More on Analyzing the Phillips Curve for the United States, 1950-1975

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MORE ON ANALYZING THE PHILLIPS CURVE FOR THE UNITED STATES, 1950-1975 (*)

I. - *Introduction*

Some years ago, A. W. Phillips (1958, p. 298) argued

> . . . that the rate of change of money wages can be explained by the level of unemployment and the rate of change of unemployment . . .

Conceding that his conclusions were « tentative », Phillips (1958, p. 299) observed the

> . . . need for much more detailed research into the relations between unemployment, wage rates, prices, and productivity.

Since the publication of Phillips' article, there has been an enormous volume of research exploring the « Phillips curve » relation. This phenomenon has been examined for a number of countries, ordinarily with the objective of ascertaining whether the Phillips curve exists for the country involved.

Two different approaches to the Phillips relation have been taken; one that is consistent with the original formulation by Phillips himself and its modification by Lipsey (1960) (1), and a second which deviates from this path either by incorporating a number of additional variables in the Phillips curve relationship or by completing revising it (2).

Empirical studies of the Phillips curve relation ordinarily adopt a single-equation approach to the issue, with the coefficients being estimated by ordinary least squares (OLS) (3). The problem with the single-equation

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(1) See, e. g., KALISKI (1964), ZAIDI (1969), HOFMAN (1969), or BOWEN and BERRY (1963).

(2) See, e.g., BRECHLING (1968), ECKSTEIN (1968), KUH (1967), PERRY (1966), or PHELPS (1969).

(3) CARGILL and MEYER (1974) and ASHENFELTER, *et. al.* (1972) offer effectively the only real exceptions to the single-equation approach to the Phillips curve in the United States, although the simultaneity issue has been recently considered for elsewhere (e.g., the United Kingdom).

approach is that it ignores any possible simultaneity among the variables, such as might very well exist, for example, between the rate of change of money wages and the rate of change of the aggregate price level. If a significant feedback between, say, these two variables does in fact exist, then studies of the Phillips curve which do not allow for such a feedback relationship will produce biased and inconsistent estimators.

Accordingly, the objective of this Note is to examine, both analytically and empirically, whether in fact there may exist a simultaneity (feedback) relationship between the rate of change of money wages and the rate of change of the price level in the United States, and if so, what the implications thereof are for studying the Phillips curve relationship.

To accomplish this, this paper first develops a simple model to analytically explain the feedback phenomenon. After doing so, it then empirically deals with two types of models: one which has no time lags built in and one which *does* include time lags. In the first case, a wage equation using annual data for the U.S. is estimated by OLS. Next a two-equation model using the same data is estimated by two-stage, least squares (TSLS). Then the results from the single-equation approach are contrasted with those of the two-equation approach. The same procedure is followed in the section dealing with the lagged model. Data in all cases will cover the 1950-1974 period. It is hoped that the importance of using multi-equation models estimated by TSLS in lieu of the single-equation regression estimated by OLS will become evident and become more of a major consideration in future Phillips curve research in the United States.

II. - *The Issue of Feedback*

At the outset of this section, we first note that in estimating a single-equation regression to explain the rate of change of money wages, it is essential to observe that certain critical assumptions are made in the structure of the regression equation. A most basic one of these assumptions is that the casuality must always flow from the so-called exogenous variables to the so-called dependent variable; moreover, the causality is to be strictly one-way in nature. If the so-called exogenous variables in fact are not exogenous, then a single-equation regression can yield only biased and inconsistent estimators.

Accordingly, to understand now the logic underlying a feedback between the rate of change of money wages and the rate of change of prices, we can consider the expectations hypothesis for wage determination. In its simplest form (4), it can be expressed as

$$(1) \qquad W_t = \alpha_0 + \alpha_1 P_t^e + \alpha_2 Z_t + e_t$$

where W_t = rate of change of the money wage rate during period t

α_0 = constant term

P_t^e = average *expectations* of future inflation, held during period t

Z_t = other exogenous forces

e_t = error term

Since Z_t is a vector of exogenous forces, it follows that Z_t is uncorrelated with e_t, i.e., that

$$(2) \qquad E(Z_t, e_t) = 0 .$$

Expected price inflation in (1), P_t^e, is presumably some function of the past history of inflation:

$$(3) \qquad P_t^e = \beta \sum_{s=0}^{\infty} \lambda^s (P_{t-s}), 1 > \lambda > 0$$

where P_{t-s} = *observed* rate of inflation in period $t - s$.
(3) may be rewritten as

$$(4) \qquad P_t^e = \beta[\lambda^0 P_t + \lambda P_{t-1} + \lambda^2 P_{t-2} + \lambda^3 P_{t-3} + \dots \infty] .$$

For simplicity, adopt the notation that $L^\sigma P_t = P_{t-\sigma}$. Introducing such into (4), we get

$$(5) \qquad P_t^e = \beta[P_t + \lambda L P_t + \lambda^2 L^2 P_t + \lambda^3 L^3 P_t + \dots \infty] .$$

Factoring enables us to simplify (5) such that

$$(6) \qquad P_t^e = \beta P_t [1 + \lambda L + \lambda^2 L^2 + \lambda^3 L^3 + \dots \infty] .$$

(4) A number of studies have considered single-equation regressions expressing the rate of change of money wages as, in part, a function of the expected rate of change of prices. See, e.g., Berg and Dalton (1975), Swidinski (1972), Turnovsky and Wachter (1972), Desai (1975), Perry (1966), or Turnovsky (1972). Related to this relationship, see also the observations by Smith (1970, especially p. 776) and Tobin (1968).

Hence, it follows that

$$P_t^e = \frac{\beta}{1-\lambda L} P_t . \tag{7}$$

We may now substitute result (7) into our original wage equation (1); this yields

$$W_t = \alpha_0 + \frac{\alpha_1 \beta}{1-\lambda L} P_t + \alpha_2 Z_t + e_t \tag{8}$$

in terms of the *observable* variables. If we now solve for P_t, we find that

$$P_t = \frac{W_t(1-\lambda L)}{\alpha_1 \beta} - \frac{\alpha_0(1-\lambda L)}{\alpha_1 \beta} - \frac{\alpha_2(1-\lambda L) Z_t}{\alpha_1 \beta} - \frac{(1-\lambda L)}{\alpha_1 \beta} e_t . \tag{9}$$

Clearly, the rate of change of current prices (P_t) is correlated with the current and lagged residuals (e_t). Hence, attempting to estimate equation (1) by regressing the rate of change of money wages (W_t) against current observed price changes (observed rates of change in the price level) and other exogenous variables would result in biased and inconsistent estimators because the right-hand side variables [of (1)] are not strictly exogenous, i.e., there will be feedbacks from W_t to P_t under the above assumed structure. This means that the use of single-equation techniques to estimate a reduced form equation of the form

$$W_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Z_t + e_t \tag{10}$$

is clearly inappropriate. In other words, the basic assumptions underlying such a regression-equation structure have been violated.

Accordingly, it is argued that it is necessary to adopt, in lieu of single-equation regressions estimated by OLS, multi-equation models (in W_t and P_t) to be estimated by TSLS. Sections III and IV below now empirically dramatize the need for this change of approach.

III. - *An Unlagged Model*

We may begin this empirical section by postulating a wage equation such as

$$W_t = W_t(P_t, U_t, \pi_t) \tag{11}$$

where W_t = percentage rate of change in money wages (in manufacturing) in year t

P_t = percentage rate of change in the consumer price index (CPI) in year t

U_t = percentage unemployment rate in year t

π_t = average profit rate in manufacturing in year t (after tax profits a percentage of stockholders' equity).

All data were obtained from the *Economic Report of the President, 1976* (1976, Tables B-28, B-46, B-24, and B-76) (5).

The single-equation model to be estimated is

$$W_t = a_0 + a_1 P_t + a_2 U_t + a_3 \pi_t + a_4 \quad (12)$$

where a_0 is a constant and a_4 is an error term.

Estimating (12) by OLS yields

$$W_t = 11.43919 + \underset{(8.11)}{0.56942} P_t - \underset{(3.82)}{0.62186} U_t + \underset{(3.80)}{0.48065} \pi_t , \quad (13)$$

$$R^2 = .78, \qquad DF = 21, \qquad F = 24.70878, \qquad DW = 1.51003$$

where terms in parentheses are t-values.

Clearly, the coefficients are all highly significant and have the « expected » signs. These results are consistent with most studies of the Phillips curve for the U.S. Particularly noteworthy is the very high t-value for the coefficient for the P_t variable: it appears that the rate of change of the CPI is a *very* important determinant of the rate of change of money wages.

To ascertain empirically whether a simultaneity (feedback) may exist between W_t and P_t, we next estimate the following systems by TSLS:

$$W_t = b_0 + b_1 P_t + b_2 U_t + b_3 \pi_t + b_4 \quad (14)$$

and

$$P_t = c_0 + c_1 W_t + c_2 U_t + c_3 V_t + c_4 \quad (15)$$

where b_0 and c_0 are constants, b_4 and c_4 are error terms, and V_t is the percentage rate of increase in manufacturing productivity per man hour

(5) The expected signs on the partials in (11), based on « conventional wisdom », are

$$\frac{\partial W_t}{\partial P_t} > 0, \quad \frac{\partial W_t}{\partial U_t} < 0, \quad \frac{\partial W_t}{\partial \pi_t} > 0 .$$

in year t. The V_t data were obtained from the *Economic Report of the President, 1976* (1976, Table B-31).

The empirical results are given by

$$(16) \quad W_t = -3.01768 + \underset{(2.05)}{0.53499}\, P_t - \underset{(1.81)}{0.38765}\, U_t + \underset{(1.29)}{0.27331}\, \pi_t ,$$

$$R^2 = .51, \qquad DF = 21, \qquad F = 4.50374$$

and

$$(17) \quad P_t = -73.57729 + \underset{(5.02)}{1.51408}\, W_t - \underset{(3.85)}{4.63777}\, U_t - \underset{(2.01)}{0.39674}\, V_t ,$$

$$R^2 = .49, \qquad DF = 21, \qquad F = 11.85994$$

where terms in parentheses are t-values (6).

Observing the results in both (16) and (17), there appears to be a significant simultaneity between W_t and P_t; as already mentioned, this is a fact not ordinarily allowed for in Phillips curve studies. The effects (implications) of the simultaneity in terms of the Phillips curve relation per se can be readily seen by contrasting the results of wage equations (13) and (16). Obviously, when the simultaneity between W_t and P_t is allowed for, as in (16), this has a profound effect on the alleged impact of P_t, U_t, and π_t on W_t. In particular, the profit variable becomes statistically insignificant (at normally accepted levels), and the t-value for the unemployment variable falls to less than half of its value in the single-equation model (from 3.82 to 1.81). Even more impressive is the enormous fall in the t-value for P_t. In equation (13) it had a *very* high value, 8.11, whereas its value declined dramatically in wage equation (16), to 2.05.

Thus, using annual data within a two-equation model (unlagged), estimation by TSLS reveals an apparent strong simultaneity between the rate of change of money wages and the rate of change of prices. As inspection of the results in (13) vis-á-vis those in (15)-(16) indicates, allowing for this simultaneity dramatically alters the wage-equation results; in fact, in all cases, the t-values in the wage equation fall enormously. Clearly, the single-equation OLS estimate yields biased and inconsistent estimators. Finally, the extremely large t-value for the W_t coefficient in (16) may suggest the presence of wage-push inflation in the U.S. economy over this 1950-1974 period.

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(6) $DW = 1.43165$.

IV. - *A Lagged Model*

In this empirical section, the single-equation regression to be estimated has time lags built into the unemployment and profit variables; the linear regression equation to be estimated is

$$W_t = d_0 + d_1 P_t + d_2 U_{t-1} + d_3 \pi_{t-1} + d_4 \tag{18}$$

where d_0 is a constant and d_4 is a stochastic error term.

Estimating (18) by OLS yields

$$\underset{}{W_t} = 8.34165 + \underset{(7.88)}{0.51211\, P_t} - \underset{(2.71)}{0.45063\, U_{t-1}} + \underset{(1.99)}{0.26171\, \pi_{t-1}} \tag{19}$$

$$R^2 = .72, \qquad DF = 21, \qquad F = 17.91956, \qquad DW = 1.54099$$

where terms in parentheses are t-values.

The results in (19) appear to be very good. All of the independent variables had the expected sign and were highly significant (especially the rate of change of the price level). Overall, the results seem to imply that the rate of change of money wages was strongly influenced by the rate of change of the price level, unemployment in the previous period (year), and previous-period (year) profits.

Now, it remains to be seen whether these same conclusions would follow in a system which allows for the possible simultaneity between W_t and P_t. The two-equation model to be estimated by TSLS is now given by

$$W_t = e_0 + e_1 P_t + e_2 U_{t-1} + e_3 \pi_{t-1} + e_4 \tag{20}$$

and

$$P_t = f_0 + f_1 W_t + f_2 U_{t-1} + f_3 V_{t-1} + f_4 \tag{21}$$

where e_0 and f_0 are constants and e_4 and f_4 are error terms. Obviously, in this case the productivity variable has been lagged one period.

The results from estimating system (20)-(21) are

$$W_t = 2.16322 + \underset{(0.98)}{0.46210\, P_t} - \underset{(1.99)}{0.58439\, U_{t-1}} + \underset{(1.66)}{0.30609\, \pi_{t-1}} \tag{22}$$

$$R^2 = .21, \qquad DF = 21, \qquad F = 2.75726$$

and

$$(23) \qquad P_t = -37.30648 + \underset{(4.85)}{1.33391\, W_t} - \underset{(4.15)}{3.45578\, U_{t-1}} - \underset{(2.90)}{0.54044\, V_{t-1}}$$

$$R^2 = .53, \qquad DF = 21, \qquad F = 18.00909$$

where terms in parentheses are t-values (7).

Contrasting the results estimated by OLS in (19) with those estimated by TSLS in equations (22)-(23) reveals some striking differences. The issue of prime concern here is that of the wage equation; therefore, the focus primarily is on equation (19) vis-á-vis equation (22).

Clearly, the t-values in equation (22) are distinctly lower for all of the estimated coefficients (i.e., those for P_t, U_{t-1}, and π_{t-1}). Although the t-values for the profits and unemployment variables fell perceptibly, the decline in the t-value for the price variable by far was the most dramatic. In particular, the price variable was significant in the single-equation model at *far* beyond the one per cent level, whereas it was insignificant in the two-equation system at even the ten per cent level. Moreover, in equation (23), the wage variable (W_t) is significant at well beyond the one per cent level, a result (again) suggestive of wage-push inflation. Finally, the F-ratio in (22) was *far* below that in (19). Thus, after allowing for the possible simultaneity between W_t and P_t, we derive *very* different conclusions regarding the nature of the Phillips curve relation (8).

In conclusion, then, it appears that in order to gain valid and meaningful insight into the determinants of the rate of change of money wages, it may be necessary to adopt the simultaneous-equations approach and to estimate by TSLS. As shown in this section, the single-equation estimation by OLS implied, among other things, that the price variable *very* significantly affected the rate of change of money wages; however, in the model which allowed for simultaneity between W_t and P_t, this was shown to be clearly untrue. Thus, single-equation estimates of the Phillips curve, which ignore any possible simultaneity between the rate of change of money wages and the rate of change of prices, yield biased and inconsistent estimators and hence very misleading and irrelevant empirical results (9).

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(7) $DW = 1.62371$.

(8) TSLS estimation of a two-equation system such as (20)-(21), except with the productivity variable in (21) unlagged yields essentially the same results as in (22)-(23).

(9) Upon written request, the author will supply all data in an organized tabular form.

V. - *Conclusion*

This paper has questioned the use of single-equation estimates so common in the analysis of the Phillips curve relation. The analysis in Section II and the empirical results in both Sections III and IV suggest that further research on the Phillips curve relation should consider the merits of using simultaneous-equations models and estimating by TSLS. Failure to allow for possible simultaneity problems, such as might (appear to) exist between W_t and P_t, may result in empirical results and subsequent policy statements which have very questionable validity and relevance. Given the importance of Phillips curve research for policy, the methodological issue at hand clearly warrants, indeed *requires*, further examination.

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