Inflation and Unemployment in a Macroeconometric Model

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1. Introduction

The main question of this conference is why there has recently been both high inflation and high unemployment in the U.S. economy. The purpose of this paper is to consider this question within the context of a macroeconometric model. Much of the literature on inflation and unemployment since Phillips wrote his classic paper [10] has centered around the question of whether the relationship between inflation and unemployment is stable over time. The fact that this relationship does not appear to be stable (i.e., appears to "shift" over time) has caused much puzzlement. From the perspective of a macroeconometric model builder, however, this lack of stability is not necessarily surprising. Inflation and unemployment are two endogenous variables out of many in a model, and there is in general no reason to expect that the combined influences on any two endogenous variables in a model are such as to lead to a stable relationship between them. This holds true not only for the relationship between inflation and unemployment, but also for the relationship between such variables as unemployment and output ("Okun's law") and inflation and output.

A model builder must approach the task of explaining inflation and unemployment with considerable caution. A major problem in this area is the difficulty of testing alternative hypotheses. It is relatively easy with aggregate time series data to fit the data well within the sample period, but a good within-sample fit is by no means a guarantee that the particular equation or model is a good representation of the actual process generating the data. It is also difficult to make comparisons of predictive accuracy across models because of differences in the number and types of variables that are taken to be exogenous in models. These difficulties and the fact that inflation has not been particularly well explained in the past obviously (and justifiably) make people skeptical of any new attempt at an explanation.

This paper is primarily a review of that part of my recent work ([2], [3], [4], [5], [6]) that relates to the inflation-unemployment question, and so the value added of this paper to someone who is already familiar with this work is small. Sections II-IV contain a review of the determination of inflation and unemployment in my theoretical and empirical macro models, and Section V contains a discussion of some of the important properties of the empirical model

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regarding the relationship between these two variables. Some estimates of the accuracy of the empirical model regarding the explanation of the two variables are presented in Section VI. The main conclusions of my work with respect to the inflation-unemployment question are presented in Section VII. It is difficult to explain the structure and properties of a large-scale model in a short paper, but I hope that I have been at least partly successful in this paper in presenting my response to the main question of this conference.

II. The Theoretical Model[1]

My approach to the construction of an econometric model has been to develop a theoretical model first and then to use this model to guide the specification of the econometric model. The two main features of the theoretical model that are relevant to the present discussion are (1) the decisions of the individual agents in the model are derived from the solutions of multiperiod optimization problems and (2) explicit consideration is given to possible disequilibrium effects in the system. The following is a brief discussion of these two features.

With respect to the first feature, firms and banks in the theoretical model maximize the present discounted value of expected future profits, and households maximize the present discounted value of expected future utility. At the beginning of each period each agent solves its maximization problem, knowing all past values, receiving in some cases information from others regarding certain current-period values, and forming expectations of future values. Expectations are generally assumed to be formed in simple ways in the model, although in a few cases the agents estimate some of the important parameters in the system before making their expectations. No agent knows the complete model, and so expectations can turn out to be wrong even though there are no random shocks in the model. The main decision variables of a bank are its loan rate and the maximum amount of money that it will lend in the period; the main decision variables of a firm are its price, production, investment, wage rate, and the maximum amount of labor that it will employ in the period; and the main decision variables of a household are the number of goods to purchase and the number of hours to work. The determinants of an agent's decisions in a given period are the variables that affect the solution of its optimal control problem.

With respect to the disequilibrium feature, an important distinction is made in the model between the *unconstrained* and *constrained* decisions of firms and households. A firm or household in a period may be constrained in how much money it can borrow at the current loan rate, and a household may also be constrained in how many hours it can work at the current wage rate. An unconstrained decision of a firm is defined to be a decision that results from the solution of its optimal control problem when the loan constraint is not imposed, and a constrained decision is defined to be a decision that results when the loan constraint is imposed. Similarly, an unconstrained decision of a household is

[1] The discussion in this section is a review of some of the material in [2]. See also Section 1.1 in [3].

defined to be a decision that results from the solution of its optimal control problem when neither the loan constraint nor the hours constraint is imposed, and a constrained decision is defined to be a decision that results when one or both constraints are imposed.[2] The actual quantities traded in a period in the model are the quantities determined from the constrained optimization problems.

There are different "regimes" in the model corresponding to the different cases of binding and nonbinding constraints. Periods of "disequilibrium" are periods in which one or more of the constraints are binding. Binding constraints in the loan market are due to mistakes on the part of banks in setting loan rates, and binding constraints in the labor market are due to mistakes on the part of firms in setting prices and wages. These mistakes are the result of expectation errors. There is a continual adjustment to past mistakes in the model in that each period the individual agents reoptimize on the basis of information from the previous period.

The main determinants of a household's decision variables, other than the loan and hours constraints when they are binding, are the initial value of its assets or liabilities and the current and expected future values of the price of goods, the wage rate, interest rates, tax rates, and nonlabor income. Except for the constraints, a household's decision problem is a straightforward problem in choosing the optimal time paths of consumption and leisure, and the variables that affect this decision are well known from microeconomics.

The decision problem of a firm is more complicated and less tied to the previous literature. The five main decision variables of a firm mentioned above are simultaneously determined in the model, and this approach has generally not been followed in the past. It is usually the case that the price, production, investment, wage, and employment decisions of a firm are analyzed separately rather than within the context of a complete behavioral model. Space limitations prevent a detailed discussion of a firm's decision problem here, but two features of this problem should be mentioned. The first is that the concepts of "excess labor" and "excess capital" play an important role in the model. The underlying technology of a firm is of a putty-clay type, and given this technology it is possible to compute for any period the amounts of labor and capital that are required to produce the output. The differences between the actual amounts of labor and capital on hand and the required amounts are defined to be the "excess" amounts on hand. Because of adjustment costs, it is sometimes optimal for a firm to plan to hold either excess capital or excess labor or both during certain periods. The fact that firms may hold as an optimizing strategy excess labor and/or excess capital during certain periods provides a reconciliation of the commonly observed phenomena of cyclical swings in "productivity" with optimizing behavior.

The second feature that should be mentioned is that market share considerations play an important role in determining a firm's price and wage behavior. A

[2] There are obviously other constraints facing firms and households, such as budget constraints, but for purposes of the present discussion nothing is lost by using "constrained" to refer only to the loan and hours constraints.

firm has a certain amount of monopoly power in the short run in the sense that raising its price above prices charged by other firms will not result in an immediate loss of all its customers and lowering its price below prices charged by other firms will 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. A firm also expects that the future prices of other firms are in part a function of its own past prices. Similar considerations apply to a firm's wage decision and its ability to gain or lose workers. Because of this market share nature of the model, some of the most important factors affecting a firm's decisions are its expectations of other firms' price and wage decisions.

The main determinants of a firm's decision variables are the amounts of excess labor and capital on hand, the stock of inventories on hand, the current and expected future values of the loan rate and other determinants of the cost of capital, and variables affecting the firm's expectations of other firms' price and wage decisions. There are also two constraints that may be binding on a firm. One is the loan constraint, which has been mentioned above. The other, which will be called the labor constraint, results from the fact that a firm may (by mistake) set its wage rate too low to attract the amount of labor that it planned to employ in the period. In this case the firm may be forced to produce less output in the period than it originally planned.

One important property of this theoretical model of firm behavior that will be useful to keep in mind in the following discussion of the empirical model is that an increase in the loan rate or other determinants of the cost of capital causes, among other things, a firm to raise its price. This "cost-of-capital" effect on price, which comes out of the optimizing process of the firm, is not generally a part of other models, Nordhaus [8, p. 40], for example, notes that none of the studies of price behavior that he has reviewed introduced capital costs into the analysis.

III. The Transition from the Theoretical to the Empirical Model[3]

The application of the theoretical model to macro time series data is subject to the usual caveats. There is first the aggregation problem. I have, for example, used the analysis of the behavior of the individual firms and households in the theoretical model to guide the specification of the behavioral equations that pertain to the entire firm and household sectors in the empirical model. Because of this jump from individual to aggregate behavior, there is obviously a wide gap between the theoretical and empirical models, and these two models are not in a strict sense the same model. I have really nothing further to say about this except to stress that my choice of the general structure of the empirical model and of the explanatory variables to use in the estimated equations has been heavily influenced by the general structure of the theoretical model and by the determinants of the decision variables of the individual agents in the model.

The application of the theoretical model to the data also poses another problem, namely that two important types of variables in the model, expecta-

[3] The discussion in this section is a review of some of the material in [3].

tions and unconstrained decisions, are unobserved. With respect to expectations, the standard procedure in accounting for expectational effects in econometric work is to use current and lagged values as "proxies" for expected future values, and this is the procedure that I have followed. Lagged values of endogenous variables have been used freely to try to account for expectational effects. It is well known, of course, that it is difficult to separate expectational effects from lagged response effects when lagged endogenous variables are used as explanatory variables, and I have made no attempt to do this in the empirical work. The lagged endogenous variables in the estimated equations below should thus be interpreted as picking up some unknown mix of expectational and lagged response effects. It also should be noted that the use of current and lagged values as proxies for expected future values does not necessarily imply that people are naive in their formation of expectations. It is true that expectations are not rational in the model since no constraints have been imposed requiring that people's expectations be equal to the model's predictions. The present procedure is, however, consistent with the use of considerable current and past information in forming expectations; it is just not consistent with complete knowledge of the model.

With respect to the unconstrained decision values, these values are the actual (observed) values in the theoretical model if none of the constraints are binding on the behavioral unit in question. Otherwise, however, only the constrained decision values are assumed to be observed. In the empirical application of this model some way must be found for distinguishing between the case in which the observed values are unconstrained and the case in which the observed values are constrained. This is a difficult problem, and much of the empirical work for the model has been concerned with this issue. The following is a brief discussion of the treatment of disequilibrium effects in the empirical model.

For present purposes it will be useful to ignore the possibility of a binding loan constraint on firms and households and use "constrained" to refer only to the hours and labor constraints. Also, since the empirical model is now under consideration, the following variables should be interpreted as pertaining to the entire household and firm sectors. Let:

LUN_t^S = household sector's unconstrained supply of labor,

L_t = household sector's constrained supply of labor (observed),

XUN_t^D = household sector's unconstrained demand for goods,

X_t = household sector's constrained demand for goods (observed),

LUN_t^D = firm sector's constrained demand for labor,

PUN_t = firm sector's price if it is unconstrained,

P_t = first sector's actual price (observed).

Consider the household sector first. From the theoretical model the determinants of LUN_t^S and XUN_t^D are known and have been mentioned above. Write the equations determining these two variables as

$$(1) \qquad LUN_t^S = f_1(\ldots),$$

$$(2) \qquad XUN_t^D = f_2(\ldots).$$

The observed supply of labor and demand for goods are L_t and X_t, respectively, and if the hours constraint is not binding, $L_t = LUN_t^S$ and $X_t = XUN_t^D$. Otherwise, the observed quantities are less than the unconstrained quantities, and the approach that I have taken is to postulate equations explaining the ratios of the observed and unconstrained quantities. In the present notation these equations are:

$$(3) \qquad \frac{L_t}{LUN_t^S} = Z_t^{\gamma_1}, \gamma_1 > 0,$$

$$(4) \qquad \frac{X_t}{XUN_t^D} = Z_t^{\gamma_2}, \gamma_2 > 0,$$

where Z_t is some variable that takes on a value of one when the hours constraint is not binding and of less than one otherwise. For the empirical work Z_t was taken to be a nonlinear function of a measure of labor market tightness in the model, J_t^*. J_t^* is a detrended ratio of total worker hours paid for to the total population 16 and over. Although J_t^* was used as the measure of labor market tightness, the results were not sensitive to this particular choice: similar results were obtained using one minus the unemployment rate as the measure of labor market tightness. The nonlinear function that was chosen has the property that Z_t is close to one when the labor market is very tight and becomes progressively less than one as the labor market becomes progressively looser.

Equations (1) and (3) can be combined to eliminate the unobserved variable LUN_t^S. If, as is assumed for the empirical work, equation (1) is in log form and contains only observed right-hand side variables, then combining (1) and (3) yields an equation with log L_t on the left-hand side and only observed variables, including γ_1 log Z_t, on the right-hand side. This equation can then be estimated. The coefficient γ_1, which is unknown, can be estimated along with the other unknown coefficients in equation (1). Similar considerations apply to equations (2) and (4).

Consider now the firm sector. From the theoretical model the determinants of PUN_t are known. Write the equation determining this variable as

(5) $PUN_t = f_5(\ldots)$.

If the labor constraint is not binding $(LUN_t^S > LUN_t^D)$, then $P_t = PUN_t$. If, on the other hand, the labor constraint is binding, then the firm sector is assumed to adjust to this by raising its price. In particular, it is assumed that

$$\frac{P_t}{PUN_t} = (Z_t')^{\gamma_3}, \gamma_3 < 0, \tag{6}$$

where Z_t' is some variable that takes a value of one when the labor constraint is not binding and of less than one otherwise. For the empirical work Z_t' was also taken to be a nonlinear function of a measure of labor market tightness, in this case one minus the unemployment rate. The nonlinear function that was chosen has the property that Z_t' is close to one when the labor market is very loose and becomes progressively less than one as the labor market becomes progressively tighter. Equations (5) and (6) can also be combined to eliminate the unobserved variable PUN_t, thus ending up with an equation that can be estimated. This equation contains log P_t on the left-hand side and, among other terms, γ_3 log Z_t' on the right-hand side.

The possible labor constraint on the firm sector is thus handled in the empirical model through the price equation. If this constraint is binding, the firm sector is assumed to raise its price. A higher price leads in the model to a lower level of sales, which in turn leads to a lower level of production, which then results in less labor demand. There is, in other words, an indirect link in the model between a higher price level and a lower demand for labor. In the case in which the labor constraint is binding on the firm sector, the price is assumed to be raised enough so that the new demand for labor is equal to the supply from the household sector.

In the theoretical model the labor and hours constraints are never binding at the same time. Either the households are constrained, in which case the observed quantity of labor is equal to the demand from the firms, or the firms are constrained, in which case the observed quantity of labor is equal to the supply from the households. In practice, of course, this dichotomy is not literally true. At any one time some households and some firms are likely to be constrained, and it is a matter of degree as to which type of constraint is quantitatively more important.[4] The above approach for the empirical model does allow for this kind of flexibility. The nonlinear functions that relate labor market tightness to Z_t and Z_t' do not have the property that Z_t is equal to one when Z_t' is less than one and vice versa. Z_t is equal to one only for very tight labor markets, and Z_t' is equal to one only for very loose labor markets. In between these two extremes Z_t and Z_t' are both less than one, although Z_t is, of course, much closer to one in relatively tight labor markets than is Z_t', and vice versa in relatively loose labor markets.

[4] This heterogeneity of labor markets, which I argue in the following discussion has at least been partly accounted for in the empirical model, has been emphasized by Tobin [11], among others.

IV. Some Equations of the Empirical Model[5]

The following is a discussion of the equations of the empirical model that relate most directly to the determination of inflation and unemployment. The procedure that I followed in the empirical work for the household sector was first to regress each of its main decision variables (four consumption variables and three labor supply variables) on the same set of variables. This set consisted of the hours constraint variable (Z_t above and ZJ_t in the following notation), a similar loan constraint variable, and variables that were expected from the theoretical analysis to affect a household's unconstrained optimization problem. The highly insignificant variables were then dropped from each equation, and each equation was reestimated on a smaller set. The variables in the original set were highly collinear, and there were generally a number of insignificant variables in the first estimate of each equation.

The three labor supply equations in the model explain the labor force of males 24-54 *(TLF_{1t})*, the labor force of all others 16 and over *(TLF_{2t})*, and the number of people holding two jobs *($MOON_t$)*. These equations are:[6]

$$5.\quad \log\frac{TLF_{1t}}{POP_{1t}} = \underset{(1.43)}{-0.0834} + \underset{(5.76)}{0.540}\log\frac{TLF_{1t-1}}{POP_{1t-1}} + \underset{(1.88)}{0.0170}\log\frac{WT_t}{PH_t}$$

$$\underset{(1.42)}{-0.00804}\log\frac{YNLH_{t-1}}{PH_{t-1}POP_{t-1}} + \underset{(3.92)}{0.0813}\log(1.0 - d^M_{3t-1} - d_{6t-1}),$$

$$R^2 = 0.969,\ SE = 0.00199,\ DW = 2.06,$$

$$6.\quad \log\frac{TLF_{2t}}{POP_{2t}} = \underset{(3.41)}{-0.356} + \underset{(16.38)}{0.842}\log\frac{TLF_{2t-1}}{POP_{2t-1}} - \underset{(3.15)}{0.0403}\log\frac{AA_{t-1}}{POP_{t-1}}$$

$$+\underset{(3.43)}{0.0647}\log\frac{WT_{t-1}}{PH_{t-1}} + \underset{(0.07)}{0.000553}\log RMORT_t + \underset{(3.92)}{0.139}\log ZJ_t,$$

$$R^2 = 0.988,\ SE = 0.00508,\ DW = 1.86,$$

[5] The empirical model has been changed slightly and updated since [3] was published, and the updated version has been used for the results cited in this paper. The main change that has been made to the original model is the addition of an equation explaining the behavior of the Federal Reserve. This addition is discussed in [4]. The updated version of the model consists of 97 equations, 29 of which are stochastic, and has 188 unknown coefficients to estimate. The complete list of the equations of this version is contained in [7], which is available from the author upon request.

[6] The sample period for all the estimated equations presented in this section was 1954 I - 1977 IV, a total of 96 observations. All the equations were estimated by two-stage least squares, with in the case of equation 12 below, account also taken of the first order serial correlation of the error term, *t*-statistics in absolute value are in parentheses. The variables that were used as regressors in the first-stage regressions for each equation are listed in Table 2-5 in [7].

$$7.\quad \log\frac{MOON_t}{POP_t} = \underset{(3.63)}{-1.23} + \underset{(7.51)}{0.695}\log\frac{MOON_{t-1}}{POP_{t-1}} + \underset{(1.73)}{0.211}\log\frac{WT_t}{PH_t}$$

$$+\underset{(0.96)}{0.305}\log(1.0 - d^M_{3t-1} - d_{6t-1}) + \underset{(2.36)}{1.46}\log ZJ_{t-1}\,,$$

$$R^2 = 0.810\,, SE = 0.0653\,, DW = 2.04\,.$$

The variables are defined in Table 1. The equation numbers are as in [3], Table 2-2. Equation 5 states that the labor force participation of males 25-54 is a positive function of the real wage, a negative function of nonlabor income, and a negative function of the marginal personal income tax rate and the social security tax rate. Equation 6 states that the labor force participation of all others 16 and over is a positive function of the real wage, a negative function of net wealth of the household sector, a positive (although negligible) function of the mortgage rate, and a positive function of the hours constraint variable ZJ_t. Equation 7 states that the percent of the population holding two jobs in a positive function of the real wage, a negative function of the two tax rates, and a positive function of the hours constraint variable.

Although not every variable in the basic set of explanatory variables was significant in every equation, the above results do seem to indicate that the variables that one expects from microeconomics to affect labor supply are in fact important in explaining the aggregate data. It should also be noted that the significance of the hours constraint variable in an equation like 6 means that the observed labor force participation rate is less when the hours constraint is binding than when it is not. This effect can be interpreted as being similar to what are sometimes referred to in the literature as "discouraged worker" effects. The main difference here is that the hours constraint affects both the consumption and labor supply decisions; there are thus both "discouraged consumption" and "discouraged worker" effects in the model.

The link from the theoretical model to the empirical model is somewhat looser for the firm sector than it is for the household sector. Although a firm's decisions are determined simultaneously in the theoretical model, for empirical purposes the decisions were assumed to be made sequentially. This sequence is from the price decision, to the production decision, to the investment and employment decisions, to the wage rate decision. A firm is first considered as having chosen its optimal price path. This path implies a certain expected sales path, from which the optimal production path is chosen. Given the optimal production path, the optimal paths of investment and employment are chosen. Finally, given the optimal employment path, the optimal wage rate path is chosen. The optimal wage rate path is assumed to be that path that the firm expects is necessary to attract the amount of labor implied by its optimal employment path.

The equations of the firm sector that are relevant for present purposes are equations explaining its demand for workers $(JOBF_t)$, its price level (PF_t), and

TABLE 1

Selected Variables in the Empirical Model in Alphabetic Order

AA_t	=	total net wealth of the household sector.
$^{\dagger}d_{1t}$	=	profit tax rate.
d_{3t}^{M}	=	marginal personal income tax rate.
$^{\dagger}d_{6t}$	=	employee Social Security tax rate.
$^{\dagger}DTAXCR_t$	=	investment tax credit variable.
$EMPL_t$	=	total number of people employed.
J_t	=	ratio of total worker hours paid for to the total population 16 and over.
J_t^*	=	J_t detrended.
$JOBF_t$	=	number of jobs in the firm sector.
$^{\dagger}JOBGC_t$	=	number of civilian jobs in the government sector.
$^{\dagger}JOBGM_t$	=	number of military jobs in the government sector.
$M_tH_t^M$	=	number of worker hours required to produce Y_t.
$MOON_t$	=	difference between the total number of jobs in the economy and the total number of people employed.
PF_t	=	implicit price deflator for nonfarm output of the firm sector.
PH_t	=	implicit price deflator for domestic sales inclusive of indirect business taxes.
$^{\dagger}PIM_t$	=	implicit price deflator for imports.
$^{\dagger}POP_t$	=	noninstitutional population 16 and over.
$^{\dagger}POP_{1t}$	=	noninstitutional population of men 25–54.
$^{\dagger}POP_{2t}$	=	noninstitutional population of all persons 16 and over except men 25–54.
PX_t	=	implicit price deflator for total output of the firm sector.
$RAAA_t$	=	Aaa corporate bond rate.
$RMORT_t$	=	mortgage rate.
$^{\dagger}t$	=	linear time trend, $t = 1$ in 1952 I.
TLF_{1t}	=	total labor force of men 25–54.
TLF_{2t}	=	total labor force of all persons 16 and over except men 25–54.
U_t	=	number of people unemployed.
UR_t	=	civilian unemployment rate.
WFF_t	=	average hourly earnings, excluding overtime, of workers in the firm sector.
WT_t	=	average hourly earnings, excluding overtime, of all workers in the economy.
Y_t	=	output of the firm sector.
$YNLH_t$	=	nonlabor income of the household sector.
ZJ_t	=	hours constraint variable for the household sector.
ZJ_t'	=	labor constraint variable for the firm sector.

†exogenous variable

its wage rate (WFF_t).[7] These equations are:

$$12.\ \log JOBF_t - \log JOBF_{t-1} = \underset{(3.25)}{-0.623} \underset{(3.23)}{- 0.0990} (\log JOBF_{t-1} - \log M_{t-1}H^M_{t-1})$$

$$+ \underset{(3.52)}{0.000156t} + \underset{(4.84)}{0.269}(\log Y_t - \log Y_{t-1})$$

$$+ \underset{(4.21)}{0.190}(\log Y_{t-1} - \log Y_{t-2}) + \underset{(0.72)}{0.0285}(\log Y_{t-2} - \log Y_{t-3})$$

$$+ \text{ 2 strike dummies,}$$

$$\hat{\rho} = \underset{(2.62)}{0.304}\ ,\ R^2 = 0.747\ ,\ SE = 0.00385\ ,\ DW = 2.06,$$

$$9.\quad \log PF_t = \underset{(7.63)}{-0.183} + \underset{(35.11)}{0.785} \log PF_{t-1} + \underset{(13.25)}{0.0702} \log PIM_t + \underset{(6.28)}{0.0833} \log WFF_t$$

$$+ \underset{(2.02)}{0.0107} \log RAAA_t - \underset{(1.66)}{0.00225}\ DTAXCR_t + \underset{(2.03)}{0.0684} \log (1.0 + d_{1t-1})$$

$$- \underset{(3.52)}{0.00335} \log ZJ'_t\ ,\ R^2 = 0.9998\ ,\ SE = 0.002986\ ,\ DW = 2.03,$$

$$15.\quad \log WFF_t = \underset{(4.96)}{0.195} + \underset{(17.28)}{0.766} \log WFF_{t-1} + \underset{(5.76)}{0.00191t} + \underset{\text{(constrained)}}{0.508} \log PX_t$$

$$- \underset{(3.26)}{0.344} \log PX_{t-1} - \underset{(1.14)}{0.00214} \log ZJ'_t\ ,$$

$$R^2 = 0.999,\ SE = 0.006179\ ,\ DW = 1.92\ .$$

Equation 12 explains the number of jobs in the firm sector. The first term after the constant term on the right-hand side is a measure of the amount of excess labor on hand. The inclusion of the constant term and time trend in the equation is due to the particular form of the excess labor variable, and so the first three right hand side terms can be thought of as the excess labor term. The equation states that the change in the number of jobs (in log form) is a function of the amount of excess labor on hand and of three change-in-output terms. The two lagged change-in-output terms can be interpreted either as representing the effects of past output behavior on current employment decisions that are not captured in the measure of excess labor or as being proxies for expected future output changes. Equation 12 is meant to approximate the employment decisions

[7] For the model as presented in [3] and [7], WFF_t is in units of millions of dollars per hour per job, but for the results cited in this paper WFF_t is in units of dollars per hour per job. Also, as discussed in [7], WFF_t rather than WF_t is now used as the variable explained by the wage equation. WF_t has been dropped from the model.

of firms that result from the solutions of their multiperiod optimization problems in the theoretical model. The sequential assumption mentioned above is reflected in this equation in that Y_t is used as an explanatory variable. If the decisions on $JOBF_t$ and Y_t were truly made simultaneously, it would not be appropriate to use one of the variables to explain the other. Equation 12 is also similar to the equation that I used in [1] to explain the demand for employment by three digit industries.[8]

Before discussing equations 9 and 15, it will be useful to note how the unemployment rate is determined in the model. Given the endogenous variables TLF_{1t}, TLF_{2t}, $MOON_t$, and $JOBF_t$ and the exogenous government variables $JOBGC_t$ and $JOBGM_t$, the following three definitions determine the unemployment rate:

81. $EMPL_t = JOBF_t + JOBGC_t + JOBGM_t - MOON_t$, [total number of people employed]

82. $U_t = TLF_{1t} + TLF_{2t} - EMPL_t$, [total number of people unemployed]

83. $UR_t = \dfrac{U_t}{TLF_{1t} + TLF_{2t} - JOBGM_t}$. [civilian unemployment rate]

Equation 81 states that the total number of people employed equals the total number of jobs in the economy less the number of people holding two jobs. Equation 82 states that the number of people unemployed is equal to the number in the labor force less the number employed, and equation 83 states that the civilian unemployment rate is equal to unemployment divided by the civilian labor force.[9] The definition of the labor constraint variable ZJ'_t should

[8] For the work with the three digit industry data in [1] actual future values of output were used with some success as proxies for expected future values. For the work with the aggregate data, however, this was not the case, and so only lagged values are used in equation 12 as proxies for expected future values.

[9] One link between the discussion of disequilibrium effects in Section III and the equations presented in this section should be noted. Although three labor supply equations have been estimated (equations 5, 6, and 7), no equation explaining the supply of *jobs* has been estimated. The difference between the supply of labor as reflected in TLF_{1t}, TLF_{2t}, and $MOON_t$ and the demand for labor as reflected in $JOBF_t$, $JOBGC_t$, and $JOBGM_t$ is the unemployment variable U_t. U_t is thus indirectly affected by both the hours and labor constraint variables. The hours constraint variable directly affects two of the three labor supply variables, and the labor constraint variable indirectly affects $JOBF_t$ through its effect on the price variable PF_t.

It should be stressed that this approach is not the only way that one might try to account for disequilibrium effects. One alternative approach would be i) specify an equation explaining the supply of jobs to the firm sector (say, $JOBF_t^S$), ii) postulate that the observed number of jobs is equal to the minimum of the supply and demand ($JOBF_t = \min[JOBF_t^S, JOBF_t^D]$), and iii) use some of the recent econometric techniques that have been developed for estimating markets in disequilibrium to estimate the equations. Whether an approach like this would provide a better explanation of the data than has so far been achieved with the present approach is clearly an open question.

also be noted. As mentioned above, ZJ'_t is a nonlinear function of the unemployment rate:

$$78.\ ZJ'_t = 4.454062 + \frac{1}{1 - UR_t - 1.199514}\ .$$

The two coefficients in equation 78 are chosen so that ZJ'_t equals one when the unemployment rate is 9.0 percent and zero when the unemployment rate is 2.5 percent.

Equation 9 explains the price of nonfarm output of the firm sector. The explanatory variables include the lagged dependent variable, the price of imports *(PIM)*, the wage rate *(WFF)*, three cost-of-capital variables (the bond rate, *RAAA*, the investment tax credit variable, *DTAXCR*, and the profit tax rate, d_1), and the labor constraint variable *(ZJ')*. In a manner similar to that for equation 12, equation 9 is meant to approximate the price decisions of firms that result from the solutions of their multiperiod optimization problems in the theoretical model. The inclusion of the *PIM*, *WFF*, and lagged dependent variable terms in the equation is in part designed to pick up expectational effects. As noted above, a firm's expectations of other firms' prices play an important role in the theoretical model in determining the price that the firm sets for the period, and after some experimentation, the three variables just mentioned were chosen to represent expectational effects in the empirical model. The reason for the inclusion of the cost-of-capital variables has been mentioned above. The cost of capital does appear from the present results to have an effect on the price level.

The only variable in equation 9 that can be considered to be like a demand pressure variable is the labor constraint variable. Other demand variables were tried, but none proved to be significant. In particular, the following four variables, which have an influence in the theoretical model on the price that a firm sets, were tried and found not to be significant: the ratio of the stock of inventories to the level of sales, the level of sales itself, the amount of excess labor on hand, and the amount of excess capital on hand (all lagged one period). Since ZJ'_t is close to one for high unemployment rates (and thus log ZJ'_t close to zero), there is essentially no effect of the current unemployment rate on the price level in equation 9 in periods of high unemployment rates. In periods of low unemployment rates, on the other hand, the effect is large, and it in fact approaches infinity as the unemployment rate approaches 2.5 percent.

Although ZJ'_t as defined in equation 78 is used in the price equation to pick up demand effects on the price level, it is important to note that many other variables work equally well in this regard. Alternative measures of labor market tightness are highly correlated, and it is my conclusion from trying different measures in the price and wage equations that it is not possible using aggregate time series data to choose any one measure as being best. To give an example of this, I estimated equation 9 14 times using 14 different measures of labor market tightness, and the following is a summary of these results:[10]

	SE	t-statistic for the coefficient estimate of the measure	Measure	
1.	0.002986	−3.52	$\log ZJ_t'$,	where ZJ_t' is as defined in equation 78: $ZJ_t' = 1.0$ when $UR_t = 0.090$ and $ZJ_t' = 0.0$ when $UR_t = 0.025$.
2.	0.002987	−3.52	$\log ZJ_t'$,	where the coefficients in equation 78 are changed so that $ZJ_t' = 1.0$ when $UR_t = 0.090$ and $ZJ_t' = 0.0$ when $UR_t = 0.020$.
3.	0.002988	−3.52	$\log ZJ_t'$,	where the coefficients in equation 78 are changed so that $ZJ_t' = 1.0$ when $UR = 0.090$ and $ZJ_t' = 0.0$ when $UR_t = 0.015$.
4.	0.002988	−3.38	$\log ZJ_t'$,	where UR_t is the unemployment rate for married men and where the coefficients in equation 78 are changed so that $ZJ_t' = 1.0$ when $UR_t = 0.090$ and $ZJ_t' = 0.0$ when $UR_t = 0.010$.
5.	0.002994	−3.28	$\log ZJ_t'$,	where ZJ_t' is as in 2 except that UR_t is Perry's weighted unemployment rate.
6.	0.002983	−3.45	$\log ZJ_t'$,	where ZJ_t' is as in 3 except that UR_t is Perry's weighted unemployment rate.
7.	0.002978	−3.51	$\log ZJ_t$,	where ZJ_t' is as in 4 except that UR_t is Perry's weighted unemployment rate.
8.	0.002998	3.43	$\log (1-UR_t)$,	where UR_t is as defined in equation 83.
9.	0.002990	−3.52	$\log UR_t$,	where UR_t is as defined in equation 83.
10.	0.002970	3.45	$\log (1-UR_t)$,	where UR_t is the unemployment rate for married men.
11.	0.002974	−3.51	$\log UR_t$,	where UR_t is the unemployment rate for married men.
12.	0.002973	3.44	$\log (1-UR_t)$,	where UR_t is Perry's weighted unemployment rate.
13.	0.002973	−3.54	$\log UR_t$,	where UR_t is Perry's weighted unemployment rate.
14.	0.002985	3.54	$\log J_t^*$,	where J_t^* is a detrended ratio of total worker hours paid for in the economy to the total population 16 and over.

[10] The unemployment rate for married men that was used for some of these results is only available from 1955 on, and so for 1954 this series was spliced to the standard unemployment rate series. For a discussion of Perry's weighted unemployment rate series, see [9]. I am indebted to George Perry for supplying me with the latest data on this series.

It is clear from these results that essentially the same fit of the price equation has been achieved for each measure. Also, when different pairs of the above variables were tried in the equation, no one variable was ever individually significant. These results indicate, in other words, that one cannot distinguish among the total civilian unemployment rate, the unemployment rate for married men, Perry's weighted unemployment rate, and a detrended employment-population ratio as the variable to be used in the price equation. Nor can one distinguish among alternative nonlinear functions of these variables. This situation is unfortunate because, among other things, one's policy conclusions are likely to differ depending on which measure is used. It does seem from these results, however, that any policy conclusions that are sensitive to the particular measure used are not supported by the aggregate data.

It should finally be noted with respect to the price equation that some experimentation was done, primarily through the use of dummy variables, to see if the effects of price controls should be taken into account. These effects at best seemed small, and so the decision was made not to incorporate them into the model. To give an example, when dummy variables for 1971 IV, the quarter affected by the first price freeze, and 1972 I, the quarter following the lifting of the freeze, were added to equation 9, their coefficient estimates were 0.00102 and 0.00906, respectively, with *t*-statistics of 0.34 and 3.07. The first coefficient estimate is of the wrong expected sign, but it is clearly not significantly different from zero. The second coefficient estimate is positive, as expected, and significant. Foes of price controls may like these results as indicating that price controls, if anything, exacerbate inflation in the long run, but a better conclusion is probably that there is little evidence in the aggregate data of any lasting effects of price controls on inflation.

Equation 15 explains the wage rate paid by the firm sector. The explanatory variables include the lagged dependent variable, the current and lagged value of the price deflator of the total output of the firm sector *(PX)*, a time trend, and the labor constraint variable. This equation is meant to approximate the wage decisions of firms in the theoretical model. It can also be considered, at least in a loose sense, as reflecting the outcome of bargaining between the firm and household sectors over the real wage. In the theoretical model bargaining takes the form of the firm sector adjusting over time to changes in the labor supply curve facing it, the labor supply curve being determined each period by the household sector. If the equation is interpreted in this way, an important question is which price variable is relevant for the bargaining process. The choice here of *PX*, which excludes import prices and indirect business taxes, reflects the assumption that the household sector is aware that some price increases benefit the foreign and government sectors rather than the firm sector and considers only the prices that benefit the firm sector in its bargaining process with the firm sector.

The above conclusion about the inability to distinguish among alternative measures of labor market tightness for the price equation also holds for the wage equation. The measure that is used for the wage equation ($\log ZJ_t'$) is the same as the one used for the price equation, but the other 13 measures discussed above gave similar results. These results are:

	SE	t-statistic for the coefficient estimate of the measure		SE	t-statistic for the coefficient estimate of the measure
1.	0.006179	−1.14	8.	0.006173	1.18
2.	0.006176	−1.17	9.	0.006173	−1.21
3.	0.006175	−1.19	10.	0.006210	0.99
4.	0.006202	−1.12	11.	0.006200	−1.12
5.	0.006201	−0.99	12.	0.006193	1.13
6.	0.006192	−1.09	13.	0.006188	−1.17
7.	0.006189	−1.13	14.	0.006234	2.20

It is clear from these results that essentially the same fit has been achieved for each measure.

One other point about the price and wage equations should be noted, which is that a restriction has been imposed on the coefficients of the wage equation. This restriction is as follows. First, since PX_t and PF_t are approximately the same variable, for sake of the following analysis the latter can be substituted for the former in the wage equation. Therefore, write these two equations as follows:

9. $\log PF_t = \beta_1 \log PF_{t-1} + \beta_2 \log WFF_t + \ldots$

15. $\log WFF_t = \gamma_1 \log WFF_{t-1} + \gamma_2 \log PF_t + \gamma_3 \log PF_{t-1} + \ldots$

From these two equations the reduced form equation for the real wage (forgetting about the other endogenous variables in equations 9 and 15) is:

$$\text{(i)} \quad \log WFF_t - \log PF_t = \frac{1}{1-\beta_2\gamma_2}(\gamma_1 - \beta_2\gamma_1)\log WFF_{t-1} + \frac{1}{1-\beta_2\gamma_2}(\beta_1\gamma_2 + \gamma_3 - \beta_2\gamma_3 - \beta_1)\log PF_{t-1} + \ldots$$

Now, in order for the real wage not to be a function of the absolute size of the money wage and price level in the long run, it must be the case that the coefficient of log WFF_{t-1} in (i) be equal to the negative of the coefficient of log PF_{t-1}. This requires that:

$$\gamma_1 - \beta_2\gamma_1 + \beta_1\gamma_2 + \gamma_3 - \beta_2\gamma_3 - \beta_1 = 0,$$

or

$$\text{(ii)} \quad (\gamma_1 + \gamma_3)(1 - \beta_2) - \beta_1(1 - \gamma_2) = 0 \, .$$

Since it does not seem sensible for the real wage to be a function of the price level in the long run, the constraint in (ii) was imposed in the estimation work. This was done by (1) estimating the PF_t equation in the usual way by two stage least squares (TSLS), (2) using the resulting estimates of β_1 and β_2 to impose a linear restriction on the γ coefficients in the WFF_t equation, and (3) estimating the WFF_t equation by TSLS under this restriction. Given the β estimates, the linear restriction is merely:

$$\text{(iii)} \quad \gamma_2 = 1 - \frac{(1 - \hat{\beta}_2)}{\hat{\beta}_1}(\gamma_1 + \gamma_3) \, .$$

This restriction can be easily imposed within the context of the TSLS procedure.[11,12]

V. Some Properties of the Empirical Model

It should be fairly clear from the equations presented in the previous section that many factors affect inflation and unemployment in the model, and there is no particular reason to expect that the relationship between these two variables is stable. The price level is affected by the price level lagged one period, the price of imports, the wage rate, three cost-of-capital variables, and the labor constraint variable (when it is binding). The unemployment rate is residually determined as one minus the ratio of employment to the labor force. The labor force is affected by the wage rate, the price level, the marginal personal income tax rate and the social security tax rate, the net wealth of the household sector, nonlabor income, and the hours constraint variable (when it is binding). Employ-

[11] William Parke, a student at Yale, has recently developed a computationally feasible algorithm for obtaining full information maximum likelihood estimates (FIML) of large-scale models. In future work I plan to use this algorithm to obtain FIML estimates of my model, and when this is done, it will be possible to impose the restriction in (ii) directly on the coefficients (i.e., without resorting to the above two-step procedure). For the present results, the hypothesis that the restriction (iii) is valid in the wage equation was (using the conventional F test) rejected at the 5 percent confidence level, but accepted at the 1 percent level.

[12] Note that the decision sequence of the firm sector outlined on page 172 is not quite right for the price equation because the current wage rate is on the right-hand side of it. To be consistent with the sequence, the lagged wage rate should appear on the right-hand side of the price equation rather than the current wage rate, and in fact quite similar results were obtained using WFF_{t-1} in place of WFF_t in equation 9. The use of WFF_t rather than WFF_{t-1} in equation 9 should be interpreted as being dictated by the use of quarterly data (as opposed to data for a shorter interval) rather than as being derived from any theoretical proposition.

ment demand is affected by the amount of excess labor on hand and current and past levels of output. Finally, the number of people holding two jobs, which is needed to link employment in terms of jobs to employment in terms of people, is affected by the wage rate, the price level, the two tax rates, and the hours constraint variable (when it is binding). Given the large number of diverse factors that influence the price level, the labor force, and employment, it would clearly be surprising if the net result of all these factors were a stable relationship between inflation and unemployment.[13]

It is also interesting to note, although this is off the main topic of this paper, that there is no reason to expect the relationship between real output and the unemployment rate to be stable in the model. In other words, there is no reason to expect a stable Okun's law. The relationship between output and employment is affected, among other things, by the amount of excess labor on hand, and the large number of factors that affect the labor force have already been mentioned. Even though no stable Okun's law is expected in the model, the model does provide an explanation of the short-run leakages between changes in output and changes in the unemployment rate. When, say, output increases by 1 percent, the number of jobs increases by less than 1 percent in the current period (equation 12). Also, an increase in the number of jobs results in a less binding hours constraint, which in turn results in an increase in the labor force (equation 6) and, with a lag of one period, in the number of moonlighters (equation 7). Both an increase in the labor force and in the number of moonlighters causes the unemployment rate to fall less than it otherwise would in response to the increase in jobs.

An important characteristic of the model with respect to the relationship between inflation and unemployment or output is that when loss functions that target a given level of output and a given rate of inflation each period are minimized, the optima tend to correspond more closely to the output targets being achieved than they do to the inflation targets being achieved.[14] This is true even when the output target is weighted much less than the inflation target in the loss function. The model has the property that output can be increased by government policies to a high-activity level without having too much effect on the rate of inflation, whereas the rate of inflation cannot be decreased much without having a serious effect on output. As noted above, the only type of demand pressure variable in the price and wage equations is log ZJ_t', and the

[13] To drive home this point once more, note that government tax policy affects the relationship between inflation and unemployment through, among other things, its effect on the labor force. If, say, net taxes are increased by increasing the marginal personal income tax rate (d_3^M), this causes, other things being equal, a decrease in the labor force, whereas if net taxes are increased by decreasing transfer payments (which are included in the nonlabor income variable *YNLH*), this causes, other things being equal, an increase in the labor force (equation 5).

[14] The optimal control results cited in this paragraph are presented in [3], Chapter 10, and in [5].

estimated effects of this variable on the price level and wage rate only become large as the unemployment rate approaches 2.5 percent. In other words, the estimated demand effects on prices and wages are generally not large, and so high-activity output levels can be achieved for relatively modest increases in inflation. This property of the model is also true when the other measures of labor market tightness discussed in the previous section are used, although it obviously makes some difference to the optimal control results which nonlinear function of the unemployment rate is used. This basic result of small estimated demand effects on prices clearly has important policy implications if it is in fact an accurate characterization of the real world.

Another important property of the model is that the price of imports has a fairly large effect on the domestic price level. As can be seen from equation 9, an increase in *PIM* of, say, 1 percent has an impact effect on *PF* of 0.0702 percent and a long-run effect (ignoring all variables in the equation except the lagged dependent variable) of 0.327 percent. Prior to 1969 *PIM* grew very little, and so it contributed little to the domestic inflation rate. (For the 1952 I - 1968 IV period the annual average rate of growth of *PIM* was 0.05 percent.) For the 1969 I-1972 IV period, *PIM* grew at an average annual rate of 6.17 percent, and so it contributed somewhat more. The largest contribution of *PIM* to the domestic inflation rate, however, was during the 1973 I - 1974 IV period, when it grew at an average annual rate of 34.37 percent.

In order to see the contribution of *PIM* to the domestic inflation rate during the 1973–1975 period in the model, the following experiment was performed. A perfect tracking solution was first obtained by adding the estimated residuals to the stochastic equations. The model was then simulated for the 1973 I - 1975 IV period (using these same estimated residuals) under the assumption of a 6 percent annual rate of growth of *PIM*. The results of this simulation for selected variables are presented in Table 2. The results show that had *PIM* only grown at 6 percent, there would have been no double digit inflation in the United States. The GNP deflator, for example, would have risen at an annual rate of about 3 percent in 1974 rather than at the actual rate of about 11 percent. Also, real output growth would have been larger, and the unemployment rate would have been about 1.5 percentage points lower by the end of 1975. This experiment is useful in that it demonstrates, in addition to the large influence of *PIM* in the model, that there can at times be a positive relationship between inflation and unemployment.

The final property that will be discussed here is the effect of the Fed in the model. In the version of the model used for the *PIM* results in Table 2, the behavior of the Fed is endogenous. The Fed is assumed to choose each period an optimal value of the bill rate and then to achieve this value through changes in its policy variables. The equation explaining Fed behavior, which is presented and discussed in [4], has the bill rate on the left-hand side and variables that seemed likely to affect the Fed's optimal value of the bill rate on the right-hand side. The right-hand side variables include the lagged bill rate, the lagged rate of inflation, the current degree of labor market tightness (as measured by J_t^*), the current and lagged growth rate of real GNP, and the lagged growth rate of the

TABLE 2

The Estimated State of the Economy for 1973 I – 1975 IV

a) if import prices had grown at a 6 percent annual rate.
b) if the bill rate had been 5 percent.

	1973				*1974*				*1975*			
	I	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
%GNPD												
Actual	5.7	7.1	7.5	9.7	8.5	11.3	11.6	12.6	10.9	5.7	7.3	6.3
a)	5.2	4.9	4.7	5.2	1.5	2.3	2.5	4.4	3.9	1.5	4.4	2.4
b)	5.6	7.0	7.2	9.9	8.7	11.9	11.8	12.6	10.9	5.9	7.5	5.2
UR												
Actual	4.9	4.9	4.8	4.7	5.0	5.1	5.6	6.5	8.2	8.8	8.5	8.3
a)	4.9	4.9	4.8	4.7	5.0	5.0	5.3	6.1	7.4	7.7	7.1	6.8
b)	4.9	4.8	4.5	4.1	4.1	3.9	4.0	4.7	6.2	6.9	6.6	6.4
%GNPR												
Actual	9.6	0.4	1.8	2.0	–4.0	–1.8	–2.5	–5.5	–9.6	6.4	11.4	3.0
a)	9.7	0.5	2.0	2.6	–3.0	–0.2	–0.3	–2.6	–5.2	11.8	15.1	4.2
b)	9.9	1.3	3.6	4.5	–2.8	–0.0	–0.5	–3.4	–7.4	7.9	12.4	3.3
%WFF												
Actual	11.5	6.5	9.8	9.3	3.3	8.9	8.5	13.0	11.6	7.2	7.5	5.8
a)	11.2	5.4	8.2	6.8	–0.5	3.7	3.0	7.5	6.6	3.6	4.6	3.7
b)	11.4	6.5	9.8	9.7	3.7	9.4	9.0	13.3	11.6	7.1	7.3	5.7
RBILL												
Actual	5.6	6.6	8.4	7.5	7.6	8.3	8.3	7.3	5.9	5.4	6.3	5.7
a)	5.6	6.6	8.2	7.1	7.1	7.4	7.1	6.1	4.9	5.1	6.7	6.4
b)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
%PIM												
Actual	13.8	33.3	21.9	41.9	63.7	62.8	33.8	13.6	8.5	–5.2	0.1	–4.7
a)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
b)	13.8	33.3	21.9	41.9	63.7	62.8	33.8	13.6	8.5	–5.2	0.1	–4.7

Notes: *%GNPD* = percentage change in the GNP deflator (annual rate).
UR = civilian unemployment rate.
%GNPR = percentage change in real GNP (annual rate).
%WFF = percentage change in the wage rate (annual rate).
RBILL = three-month Treasury bill rate.
%PIM = percentage change in the price of imports (annual rate). *PIM* is an exogenous variable.

money supply. The behavior that is reflected in this equation is behavior in which the Fed "leans against the wind." As the economy expands or as inflation increases, the Fed is estimated to cause the bill rate to rise. From the *PIM* results in Table 2 it can be seen that the model predicts that the bill rate would have been smaller at the beginning of the 1973–1975 period and larger at the end had *PIM* grown at 6 percent rather than at its actual rate. In other words, the net effect on Fed behavior of the lower inflation and higher real growth that resulted from the lower *PIM* growth was, according to the model, for the Fed to target lower bill rates at the beginning of the period and higher bill rates at the end.

In order to examine the effects of the relatively high interest rate policy of the Fed during the 1973–1975 period, the model was simulated for this period (using the same estimated residuals as above) under the assumption that the Fed instead kept the bill rate at 5 percent throughout the period. (In other words, the equation explaining Fed behavior was dropped from the model, and the bill rate was taken to be exogenous.) The actual values of *PIM* were used for this simulation. The results for selected variables are also presented in Table 2. They show that the unemployment rate by the end of the period would have been 1.9 percentage points lower than it actually was had the Fed kept the bill rate at 5 percent. Inflation, on the other hand, would have been little changed. This is a good illustration of the above mentioned property of the model that demand variables have little effect on inflation in periods in which the unemployment rate is relatively high. It is also the case with respect to the effects of Fed behavior on inflation that higher interest rates lead, other things being equal, to higher rates of inflation because of the cost-of-capital effects on the price level. The bond rate *(RAAA)* has a positive effect on *PF* in equation 9, and the Fed has an effect on the bond rate through its effect on short-term rates. The rates of inflation in the 5 percent bill rate case in Table 2 are thus somewhat lower than they otherwise would be because of the cost-of-capital effects on inflation.

VI. An Estimate of the Accuracy of the Model

The standard procedure that is followed in examining the predictive accuracy of econometric models is to compute root mean squared errors (RMSEs) of their *ex post* forecasts. Although this is a common practice, there are a number of problems associated with it. First, it is well known that the true variances of forecast errors are not constant across time, and so RMSEs are not estimates of true variances. RMSEs are in some loose sense estimates of the averages of the variances across time, but no rigorous statistical interpretation can be placed on them. Second, as noted in the Introduction, models differ in the number and types of variables that are taken to be exogenous, and so it is difficult to compare RMSEs, which are generally based on the use of actual exogenous variable values, across models. Finally, if RMSEs are based on within-sample forecasts, as is often the case, there is the obvious danger that the accuracy of the model has been overestimated because of data mining.

In a recent study [6] I have proposed a method for estimating the uncertainty of a forecast from an econometric model. This 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-variable forecasts, and (4) the possible misspecification of the model. It also accounts for the fact that the variances of forecast errors are not constant across time. Because the method accounts for all four sources of uncertainty, it is possible to use it to make comparisons of predictive accuracy across models.

I have applied this method to a recent forecast from my model, and the results of this exercise for five selected variables are presented in Table 3. For comparison purposes I have also applied the method to a forecast from an eight-order autoregressive model, and these results are also presented in Table 3. The autoregressive model is one in which each variable is regressed on a constant, a time trend, and its first eight lagged values.

Space limitations prevent a detailed discussion of the method here. Estimating the uncertainty from the error terms and coefficient estimates is a straightforward exercise in stochastic simulation, given estimates of the relevant variance-covariance matrices. The uncertainty from the exogenous-variable forecasts can also be estimated by means of stochastic simulation, although this requires that one first estimate the uncertainty of the exogenous-variable forecasts themselves. The procedure that was followed for the present results was to regress each exogenous variable in the model on a constant, a time trend, and its first eight lagged values, and then to take the estimated standard error from this regression as the estimate of the uncertainty attached to forecasting the change in this variable for each quarter. Estimating the uncertainty from the possible misspecification of the model is the most difficult and costly part of the method, and it also rests on one strong assumption. This part of the method 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 forecast errors. The strong assumption is that the model is misspecified in such a way that for each variable and length of forecast, the expected value of the difference between the two estimates of the variance is constant across time. Given this assumption, it is possible to estimate the total variance of the forecast error for each variable and length of forecast. The square roots of these estimated variances are printed in the *d* rows in Table 3. These results are based on 35 sets of estimates of each model.[15]

Comparing the results in the *d* rows in Table 3, it can be seen that my model is more accurate than the autoregressive model for the GNP deflator, the unemployment rate, real GNP, and the bill rate. It is less accurate for the wage rate. With respect to the GNP deflator, the estimated standard error of the eight-quarter-ahead forecast is 3.48 percent for my model and 6.20 percent for the autoregressive model. With respect to the wage rate, the estimated standard

[15] All sample periods for my model began in 1954 I, and all sample periods for the autoregressive model began in 1954 II. For the first set of estimates of each model the sample period ended in 1968 IV; for the second set the sample period ended in 1969 I; and so on through 1977 II. For the results in Table 3 except the d-row results, and for all the results in the previous sections, the sample period ended in 1977 IV.

TABLE 3

Estimated Standard Errors of Forecasts for Five Variables

a = uncertainty due to error terms.
b = uncertainty due to error terms and coefficient estimates.
c = uncertainty due to error terms, coefficient estimates, and exogenous-variable forecasts.
d = uncertainty due to error terms, coefficient estimates, exogenous-variable forecasts, and possible misspecification of the model.

Forecast Period = 1978II–1981IV.

Model I = model in [7].
Model II = autoregressive model. For the autoregressive model there are no exogenous variables, so $c = b$ for this model.

For the unemployment rate and the bill rate, the errors are in the natural units of the variables. For the other variables, the errors are expressed as percentages of the forecast means (in percentage points).

	1978			*1979*				*1980*				*1981*			
	II	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
Model I. GNP Deflator															
a	0.28	0.35	0.42	0.47	0.51	0.55	0.59	0.61	0.64	0.65	0.65	0.65	0.66	0.67	0.68
b	0.31	0.47	0.58	0.71	0.83	0.93	1.02	1.10	1.19	1.28	1.37	1.44	1.50	1.57	1.63
c	0.44	0.67	0.84	1.04	1.21	1.36	1.49	1.62	1.75	1.88	1.98	2.09	2.23	2.35	2.43
d	0.53	0.93	1.37	1.87	2.33	2.74	3.15	3.48							
Model II. GNP Deflator															
a	0.20	0.36	0.53	0.71	0.90	1.08	1.24	1.37	1.49	1.58	1.65	1.71	1.76	1.80	1.83
b, c	0.24	0.45	0.70	1.00	1.36	1.73	2.10	2.48	2.84	3.18	3.52	3.85	4.17	4.48	4.80
d	0.45	0.94	1.53	2.25	3.12	4.05	5.10	6.20							

TABLE 3, continued

	1978			1979				1980				1981			
	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Model I. Unemployment Rate (units of percentage points)															
a	0.27	0.45	0.57	0.64	0.71	0.77	0.80	0.82	0.82	0.85	0.90	0.92	0.93	0.96	0.97
b	0.36	0.58	0.76	0.92	1.03	1.12	1.16	1.23	1.28	1.34	1.38	1.42	1.50	1.56	1.62
c	0.36	0.60	0.80	0.95	1.08	1.17	1.24	1.31	1.35	1.41	1.47	1.50	1.55	1.59	1.64
d	0.35	0.60	0.77	0.82	0.85	0.83	0.77	0.71							
Model II. Unemployment Rate (units of percentage points)															
a	0.28	0.55	0.77	0.94	1.02	1.08	1.12	1.14	1.15	1.16	1.16	1.16	1.15	1.15	1.16
b, c	0.29	0.58	0.84	1.04	1.17	1.27	1.34	1.40	1.44	1.48	1.52	1.55	1.59	1.63	1.66
d	0.36	0.74	1.12	1.48	1.73	1.91	2.07	2.19							
Model I. Real GNP															
a	0.65	0.88	1.03	1.15	1.25	1.30	1.35	1.34	1.36	1.40	1.43	1.44	1.47	1.46	1.43
b	0.67	0.95	1.19	1.38	1.49	1.59	1.66	1.69	1.77	1.81	1.82	1.84	1.88	1.88	1.94
c	0.74	1.09	1.37	1.63	1.76	1.94	2.04	2.08	2.15	2.18	2.22	2.30	2.34	2.36	2.43
d	0.80	1.23	1.54	1.96	2.27	2.51	2.48	2.27							
Model II. Real GNP															
a	0.61	1.02	1.34	1.64	1.84	1.94	2.01	2.03	2.04	2.03	2.04	2.04	2.03	2.03	2.03
b, c	0.67	1.13	1.53	1.90	2.20	2.38	2.50	2.59	2.64	2.68	2.73	2.77	2.81	2.84	2.87
d	1.09	1.93	2.72	3.45	4.01	4.32	4.58	4.74							
Model I. Wage Rate															
a	0.60	0.77	0.88	0.89	0.96	1.01	1.03	1.05	1.07	1.10	1.08	1.07	1.08	1.04	1.05
b	0.70	0.93	1.12	1.34	1.52	1.65	1.76	1.82	1.94	2.04	2.15	2.27	2.35	2.45	2.51
c	0.67	0.95	1.16	1.35	1.53	1.66	1.80	1.94	2.08	2.20	2.32	2.40	2.52	2.61	2.69
d	0.65	1.06	1.45	2.01	2.53	3.07	3.59	4.16							

TABLE 3, continued

	1978			1979				1980				1981			
	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Model II. Wage Rate															
a	0.30	0.40	0.48	0.53	0.59	0.61	0.67	0.72	0.76	0.81	0.85	0.88	0.91	0.94	0.98
b, c	0.36	0.48	0.59	0.75	0.86	0.97	1.15	1.29	1.46	1.64	1.81	1.99	2.19	2.39	2.59
d	0.63	0.84	1.04	1.26	1.41	1.56	1.81	2.04							
Model I. Bill Rate (units of percentage points)															
a	0.45	0.67	0.78	0.84	0.91	0.93	0.97	0.98	0.97	0.98	0.98	0.97	0.97	1.01	1.03
b	0.48	0.71	0.86	1.01	1.08	1.14	1.21	1.25	1.28	1.32	1.32	1.35	1.37	1.37	1.42
c	0.49	0.72	0.92	1.06	1.16	1.25	1.31	1.37	1.44	1.51	1.53	1.54	1.56	1.58	1.61
d	0.61	0.96	1.08	1.17	1.31	1.47	1.56	1.76							
Model II. Bill Rate (units of percentage points)															
a	0.46	0.72	0.80	0.85	0.90	0.93	0.94	0.94	0.94	0.94	0.96	0.99	1.02	1.03	1.04
b, c	0.47	0.77	0.93	1.05	1.14	1.20	1.22	1.19	1.16	1.14	1.11	1.14	1.15	1.16	1.18
d	0.69	1.12	1.33	1.51	1.63	1.71	1.77	1.83							

Note: *d* row estimates are available only for the first eight quarters.

error of the eight-quarter-ahead forecast is 4.16 percent for my model and 2.04 percent for the autoregressive model. For the unemployment rate the estimated standard error of the eight-quarter-ahead forecast is 0.71 percentage points for my model and 2.19 percentage points for the autoregressive model.

The estimates in Table 3 do not show how the models performed in any particular period, and this is sometimes useful information. The 1973–1975 period is one of the most difficult to forecast, and so it is of some interest to see how the models performed during this period. There is, of course, a serious problem with examining the performance of a model for any given period, which is that some assumption must first be made about the exogenous-variable values. For present purposes, I have used actual values of the exogenous variables to examine the performance of my model during the period, and this should be kept in mind in the following discussion. The model is not as accurate as the following results reveal in that the uncertainty from the exogenous variables has been ignored. The results are presented in Table 4 for five selected variables. Results for the autoregressive model, which has no exogenous variables except the time trend, are also presented in Table 4.[16]

Consider the results for my model first. With respect to the GNP deflator, the model forecast the double digit inflation quite well, although the rate of inflation is somewhat overestimated for the outside-sample results. The price of imports is, of course, the key exogenous variable that is affecting the predictions of inflation during this period. The rate of wage inflation is considerably overestimated for the outside-sample results. The coefficient estimates of the wage equation changed considerably from the sample periods that ended in 1973 IV or before to the sample periods that ended in 1974 III or after, and this is in fact the primary cause of the large d-row estimates for the wage rate in Table 3. For the more recent sample periods the coefficient estimate of the lagged dependent variable in the equation is larger. This difference reflects itself in Table 4 in larger outside-sample than within-sample predictions of the wage rate. With respect to the unemployment rate, the outside-sample predictions are more accurate than the within-sample predictions because (speaking loosely) of the larger inflation-rate predictions, and this reflects itself in Table 4 in more accurate predictions of real GNP and the unemployment rate. With respect to the bill rate, the outside-sample predictions are much lower than the within-sample predictions by the end of the period. The Fed was estimated to respond less to the inflation rate for the sample period that ended in 1972 IV than it was for the sample period that ended in 1977 IV, and this is the main reason for the different bill rate predictions in Table 4.

[16] The predicted values in Table 4 are computed from deterministic simulations (i.e., by setting the error terms equal to zero and solving once) rather than from stochastic simulations. As can be seen from Table 3 in [6], the predicted values computed from deterministic simulations are quite close to the mean values from the stochastic simulations for the two models. This result has also been obtained by a number of others for different models. There thus seems to be little harm in the present case in using deterministic simulations for the results in Table 4.

TABLE 4

Predicted Values for 1973 I – 1975 IV
(Dynamic Simulation for Each Model Beginning in 1973 I)

Model I = model in [7]
Model II = autoregressive model.
OS = outside sample. (Sample period for the coefficient estimates ended in 1972 IV.)
WS = within sample. (Sample period for the coefficient estimates ended in 1977 IV.)

	1973				*1974*				*1975*			
	I	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
%GNPD												
Actual	5.7	7.1	7.5	9.7	8.5	11.3	11.6	12.6	10.9	5.7	7.3	6.3
Model I:												
OS	7.4	9.7	9.5	9.7	11.0	11.4	13.3	12.4	11.1	10.5	9.5	8.2
WS	6.3	8.5	8.2	8.6	9.7	10.4	11.6	10.8	9.8	9.5	8.6	5.9
Model II												
OS	3.5	3.2	3.7	3.1	2.9	3.1	2.8	2.6	2.6	2.4	2.2	2.2
WS	4.6	5.0	5.6	5.9	6.3	6.5	6.7	6.8	6.8	6.8	6.7	6.7
UR												
Actual	4.9	4.9	4.8	4.7	5.0	5.1	5.6	6.5	8.2	8.8	8.5	8.3
Model I:												
OS	4.9	4.7	4.9	5.2	5.8	6.4	6.9	7.5	8.0	8.4	8.3	8.2
WS	4.9	4.6	4.6	4.7	4.9	5.1	5.3	5.6	5.9	6.2	6.3	6.2
Model *II:*												
OS	5.2	5.1	5.0	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1
WS	5.2	5.2	5.3	5.5	5.6	5.7	5.8	5.9	5.9	6.0	6.0	6.1
%GNPR												
Actual	9.6	0.4	1.8	2.0	−4.0	−1.8	−2.5	−5.5	−9.6	6.4	11.4	3.0
Model I:												
OS	7.0	3.4	2.5	0.7	−2.0	−0.2	−2.4	−2.7	−2.9	−2.6	5.0	3.4
WS	6.9	3.6	3.0	1.7	0.0	2.0	−0.1	−0.1	−0.3	−0.3	6.1	3.8
Model II:												
OS	4.5	2.9	2.2	2.5	2.2	2.6	3.3	3.1	3.0	2.8	2.7	2.5
WS	4.7	2.2	1.6	1.6	0.7	1.1	2.0	2.0	1.9	2.2	2.2	2.0
%WFF												
Actual	11.5	6.5	9.8	9.3	3.3	8.9	8.5	13.0	11.6	7.2	7.5	5.8
Model I:												
OS	10.3	11.9	12.1	11.4	12.8	12.2	15.1	14.4	13.0	12.2	11.8	10.4
WS	6.8	8.3	8.7	8.6	9.6	9.4	11.4	10.8	10.0	9.5	9.2	8.3
Model II:												
OS	5.5	6.9	5.8	6.3	5.9	6.5	6.3	6.3	6.2	6.2	6.2	6.3
WS	7.2	6.5	8.4	6.9	6.5	8.1	7.4	7.5	8.1	7.6	7.6	8.1
RBILL												
Actual	5.6	6.6	8.4	7.5	7.6	8.3	8.3	7.3	5.9	5.4	6.3	5.7
Model I:												
OS	5.5	5.7	5.9	5.8	5.6	5.2	4.8	4.2	3.6	3.0	2.8	2.7
WS	5.7	6.0	6.4	6.6	6.8	7.0	7.2	7.2	7.1	6.8	6.9	7.0
Model II:												
OS	5.5	5.9	6.2	6.5	6.8	6.8	6.8	6.7	6.6	6.5	6.4	6.3
WS	5.2	5.8	6.3	6.7	6.9	7.0	7.0	6.9	6.7	6.5	6.3	6.2

Notes: See notes to Table 2.

The predictions from the autoregressive model are about as expected in Table 4. They show less variability across time than do the predictions from my model. The autoregressive model considerably underpredicts the rate of change of the GNP deflator throughout the period. It also tends to underpredict the rate of change of the wage rate, although on average the model is more accurate with respect to the wage rate than it is with respect to the GNP deflator. The error in predicting the unemployment rate by the end of the period is 3.2 percentage points for the outside-sample results and 2.2 percentage points for the within sample results.

VII. Summary and Conclusion

I have reviewed in this paper that part of my recent theoretical and empirical work that relates to the explanation of inflation and unemployment. The discussion in Section II is meant to provide a general idea of the theoretical framework upon which the empirical work is based. The determinants of labor supply are those factors that affect the solutions of the multiperiod optimization problems of households, including expectations of future values and possible loan and hours constraints. The determinants of prices, wages, and labor demand are those factors that affect the solutions of the multiperiod optimization problems of firms, including expectations of future values and possible loan and labor constraints. Disequilibrium can arise in the system because of expectation errors. Because of the many factors that affect the decisions of households and firms, it has been argued in this paper that there is no particular reason to expect the relationship between inflation and unemployment to be stable over time.

The main conclusions from the empirical work are the following:

1. The aggregate data do not appear to be able to distinguish among alternative measures of labor market tightness as the measure to include in price and wage equations. Essentially the same fits of the price and wage equations were obtained using 1) the standard unemployment rate, 2) the unemployment rate for married men, 3) Perry's weighted unemployment rate, 4) a detrended employment-population ratio, and 5) various nonlinear functions of these variables. Therefore, any policy conclusions that are sensitive to a particular measure used in a price or wage equation do not appear to be supported by the aggregate data.
2. Irrespective of which measure is used, the effect of labor-market conditions on prices and wages is fairly small except when the labor market is very tight. Because of this, optimal control experiments with the model tend to result in more closely met output than inflation targets.
3. The estimated effect of import prices on domestic prices is fairly large, and the large increase in import prices in the 1973-1975 period is, according to the model, the cause of the double digit domestic inflation rates during this period.

4. The cost of capital is estimated to have an effect on the price level. This means that Fed behavior that results in higher interest rates is, other things being equal, inflationary.

The estimates of the model's accuracy that are presented in Table 3 should help one in deciding how much confidence to place on future forecasts from the model. I am, of course, somewhat embarrased that my model is less accurate than the autoregressive model for the wage rate forecasts, and all that I can say is that I hope to do better in the future. In general, however, I would say that the results in Table 3 show that my model is considerably more accurate than the autoregressive model, although I leave it to the reader to judge whether the absolute sizes of the errors for my model are small or large. The results in Table 3 can also be used as a basis of comparison for other models. Were other model builders to carry out the calculations that are necessary for results like those in the table, this would be a useful way of comparing the accuracy of alternative models. I hope in the future that this can be done and that there is a gradual weeding out of alternative explanations of inflation and unemployment until only the one best explanation remains. Then a conference like this can be devoted to complete fun and frolic on the island without any need to spend the morning listening to yet another paper on inflation and unemployment.

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Discussion

Franco Modigliani

I have been following all the speakers and discussants as though I were following a match. Whoever was speaking was right, and the next one was right too. So, now I must reconcile all these ideas.

Of course, I don't really mean everyone was right. I still have a lot of very deep reservations about the so-called equilibrium theories – particularly the emphasis on a supposed crisis of Keynesian economics and of econometric models which would have become altogether useless.

I trust that in the final version of their paper Lucas and Sargent will choose to stress that their analysis of rational expectations is not to be seen as a radical break with a hopelessly mistaken past but merely as a useful, or at least logically stimulating, contribution to an area which has long been recognized as deficient and open to the criticism of "ad hockery" – namely that of modeling expectations. It is true that there is one extreme version of rational expectation – which I have earlier labeled Macro Rational Expectations – which would largely do away with all macroeconometric models, at least for purposes of demand management. But this is an extreme formulation which rests not so much on superrational expectations as on a host of other assumptions such as competitive markets, fluid prices, including no long-term contracts, and the like.

This portion of the equilibrium theorist contribution is, in my view, of notable theoretical or logical interest and deserves high recognition but its empirical relevance is close to zero. Personally I am convinced that an empirically relevant modeling of expectations must rely on what I call the theory of nonirrational expectations. Of course, it includes rational expectations at one extreme and mechanical formulas at the other because the essence of nonirrational expectations is that they are not obviously silly, taking into account the knowledge of the time and the cost and bother of refined forecasting. One aspect of being silly is that somebody could exploit you if you held those expectations. One reason why I don't think that rational expectations play a very important role in the labor market is precisely that I do not see any easy way by which anybody can arbitrage. I can see it in the stock market, in the bond market, in the foreign exchange markets, and to some extent in the very well-organized, very highly competitive markets. As you move from these toward markets which, for a variety of reasons, are less and less close to the perfectly competitive paradigm and involve more and more features of oligopoly

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and bilateral monopoly and so forth, the more difficult it becomes both to see the relevance of very refined expectations and to show some obvious loss involved by the people who fail to hold those expectations. In particular, to assume that, empirically, people in the labor market know what price level is consistent with full employment, given announced monetary policy, are able to decide what individual wages go with those prices and then to enforce those wages promptly, just seems to be so clearly inconsistent with what we know about the process of bargaining in the labor market that nothing but errors can arise from postulating the empirical relevance of that kind of model, even as a very first approximation.

All this is relevant to the specific problem of commenting on Fair's paper because it explains a dilemma that paper poses for me. I feel his paper does show that there really wasn't any crisis of either Keynesian economics or macroeconometric models. Of course for Keynesian economics there can't be any crisis because we are talking about the implications of a pretty universal phenomenon – lack of perfect instantaneous price flexibility. One can argue how important certain lags are but on the principles there can be no "crisis." And Fair certainly has shown that there is no crisis of models, given the quality of his results. It is quite clear that the model he presents, fitted through '72 for instance, does do a remarkably good job of explaining what happened in the three very disturbed years following that period and does a great deal better than any mechanical extrapolation could have done.

To a large extent the sweeping indictment of the Lucas and Sargent paper confuses two kinds of crises. One is the crisis of whether these models have captured the world itself. The second crisis which I believe is the real problem is that the world we capture is extremely hard to tame, to cure from inflationary shocks, the new disease of '73-74 and thereafter. So the crisis is right there in the structure of the world, not in our ability to capture that structure. I think the Fair model provides strong evidence in this direction.

However, when I look in detail at the way his equations, particularly the price-wage equation, are structured, I find a number of fairly serious objections, some perhaps more logical than empirical – so that to some extent I am a little surprised though pleased that it did as well as it did. Maybe it shows – though I hate to admit it – that somebody with a different model can do as well as I, or even better!

Let me, therefore, start out with a brief criticism of those portions of the model which he reports in his paper – the labor supply equations and the price/wage sector. He has explained how conceptually he relies on the notion of constrained maximization, where economic agents are constrained either in the quantity they sell or the quantity they buy, and how he tries to take into account these constraints. I think it is an elegant formulation although it appears to result in practice in specifications similar to those of other models. For instance, for his labor supply equation it results in the participation rate being reduced when there is a slack as measured by his J variable. This specification is clearly similar to that used by other models, sometimes under the name of the "discouraged worker" effect. Let me mention also here a number of detailed objections to the labor supply equations which are of some importance because they reappear later. For instance in the participation equation for the prime group two variables appear, one of which is wealth per capita. The idea of introducing wealth is an interesting one but it seems to me it should be the wealth-income ratio rather than wealth per capita, which is fundamentally a trend.

Similarly, he has the mortgage rate and here as elsewhere all rates are nominal. It seems questionable whether the *nominal* mortgage rate should appear. Furthermore, its quantitative importance is doubtful because it only affects new buyers in the housing market, not people who already have mortgages. For this same reason I think its importance in the cost of living index is greatly exaggerated. In any event this variable is so insignificant in this equation that one can forget it.

I have a suggestion for his "moonlighting" equation. This subject has concerned me a great deal recently because of my interest in Italy, an economy that seems to rest on moonlighting. It has been estimated that something like 25 percent of the jobs in Italy are second jobs or somehow jobs outside of the regular market where workers and employers don't pay taxes, don't pay social security, etc. In Italy moonlighting is spectacular and in many other parts of Europe it is important but I think it is a universal phenomenon and my suspicion is that one important variable here is the number of hours worked per week. As unions and other forces have reduced the number of regular weekly hours, people who want to work more than the regular hours, end up working several shifts. So I hope Fair can test the effect of the number of average weekly hours including its cyclical aspects. I suspect that if the hours you work in your main job are curtailed for whatever reason, then you are more likely to take a second job.

Let me come to the price/wage sector which is by far the most important for our purposes. Here I was disturbed by the layout from the very beginning because it runs pretty much against my fundamental view of the wage price mechanism, a view which I am not prepared to abandon lightly. I am referring to the notion that the wage equation, the wage bargaining sector, is the one in which *money* wages are set, whereas *real* wages are set in the business sector where prices are set. In other words, we'll bargain about the wage. But once I know the wage I set the price and that gives the real wage. That is fundamental in our system. Wages are not continuously set but prices are, so that fundamentally the real wage is something which is set in the business sector. This should be described by a price equation that sets prices for given wages (and other variables affecting cost and possibly demand). The wage equation might involve a number of variables but should not involve *current* prices, at least for a short enough time period.

In the light of these considerations equation 9 in no way fits my model of price determination for given costs for two fundamental reasons. One is that, if it sets prices for given wages, then it must take into account unit labor costs, therefore productivity, at least through a time trend. As far as I know, other price equations typically include a measure of productivity or a time trend. The

MIT–PENN–SSRC happens to use both. This equation has neither. That's the first reason why it disturbs me. The second is the fact that the coefficient of wage is extremely small. Of course, to determine the long-run properties one must allow for the lagged dependent variable. But if one does that, one still finds that the wage coefficient is well below one-half. That just doesn't square for an equation which is an aggregate value-added equation in the economy and so doesn't include material costs.

The foreign import price coefficient is very big but I am willing to agree with that on the ground that foreign prices do enter here not just as costs but also as foreign competition which may affect markups. This experience is confirmed in very open countries like Italy where the indirect effect from competing import prices is much larger than the direct cost effect. The other disturbing feature is that the sum of the coefficient is less than one, although in this equation the departure is not so striking. In other words the equation is not homogeneous of the degree one, which means that in the long run, if wages and foreign prices rise, prices will not rise at the same rate.

But this problem gets much more serious in the wage equation. If the wage equation sets money wages, then no time trend is needed and productivity is not important. Some formulations which I think are quite acceptable suggest a role for productivity, e.g., the hypothesis that money wages adjust gradually to the difference between real wages and productivity. So one might include productivity, although I found in our own work that for the United States one could do as well without it. But in Fair's formulation the time trend appears only in the wage equation. Since the wage equation has current wages and current prices, there is a terrible identification problem. As far as I know, the wage equation really is the price equation, in which prices depend on current wages and time trend and the demand pressure variable. If you look at the MIT–PENN–SSRC equation, that is fundamentally the way the price equation looks.

My next qualm is that wage equations have usually been designed to explain not the level of wages but the change of wages, which is seen as a response to demand pressures and the like. Fair's equation instead "explains" the level. Of course, if on the right-hand side you had the level lagged or a series of lag terms adding up to one, then one would always be able to interpret it as a wage-change equation. But again this is not the case here – the lagged variables do not add up to one.

To be sure because the wage and price equations form a simultaneous system, to understand fully the behavior of wages and prices implied by his model one must solve the equations simultaneously and look at the reduced forms. When I did this, and assuming that I had the better of a somewhat messy algebra, I find that in the last analysis demand pressure determines the *change* and not the *level* of prices or wages, as it should. But I also found two less agreeable surprises. The first is that Fair's model implies a nonvertical long-run Phillips curve – a stable long-run tradeoff between inflation and unemployment or whatever is used for his J variable. I personally am not terribly upset by a nonvertical Phillips curve, and indeed am inclined to the view that this is a good approximation at least for excess unemployment. However, his is nonvertical throughout and the departure from verticality is appreciable. The second surprise is that the rate of change of wages depends on the time trend. That doesn't make much sense, because it implies that inflation will grow in time no matter what the demand pressure might be. In summary, the wage equation seems to me particularly unsatisfactory, and so I was not too unhappy that the one equation to which I objected most is the one that repeatedly does least well.

Turning to a couple of other matters relating to the wage price model, Fair questions why the Phillips curve should be stable, given all the variables that appear in it. But the issue of stability depends on its meaning. In the course of a private exchange with Sargent and Lucas we concluded that what they really meant by a "stable" Phillips curve is the existence of a long-run tradeoff between employment (or unemployment) and inflation. The instability to which Fair seems to refer on the other hand is that of the short-run relation between inflation and unemployment. Obviously as soon as you have lagged prices, the Phillips curve understood in this sense is not going to be stable. But as we have just seen, Fair's Phillips curve is indeed "stable" in the Lucas and Sargent sense (though its behavior might be affected by a few minor exogenous variables).

Next a few words about the effect of interest rates on prices in Fair's model – a feature which he regards as important and novel. My first comment here is that this effect, properly understood, is quite classical and follows from well-behaved production functions and competitive behavior. Specifically, a rise in the *real* interest rate must increase prices relative to wages – i.e., reduce the real wage (technology constant). But clearly what must be relevant is the real rate. Yet Fair uses the nominal rate. Thus his model has the most questionable implication that a higher rate of inflation by resulting in higher *nominal* rates reduces real wages – an implication which incidentally is clearly rejected for the United States by an analysis of the relation between inflation and income shares. Finally, to acknowledge that a rise in interest rates will raise prices relative to wages does not justify saying that it will raise prices; that depends on many things and, in particular, on monetary policy.

One last comment relates to Fair's remarks that the effect of demand pressure on inflation is so highly nonlinear. I think he should be very careful here because his J variable is by construction a complicated highly nonlinear function of U. But as he shows himself, he would get just about the same result if he used log U, which is not so nonlinear and I would suggest that, if he tried just plain U, as I have, he might be surprised to find that it does not make much difference either. So we really do not know at this time whether these effects are highly nonlinear. I have desperately looked for clear evidence of nonlinear effects in which I firmly believe but with little success so far. Yet the curvature of the Phillips curve is a very important characteristic for the choice of anti-stagflation demand policies.[1]

Now turning to the forecasting results, I was really quite pleased with what I saw. It seems to me that the first set of results from the simulation in Table 2 is

[1] Cf. F. Modigliani and L. Papademos, "Optimal Demand Policies Against Stagflation," *Weltwirtschaftliches Archiv,* forthcoming in the December issue, 1978.

quite interesting and quite credible. I do believe firmly that what happened in the period '73–'75 was a result of two combined effects – a carry-over of excess demand including the over-expansion of '72 and perhaps early '73; and the great oil problem of '74 which, per se, plays a very large role. Therefore I certainly am inclined to agree with the result that with no oil problem the picture would have been a great deal different even though I find his simulations a little too optimistic in the sense that prices come down rather fast, perhaps faster than I would have expected. The general picture does seem too square, however.

These results, incidentally, also square well with a very elementary reduced-form equation of the wage price sector which Papademos and I have fitted and reported in the Brookings Paper and which explains inflation in terms of unemployment, food prices, and import prices. That equation, which we fitted through 1971, explains quite well what happened in 1974 and 1975, largely in terms of the role of the exogenous prices.

Among the contributions of Fair's paper one of the most valuable in my view is that of the decomposition of the errors of models carried out in Table 3. In the past people had gone as far as looking at the effect of errors of a single equation, and then to their joint effect, by stochastic simulations relying on the joint distribution of such errors. But Fair goes on to an exercise which everybody agreed needed doing, but has actually seldom been done – namely, to examine the effect of errors of the coefficients. And finally he goes on to an important and novel step, that of trying to estimate the effect of possible misspecification of the equation. Essentially he asks how does the equation perform out of the sample as compared with its in-sample errors, because if the equation is misspecified – in particular in order to fit the historical data (data mining) – then as soon as you go out of sample you should do poorly. So his decomposition is a very interesting and valuable one and the results of his Table 3. shed interesting light on the results of various other tables. What is particularly interesting is that simple autoregressive schemes can do quite well in forecasting one period ahead but over longer horizons the forecasts quickly deteriorate because their coefficients seem to be extremely unstable – which is precisely what one would expect of reduced forms. The difference in this respect between structural and autoregressive "reduced" forms is quite striking, except in the case of wages.

Let me finally come to Table 4. It is the most relevant one to judge whether models fitted to earlier periods failed to account for what happened during the great inflation of '74 and the great contraction of '75. I think the results in this table are really quite encouraging. When extrapolated out of sample using the true exogenous variables to 72:4 this model does remarkably well in every respect. The only really surprising feature of Table 4 is that, on the whole, the outside-sample forecast does better than the within-sample forecast. I am at a loss for an explanation, unless it is plain chance.

I would like to raise here an issue that is relevant to the tests of Table 4 and also to McNees' tests. The point has been made that, in comparing an out-of-sample forecast with an out-of-sample extrapolation of a time series model, the procedure of relying on the actual value of the exogenous variables, as is normally done, may load the test in favor of the econometric model. To even things up the exogenous variable used in the model's extrapolation should also be forecast by some mechanical formula. In my view, however, it would be appropriate and highly desirable to have an intermediate step which examines the accuracy of the model conditional on the actual value of the policy variables – with the remaining noncontrolled variables still projected by whatever means. This test is appropriate since the models hypothesize that the policy variables do affect the economy in the manner specified by the model. Indeed, this particular test of accuracy is clearly the one that is relevant to establish the reliability of the model for policy purposes. Furthermore, anyone who does not believe that policy variables affect the economy cannot object that this procedure biases the test. So I hope that some such tests will be worked out in the near future.

Let me conclude by stressing that, though I have chosen to emphasize points of difference, I find Fair's paper a very interesting one and that the areas of agreement far overshadow those of differences. This assessment is confirmed by the choice of points which Fair chooses to emphasize in his itemized conclusions, which turn out to be those on which disagreement, if any, is at a minimum. In conclusion 1) I might differ a bit in interpretation: the fact that the data cannot clearly discriminate between alternative measures of tightness need not be of great consequence since presumably these measures are highly intercorrelated. What it does warn against is fine tuning relying on presumed nonlinear effects of demand pressure – as I have emphasized earlier.

On the other hand I fully agree with his emphasis on the importance of exogenous prices, and with the view that the effect of demand pressure on the course of inflation, though systematic, is quantitatively distressingly small. This conclusion incidentally is consistent with my reduced form equation referred to earlier which tracks rather well through 1977. It suggests that, because the systematic effect is so weak, it is easily overshadowed by random shocks – especially when reinforced by systematically poor government policies. It also implies, unfortunately, that a policy of relying on slack to wind down inflation is bound to involve horrendous social costs.