

THE DETERMINATION OF AGGREGATE PRICE CHANGES

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The large increase in prices in the United States during 1968 and 1969 has produced a valuable new set of observations to be analyzed. Not since the Korean War have prices risen as fast as they did in 1969. Two important questions are how well these price increases can be explained by econometric equations and whether any new information on price determination can be gleaned from these observations. Of particular interest is whether the recent data confirm or refute the view of Friedman (1968) that the short-run Phillips curve is not stable and will continually shift upward when the unemployment rate is below the "natural rate". In this paper an attempt is made to analyze these questions by specifying and estimating a model of aggregate price determination. The model is part of a larger forecasting model which has been developed by the author and which is described in Fair (1969a) and (1969b).

In most macro-economic models the expenditure equations are in real terms, prices are determined in the wage-price sector by various cost and excess demand variables, and money expenditures are determined by multiplying the real expenditures by their respective prices. In most of these models the

wage-price sector has tended to be a large source of error.¹ The simultaneous and lagged relationships in the wage-price sector make the sector difficult to specify and estimate with precision, and in simulation the possibilities for error compounding in the sector are generally quite large. The model of price determination developed in this paper avoids the whole wage-price nexus and essentially takes prices as being determined by current and past aggregate demand pressures. The price equation of the model can thus be considered to be a reduced form equation of a more general wage-price model. The equation is also similar to simple Phillips curve equations, where wage changes (or price changes) are taken to be a function of excess supply (as approximated by the unemployment rate) in the labor market. A secondary purpose of this paper is to explain how the price equation of the model is used in the larger forecasting model referred to above in place of a more detailed wage-price sector to provide a link between money and real GNP.

Potential output plays an important role in the model, and the concept and measurement of potential output will be discussed in Section I. The model is discussed in Section II, and the results of estimating the model under various assumptions are presented in Section III. The paper concludes in Section

¹See, for example, Fromm and Taubman (1968, p. 11) for a discussion of the limited success so far achieved by the Brookings model in this area.

III with a discussion of what the results imply about the ability of the model to explain the inflation in 1968 and 1969 and whether the results appear to confirm or refute Friedman's view.

I. THE CONCEPT AND MEASUREMENT OF POTENTIAL OUTPUT

Let Y_t denote the amount of output produced during period t , M_t the number of workers employed during period t , H_t^M the number of hours worked per worker during period t , K_t the stock of capital (machines) in existence during period t , and H_t^K the number of hours each machine is utilized during period t . Y_t and M_t , H_t^M , K_t and H_t^K are assumed to be related by the following production function:

$$(1) \quad Y_t = f(M_t H_t^M, K_t H_t^K),$$

where $M_t H_t^M$ is the total number of man hours worked during period t and $K_t H_t^K$ is the total number of machine hours used during period t .

"Potential output" is defined in this study to be that level of output which results from equation (1) when the "potential" values of M_t , H_t^M , K_t , and H_t^K are used in the equation. The "potential" values of M_t , H_t^M , K_t , and H_t^K will

be derived below, but essentially they are the values of the variables which would occur at a 4 per cent unemployment rate. "Potential output" is thus not meant to connote "maximum output". Output greater than "potential" could always be produced by using greater than "potential" values of M_t , H_t^M , K_t and H_t^K . "Potential output" is rather meant to refer to that level of output which is capable of being produced by working people and machines at rates which have been observed to occur during periods when the unemployment rate was 4 percent.

The measurement of potential output in this study is based on a model of the employment sector which is described in Fair (1969b). The production function (1) is assumed to be characterized by a) no short-run substitution possibilities between workers and machines and b) constant short-run returns to scale both with respect to changes in the number of workers and machines used and with respect to changes in the number of hours worked per worker and machine per period. Because of assumptions a) and b), the number of hours worked per worker, H_t^M , is equal to the number of hours worked per machine, H_t^K . Denote this common number of hours worked per worker and machine as H_t . Then the production function is taken to be:

$$(2) \quad Y_t = \min\{\alpha_t M_t H_t, \beta_t K_t H_t\},$$

where α_t and β_t are coefficients which may be changing

through time as a result of technical progress. Implicit is the definition of H_t and the other assumptions above is the assumption that $\alpha_t M_t H_t$ equals $\beta_t K_t H_t$ in (2), so that (2) implies²

$$(3) \quad Y_t = \alpha_t M_t H_t \quad .$$

Let HP_t denote the (observed) number of hours paid-for per worker during period t . It is argued in Fair (1969b), and more extensively in Fair (1969c), that HP_t is not likely to be equal to the (unobserved) number of hours worked per worker, H_t , except during peak output periods. If this is true, then direct estimates of α_t in (3) cannot be made, since $M_t H_t$ is not observed. What can be observed is output per paid-for man hour, $Y_t/M_t HP_t$ and this is plotted quarterly in Figure 1 for the 471-694 period.³ The dotted lines in the figure are peak to peak interpolation lines of the series.

The assumption is made that at each of the interpolation peaks in Figure 1 $Y_t/M_t HP_t$ equals $Y_t/M_t H_t$, i.e., that output

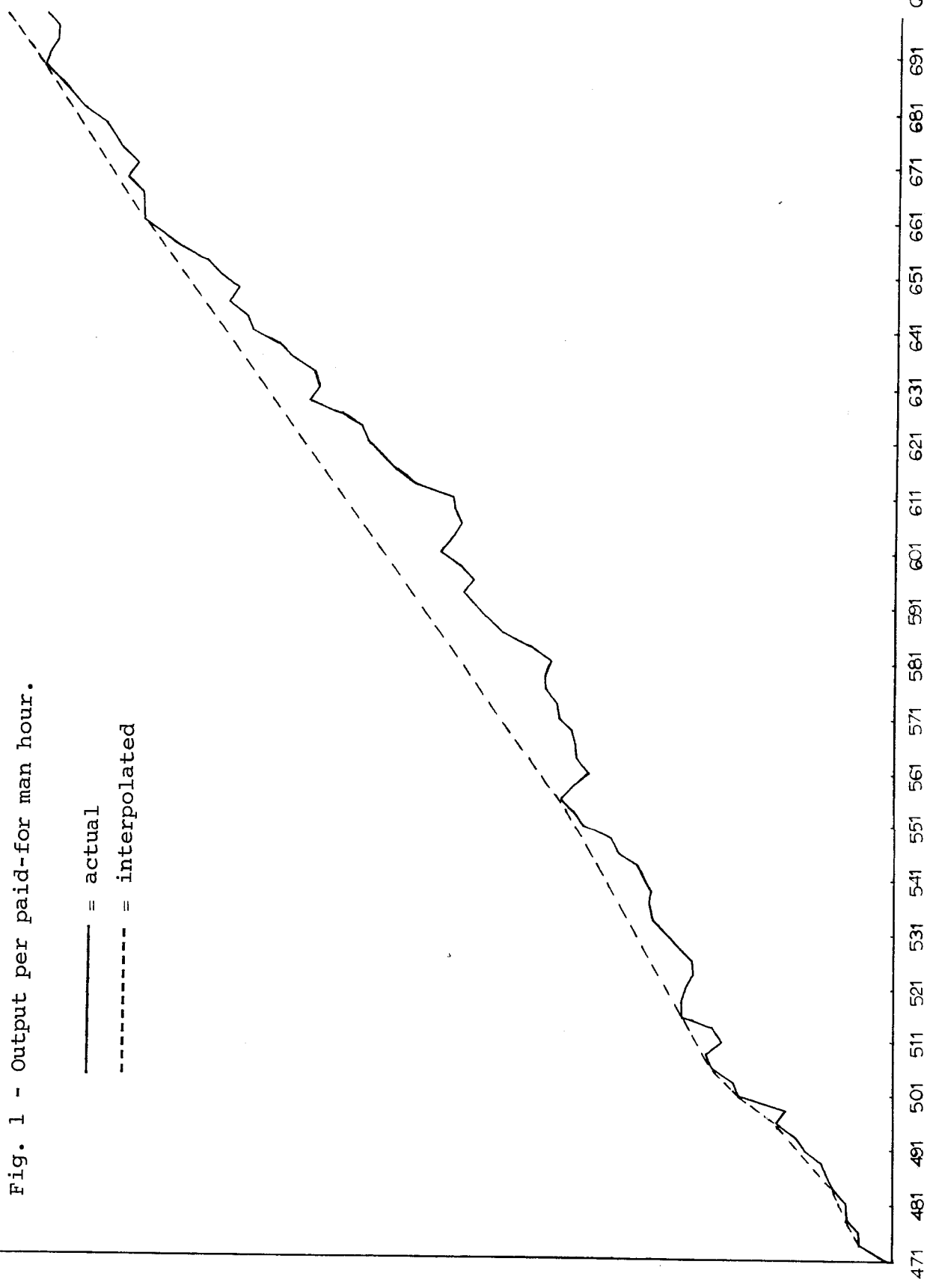
²The derivation of this particular production function is explained in more detail in Fair (1969c, Chapter 3).

³The data on Y_t , M_t , and HP_t are seasonally adjusted quarterly data for the private nonfarm sector compiled by the Bureau of Labor Statistics (BLS). The data were obtained directly from the BLS (in non-index number form), although data on Y_t , HP_t , and $Y_t/M_t HP_t$ are currently published in index number form in the Monthly Labor Review, Table 32. Because seasonally adjusted data are used (the data are not available on a seasonally unadjusted basis), the above "production function" should be interpreted somewhat loosely. See Fair (1969b) for a more complete discussion of this point.

$$\frac{Y_t}{M_t H P_t}$$

Fig. 1 - Output per paid-for man hour.

— = actual
- - - = interpolated



per paid-for man hour equals output per worked man hour. From (3) this provides an estimate of α_t to be made at each of the peaks. The further assumption is then made that α_t moves smoothly through time along the interpolation lines, which provides an estimate of α_t to be made for each quarter of the sample period.⁴

The first step in the construction of a potential output series has thus been to estimate values of the production function parameter α_t . The next step is to develop equations which can be used to construct a potential man-hours series. It should first be noted, however, that while the potential output series which needs to be constructed is the potential GNP series, the output and employment data used to estimate α_t refer only to the private nonfarm sector (see footnote 3). Consequently, the government and agricultural sectors have had to be considered separately in the calculations below. Also, the employment data used in the estimation of α_t are based primarily on establishment data, as opposed to the household survey data which are used to estimate the size of the labor force and the unemployment

⁴The 661-684 line was extrapolated to get the 691, 692, 693, and 694 values for α_t . The choice of the peaks in Figure 1 is, of course, somewhat arbitrary, although the results below were not very sensitive to the choice of slightly different peaks. The 601 and 624 "peaks" were not used as interpolation peaks because demand was still relatively weak during these periods and it seemed likely that output per paid-for man hour was still below output per worked man hour during 601 and 624.

rate. Since data on the labor force are used below, a link has thus had to be found between the establishment data and the household survey data.

Let MA_t denote the number of agricultural workers employed, MCG_t the number of civilian government workers employed, and E_t the total number of civilian workers employed according to the household survey. They D_t is defined to be

$$(4) \quad D_t = M_t + MA_t + MCG_t - E_t .$$

D_t is positive and consists in large part of people who hold more than one job. (The establishment series are on a job number basis and the household survey series are on a person employed basis.) D_t appears to respond to labor market conditions, and the following equation was estimated for the 482-694 period under the assumption of first order serial correlation of the error terms.⁵

$$(4) \quad D_t = -12982 - 62.54t + .347M_t, \quad \hat{\rho} = .699, \quad SE = 226.1, \\ (7.21) \quad (6.47) \quad (8.73) \\ R^2 = .910, \\ 87 \text{ obs.}$$

⁵t-statistics (in absolute values) are in parentheses. $\hat{\rho}$ is the estimate of the first order serial correlation coefficient. The R^2 is calculated taking the dependent variable in "untransformed" form. The equation was estimated by the Cochrane-Orcutt iterative technique.

P_{2t} the non-institutional population of all others over 16. (All four variables include people in the armed forces.) AF_t denotes the number of people in the armed forces, and t is a time trend. Equations (6) and (7) are relatively standard kinds of labor force participation equations. In (6) the participation of primary workers is estimated as slowly falling over time, and in (7) the participation of secondary workers is estimated as responding to labor market conditions as measured by the ratio of total employment to working age population.

Let YA_t denote agricultural output during period t and let YG_t denote government output during period t . Then by definition real GNP during period t (denoted below as $GNPR_t$) is equal to $Y_t + YA_t + YG_t$. With respect to the government sector, government output and the number of government workers employed (both civilian, MCG_t , and non-civilian, AF_t) were taken to be exogenous, i.e., the potential values for these series were taken to be equal to the actual values. Likewise, P_{1t} and P_{2t} were taken to be exogenous. The agricultural sector, on the other hand, was not taken to be exogenous. Rather, potential agricultural output and the potential number of agricultural workers employed were derived in the following manner. YA_t was first plotted for the 471-694 period, and the series was interpolated peak to peak. The interpolated series was then taken as the potential agricultural output

series (denoted as YA_t^*). Agricultural output per worker, YA_t/MA_t , was next plotted for the 471-694 period, and a peak to peak interpolation of this series was made (denoted as PA_t^*). Finally, YA_t^* was divided by PA_t^* to yield a series on the potential number of agricultural workers employed (denoted as MA_t^*). Fortunately, the agricultural sector is small enough relative to the total economy so that the measurement of total potential output is not very sensitive to how the agricultural sector is treated. The treatment in this study has the advantage of smoothing out the erratic fluctuations which occur in the YA_t and MA_t series, many of which are undoubtedly due to measurement of error.⁷

The final step which is necessary before the potential GNP series can be calculated is to derive a series for the potential number of hours worked per private, nonfarm worker (to be denoted as H_t^*). This was done by regressing hours paid-for per worker on a constant and time and taking the predicted values from this equation as values of H_t^* .⁸ The estimation of the production function parameter α_t above

⁷See President's Committee to Appraise Employment and Unemployment Statistics (1962, pp. 123-129) for a discussion of the lack of quality of most of the agricultural data.

⁸The equation, estimated for the 471-694 period, was:

$$HP_t = \begin{matrix} 41.05 \\ (855.87) \end{matrix} - \begin{matrix} .032t \\ (35.77) \end{matrix}, \quad SE = .23$$

TABLE 1

Estimates of Potential Real GNP (Billions of 1958 Dollars)

Quarter	GNPR _t	GNPR _t *	$\frac{4}{\text{GNPR}_{t-1}^*} \frac{\Delta \text{GNPR}_t^*}{\text{GNPR}_{t-1}^*}$	Quarter	GNPR _t	GNPR _t *	$\frac{4}{\text{GNPR}_{t-1}^*} \frac{\Delta \text{GNPR}_t^*}{\text{GNPR}_{t-1}^*}$
541	402.9	426.5	.037	621	519.5	567.3	.026
542	402.1	430.0	.033	622	527.7	572.3	.035
543	407.2	433.3	.030	623	533.4	578.4	.043
544	415.7	437.0	.034	624	538.3	584.8	.044
551	428.0	441.0	.037	631	541.2	591.7	.047
552	435.4	445.0	.036	632	546.0	597.9	.042
553	442.1	449.4	.039	633	554.7	603.4	.037
554	446.4	453.3	.035	634	562.1	608.0	.031
561	443.6	456.8	.031	641	571.1	614.3	.041
562	445.6	460.4	.031	642	578.6	619.8	.036
563	444.5	464.7	.037	643	578.6	619.8	.036
564	450.3	468.3	.031	644	585.8	625.9	.039
571	453.4	471.9	.030	651	588.5	630.9	.032
572	453.2	475.9	.034	652	601.6	636.7	.037
573	455.2	480.8	.041	653	610.4	642.4	.036
574	448.2	486.0	.043	654	622.5	646.8	.028
581	437.5	490.5	.037	661	636.6	651.4	.028
582	439.5	494.6	.033	662	649.1	654.7	.020
583	450.7	498.5	.032	663	649.1	654.7	.020
584	461.6	503.5	.040	666	655.0	658.1	.021
591	468.6	507.7	.033	667	660.2	662.3	.026
592	479.9	512.8	.040	668	668.1	666.1	.023
593	475.0	517.7	.038	671	666.5	671.4	.032
594	480.4	521.7	.031	672	670.5	676.8	.032
601	490.2	529.8	.062	673	678.0	684.3	.045
602	489.7	534.6	.036	674	683.5	690.4	.035
603	487.3	539.2	.034	681	693.3	696.1	.033
604	483.7	544.7	.041	682	705.8	701.7	.032
611	482.6	550.2	.041	683	712.8	708.1	.036
612	492.8	555.3	.037	684	718.5	714.4	.036
613	501.5	560.2	.035	691	723.1	721.4	.039
614	511.7	563.6	.024	692	726.7	727.6	.034
				693	730.6	735.2	.042
				694	729.8	742.0	.037

is based on the assumption that hours paid-for per worker are greater than hours worked per worker except during peak output periods, and thus it does not seem unreasonable to take the potential number of hours worked per worker to be equal to the trend number of hours paid-for per worker. Consistent with the derivation which follows, one also might use an interpolation of the hours paid-for per worker series as the series for H_t^* , where the benchmark quarters were chosen as those quarters in which the unemployment rate was approximately 4 per cent. The value of hours paid-for during quarters in which the unemployment rate was approximately 4 per cent showed no apparent consistency, however, -- the value was sometimes below trend and sometimes above trend -- and this idea was thus dropped from further consideration.

From the above equations and assumptions potential output was computed as follows. In equation (7) $(E_t + AF_t)/(P_{1t} + P_{2t})$ was set equal to .586 (the approximate value reached during periods when the unemployment rate was 4 percent) for all t . Using this value and ignoring the serial correlation of the error terms, the potential labor force of primary and secondary workers (denoted as $LF_{1t}^* + LF_{2t}^*$) was calculated from (6) and (7) for all t . The potential civilian labor force was then calculated as $LF_{1t}^* + LF_{2t}^* - AF_t$. Potential civilian (household

survey) employment (denoted as E_t^*) was next calculated as $.96 (LF_{1t}^* + LF_{2t}^* - AF_t)$, where $.96$ is the employment rate corresponding to a 4 percent unemployment rate. Given E_t^* and MA_t^* as computed above and taking MCG_t to be exogenous, potential, private, nonfarm employment (denoted as M_t^*) was calculated using equations (4) and (5).⁹ M_t^* was next multiplied by H_t^* as constructed above to yield an estimate of potential, private, nonfarm man hours, which from the production function (3) and the estimates of α_t allowed an estimate of potential, private, nonfarm output (denoted as Y_t^*) to be made. Finally, potential real GNP (denoted as $GNPR_t^*$) was calculated as $Y_t^* + YA_t^* + YG_t$.

In Table 1 the actual values of $GNPR_t$, the estimated values of $GNPR_t^*$, and the percentage changes in $GNPR_t^*$ (at annual rates) are presented quarterly for the 541-694 period. Note that $GNPR_t^*$ grew less than average during late 1965 and 1966. This was due primarily to the Vietnam troop buildup during this period. As measured by the national income accounts average output per government worker is less than average output per private worker, so that the movement of workers from

⁹For these calculations the serial correlation of the error terms in equation (5) was ignored. The equation for D_t in (5) can be substituted into (4), and the resulting equation can be solved for M_t in terms of MA_t , MCG_t , and E_t . This was the equation which was then used to compute M_t^* , given values for MA_t^* , MCG_t , and E_t^* .

private to government work (as when the level of the armed forces is increased) has a negative effect on total potential output. In general, the $GNPR_t^*$ series in Table 1 is fairly smooth, but it is by no means as smooth as a simple trend measure like that of the Council of Economic Advisors (CEA).

The measurement of potential output in this study differs from that of Black and Russell (1969) in two basic respects. First, the man-hours series used in this study covers only the private, nonfarm sector, whereas Black and Russell derive a series for the total economy including the armed forces. The private, nonfarm man-hours and output series are of greater reliability than the series for the total economy, and this is the reason why only the private, nonfarm data were used to derive the above estimates of "potential productivity". The second way the measurement of potential output in this study differs from that of Black and Russell is that the above estimates of potential productivity are based on the idea that the number of hours paid-for per worker does not equal the number of hours actually worked per worker except during peak output periods. Black and Russell do not distinguish between these two concepts and attempt to estimate the parameters of their "production function" directly. The defense of the idea that hours paid-for do not equal hours worked is made in Fair (1969c) and will not be repeated here.

This completes the discussion of potential output. In the work below two measures of potential output were tried: the measure presented in Table 1 and the CEA measure.¹⁰ The results of using these two measures will be presented in Section III.

II. THE MODEL OF PRICE DETERMINATION

The theory behind the present model is simple. Aggregate price changes are assumed to be a function of current and past demand pressures. Current demand pressures have an obvious effect on current prices. If current demand is strong relative to the available supply, prices are likely to be bid (or set) higher, and if current demand is weak relative to the available supply, prices are likely to be bid (or set) lower.

There are two ways in which past demand pressures can affect current prices. One way is through the lagged response of individuals or firms to various economic stimuli. It may take a few quarters for some individuals or firms to change their prices as a result of changing demand conditions. This may, of course, not be irrational behavior, since people may want to determine whether a changed demand situation is likely

¹⁰The potential GNP measure of the CEA grows at 3.5 percent from 552 through 624, at 3.75 percent from 631 through 654, and at 4.0 percent from 661 through 694.

to be temporary or permanent before responding to it. The other way in which past demand pressures can affect current prices is through input prices. If, for example, past demand pressures have caused past input prices to rise, this should lead to higher current output prices, as higher production costs are passed on to the customer. The lag in this case is the time taken for higher input prices to lead to higher costs of production¹¹ and for higher costs of production to lead to higher output prices. It may also take time for input prices to respond to demand pressures, which will further lengthen the lag between demand pressures and output prices.

Note that nothing specifically has been said about wage rates. In the present model, labor is treated like any other input -- demand pressures are assumed to lead (usually with a lag) to higher wage rates, which then lead (perhaps with a lag) to higher output prices. The present approach avoids the problem of having to determine unit labor costs or wage rates before prices can be determined.

The first question which arises in specifying the model is what measure of demand pressure should be used. Two measures, denoted as $GAP1_t$ and $GAP2_t$ respectively, were considered in this study:

¹¹Since firms stockpile various inputs, this lag is not necessarily zero.

$$(8) \quad \text{GAP1}_t = \text{GNPR}_t^* - \text{GNPR}_t ,$$

$$(9) \quad \text{GAP2}_t = \text{GNPR}_t^* - \text{GNPR}_{t-1} - (\text{GNP}_t - \text{GNP}_{t-1}) .$$

GNP_t in (9) denotes the level of money (current dollar) GNP during period t . GAP1_t as defined by (8) is the difference between potential and actual real GNP and is a commonly used measure of demand pressure. $\text{GNPR}_t^* - \text{GNPR}_{t-1}$ in (9) is the change in real GNP during period t which would be necessary to make GNPR_t equal to GNPR_t^* ,¹² and $\text{GNP}_t - \text{GNP}_{t-1}$ is the actual change in money GNP during period t . GAP2_t as defined by (9) is thus the difference between the potential real change in GNP and the actual money change. GAP2_t can also be considered to be a measure of demand pressure. If, for example, the potential real change in GNP is quite large, then the money change can be quite large and still lead to little pressure on available supply, but if the potential real change is small, then even a relatively small money change will lead to pressures on supply.

Let GNPD_t denote the GNP deflator for period t . Then by definition GNP_t equals $\text{GNPR}_t \cdot \text{GNPD}_t$, or GNPR_t equals $\text{GNP}_t / \text{GNPD}_t$. GNPD_t is taken to be endogenous, and whether GAP1_t or GAP2_t is used as the measure of demand pressure in the equation determining GNPD_t depends to some extent on

¹²This change will be referred to as the "potential real change in GNP."

TABLE 2

Values of PD_t , $PD_t - PD_{t-1}$, and $GAP2_t$

Quarter	PD_t	$PD_t - PD_{t-1}$	$GAP2_t$	Quarter	PD_t	$PD_t - PD_{t-1}$	$GAP2_t$
561	93.15	.94	8.6	631	105.38	.30	48.0
562	93.97	.82	11.2	632	105.70	.31	49.9
563	95.14	1.17	14.7	633	105.88	.18	46.9
564	95.89	.75	14.9	634	106.23	.34	42.2
571	96.87	.98	14.2	641	106.47	.24	40.2
572	97.52	.65	19.5	642	106.82	.35	38.4
573	98.45	.93	21.2	643	107.21	.40	36.4
574	98.82	.37	35.6	644	107.70	.49	38.9
581	99.52	.70	49.1	651	108.24	.54	30.5
582	99.77	.25	53.5	652	108.77	.52	27.9
583	100.07	.30	45.9	653	108.96	.19	21.0
584	100.48	.40	39.8	654	109.30	.35	10.0
591	100.99	.51	36.5	661	110.08	.78	- 1.4
592	101.23	.25	31.3	662	111.15	1.07	- 4.8
593	101.64	.41	40.7	663	112.03	.88	- 5.3
594	101.78	.14	40.2	664	112.91	.88	- 8.9
601	102.24	.46	36.9	671	113.52	.60	- .2
602	102.67	.43	42.7	672	114.09	.58	1.0
603	102.84	.17	50.0	673	115.21	1.12	- 3.1
604	103.34	.50	58.3	674	116.26	1.05	- 3.3
611	103.58	.24	66.2	681	117.24	.98	- 6.6
612	103.61	.03	61.4	682	118.39	1.15	-15.0
613	103.59	-.02	58.1	683	119.41	1.03	-15.4
614	104.10	.51	48.6	684	120.61	1.20	-14.5
621	104.44	.34	45.5	691	122.02	1.41	-13.3
622	104.58	.14	43.4	693	123.57	1.55	-11.6
623	104.79	.22	43.5	693	124.98	1.41	- 9.5
624	105.09	.30	43.8	694	126.34	1.36	2.0

whether $GNPR_t$ is taken to be endogenous, with GNP_t being treated as the "residual", or whether GNP_t is taken to be endogenous, with $GNPR_t$ being treated as the "residual". In the forecasting model developed in Fair (1969a), for example, the expenditure equations are in money terms and money GNP is endogenous. In this model it would not be appropriate to use $GAP1_t$ in the equation determining $GNPD_t$, since the $GNPR_t$ part of $GAP1_t$ is determined as $GNP_t/GNPD_t$ (i.e., as the residual) and thus $GNPD_t$ enters on both sides of the equation. It would be appropriate to use $GAP2_t$, however, as long as it could be assumed that the variables and error terms which determine GNP_t in the model are independent of the error term in the equation determining $GNPD_t$. Conversely, for models in which $GNPR_t$ is endogenous and is determined by variables and error terms which are independent of the error term in the equation determining $GNPD_t$, it would be appropriate to use $GAP1_t$ in the equation, but not $GAP2_t$.

In most macro-economic models of any size, of course, $GNPD_t$, GNP_t , and $GNPR_t$ are all endogenous in that they are all determined within a simultaneous system of equations. No one variable can be considered to be determined simply as the ratio of product of the other two. Since in most of these models the expenditure equations are in real terms, however, it is probably true that GNP_t is closer to being the residual variable in these

models than is $GNPR_t$. Whether a given expenditure equation in a model should be specified in real or money terms depends on whether the people doing the spending take money income and other money variables as given and determined how much money to spend as a function of these variables, or whether they deflate money income and the other money variables by some price level and determine how many goods to purchase as a function of these "real" variables. In the first case the number of goods purchased is the residual variable (people spend a given amount of money, and real expenditures are determined merely as money expenditures divided by the price level), and in the second case the money value of goods purchased is the residual variable (people purchase a given number of goods, and money expenditures are determined merely as real expenditures times the price level). In the long run it seems clear that real expenditures are determined by real variables, as standard economic theory suggests, but in the short run the case is not so clear. Given the uncertainty which exists in the short run and the lags involved in the collection and interpretation of information on price changes, people may behave in the short run in a way which is closer to the first case described above than it is to the second.

An argument can thus be made for specifying expenditure equations in short-run models in money terms, although even for short-run models it may be the case that some equations should be specified in real terms. It may also be the case that consumption expenditure equations should be specified in the manner suggested by Branson and Klevorick (1969) to incorporate money illusion directly. Whatever the case, for most of the work below $GAP2_t$ has been used as the excess demand variable, on the assumption that in the short run real GNP is closer to being the residual variable than is money GNP, but some results using $GAP1_t$ will also be presented.

The price deflator which has been used for the estimates below is actually not the GNP deflator (denoted above as $GNPD_t$), but is the private output deflator (denoted as PD_t). Because of the way the government sector is treated in the national income accounts, $GNPD_t$ is influenced rather significantly by government pay increases, such as those that occurred in 683 and 693, and PD_t is likely to be a better measure of the aggregate price level.¹³ In Table 2 values of PD_t , $PD_t - PD_{t-1}$,

¹³The fact that the private output deflator is used as the price variable might imply that the demand pressure variables should be net of government output. Note from equation (8) that $GAP1_t$ is net of government output, since government output (denoted above as YG_t) is included in both $GNPR_t^*$ and $GNPR_t$. It can be seen from equation (9), however, that $GAP2_t$ is not net of government output. When, for example, a government pay increase occurs, government output in money terms is increased by this amount (and thus GNP_t is increased), but government

cont.

TABLE 3

Parameter Estimates of Equation (10) Under Various Assumptions

	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	SE	R ²	DW	681	682	683	684	691	692	693	694
(a) n = 8														
(b) n = 8, values of GNP _t * from CEA	-1.16 (1.39)	200.9 (1.11)	91.1 (1.91)	.179	.803	1.78	0.98	1.15	1.03	1.20	1.41	1.55	1.41	1.36
(c) n = 8, GAP1 used instead of GAP2	-1.55 (1.01)	253.4 (0.72)	107.5 (1.38)	.196	.764	1.49	1.14	1.17	1.21	1.23	1.28	1.32	1.35	1.33
(d) n = 4														
(e) n = 8, sample period 561-674														
Actual Values of PD - PD _{t-1}														
(a)	-1.16 (1.39)	200.9 (1.11)	91.1 (1.91)	.179	.803	1.78	0.98	1.15	1.03	1.20	1.41	1.55	1.41	1.36
(b)	-1.55 (1.01)	253.4 (0.72)	107.5 (1.38)	.196	.764	1.49	1.14	1.17	1.21	1.23	1.28	1.32	1.35	1.33
(c)	-.55 (1.34)	75.3 (1.47)	40.6 (2.04)	.182	.797	1.76	1.13	1.14	1.15	1.15	1.18	1.21	1.22	1.19
(d)	-1.30 (1.25)	252.1 (0.94)	110.8 (1.68)	.182	.796	1.71	1.15	1.19	1.22	1.23	1.27	1.30	1.31	1.28
(e)	-12.09 (0.14)	10991.5 (0.07)	841.5 (0.14)	.184	.652	1.90	1.03	1.03	1.07	1.08	1.11	1.13	1.15	1.14

(t-statistics in absolute values are in parentheses)

and $GAP2_t$ are presented quarterly for the 561-694 period.¹⁴ Notice that $GAP2_t$ was quite large during the early 60's when there was little increase in the aggregate price level, and that it was much smaller (and in fact negative) during the late 60's when the price level was increasing quite rapidly. (Low values of $GAP2_t$ correspond to periods of high demand pressure.)

The basic equation explaining the change in the deflator has been taken to be:

$$(10) \quad PD_t - PD_{t-1} = \alpha_0 + \alpha_1 \left(\frac{1}{\alpha_2 + \frac{1}{n} \sum_{i=1}^n GAP2_{t-i+1}} \right) + \epsilon_t,$$

where ϵ_t is the error term and n is the number of periods over which lagged values of $GAP2_t$ have an influence on the current change in the deflator. $\frac{1}{n} \sum_{i=1}^n GAP2_{t-i+1}$ is the simple n -quarter moving average of $GAP2$. Equation (10) is consistent with the theory expounded above. The current change in the price level is taken to be a function of current and past demand pressures as measured by the n -quarter moving average of $GAP2$. A non-linear functional form has been chosen, the functional form being similar to that used in studies of the

output in real terms is not affected (and thus $GNPR_t^*$ is not affected). A government pay increase thus has a negative effect on $GAP2_t$. For the work below, government output was not netted from $GAP2_t$, since it seemed reasonable to suppose that government pay increases and the like have a positive effect on the excess demand status of the private output market. In practice, however, using $GAP2_t$ net of government output produced results almost identical to those reported below using $GAP2_t$ directly.

¹⁴ PD_t is taken to be in units of 100, rather than in units of 1.

Phillips curve, where the reciprocal of the unemployment rate is most often used as the explanatory variable.

Equation (10) is non-linear in α_2 and must be estimated by a non-linear technique. In studies of the Phillips curve where the reciprocal of the unemployment rate is taken to be the explanatory variable a coefficient like α_2 in (10) does not arise, since it is assumed that as the unemployment rate (excess supply) approaches zero the change in wages (or prices) approaches infinity. In the present case, no such assumption can be made. $GAP2_t$ is a simple and highly aggregative measure of demand pressure, and there is no reason why zero values of $GAP2_t$ should correspond to infinite changes in PD_t . Indeed, $GAP2_t$ has actually been negative during part of the sample period, as can be seen from Table 2. Even $GAP1_t$ (potential minus actual real GNP) has been negative during part of the sample period, and again there is no reason to think that a zero or slightly negative gap between potential and actual real GNP should result in an infinite change in the price level. Remember that potential GNP is not meant to refer to maximum GNP, but to that GNP level which is capable of being produced when the unemployment rate is 4 percent. Including α_2 in equation (10) allows the equation to estimate the value of the moving average variable which would correspond to an infinite rate of change of prices. Another way of looking at this is that including α_2 in equation (10) allows

the excess demand variable in the equation to differ from the "true" measure of excess demand ("true" meaning that zero values of this variable correspond to infinite price changes) by some constant amount and still not bias the estimates of α_0 and α_1 . The error will merely be absorbed in the estimate of α_2 .

Equation (10) has been estimated under a variety of assumptions, and these results will now be presented.

III. THE RESULTS

Equation (10) was estimated for the 561-694 sample period for various values of n .¹⁵ Various weighted averages of the current and past values of $GAP2_t$ were also tried in place of the "equally" weighted average specified in equation (10). The equation finally chosen used the equally weighted average and a value of n of 8 . The results of estimating this equation are presented in line (a) of Table 3. The estimates of α_0 , α_1 and α_2 are fairly collinear, and thus the t-statistics presented in the table are low. When, for example, the value of α_2 was set equal to 91.1 (the estimated value) and equation (10)

¹⁵The equation was estimated by an iterative technique which has been programmed into Princeton's version of the TSP regression package program. The equation to be estimated is first linearized by means of a Taylor series expansion around an initial set of parameter values. Using the linear equation, the difference between the true value and the initial value of each of the parameters is then estimated by ordinary least squares. The procedure is repeated until the estimated difference for each of the parameters is within some prescribed tolerance level. Convergence is not guaranteed using this technique, but for the work in this study achieving convergence was no problem.

estimated by ordinary least squares, the resulting t-statistics for α_0 and α_1 were 9.54 and 14.80 respectively. The fit of the equation is quite good, with a standard error of only .179.¹⁶ The inflation in 1968 was only moderately underpredicted, with errors in the four quarters of .13, .23, .06, and .03 respectively. More will be said about this later.

Equation (10) was also estimated using the CEA estimates of potential GNP, and these results are presented in line (b) of Table 3. The standard error of the equation is .196, which is larger than the standard error in line (a), and the inflation in 1969 was considerably underpredicted by the equation. The results are clearly not as good as those achieved in line (a) using the potential GNP estimates presented in Table 1, which perhaps indicates that the potential GNP series derived in this paper is a better measure of supply constraints than is the trend series of the CEA.

Equation (10) was estimated using GAP1 instead of GAP2 as the demand pressure variable, and these results are presented in line (c) of Table 3. The results are almost as good as those achieved in line (a) using GAP2, but the fit is slightly worse and the inflation in 1969 was not captured as well. The results thus seem to indicate that GAP2 is the better measure of demand pressure, although whether GAP1 or GAP2 should be used in the equation depends to some extent on whether $GNPR_t$ or GNP_t is closer to being determined as the residual variable in the short run.

¹⁶Remember that PD_t is in units of 100.

Equation (10) was estimated for n equal to 4, and these results are presented in line (d) of Table 3. The fit is only slightly worse than the fit in line (a) for n equal to 8, but the inflation in 1969 was not captured nearly as well. As can be seen from Table 2, $GAP2_t$ was negative and large throughout 1968, and only including the current and one-, two-, and three-quarter lagged values of $GAP2$ in the equation is not enough to capture the demand pressure which built up during 1968 and which presumably led to the large price increases in 1969. Going from n equal to 4 to n equal to 8 substantially improved the ability of the equation to explain the inflation in 1969. Also, the equally weighted average worked better in explaining the inflation in 1969 than did various declining weighted averages which were tried. Giving less and less weight to the lagged values of $GAP2_t$ resulted in larger underpredictions in 1969. The fit of the overall regression was about the same (for n equal to 8) regardless of which weighted average was used. Various linear versions of equation (10) were also estimated, and the fit of each of the linear versions was always worse than the fit of the corresponding non-linear version and the inflation in 1969 was always underpredicted more.

Finally, equation (10) was estimated for the shorter 561-674 period and the equation used to predict values for 1968 and 1969 ($GAP2$ continuing to be treated as exogenous). The results are presented in line (e) of Table 3. The coefficient estimates

are much different for the shorter period, although the collinearity among the estimates makes the results look more different than they actually are. More importantly, however, the equation did not extrapolate well into 1969. The inflation in 1969 was substantially underpredicted. It was necessary, in other words, to estimate equation (10) through 1968 and 1969 before it was capable of explaining the inflation in 1969 at all well.

Two arguments can be given for why equation (10) did not do well when it was only estimated through 1967. One is the Friedman argument that an excess demand equation like (10) is not stable over time because the curve continually shifts upward whenever excess demand is above its "natural" level. Assuming that excess demand was above its natural level in 1968 and 1969, one would thus expect from this argument that any attempt to extrapolate the equation into 1968 and 1969 would result in an underprediction of the rate of inflation, which is what happened. The second argument which can be given for why equation (10) did not extrapolate well when it was only estimated through 1967 is a statistical argument. As can be seen in Table 2, the price increases in the four quarters of 1969 were considerably larger than for any other quarter of the sample period, and similarly the values of $\frac{1}{8} \sum_{i=1}^8 \text{GAP2}_{t-i+1}$ were considerably smaller in 1968 and 1969 than for the rest of the sample period. As a

practical matter, one generally cannot expect an equation which has been estimated by least squares to extrapolate well into periods in which the values of the dependent and independent variables are considerably different from what they were during the period of estimation. From this argument, therefore, it is not too surprising that equation (10) did not extrapolate well into 1969 when only estimated through 1967. Notice from line (e) of Table 3 that equation (10) did extrapolate fairly well into 1968 and that it was only for 1969 (for which the values of the dependent and independent variables were considerably different) that the results were poor. Also, a Chow test which was performed rejected the hypothesis that the coefficients of equation (10) were different for the 681-694 period than they were for the 561-674 period.¹⁷

The results in Table 3 are thus consistent with Friedman's view, but they can also be explained by an alternative argument. It should be noted from line (a) of Table 3 that when equation (10) was estimated through 1969, it did a fairly good job of explaining the inflation in 1969. Only in 692

¹⁷The estimated value of the F statistic was 1.29, which compares with a 5 percent value of 2.79 (at 3,50 degrees of freedom). Because of the non-linear nature of equation (10), the use of the Chow test in the present circumstances must be interpreted with some caution.

was the error (of .23) larger than the standard error (of .18) of the regression, and for 693 and 694 the errors were only .06 and .03 respectively. In summary, then, a simple excess demand equation like (10) appears to be capable of explaining most of the inflation of 1969 (in addition to explaining quite well the price changes in the other quarters of the sample period), but because the equation had to be estimated through 1969 in order to accomplish this, the possibility that the equation is not stable over time cannot be ruled out.

Assuming that equation (10) is stable over time, there is still the question as to why it underpredicted the rate of inflation in 1969, especially in the first two quarters of 1969. From the results in line (a) of Table 3, the rate of inflation in the first half of 1969 appears to have been somewhat larger than current and past demand pressures would have warranted. In 1969 a new administration came to power with an avowed hands off policy on wage and price negotiations, and this may have resulted in those corporations with some degree of market power raising their prices in the first half of 1969 more than they otherwise would have. This would then have caused prices to rise faster in the first half of 1969 than would have been predicted from current and past excess demand considerations alone. More refined tests of this hypothesis can be made, however, and this line of argument will not be pursued further in this paper.

The long-run implications of any study of short-run behavior are of questionable validity, but for what they are worth, the long-run implications of the results achieved in this study will be mentioned. When discussing long-run effects it is more convenient to use GAP1 as the measure of excess demand, and so the following analysis will focus on the GAP1 results. First, the results in line (c) of Table 3 imply that holding real GNP continuously at its potential level (GAP1 continuously equal to zero) results in a change in PD_t of 1.30 each quarter ($-.55 + 75.3/40.6 = 1.30$). Using the 694 value of PD_t as a base, this is an annual rate of price increase of 4.1 percent. This is using the potential GNP series corresponding to an unemployment rate of 4 percent. From the analysis in Section I different potential GNP series can be computed corresponding to different unemployment rates, and series corresponding to unemployment rates of 3, 3.5, 5, 6, and 7 percent were computed.¹⁸ It turned out, not surprisingly, that the difference between each of these series and the series in Table 1 corresponding to an unemployment rate of 4 percent was roughly

¹⁸The value of $(E_t + AF_t)/(P_{1t} + P_{2t})$ was also changed for each series to correspond to the approximate value which was observed during periods when the actual unemployment rate was equal to the unemployment rate in question. For 3, 3.5, 5, 6, and 7 percent unemployment rates the values were .594, .591, .568, .564, and .561 respectively.

constant over time. This meant that the estimates in line (c) of Table 3 could be used to compute the rate of price increase which would result if real GNP were held continuously at the level of each of the potential GNP series. For the series corresponding to unemployment rates of 3, 3.5, 5, 6, and 7 percent the rates of price increase were 7.8, 5.6, 2.2, 1.5, and 1.0 percent respectively. To the extent that the estimates in line (c) of Table 3 have (erroneously) picked up rate of change effects which would wash out in the long run, these rates of increases are probably too high. It is difficult to know how serious a problem this is likely to be: testing for various rate of change effects in equation (10) did not produce any positive results. Friedman, of course, would argue that holding real GNP continuously above the level of the potential GNP series corresponding to the "natural" unemployment rate would result in the long run in an infinite rate of change of prices. To the extent that this is true, the above rates of increase corresponding to the low unemployment rates are obviously too low. In general, the long-run implications of the results in this study should be interpreted with some caution.

It should finally be noted that an equation like (10) can be used quite easily in a macro-economic model to link predictions of money GNP to predictions of real GNP. Given current and lagged values of $GNPR^*_t$, $GNPR_{t-1}$, and GNP_t , PD_t can be

computed from (10). Given government output in money terms (denoted as G_t), real private output can be computed as $100 \cdot (GNP_t - G_t) / PD_t$, and then given government output in real terms, $GNPR_t$ can be computed as real private output plus real government output. This value of $GNPR_t$ can then be used in computing PD_{t+1} , and so on. This is the approach taken in the forecasting model referred to above. For a model which is specified in real terms, an equation like (10), with $GAP1$ being used in place of $GAP2$ in the equation, can be used in a similar manner to link predictions of real GNP to predictions of money GNP. For large-scale models, of course, an equation like (10) is not likely to be of much use. For small-scale models and forecasting models the justification for using an equation like (10) is much stronger than it is for large-scale structural models.

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