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A MODEL OF INCOME, UNEMPLOYMENT AND INFLATION FOR THE U.S.A.

by

B. Bhaskara Rao

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Abstract

This paper develops a simple three equation macroeconomic model to explain the dynamics of output, unemployment and inflation for the U.S.A. The model is estimated, with the annual data, for 1946-1989. Insights gained through some recent developments are used to specify and estimate the model.

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A MODEL OF INCOME, UNEMPLOYMENT AND INFLATION FOR THE U.S.A.*

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I. INTRODUCTION

Recent developments seem to be swinging the balance in favour of a Keynesian approach to macroeconomic analysis. The new classical equilibrium model and the policy ineffectiveness proposition are now seen to be less than satisfactory for explaining macroeconomic facts in a world with sluggish price adjustments. The equilibrium real business cycle theories do not explain why technological progresses and regresses uniformly affect with such regularity the entire economy. Therefore models which are essentially Keynesian in spirit, albeit with some modifications for the existence of implicit or explicit contracts, monopolistic market structures and sluggish price adjustments, are now considered to be promising alternatives to the equilibrium models; for a recent survey of the literature see Fischer (1988), McCallum (1989) and Mankiw (1990).

In this paper we develop and estimate a simple three equation prototype macro model for the U.S. economy for the period 1946-1989. Our model is Keynesian in spirit and incorporates, in a simple manner, some interesting recent developments in disequilib-

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rium economics, the Keynesian criticisms of the policy ineffectiveness proposition, the triangle model of inflation and the general to specific approach in econometrics. Its simple structure is not only attractive for pedagogic purpose, but as a bench-mark model, it can be also useful in the development of larger models. The specification of the model is developed in section II. Empirical estimates are given in section III. Simulation results are discussed in section IV. Conclusions and limitations are stated in section V.

II. THE MODEL

It can be said that the new classical model has revived interest in the estimation of small scale models. Much of this literature and its criticisms are based on simple three equation models of aggregate demand and supply and their reduced form equations. Prior to this, small scale Keynesian models based on the semi-reduced form equations approach were also popular. These models have used, essentially, the reduced form output equation from the IS–LM model, the expectations augmented Phillips curve, a mark-up price equation and Okun's law to explain the dynamics of output, inflation and unemployment.[1] The specifications of these four relationships are well-known. A similar model has been also used to develop the aggregate demand and supply model in several editions of the popular textbook by Dornbusch and Fischer (1987).[2] Briefly the general structure of this model, abstracted from its dynamics and the disturbance terms, is as follows

$$Y = Y((M/P), G) \tag{1}$$

$$\Delta P = P(\Delta W, \Delta Q) \tag{2}$$

$$\Delta W = W(U) + \Delta P^e \tag{3}$$

$$U = U(GAP) \tag{4}$$

where Y = real output, M = nominal money supply, P = price level G = real government expenditure, W = money wage rate, Q = productivity, P^e = expected value of P, U = unemployment rate and GAP = Okun gap, measured as the difference between the trend and actual values of output.

This model is Keynesian in spirit because output is given by demand for output and prices are determined by the mark-up rule. Changes in the wage rate are determined by the standard expectations augmented Phillips curve. Implicit in this model are the assumptions that both the goods and labour markets are disequilibrium markets with sluggish price and wage adjustments and the money and bond markets are flexprice equilibrium markets; see Hicks (1983). A reduced form interest rate equation such as

$$r = R(M, G, \Delta P^e) \tag{5}$$

where r = nominal rate of interest can be also added to the above model to explain how prices and quantities are determined in a four market model of the economy. We shall ignore, however, the recursive interest rate equation.

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[1] I have been using this type of four equation model in my macroeconomics courses at the University of New South Wales since 1975. The main feature of my model is that the Phillips curve is non-linear and, therefore, the cost of rapidly reducing inflation increases. To simplify the derivation of the reduced form equations, Okun's law is reformulated in the reciprocal form. Students are encouraged to dynamically simulate the model to grasp the differences between alternative policies to reduce inflation. The model also fits the Australian data well; see Rao (1979). Recently Gordon (1990a, pp.6–7) pointed out that both Rudi Dornbusch and himself have used similar models in their macroeconomic courses.

[2] There are two types of aggregate demand and supply models in the existing textbooks. In both types the aggregate demand function is derived as the reduced form output equation from the IS–LM model. While the majority of the textbooks derive the aggregate supply function from the neo classical equilibrium labour market, Dornbusch and Fischer (1987) have used the Phillips curve, the mark-up price equation and Okun's law to derive an upward sloping relationship between output and prices. For a discussion of some conceptual problems in these two types of models see Rao (1987).

Three interesting recent developments warrant some significant changes to the above model. Firstly, developments in disequilibrium economics point out the need to distinguish between the notional and effective demands. The main distinction between the notional and effective demands is that the latter incorporates the spillover effects. Since both the goods and labour markets are disequilibrium markets in the above model, it is of some interest to examine if the spillover effect from the labour market exerts any significant effect on the goods market. The simplest way to examine this effect is to introduce the unemployment rate as an additional variable into the output equation. Unemployment rate is thus a simple proxy for the labour market spillover effects.[3]

It should be noted, however, that the goods market spillover effect on the labour market is already incorporated through Okun's law in equation (4). We therefore, reformulate equation (1) as

$$Y = \Phi((M/P), G, U) \qquad (1.A)$$

with the expectation that $\Phi_u \leq 0$.

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[3] It can be argued that the spillover effect from the labour market has been already incorporated into the reduced form output equation of the IS–LM model through the Keynesian consumption function. However, an alternative and observationally equivalent output equation can be derived from the disequilibrium approach in which private expenditures depend on real money balances and government expenditure is exogenous. If the goods market is always in a state of excess supply the Min. condition implies that output equals demand. This output equation is observationally equivalent to the reduced form equation of the IS–LM model. If the labour market is also a disequilibrium market, the aforesaid demand function should allow for the spillover effects from the labour market. If this spillover effect is proxied by the unemployment rate, it should have a negative coefficient in the output equation.

The issues involved here clearly warrant a more careful theoretical analysis. But a variable deletion test can be used, for the time being, as a simple criterion. Our subsequent empirical results show that when the unemployment variable is deleted from the output equation, the variable deletion test rejected the null hypothesis.

Secondly, in the empirical literature of the new classical model and its critiques the unemployment equation received much attention. Barro (1977), for example, showed that the minimum wage rate and a measure of the military conscription are significant in his new classical U.S. unemployment equations for the period 1946–73. Subsequently in the interesting debate between Rush and Waldo (1988) and Pesaran (1988), the latter showed that a time trend, the military conscription variable and a dummy variable to capture the effects of the end of the Korean and Vietnam wars were all significant in the Keynesian unemployment equation for the period 1946–85. However, the minimum wage variable was found to be insignificant in Pesaran (1988) as well as in the updated version of the Barro (1981) new classical unemployment equation. In the light of these developments, the unemployment equation, based on the simple Okun law, can be reformulated as

$$U = \Psi(GAP, WAR, MIL, t) \qquad (4.A)$$

where WAR = a dummy variable to capture the effects of the end of the Korean and Vietnam wars, MIL = conscription variable and t = time trend.

Finally, Gordon (1990a) recently argued in favour of a much simpler explanation of inflation, known as the triangle model of inflation. The three elements of this model are inertia, demand and supply. It differs from the above Phillips curve and markup-price equation approach in that the wage rate, unemployment and expectations do not appear in the inflation equation. Therefore, the triangle model has the advantage of reducing the output-inflation dynamics to a two equation model because Okun's law is not necessary to link the unemployment variable in the Phillips curve with output. Furthermore, according to Gordon (1990a, pp.10–11), the mark-up hypothesis is dead and the earlier approach to inflation through the Phillips curve and the mark-up equation was a mistake. An important implication of this earlier approach is that the share of labour income remains invariant across the cycles. However, the share of labour income in U.S. showed a strong upward secular movement between the mid 1960s and late 1970s and a strong downward trend since then; see Gordon (1988). Gordon's triangle model of inflation implies that equations (2) and (3) can be ignored. The rate of inflation is assumed to be determined by the lagged rate of inflation to capture inertia, and the level and rate of change of the detrended output to proxy the demand and supply conditions in the goods market. Thus we have

$$\Delta P = \Gamma(GAP, \Delta GAP, \Delta P_{-1}, \Delta P_{-2} \cdots) \tag{6}$$

Our bench-mark model of income, unemployment and inflation thus consists of equations (1.A), (4.A) and (6). It should be pointed out, however, that our subsequent empirical results did not strongly support this triangle model of inflation. But we shall examine such modifications, necessasitated by data, in the following section.

III. EMPIRICAL RESULTS

The three equation model has been estimated with the U.S. annual data for the period 1946–1989. The definitions of the variables and sources of data are given in the Appendix. The equations are first estimated with the OLS method and the general to specific approach is used to determine the specification and the dynamics of the equations. The general to specific approach is popularised by Hendry (1979) and succinct summaries can be found in Cuthbertson (1985, pp.257–72) and Maddala (1988, pp.423–25). Basically this method suggests that one should start with a more general dynamic specification of an equation (autoregressive distributed lag model, *ADL* for brevity) in which the current and several lagged values of the explanatory variables as well as the lagged dependent variables are included. For this reason it can be said that the initial dynamic equation is *overparameterized.* The equation is then *reparameterized* by dropping variables with higher order lags that are insignificant and by smoothing the parameters. We shall use the output equation as an example. The lag structure is limited to three periods because higher order lags were not significant. Furthermore, in the *non-ADL* specification of the output equation the

residual serial correlation did not exceed the 3*rd* order. The equation is assumed to be linear in logarithms. *OLS* estimate of the *ADL* model of the output equation for the period 1946–1989 is as follows.

$$\begin{aligned}
Y_t = &-\underset{(0.30)}{0.0448} + \underset{(1.95)}{0.2807}\,(M/P)_t - \underset{(0.98)}{0.2796}\,(M/P)_{t-1} - \underset{(1.10)}{0.3577}\,(M/P)_{t-2} \\
&+ \underset{(1.75)}{0.4265}\,(M/P)_{t-3} \\
&+ \underset{(1.07)}{0.0415}\,G_t - \underset{(1.30)}{0.0562}\,G_{t-1} + \underset{(0.84)}{0.0322}\,G_{t-2} + \underset{(0.24)}{0.0060}\,G_{t-3} \\
&- \underset{(3.22)}{0.0707}\,U_t + \underset{(2.92)}{0.0799}\,U_{t-1} + \underset{(0.56)}{0.0184}\,U_{t-2} - \underset{(0.71)}{0.0181}\,U_{t-3} \\
&+ \underset{(5.13)}{1.0401}\,Y_{t-1} + \underset{(0.75)}{0.2497}\,Y_{t-2} - \underset{(1.15)}{0.3008}\,Y_{t-3}
\end{aligned} \tag{7}$$

$$\overline{R}^2 = 0.9986, \ SEE = 0.0185, \ DW = 2.2009$$

where all variables are in the logarithms and the t ratios are in parentheses below the coefficients.

Before the insignificant higher order lagged variables are deleted from the above equation, it is worth recognizing that smoothing can be done by noting that some restrictions on the parameters are plausible. For example the coefficients of $(M/P)_{t-1}$, G_{t-1}, and U_{t-1} are opposite in sign but approximately of the same magnitude as the coefficients of their current period values. Furthermore, the coefficient of Y_{t-1} is not significantly different from unity. Therefore it is worth estimating this equations in the differenced form.[4] The estimate of the new equation is as follows.

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[4] It is well-known that several macroeconomic time series follow random walk with drift; see Nelson and Plosser (1982). Therefore a regression of differenced variables reduces the risk of spurious correlations in the levels of the variables. See Nelson and Kang (1984) and Dickey, Bell and Miller (1986) for a justification for estimation with the differenced variables. The latter point out that the consequences of unnecessary differencing are far less serious than

$$\begin{aligned}\Delta Y_t = & \underset{(1.15)}{-0.1173} + \underset{(2.65)}{0.2487}\ \Delta(M/P)_t - \underset{(2.54)}{0.3419}\ \Delta(M/P)_{t-2} - \underset{(1.07)}{0.0551}\ (M/P)_{t-3}\\ & \underset{(2.02)}{0.0385}\ \Delta G_t + \underset{(0.78)}{0.0161}\ G_{t-2} - \underset{(0.24)}{0.0041}\ G_{t-3}\\ & - \underset{(5.43)}{0.0773}\ \Delta U + \underset{(1.09)}{0.0220}\ \Delta U_{t-1} + \underset{(1.30)}{0.2429}\ \Delta Y_{t-2}\end{aligned} \tag{8}$$

$$\overline{R}^2 = 0.8264,\ SEE = 0.0179,\ DW = 1.9264.$$

It is interesting to note that the coefficients of the differenced variables are close to those implied by their levels in the previous equation. Therefore, the differenced version of equation (7) is satisfactory. Using the values of the t ratios as a guide-line, the above equation has been reestimated several times after deleting each time the variable with the lowest t ratio. The final estimate of the output equation, obtained in this manner, is as follows

$$\begin{aligned}\Delta Y_t = & \underset{(11.57)}{0.0294} + \underset{(3.43)}{0.2614}\ \Delta(M/P)_t - \underset{(2.63)}{0.1870}\ \Delta(M/P)_{t-2}\\ & + \underset{(1.91)}{0.0304}\ \Delta G_t - \underset{(6.66)}{0.0825}\ \Delta U_t\end{aligned} \tag{9}$$

$$\overline{R}^2 = 0.8304,\ SEE = 0.0165,\ DW = 2.0772.$$

$$\chi^2_{sc(1)} = 0.3479,\ \chi^2_{ff(1)} = 7.5974,\ \chi^2_{n(2)} = 1.6444,\ \chi^2_{h(1)} = 0.8355$$

where the χ^2 test statistics are, respectively, for serial correlation, functional form misspecification, normality and heteroscedasticity of the residuals. The degrees of freedom are shown in the parentheses with the subscripts.

The coefficients of equation (9) are well determined and significant at the 5% level. However the coefficient of ΔG_t is significant only at a slightly higher level. It is noteworthy that the spillover effect is strong and significant. The χ^2 statistics, except χ^2_{ff}, are all insignificant. The significance of χ^2_{ff} even at the 1% level indicates some functional misspecification. We, therefore, estimated variants of the above equation and found that χ^2_{ff} becomes insignificant at the 1% level when $\Delta(M/P)_{t-2}$ is replaced with $\Delta(M/P)_{t-1}$. Estimates of the equation with this modification are as follows

$$\begin{aligned}\Delta Y_t = & \underset{(11.04)}{0.0289} + \underset{(3.54)}{0.3413}\ \Delta(M/P)_t - \underset{(1.93)}{0.1742}\ \Delta(M/P)_{t-1}\\ & + \underset{(2.17)}{0.0361}\ \Delta G_t - \underset{(6.35)}{0.0840}\ \Delta U_t\end{aligned} \tag{10}$$

$$\overline{R}^2 = 0.8177,\ SEE = 0.0171,\ DW = 1.9730$$

$$\chi^2_{sc(1)} = 0.0001,\ \chi^2_{ff(1)} = 4.8137,\ \chi^2_{n(2)} = 1.6177,\ \chi^2_{h(1)} = 0.1655.$$

The estimates of the coefficients in this equation are close to those in the previous equation. There is, however, a small increase in the SEE but the significant reductions in the χ^2 statistics made us to prefer equation (10) as our output equation.

The final versions of the inflation and unemployment equations are obtained in a similar manner to the output equation. The *OLS* estimates of these two equations are

$$\begin{aligned}\Delta P_t = & \underset{(4.60)}{0.0191} + \underset{(5.35)}{0.4208}\ \Delta GAP_t - \underset{(2.60)}{0.1457}\ GAP_{t-2}\\ & - \underset{(3.44)}{0.2296}\ GAP_{t-3} + \underset{(2.56)}{0.1069}\ GAP_{t-4} + \underset{(3.26)}{0.0081}\ SD_t\\ & - \underset{(4.73)}{0.0481}\ \Delta U_t + \underset{(3.35)}{0.2462}\ \Delta P_{t-1} + \underset{(7.02)}{0.3408}\ \Delta P_{t-4}\end{aligned} \tag{11}$$

$$\overline{R}^2 = 0.9254,\ SEE = 0.0095,\ DW = 2.1570.$$

$$\chi^2_{sc(1)} = 0.4382,\ \chi^2_{ff(1)} = 0.0646,\ \chi^2_{n(2)} = 0.0638,\ \chi^2_{h(1)} = 0.0659$$

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doing nothing or removal of a linear trend. Estimates of parameters based on differencing are inefficient but unbiased and consistent.

$$
\begin{aligned}
U_t = & -0.2311 + 4.0641\ \Delta GAP_t + 1.2314\ GAP_t \\
& \quad (1.17) \quad (5.44) \qquad\qquad\qquad (2.01) \\
& -4.0853\ \Delta MIL_t + 0.0838\ \Delta WAR_t + 0.9209\ U_{t-1} \\
& \quad (2.95) \qquad\qquad (3.37) \qquad\qquad (13.70) \qquad\qquad (12)
\end{aligned}
$$

$$\overline{R}^2 = 0.8401,\ SEE = 0.1412,\ DW = 2.0771.$$

$$\chi^2_{sc(1)} = 0.2181,\ \chi^2_{ff(1)} = 1.7474,\ \chi^2_{n(2)} = 4.3448,\ \chi^2_{h(1)} = 0.2765.$$

In equation (11) SD = supply shock dummy; see Gordon (1990b, pp.294–300) for a brief discussion of the supply shocks. When the supply shocks are adverse (e.g. 1972–1976) $SD = 1$ and when supply shocks are favourable (e.g. 1981–1986) $SD = -1$. At other times $SD = 0$. All the coefficients in these two equations, except the intercept in the unemployment equation, are significant at the 5% level. The diagnostic χ^2 statistics are insignificant at the 5% level.

Even though the OLS estimates of the coefficients in equations (10) to (11) are biased and inconsistent, some important aspects of these estimates are noteworthy. In the output equation the labour market spillover effect is strong and significant. When this equation was reestimated without ΔU_t, the variable deletion LM test statistic ($\chi^2_{(1)} = 22.3645$) was significant and the null hypothesis is rejected at the 5% level. The effect of changes in the real money balances on output is strong and exceeds the effect of changes in real government expenditure.

The inflation equation is broadly supportive of Gordon's triangle model. The net effect of the GAP variable has the expected negative sign. The positive value for the coefficient of ΔGAP_t implies that cyclical upswings effect the markets more evenly than cyclical downswings; see Lipsey (1960). Furthermore, the response of inflation to GAP is very sluggish. It will be at least a year before inflation increases in response to excess demand.[5] The supply shock dummy SD is significant. Adverse supply shocks seem to have added roughly about 1% to the inflation rate during the year. We tried to capture the effects of the price control programme during 1971–74 through a dummy variable. Even though its coefficients was negative it was insignificant. More about this later. An interesting aspect of this equation is that ΔU_t is significant and has the expected negative sign. When ΔU_t was dropped, the variable deletion LM statistic was significant ($\chi^2_1 = 17.1544$). Since the unemployment variable can be considered to be a proxy for the missing wage rate through the Phillips curve it can be said that the mark-up theory of prices is not entirely dead and at least some prices are set on the basis of this theory. In the unemployment equation all the coefficients have the expected signs and, with the exception of the intercept, are significant. When a trend variable was introduced its coefficient was insignificant. Since the coefficient of U_{t-1} is close to unity, we also estimated this equation in the differenced version. But the summary statistics were poorer and the functional form misspecification test rejected the null hypothesis.[6] Each equation

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[5] We estimated the price equation in a slightly different form without ΔGAP to make the effect of GAP more obvious. The coefficients of GAP_t to GAP_{t-4} are 0.3869, −0.4788, −0.0792, −0.2509, −0.1418 respectively. All these coefficients, except that of GAP_{t-2}, are significant at the 5% level. The coefficients of the other variables are close to those in equation (11). Equation (11) has the advantage of showing the effects of GAP as well as its rate of change.

[6] We estimated another alternative unemployment equation into which some forward looking behaviour is introduced and it is

$$
\begin{aligned}
\Delta U_t = & 0.1073 + 6.0625\Delta GAP_t + 0.0908\Delta WAR_t - 3.3699\Delta MIL_t \\
& (3.26) \quad (11.54) \qquad (4.84) \qquad\quad (3.16) \\
& -2.0339\Delta M_{t-1} - 2.6115\Delta^2 P_t \\
& \quad (3.56) \qquad\quad (3.73)
\end{aligned}
$$

$$\overline{R}^2 = 0.8137,\ SEE = 0.1107,\ DW = 2.1486$$

$$\chi^2_{sc(1)} = 0.8593,\ \chi^2_{ff(1)} = 0.7394,\ \chi^2_{n(2)} = 1.2918,\ \chi^2_{h(1)} = 0.0130.$$

This equation is forward looking in the sense that employment is assumed to increase in anticipation of a recovery in demand with both ΔM_{t-1} and $\Delta^2 P_t$

has been also subjected to the *TIMVAR* temporal stability tests. It is found that these equations are temporally stable.

Even though these *OLS* estimates are useful, it is well known that they are inconsistent when the equations are interdependent. Moreover, the order condition shows that all the parameters are overidentified. Even though consistent estimates of the parameters can be obtained by estimating the model with the single equation methods, such as the two-stage least squares (*2SLS*) or the limited information maximum likelihood, we have used the three-stage least squares (*3SLS*) method to gain asymptotic efficiency. The initial covariance matrix of the residuals is based on the *2SLS* estimates of the model.[7]

When the model in equations (10) to (12) was estimated, all the coefficients had the expected signs. However, the coefficients of $\Delta(M/P)_{t-1}$ in the output equation and GAP_t in the unemployment equation were insignificant. All other coefficients were significant at the 5% level. Introduction of a price guide-lines dummy into the price equation did not improve the results. Even though the coefficient of the price guide-lines dummy was negative it was insignificant. In the subsequent estimation rounds we scanned for the significance of the guide-lines dummy by dropping, one at a time, the variables that are insignificant. But the guide-lines dummy was never significant. Our final estimates of the model are obtained by following the procedure described earlier for the *OLS* estimates. These are given below.

$$\Delta Y_t = \underset{(11.01)}{0.0281} + \underset{(2.97)}{0.2424}\Delta(M/P)_t + \underset{(4.54)}{0.0639}\ \Delta G_t - \underset{(3.59)}{0.0673}\Delta U_t \tag{13}$$

$$\overline{R}^2 = 0.998,\ SEE = 0.0166,\ DW = 1.9815$$

$$\begin{aligned}\Delta P_t = {} & \underset{(4.80)}{0.0176} + \underset{(6.88)}{0.5943}\ \Delta GAP_t - \underset{(1.81)}{0.1160}\ GAP_{t-2} \\ & - \underset{(2.98)}{0.1961}\ GAP_{t-3} + \underset{(2.32)}{0.0987}\ GAP_{t-4} + \underset{(3.65)}{0.0080}\ SD_t \\ & - \underset{(4.84)}{0.0608}\ \Delta U_t + \underset{(4.58)}{0.2885}\ \Delta P_{t-1} + \underset{(7.68)}{0.3263}\ \Delta P_{t-4}\end{aligned} \tag{14}$$

$$\overline{R}^2 = 0.924,\ SEE = 0.0086,\ DW = 1.9901.$$

$$\begin{aligned}U_t = {} & -\underset{(1.93)}{0.4362} + \underset{(2.85)}{2.7226}\ \Delta GAP_t \\ & - \underset{(2.49)}{3.5744}\ \Delta MIL_t + \underset{(3.15)}{0.0795}\ \Delta WAR_t + \underset{(10.92)}{0.8454}\ U_{t-1}\end{aligned} \tag{15}$$

$$\overline{R}^2 = 0.796,\ SEE = 0.1481,\ DW = 1.9446.$$

The asymptotic t ratios are shown below the coefficients in the parenthesis. The summary statistics reported in these equations are based on those obtained as part of the estimation with the T.S.P (PC Version 4.1).[8] Broadly the *3SLS* estimates support our

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signaling such a recovery. However, in our subsequent simulations, the model with this unemployment equation performed poorly.

[7] The model can be also estimated with other system methods of estimation such as the iterative three-stage least squares (*I3SLS*) or the full information maximum likelihood (*FIML*). *I3SLS* is appropriate if there are convergence problems with *3SLS*. However, since our model is simple and linear we did not encounter this problem. Both the *I3SLS* and *FIML* methods are computationally more expensive. We have, however, estimated the final version of the model with *I3SLS* using the Mainframe version of T.S.P. 4.0. The estimates are similar to those based on *3SLS*. For the *3SLS* estimates we have used the PC version of T.S.P. 4.1. It is felt that *FIML* might be inappropriate for a model of this nature because this method is sensitive to specification errors.

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[8] A comparison of the distance functions of the first stage and the final versions of our estimates seems to justify the constraints on the coefficients. The distance functions, given by $E'HH'E$, is the sum of the squared fitted residuals weighted by the covariances. For the first and final stage estimates they are 53.1756 and 44.5220 respectively. These values are inversely related to their respective likelihood functions. Note that our conclusion is based on intuition only.

observations based on the *OLS* estimates. However, the extent of the simultaneous equations bias in the parameter estimates can be seen by comparing the *OLS* and *3SLS* estimates of the coefficients of the endogenous variables. There are noticeable changes in the coefficients of ΔU_t in the output and price equations and ΔGAP_t in the inflation and unemployment equations. Furthermore, the coefficient of ΔG_t in the output equation increased. This might be partly due the absence of $\Delta(M/P)_{t-1}$ in the output equation. All the coefficients, except that of GAP_{t-2} in the price equation (which is significant at the 7% level), are significant at the 5% level. Note that a one tail test is appropriate for the intercept of the unemployment equation; see below and footnote 9.

In the output equation the significant intercept term implies that, in the absence of policy disturbances and a zero spillover effect from the labour market, real output will grow at about 3% per year. A somewhat similar result was obtained earlier by Barro (1981, p.145, eq. (8)) in his new classical output equation for the period 1947–78. In the inflation equation the coefficient of ΔU_t remained significant and implies that Gordon's claim that the mark-up equation is dead needs a more careful scrutiny. The equilibrium rate of inflation, implied by this equation, is about 4.5%. which roughly equals the trend rate of inflation of 4.3% during the sample period. The unemployment equation is interesting. The intercept term which was insignificant in the *OLS* estimates is significant now. The hypothesis that the intercept is negative (since our unemployment variable is measured as a fraction and the *log* of a fraction is negative) and significant is easily accepted at the 5% level. This equation implies that the equilibrium (or full employment) rate of unemployment is about 5.6% which is not an implausible estimate for the U.S. economy.[9] Therefore it can be said that the parametric estimates and the implications of our model are plausible.

IV. SIMULATION RESULTS

We simulated the model in equations (13) to (14) and computed various summary statistics to examine how well the model captures the dynamics of output, inflation and unemployment during the sample period. However, it should be noted that evaluation of the model, only on the basis of its simulation results, is inappropriate. It is well-known that the simulation summary statistics such as the root-mean-squared errors have no rigours statistical interpretation; see Fair (1984, pp.264–5). Furthermore, our main objective in developing a model of this nature is to examine, as stated at the outset, the significance of the recent developments in macroeconomics. It is important to check, therefore, that the signs and magnitudes of the parametric estimates are consistent with the *a priori* expectations. We have already shown that our model satisfactorily meets these criteria.

Various simulation summary statistics, based on the static and dynamic simulations, are given below in Table 1. Plots of the actual and predicted values, from static simulations, of $\Delta Y_t, \Delta P_t$ and U are given in Charts 1 to 3.

The root mean square errors (*RMSEs*) based on the static and dynamic simulations indicate that the best predictions are obtained for the level and rate of change of output and rate of inflation. Predictions of unemployment rate are less satisfactory. As one would expect, static simulation results are better than the dynamic simulation results. The Theil's inequality coefficient u tells a similar story but the values of u for ΔY_t and ΔP_t are not bad. Furthermore, since the values of this coefficient for ΔY_t, in both the static and dynamic simulations, is less than 0.3, their variances are approximately 1.7312×10^{-3} and 1.8538×10^{-3} respectively. The usual test based on the normal curve shows that the u statistics for ΔY_t are significantly less than unity. Similar conclusions also hold for the u

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[9] The absence of GAP_t does not make much difference because at the full employment level GAP_t and ΔGAP_t are both zero. Note that our definition of the unemployment rate variable U is similar to its definition in Barro (1977,1981), Rush and Waldo (1988) and Pesaran (1988). If the fraction of the actual unemployment rate is U^*, then our $U = log[U^*/(1 - U^*)]$. The equilibrium value of U can be estimated by setting the changes in the other variables to zero and then by solving for U^*.

statistic of ΔP_t. Therefore, it can be claimed that the predictions of our model are better than those of a naive static model.

Table 1

SUMMARY STATISTICS OF SIMULATIONS 1946-1989

	RMSE	u	um	us	uc
			Static Simulation		
Y	0.0237	0.0017	0.0000	0.0114	0.9886
ΔY	0.0236	0.2760	0.0000	0.0078	0.9922
ΔP	0.0122	0.1093	0.0000	0.0199	0.9801
U	0.1809	0.0310	0.0000	0.0774	0.9226
			Dynamic Simulation		
Y	0.0531	0.0038	0.0005	0.01542	0.8453
ΔY	0.0247	0.2856	0.0037	0.0796	0.9167
ΔP	0.0253	0.2385	0.0693	0.0099	0.9208
U	0.2745	0.0468	0.0173	0.1877	0.7950

Notes

RMSE = Root mean squared error.

u = Thiel's inequality coefficient, um = proportion of bias component, us = proportion of variance component and uc = proportion of covariance component. Note that um + us + uc = 1; see Pindyck and Rubinfeld (1984, pp.364-5).

The decomposition statistics show that the bias components (um) are virtually zero for all the variables and there is no systematic bias in the specification of our model. The variance components (us) are also small for all the variables. Therefore our model replicates the variability of the endogenous variables satisfactorily.

The large values for the covariance components indicates that the large *RMSPEs* for ΔY_t and ΔP_t are perhaps due to unsystematic errors.

These results thus suggest that to improve the predictive accuracy of our simple model, it is necessary to isolate the unsystematic policy and supply shocks to the system during the sample period. This calls for a careful examination of the history of the U.S. economy and also perhaps a more disaggregated approach. But these tasks are beyond the scope of the present paper.[10]

V. CONCLUSIONS

In this paper we developed a simple three equation model of output, inflation and unemployment dynamics for the U.S.A. Estimates of the parameters of our model are well determined. Our model showed several interesting aspects of model building. First, it is found that the spillover effect from the labour market is significant in the aggregate demand equation. Second, the significance of unemployment in the output and inflation equations implies that output, inflation and unemployment are interdependent. Therefore analyses of these variables should be conducted within a simultaneous equations framework. Third, the simple Okun's law needs to be augmented with the conscription and war dummy variables. Fourth, Gordon's triangle model of inflation should include the effects of the mark-up pricing behaviour. Therefore the claim that the mark-up hypothesis is dead needs further examination. Fifth, both money and government expenditure have significant effects on real output. Finally, we also found that Hendry's general to specific econometric approach is very useful for developing the specifications of various relationships.

In addition to the aforesaid general observations, our model implies that the U.S. economy has a tendency to grow at roughly 3% per year in the absence of shocks to the system. The equilibrium

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[10] Our model excluded, for example, the effects the Korean and the Vietnam wars on inflation and output. We have also excluded the effects of the controversial Regan tax cuts in 1981. It is hard to capture the effects of the Regan tax cuts through a dummy variable because the U.S. economy also experienced favourable supply shocks from 1981 through a drop in the real energy and food prices. Furthermore, we have ignored the effects of inflationary expectations from our model and the lagged inflation variables are intended to capture the inertia effects.

rate of inflation is about 4.5% per year and the full employment unemployment rate is 5.6%. Various adverse supply shocks during 1971–76 seem to have added about 1% to the annual rate of inflation. Similarly, the favourable supply shocks during the early 1980s decreased the annual inflation rate by a similar magnitude.

The simulation properties of our model are not overly impressive. But, thanks to the general to specific approach, there is no systematic bias in the model and it replicates the variability in the endogenous variables satisfactorily. It is suggested that further improvements to the predictive performance of the model can be achieved by examining more carefully the history of the U.S. economy and by incorporating into the model the unsystematic shocks to the economy. We hope that our findings will be useful in furthering the usefulness of simple macroeconomic models.

Chart 1

Predicted (- - -) and Actual (—) Values of ΔY_t

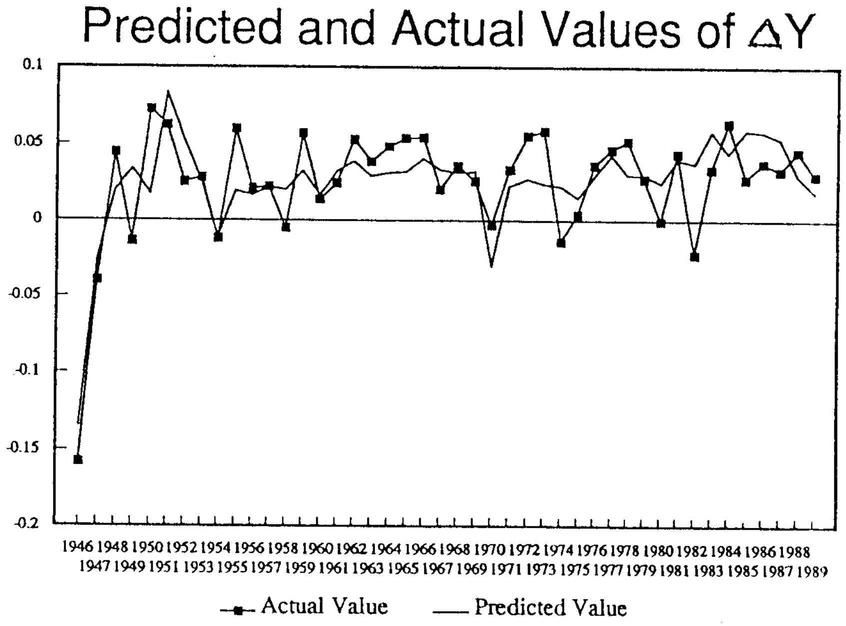


Chart 2

Predicted (- - -) and Actual (—) Values of ΔP_t

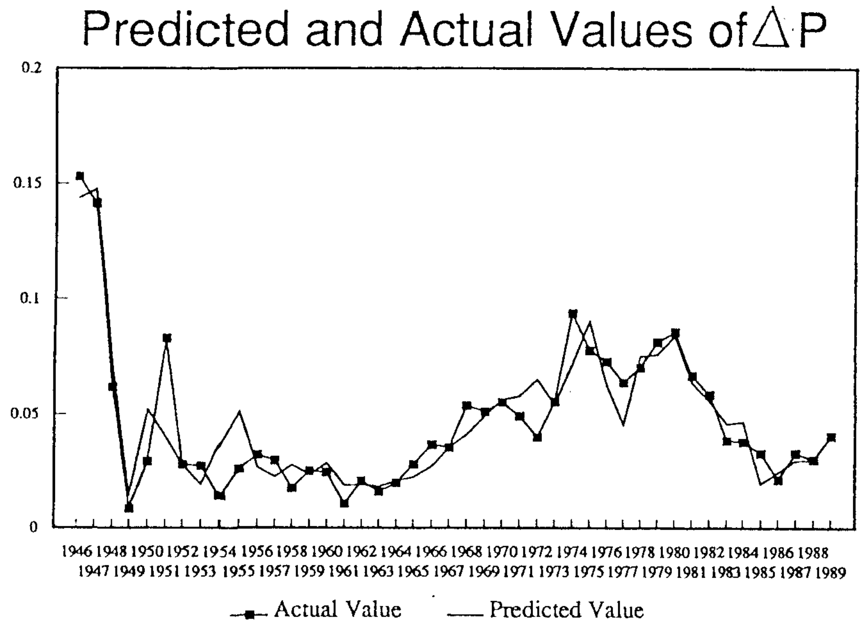
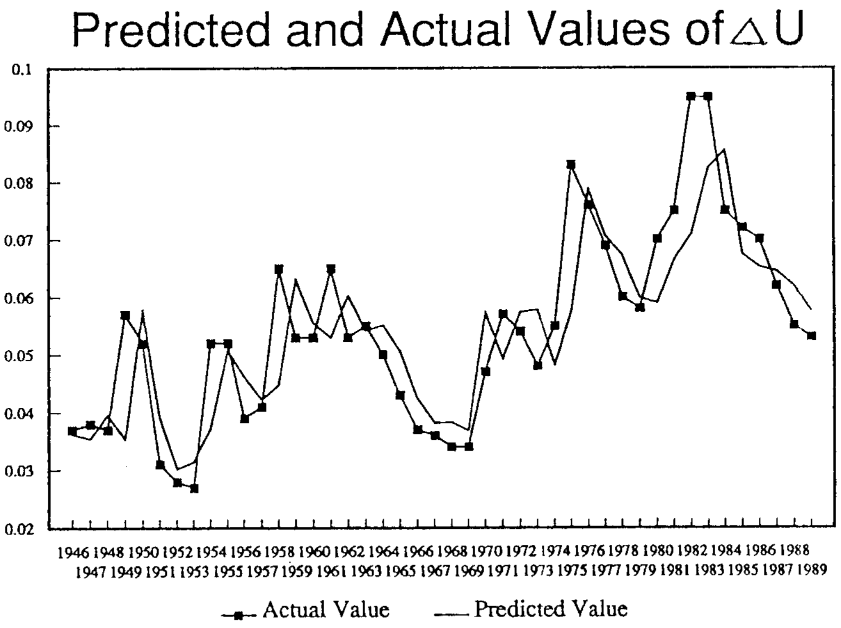


Chart 3

Predicted (- - -) and Actual (—) Values of U



Data Appendix

Y = Real G.N.P (1972 prices).
P = G.N.P. deflator (1972=100).
M = Annual average of M_1 definition of money.
G = Real federal government expenditure (1972 prices).
U = Unemployment rate, defined as $log(U/(1-U))$.
SD = Supply dummy, equals 1 in 1972–1976 and -1 in 1981–1986. In all other periods it is zero.
WAR= War dummy, equals 7.3 in 1946, 1.13 in 1954, 0.5875 in 1973, 0 in all other periods.
MIL = Measure of military conscription.
GAP = Difference between the trend and actual values of Y. Trend value of Y is based on a second degree equation.

The definitions and sources of data are the same as in Barro (1981). Most of these series can be obtained from the *U.S. Survey of Current Business, National Income and Product Accounts of the United States* and the *Federal Reserve Bulletin.*

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