter to 0.68 in the eighth quarter. For Model 2 the rate of inflation rises from 0.07 in the second quarter to 0.48 in the eighth quarter. There is thus much more of a short-run tradeoff for Model 1 than for Model 2. The rates of inflation cross at quarter 11, where they are 0.60 for Model 1 and 0.61 for Model 2. After quarter 11 the rate of inflation rises to 0.95 for Model 2 and falls to zero for Model 1. The price levels cross somewhere between quarters 20 and 30.

Consider now the results for Model 3. The unemployment rates of 6.8 and 7.8 percent are above the non-decelerating rate of 6.25, and so for both simulations the rate of inflation is decelerating. Although not shown in Table 3, the rate of inflation becomes negative in quarter 18 for the simulation in which the unemployment rate is 7.8 percent. By quarter 140 the rate of inflation is −20.96 percent. The differences in Table 3 for Model 3 are thus differences between two decelerating paths. It is interesting to note that the differences for the first few quarters for Model 3 are not all that different from the differences for Model 2, although they are somewhat higher for Model 3.

With respect to the behavior of the real wage, the results for Model 1 show little change in the long-run level of the real wage. The fall in the

TABLE 4

Response of Prices and Wages to a One Percentage Point Increase in the Rate of Change of the Import Price Deflator

Model 1

Quarters Ahead	$\frac{P^b}{P^a}$	$\dot{P}^b - \dot{P}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^a}{W^b/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$
1	1.0001	0.03	1.0000	0.02	1.0000	−0.02
2	1.0002	0.07	1.0001	0.03	0.9999	−0.03
3	1.0005	0.10	1.0002	0.05	0.9998	−0.04
4	1.0008	0.12	1.0004	0.07	0.9996	−0.06
5	1.0011	0.15	1.0006	0.08	0.9995	−0.07
6	1.0015	0.18	1.0008	0.10	0.9993	−0.08
7	1.0020	0.20	1.0011	0.11	0.9990	−0.09
8	1.0026	0.23	1.0013	0.12	0.9988	−0.10
9	1.0032	0.25	1.0017	0.13	0.9985	−0.11
10	1.0038	0.27	1.0020	0.15	0.9982	−0.12
11	1.0045	0.29	1.0024	0.16	0.9979	−0.13
12	1.0052	0.31	1.0028	0.17	0.9976	−0.14
13	1.0060	0.33	1.0032	0.18	0.9972	−0.14
14	1.0068	0.34	1.0036	0.19	0.9968	−0.15
15	1.0077	0.36	1.0041	0.20	0.9965	−0.16
16	1.0086	0.38	1.0046	0.21	0.9961	−0.16
17	1.0095	0.39	1.0051	0.22	0.9956	−0.17
18	1.0105	0.41	1.0056	0.23	0.9952	−0.17
19	1.0115	0.42	1.0062	0.24	0.9948	−0.18
20	1.0125	0.43	1.0067	0.24	0.9943	−0.18
30	1.0242	0.53	1.0133	0.31	0.9893	−0.22
40	1.0379	0.59	1.0211	0.35	0.9838	−0.23
60	1.0687	0.65	1.0389	0.39	0.9721	−0.25
80	1.1025	0.68	1.0585	0.41	0.9601	−0.25
100	1.1381	0.69	1.0791	0.42	0.9482	−0.25
120	1.1752	0.69	1.1004	0.43	0.9364	−0.25
140	1.2137	0.69	1.1223	0.43	0.9247	−0.25

Model 2

Quarters Ahead	$\frac{P^b}{P^a}$	$\dot{P}^b - \dot{P}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^b}{W^a/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$
1	1.0000	0.0	1.0000	0.0	1.0000	0.0
2	1.0001	0.06	1.0000	0.0	0.9999	−0.05
3	1.0004	0.13	1.0000	0.01	0.9996	−0.11
4	1.0008	0.15	1.0001	0.03	0.9993	−0.11
5	1.0012	0.16	1.0002	0.06	0.9990	−0.10
6	1.0016	0.17	1.0005	0.09	0.9988	−0.08
7	1.0021	0.19	1.0007	0.11	0.9986	−0.08
8	1.0026	0.21	1.0010	0.12	0.9984	−0.09
9	1.0031	0.23	1.0013	0.13	0.9982	−0.10
10	1.0037	0.24	1.0016	0.14	0.9979	−0.10
11	1.0043	0.25	1.0020	0.15	0.9977	−0.10
12	1.0050	0.26	1.0024	0.16	0.9974	−0.10
13	1.0056	0.27	1.0028	0.17	0.9972	−0.10
14	1.0063	0.28	1.0033	0.18	0.9970	−0.10
15	1.0070	0.29	1.0037	0.19	0.9967	−0.10
16	1.0078	0.30	1.0042	0.20	0.9965	−0.10
17	1.0085	0.31	1.0047	0.20	0.9962	−0.10
18	1.0093	0.31	1.0052	0.21	0.9959	−0.10
19	1.0101	0.32	1.0057	0.21	0.9957	−0.10
20	1.0108	0.32	1.0062	0.22	0.9954	−0.10
30	1.0193	0.36	1.0120	0.25	0.9928	−0.11
40	1.0283	0.37	1.0181	0.26	0.9901	−0.11
60	1.0470	0.37	1.0310	0.26	0.9848	−0.11
80	1.0661	0.38	1.0442	0.27	0.9794	−0.11
100	1.0856	0.38	1.0575	0.27	0.9741	−0.11
120	1.1055	0.38	1.0710	0.27	0.9688	−0.11
140	1.1257	0.38	1.0847	0.27	0.9636	−0.11

Model 3

Quarters Ahead	$\frac{P^b}{P^a}$	$\dot{P}^b - \dot{P}^a$	$\frac{W^b}{W^a}$	$\dot{W}^b - \dot{W}^a$	$\frac{W^b/P^b}{W^a/P^a}$	$\left(\frac{\dot{W}^b}{P^b}\right)-\left(\frac{\dot{W}^a}{P^a}\right)$
1	1.0000	0.0	1.0000	0.0	1.0000	0.0
2	1.0001	0.04	1.0000	0.0	0.9999	−0.04
3	1.0004	0.10	1.0000	0.01	0.9997	−0.09
4	1.0007	0.12	1.0001	0.03	0.9994	−0.09
5	1.0010	0.14	1.0002	0.06	0.9993	−0.08
6	1.0014	0.15	1.0005	0.09	0.9991	−0.06
7	1.0018	0.17	1.0007	0.11	0.9990	−0.06
8	1.0023	0.20	1.0011	0.13	0.9988	−0.07
9	1.0028	0.23	1.0014	0.15	0.9986	−0.08
10	1.0034	0.25	1.0018	0.17	0.9984	−0.09
11	1.0041	0.27	1.0023	0.19	0.9982	−0.09
12	1.0048	0.29	1.0028	0.21	0.9980	−0.09
13	1.0056	0.32	1.0034	0.23	0.9977	−0.09
14	1.0065	0.34	1.0040	0.25	0.9975	−0.09
15	1.0074	0.36	1.0047	0.27	0.9973	−0.09
16	1.0084	0.39	1.0054	0.29	0.9971	−0.10
17	1.0094	0.41	1.0062	0.31	0.9968	−0.10
18	1.0105	0.43	1.0070	0.33	0.9966	−0.10
19	1.0116	0.45	1.0079	0.35	0.9963	−0.10
20	1.0128	0.47	1.0088	0.37	0.9960	−0.11
30	1.0282	0.69	1.0210	0.57	0.9930	−0.13
40	1.0499	0.90	1.0387	0.76	0.9894	−0.16
60	1.1138	1.30	1.0917	1.13	0.9802	−0.22
80	1.2093	1.67	1.1712	1.47	0.9685	−0.27
100	1.3437	2.01	1.2824	1.79	0.9544	−0.33
120	1.5280	2.32	1.4332	2.09	0.9380	−0.39
140	1.7782	2.61	1.6350	2.36	0.9194	−0.44

Notes: [a]Predicted value for an annual rate of change of the import price deflator of 7.0 percent.
[b]*Predicted value for an annual rate of change of the import price deflator of 8.0 percent.*
˙Percentage change at an annual rate.

Initial conditions were the actual values through 1984 I.
The unemployment rate wr ; assumed to be 7.8 percent throughout the period.
The rate of growth of d_t wa assumed to be zero throughout the period.

unemployment rate lowered the long-run level of the real wage by only 0.32 percent. The results for Model 2, on the other hand, show that the level of the real wage is ever increasing. After 140 quarters the level of the real wage is 7.14 percent higher, which implies a fall in SHRπ of approximately $0.0075 \times 7.14 = 0.054$. This is about five times larger than the trend change over the last 121 quarters between 1954:I and 1984:I. The long-run properties of Model 2 with respect to the real wage are thus questionable.

Effects of a change in import prices

One can also examine how the models respond to a change in import prices. Again, two simulations can be run, one using one set of values for future import prices and one using another. The results of this exercise are presented in Table 4. The first simulation used an annual rate of change of import prices of 7.0 percent, and the second used a rate of 8.0 percent. The initial conditions were the same as those for the simulations in Table 3. An unemployment rate of 7.8 percent was used for these results.

The increase in the rate of change of import prices led to an increase in the rate of change of prices and wages for both Models 1 and 2. For prices, the long-run effect is 0.69 for Model 1 and 0.38 for Model 2. For wages, the two numbers are 0.43 and 0.27. The long-run rate of change in the real wage fell in both cases. The fall was larger for Model 1 than for Model 2 (-0.25 vs. -0.11). Although the long-run properties differ somewhat, the short-run properties of the two models are quite close, as an be seen from examining, say, the first eight quarters in Table 4. The short-run results for Model 3 are also fairly close to those for Models 1 and 2. The long-run results for Model 3 are, of course, vastly different.

All three models have ever falling real wage levels, which is not sensible. All three models are thus at fault in this regard. This problem is discussed in the next section.

General remarks

Long-run tradeoffs

The two key questions regarding the long-run tradeoff between unemployment and inflation are 1) whether there is any tradeoff and 2) if there is one, whether it is in terms of the level of prices or the rate of change of prices. The results of comparing the three models above indicate that Model 1 is more accurate than Models 2 and 3, and so from these results one would conclude that there is a tradeoff and that it is in terms of the level of prices. If the choice is merely between Models 2 and 3, the results are inconclusive.[12]

Although Model 1 does seem to be the best approximation of the three, the results must be interpreted with considerable caution. As noted in the first section, macro data have a difficult time discriminating among alternative lag distributions, and alternative lag distributions can have large effects on the long-run properties of a model. One should clearly put much less weight on the long-run properties of the models than on the short-run properties (say, up to eight or twelve quarters ahead).

One may at first be surprised to think that the tradeoff between unemployment and inflation may be in terms of the level of prices rather than the rate of change, but there is no theoretically compelling reason to rule out the level tradeoff without testing the two possibilities. As noted above, it seems natural, given my theoretical model, to specify the price and wage equations in level terms. In general, there seems no reason to expect that a permanent shift in demand will necessarily lead to a permanently higher rate of change of prices and thus to an ever-increasing price level. At the least, this issue seems open to empirical test, and the tests in this paper provide support for the proposition that the tradeoff is in terms of levels.

Another point that should be kept in mind about Model 1 is the following. One might argue—I think correctly—that it is not sensible to expect that the unemployment rate could be driven to, say, 1.0 percent without having any more effect on prices than on their levels. (The same argument could even be made for Model 2 regarding the rates of change of prices.) There are clearly unemployment rates below which it is not sensible to assume that any of the three models provides a good approximation. Any attempt to extrapolate a model beyond the extremes of the data is dangerous, and this seems particularly true in the case of price and wage equations.

I sometimes try to account for the nonlinearities in price responses that one expects to exist as the unemployment rate approaches very low levels by using, as the demand variable in the price and wage equations, some function of the unemployment rate (or other measure of demand). These functions approach infinity or minus infinity as the unemployment rate approaches some small value. This means that as the unemployment rate

12. In future work it may be possible to provide a better test of Model 2 versus Model 3. The comparisons in this paper were only for forecasts up to eight quarters ahead. It can be seen from Table 3 that the main differences between the two models occur after eight quarters. It may thus be possible to get more conclusive results by using a forecast horizon longer than eight quarters. No attempt was made to do this in this study.

approaches this value, prices approach infinity. In a complete model of the economy, prices can never by driven to infinity, and so this approach effectively bounds the unemployment rate from below. The problem with this approach is that the data generally cannot discriminate among alternative functional forms, and so any choice is somewhat arbitrary. The approach that I have taken in this paper is to keep the specification simple by merely using the level of the unemployment rate as an explanatory variable. The consequence of this is that one should not extrapolate the equations much beyond the range of the historical data.

The real wage and the price of imports

One of the most serious problems with the models considered in this paper is that the long-run behavior of the real wage is a function of the price of imports. In each model the price of imports is in the price equation but not in the wage equation, and the reduced form equation for the real wage has the price of imports on the right hand side with a negative coefficient. In order to constrain the price of imports not to have a long-run effect on the real wage, one would have to add it to the wage equation (with perhaps a different lag from the one in the price equation) and constrain the coefficients in the two equations to imply no long-run effect of the price of imports on the real wage.

Another possible way to look at this problem is the following. Over the sample period there has been a certain trend change in the price of imports. The coefficient estimates of the price and wage equations are based on this trend. In the case of Model 1, the key coefficient estimate is the estimate of the time trend in the wage equation. Given that the coefficient estimates are based on this trend, it is not necessarily sensible to run an experiment in which the rate of change of the price of imports is permanently changed without also changing the coefficient estimate of the time trend in the wage equation to adjust for this trend change. A similar adjustment should be made to one or both of the constant terms in Model 2. With these adjustments, the models would still show an increase in the rate of change of prices and wages in response to the increase in the rate of change of the price of imports, but the coefficient adjustments could be made to show no change in the real wage in the long run. This type of adjustment would imply no changes in the estimated equations, only changes in the coefficients at the time of a particular experiment.

It should be noted that an answer to the real wage problem is not to use as the price of imports variable in the price equation the price of imports *relative* to the domestic price level (i.e., PIM relative to P). Consider, for example, the price equation for Model 1 in Table 1, and assume that the price of imports variable were $\log PIM_t - \log P_{t-1}$ rather than $\log PIM_t$. Since $\log P_{t-1}$ is already in the equation, this change merely has the effect of making the new coefficient of $\log P_{t-1}$ equal to the old coefficient plus the coefficient of $\log PIM_t$. The reduced form equation for the real wage would still be the same.

The question of the nominal price of imports versus the relative price of imports brings up an important issue about the experiments in Table 4. Consider Model 1. The increase in the rate of change in the price of imports of 1.0 percent led to a long-run increase in the rate of change in the domestic price of 0.69 percent, which implies a long-run increase in the rate of change in the relative price of imports of about 0.31 percent. Although the relative price of imports fluctuates considerably in the short-run and even in the intermediate run, it is not necessarily sensible to assume that it will continually rise or fall in the very long run. One may thus want to design experiments in which the relative price of imports does not change in the long run. Again, however, this issue is separate from the problem of the real wage being a function of the price of imports.

If one believes that the nominal price of imports should be constrained to grow at the same rate as the domestic price level in the long run, then the coefficient constraint imposed on Model 3 should be changed. The constraint (10) should read $1 - \beta_1 - 16\beta_2\gamma_1 - 2\beta_3 = 0$, where β_3 is the coefficient of $\log PIM_{t-1} - \log PIM_{t-3}$ in the price equation. This was not done for the present set of results.

It is clear that more work needs to be done regarding the long-run behavior of the real wage and the price of imports. In some cases alternative specifications should be tried, such as the choice of constraint imposed on Model 3, and in some cases alternative experiments should be designed. This is an important area for future research.

Policy options

There is little more to be said about policy options that is not obvious from the results in Table 3. If one believes that Model 1 is the best approximation, the tradeoffs can be read from the results for Model 1. The cost of a fall in the unemployment rate of 1 percentage point is an increase in the price level of 1.30 percent after 8 quarters. If Model 2 is chosen, the cost is an increase of 0.53 percent after 8 quarters. If one's horizon is 20 quarters, the estimated cost is about the same for both models: 2.80 percent for Model 1 and 2.57 percent for Model 2. After 20 quarters, the estimated costs from the two models diverge rapidly, and this is where the most uncertainty lies. For Model 1 there is an increase in the price level of 5.15 − 2.60 = 2.55 percent left. For Model 2 there is an increase in the rate of change of prices of 0.95 − 0.81 = 0.14 left.

Consequences for macroeconomic research

One of the important results of this paper is that the no long-run tradeoff model, Model 3, does not appear to be as good an approximation to the economy as does Model 1. The comparison with Model 2 is inconclusive, although it is certainly not the case that Model 3 dominates Model 2. This result has important consequences for macroeconomic research. Economists with such diverse views as Tobin and Lucas seem to agree with the Friedman-Phelps proposition that there is no long-run tradeoff between unemployment and inflation. (See Tobin [1980], p. 39, and Lucas [1981], p. 560.) Lucas (1981) points out in his review of Tobin's (1980) book that most of the recent developments in macroeconomic theory have been motivated by the problem of reconciling the natural rate hypothesis of Friedman and Phelps with an adequate treatment of output and employment fluctuations. I think Lucas is right in arguing that Tobin cannot accept the proposition of no long-run tradeoff and at the same time accept short-run propositions that do not imply the Friedman-Phelps proposition in the long run. The long run is simply a sequence of short runs.

Where I think both Tobin and Lucas have missed the mark is in so readily accepting the Friedman-Phelps proposition. The evidence in this paper suggests that this proposition may not be true, and at the least, the validity of the proposition is highly uncertain. It seems unwise to me to have based more than a decade of macroeconomic research on such a proposition. The present results suggest that more thought should be given to the possibility that the concept of a natural rate of unemployment is not a useful one upon which to base a theory.[13] One can argue that the present results do not discredit the natural rate hypothesis if one believes that the structure of the price and wage equations is not stable because of shifts in the mechanism by which expectations are formed (see footnote 7). While this is certainly true, it again seems unwise to have based so much research on this particular belief.

13. The theory upon which my macroeconometric model is based does not use the concept of a natural rate of unemployment. See Fair (1984), in particular pp. 15-16 and 90-91.

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