UNANTICIPATED MONEY GROWTH AND OUTPUT FLUCTUATIONS

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Almost all tests of rational expectation models have been conducted under the hypothesis of complete price flexibility. In these models, it is unanticipated inflation that causes business fluctuations. William Poole [1976] recently reviewed empirical studies of rational expectation models and concluded that they fail to explain the persistence of business cycles.[1] However, rational expectation models because of their striking theoretical implications do deserve more extensive testing. In this paper, it is shown that even without instantaneous price adjustment it is possible to have cyclical fluctuations in output arising solely from informational inadequacies. A test of this hypothesis is developed which involves looking directly at unanticipated money growth and fiscal policy. Series for unanticipated money growth and fiscal variables are calculated from time-series analysis; economic actors are taken to use all currently available time-series information for forecasting. A minor econometric innovation is a procedure for preventing future values of a stochastic process from affecting current estimates of the process that the agents use.

The model developed below is related to the work of Lucas (1973a) in which firms observe the price of their goods changing but cannot distinguish between changes in the relative prices of their goods from changes in the absolute price level. His model appears to be at variance with the common notion that firms _set_ their prices (at least in the short run). Both Okun and Nordhaus have argued that this is a key, stylized feature of the United States economy although they differ on the explanation for this phenomenon.[2] According to these authors, short run fluctuations in demand are met by firms adjusting quantities rather than prices. A model of business activity is developed

1. Poole [1976], p. 481.

2. Okun [1975] and Nordhaus [1975].

below which has fixed prices yet leads to short run fluctuations in output only because of informational problems on the part of firms. The distinguishing feature of the model is that firms try to analyze inventory fluctuations to decide whether an increase or decrease in inventories is attributable to a specific demand for their product or a general increase in demand. Since prices are fixed, "informational business fluctuations" will not be associated with unanticipated inflation.

I. Price-Fixed Rational Expectations

In its simplest formulation the model begins with the quantity equation (period chosen so that velocity equals one):

$$1. \quad M_t = P_t Q_t$$

The money supply is set according to the following rule:

$$2. \quad M_t = \sum_{i=1}^{\infty} a_i M_{t-1} + u_t \qquad u_t \sim (o, \sigma_u^2) \qquad E(u_t u_{t-1}) = 0$$

Except for the uncorrelated error term, the money supply for period t can be predicted from information available at period t-1.

Given this money supply rule, prices are set to generate on average, full employment. Denoting full employment output by Q*, the price level set at the beginning of the period and maintained through the period will be:

$$3. \quad \overline{P}_t = \frac{E(M_t \mid I_t)}{Q^*}$$

where: I_t = information set available at time t

$\overline{P}_t$ = price level set at beginning of the period

If there was no other uncertainty in the model, firms would observe short run, serially uncorrelated changes in their inventories arising because of the unanticipated changes in the money supply. Firms would <u>not</u>, however, adjust their production decisions for they would realize that these short run fluctuations only arose because of temporary money supply changes. If they kept at the full employment level of output they would not witness any systematic running down or building up of inventories.[3] That is, if firms know equations (1)-(3), then they would realize that fluctuations in purchased output, Q_t, from full employment output would be uncorrelated:

$$4. \quad Q_t - Q^* = u_t/\overline{P}_t$$

Additional uncertainty does arise because firms experience random fluctuations for their <u>own</u> output. Let there be n firms and output <u>initially</u> divided among the firms by the following rule:

$$5. \quad q_t^i = Q_t/n + \epsilon_t^i. \qquad \sum_i \epsilon_t^i = 0$$

We shall specify that ϵ_t^i follows a random walk.[4] Thus, at any time, firms will have different market shares and have no expectation of their share of the market changing. The total trend <u>supply</u> in the market will remain constant but the contribution from each firm will not necessarily be identical. Formally,

$$6. \quad q_t^i = Q_t/n + \epsilon_{t-1}^i + \eta_t^i \qquad \Sigma\epsilon_t^i = 0$$

$$\eta_t^i \sim n(o,\tau^2) \qquad \Sigma\eta_t^i = 0$$

There are now two sources of uncertainty in the model--the firms uncertainty over its own market share represented by η_t^i which is a normally

3. No attempt in this model is made to allow for simultaneous inventory and price decisions--this should be viewed as the polar case to the Lucas model.

4. This assumption captures the fact that charges in market shares may be permanent. It could be relaxed to include any degree of serial correlation.

distributed random variable with mean zero and variance τ^2; and the uncertainty arising from the randomness in the money supply. Thus, firms cannot infer from their sales the amount of extra demand just arising from the change in the money stock. This is analogous to the problem of trying to estimate permanent income from actual income when actual income contains a transitory compound.

Given the variances of customer shifts (τ^2) and the money stock (σ_u^2), the firm can estimate its share of the market. The firm wishes to know:

7. $E_t[Q_t^*/n + \epsilon_{t-1}^i | q_t^i]$ = expected share of the market or "normal" sales

Since the customer flow dynamics follow a random walk, the best estimate of future sales in all following periods will also be given by equation (7) with $Q^*(t+\tau)$, which is the productive capacity of the economy at period $t + \tau$, replacing $Q^*(t)$. Calculating the conditional expectation using normal distribution theory and recognizing that the variance of Q_t/n is $\sigma_u^2/(\overline{P}_t n)^2$:

8. $$E_t[\frac{Q^*(t)}{n} + \epsilon_{t-i}^i | q_t^i] = (1-\theta)q_t^i + \theta[\frac{Q^*(t)}{n} + \epsilon_{t-i}^i]$$

$$= \frac{Q(t)}{n} + \theta[\frac{Q^* - Q(t)}{n}] + \epsilon_{t-1}^i - \theta\eta_t^i$$

where: $\theta = \dfrac{\tau^2}{\tau^2 + \sigma_1^2}$

and $\sigma_1^2 = \dfrac{\sigma_u^2}{(\overline{P}_t n)^2}$

Adding over all firms:

9. $$\sum^n \{\frac{Q(t)}{n} + \theta[\frac{Q^*(t) - Q(t)}{n}] + \epsilon_{t-i}^i - \theta\eta_t^i\} = (1-\theta)Q(t) + \theta Q^*(t)$$

Equation (9) gives the aggregate level of expected normal sales as a weighted average of trend output and current sales. Recall that $Q(t) - Q^*(t) = u_t/\overline{P}_t$ so that:

10. $(1-\theta)Q(t) + \theta Q^*(t) = Q^*(t) + (1-\theta)u_t/\overline{P}_t$

This equation has an immediate interpretation. If the money supply was larger than anticipated at the beginning of the period, sales will be larger than average. Each firm will attribute part of the increased demand to its own permanent market share. In the aggregate, all firms feel they can sell a greater amount in the long run than capacity production in the economy. The extent of the response to unanticipated money depends, of course, on $\overline{P}_t$, the price set at the beginning of the period, and also θ which is a function of the variance in the money stock and in the customer flow. The greater the variance in the money stock (σ^2) relative to the customer flow variance, firms as a whole will be less likely to infer that their share of the market has increased when sales increase. If there is no residual variance in the money supply ($\sigma^2 = 0$) then expected normal sales will always be equal to $Q^*(t)$.

If we assume that production by firms is geared to expected normal sales and inventories are utilized to buffer the temporary increase in demand arising from the unpredictable component of the money supply, then production will exceed trend when the money supply is greater than anticipated and will be below trend when the money supply is less than anticipated.[5] Some firms may have longer time horizons in their production decisions. At the time of decision, the best estimate of future sales is the current estimate the firm has of its permanent share with the appropriate adjustment of $Q^*(t)$. This, of course, is a direct implication from the fact that customer flow dynamics follow a random walk. Thus, the degree of unanticipated money growth <u>at the decision time</u> will affect actual production in the future. Therefore, both <u>current</u> and <u>past</u> mistakes in predicting the money supply will be related to

5. A higher variance on the money supply would imply larger inventory fluctuations. No allowance is made in this model for the cost of holding higher inventory levels. For a discussion of this problem see Holt [1960].

the current deviation of output from trend.

An immediate generalization of this model is apparent. Instead of a quantity equation, equation (1) could be any equation to determine nominal income. In that case, any unanticipated change in fiscal or monetary variables that leads to an unanticipated change in nominal income should have an effect on cyclical output. Only a strict monetarist viewpoint would rule out unanticipated changes in fiscal variables.[6]

Before discussing the empirical implementation of this theory, it will be helpful to review the distinguishing characteristics of this approach. Previous discussions and tests of natural rate theory have been conducted in a flexible price world. In those models unanticipated money growth only had an effect through unanticipated inflation. No role was given to unanticipated money (or broadly, unanticipated changes in nominal income) apart from its price effects.

In this model, for a given money supply rule, prices are set to aim at full employment output and are fixed during the period. Since prices are fixed, unanticipated money growth has a direct impact on output. The question of within-period price flexibility versus price fixity was skirted in the discussion, but casual observation suggests both types are important. A key result of the model is that with fixed prices chosen ex ante to lead to full employment, "normal" inventory fluctuations result--rational firms do take account of this phenomenon. This point has generally not been incorporated into existing inventory models. It is important to note that since prices are fixed temporarily there will be no relation between movements in output and unanticipated inflation which characterize most of the literature.

6. By restricting ourselves to policy variables we are implicitly assuming that there are no autonomous non-policy demand shocks. This assumption is in the spirit of the existing models in the literature.

II. Estimation of the Model

To generate a series for unanticipated money growth, a flexible autoregressive moving average procedure was employed. Agents were assumed to use an ARMA process estimated from past data to make one quarter ahead forecasts of the rate of growth of the money supply. When they learn the actual value of the rate of growth, they re-estimate their equation incorporating the new realization of the time series and again calculate a one quarter forecast.[7] This procedure insures that the information set available to agents in making forecasts does not include any future realizations of the time series. Most other studies using ARMA process fail to consider this methodological problem. It also allows agents to change their estimates of the stochastic process (as Lucas [1973b] stresses) but only as fast as new data becomes available.[8]

It has been suggested that money growth rates are affected by fiscal variables.[9] As an empirical matter, it was not possible to find a statistically significant effect from any of several measures of fiscal activity on a quarterly basis. It thus was decided not to include these variables in an equation predicting quarterly money growth rates.[10]

Following Box-Jenkins model identification procedures, an examination of the autocorrelation and partial autocorrelations of money growth rates indicated that a second order autoregressive captured the time dependency in the series;

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7. Seasonally adjusted quarterly money growth figures were utilized.

8. People are not "fully" rational in that elections, etc., are not included. We are attempting, however, to reach a workable compromise with rational expectations. See footnote 10.

9. Barro [1976] argues that fiscal variables do affect money growth in the context of a model of inflationary finance.

10. Nelson [1975] discusses some of the specification error problems which would arise if other variables did affect money growth but were incorrectly included. However, evidence presented by Feige and Pearce [1976] suggest that no other variables are, in practice, needed once the properties of the time series are fully utilized.

no moving average term was needed. For the period as a whole, the regression results were:

1. $$RG_t = \underset{(.0008)}{.0033} + \underset{(.098)}{.803}\, RG_{t-1} - \underset{(.098)}{.148}\, RG_{t-2}$$

$\bar{R}^2 = .49$ d.w. $= 1.96$ 1950:1 - 1975:3

RG_t = quarterly money growth rate.

Two important features of this difference equation should be noted. First, the durbin-watson statistic indicates that there is little remaining time dependency in the series--moving average terms were not needed. Second, the homogenous part of the difference equation has two real roots with moduli less than one, i.e., the equation is stable.

This basic equation was estimated period-by-period starting in 1952:4 up to 1975:3 and one period ahead predictions were calculated and the errors in prediction were tabulated. The correlation matrix of the errors, UM, appears in Table 1. The almost zero autocorrelations indicate that the unanticipated money growth is truly a white noise series. The standard deviation of the quarterly unanticipated money series is .004 or 1.6% of an annual basis. The data series appears in the Appendix.

It was noted above that unanticipated changes in fiscal variables could have an impact on unemployment in the exact same fashion as unanticipated money growth; they both gave rise to the same information problems when firms analyzed their sales. While this notion has not been stressed in the literature, it does deserve some analysis. An unanticipated fiscal policy series was constructed in the following manner. The rate of growth of government expenditures was detrended by a quadratic time trend and a first order autoregressive equation was fit to the residuals and used to make one quarter forecasts of the rate of growth of government expenditures. The equation that

Table 1

Autocorrelation Matrix of Errors (UM)

	UM	UM(-1)	UM(-2)	UM(-3)	UM(-4)
UM	1				
UM(-1)	-.026	1			
UM(-2)	-.062	-.033	1		
UM(-3)	.062	.009	-.025	1	
UM(-4)	-.047	.031	.003	.059	1

was used was:

2. $GG_t = .69\ GG_{t-1}$ $\quad \bar{R}^2 = .48 \quad$ d.w. = 1.90, 1950:1 to 1975:2

While this equation was sufficient to capture the time series information on the detrended government expenditure growth series, it is only a first approximation to unanticipated fiscal variables. An overwhelming amount of information about government expenditures and taxation is available even to a casual reader of the newspapers--a time series approach cannot capture all this complexity, but should be a step in the right direction.

The model that was estimated followed directly from the theoretical specifications. The following equation was estimated:

3. $X_t = C + B(L)UM + A(L)\ UF + \varepsilon_t$

where: UM = unanticipated money growth

UF = unanticipated fiscal growth

X_t = cyclical output

A(L), B(L) are lag polynomials

The only term in the equation that has yet to be defined is cyclical output. It was constructed by regressing the log of real GNP in 1972 dollars on a time trend and a constant and transforming the residuals.[11]

Our theory suggests that all the coefficients in both lag polynomials should be positive, i.e., when unanticipated values are positive, output is above trend. Most work in time series regressions with many predetermined variables requires the use of some distributed lag formulation because of the high degree of multicollinearity. However, working with unanticipated series

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11. The estimated equation was log GNP = 6.339 + .00858t $\bar{R}^2$ = .98 1953:1 to 1976:3.
(.03) (.00012)
Let the residuals from this equation be denoted R_t then $X_t = e^{R_t} - 1$ is the definition of cyclical output. The GNP series was real GNP in 1972 dollars.

Table I

Unanticipated Money and Fiscal Growth

3. $X_t = C + B(L)UM + A(L)UF + \varepsilon_t$

Variable	Coefficient	Std. Error
C	-.0012	.009
UM	.47	.217
UM(-1)	1.03	.295
UM(-2)	1.46	.342
UM(-3)	1.81	.355
UM(-4)	1.90	.346
UM(-5)	1.41	.331
UM(-6)	.977	.290
UM(-7)	.732	.213
UF	.067	.071
UF(-1)	.098	.101
UF(-2)	.177	.095
UF(-3)	.152	.063

$\hat{\rho} = .97$

Std. deviation of X_t = .0105

RMSE = .0090

Period: 1954:4 - 1975:1

constructed from variables own past history has a unique advantage; the series are constructed such that the variables in the sequence [UM, UM(-1), UM(-2)...] are nearly mutually orthogonal. Thus, the estimation need not contain any arbitrary distributed lags. According to the theory, there is no worry of bias from simultaneity. Therefore, least squares is an appropriate estimating technique with the proper correction for autocorrelation.

Equation 3 was estimated by Cochrane-Orcutt technique from 1954:4 to 1975:1. The results of the estimation are presented in Table I. First, note that all coefficients have the anticipated sign and that <u>all</u> the money terms are significant at the 5% level and the last two fiscal terms are also significant at that level. The unconstrained lag distribution for money exhibits a hump shape with the peak effect occuring 4 quarters back. The fiscal effects take at least two quarters to really become operative. Further lags were tried both for the monetary and fiscal variable, but they did not enter signficantly.

Since X_t, our variable for cyclical output, is taken from trend it should imply that the constant term is zero in the regression and, indeed, the constant term is not significant. The standard deviation of X_t was .0105 and the root mean square error was less than one standard deviation or .009.

To gauge the magnitude of the coefficients for the effect of unanticiapted money, let us take a "typical" mistake in predicting the money growth rate equal to the standard deviation of the errors, .004. Using the largest distributed lag term (1.90) and taking 1975:2 as a basis, the effect from this mistake is approximately 10.7% of cyclical output.

The most striking negative feature of the regression is the extremely high estimate of autocorrelation .97. Cyclical output is a highly correlated variable and the series for unanticipated money and fiscal growth are primarily white-noise series. Since we are using lagged values of both the money and fiscal variables there is no a priori reason why they should not be able to explain a highly autocorrelated variable.[12] However, in practice, the lagged terms are not sufficient to capture the full extent of the autocorrelation. This point has emerged in discussions of explaining unemployment by mistakes in predicting inflation and has been termed by Robert Hall [1975] "the persistence of unemployment."

To allow for the persistence effects, one could estimate a modified version of equation 3:

3′. $G(L)X_t = C + B(L)UM + A(L)UF + \varepsilon_t$

where G(L) is a lag polynomial.

The results from the estimation of (3′) by Cochrane-Orcutt appear in Table II. There is some difference in the results; in particular, significance levels fall for the money and fiscal variables and two terms change sign. Both lagged variables were significant but the presence of some residual autocorrelation suggests that the G(L) functions probably is quite complicated. Note that the RMSE is only slightly less in this equation.

Allowing for cyclical output to follow its own autoregressive pattern is troublesome, however, because it has no justification in our theory. This is a problem for rational expectations models and has prompted Lucas [1976] to try to explain the persistence of the business cycle. However, some resort must be made to information lags to generate his result. It appears from the empirical work that if rational expectations models of the economy are to account for the pattern of business cycles they must focus much more attention on the persistence problem.

12. The contrary claim is often made. See Modigliani [1977], p. 5.

Table II

The Persistence Equation

3′. $G(L)X_t = C + A(L)UM + B(L)UF + \varepsilon_t$

Variable	Coefficient	Std. Error
C	-.0015	.008
X_{t-1}	-1.57	.10
X_{t-2}	-.657	.10
UM	.56	.21
UM(-1)	.17	.23
UM(-2)	.16	.23
UM(-3)	.309	.23
UM(-4)	.14	.24
UM(-5)	-.3	.24
UM(-6)	.05	.24
UM(-7)	.04	.24
UF	.08	.081
UF(-1)	.009	.082
UF(-2)	.13	.082
UF(-3)	-.004	.07

$\hat{\rho} = -.30$

RMSE = .0086

Table III

Prediction

	Actual Value	I	II	III	IV	V	VI
1975:2	-.071	-.082	-.076	-.043	-.0825	-.076	-.090
1975:3	-.053	-.066	-.067	-.0006	-.0806	-.072	-.097
1975:4	-.054	-.046	-.055	+.007	-.0781	-.073	-.095

Percentage Errors

	I	II	III	IV	V	VI
1975:1	-16.2	-8.2	81.0	-16.2	-8.2	-27.9
1975:2	-23.0	-25.2	98.8	-50.3	-35.8	-81.5
1975:3	14.8	-1.8	112.9	-44.7	-36.5	-77.4

Errors as Percent of Real GNP

	I	II	III	IV	V	VI
1975:1	1.35	.682	-6.27	1.35	.682	2.35
1975:2	1.39	1.534	-5.61	3.10	2.19	5.12
1975:3	-.88	.1131	-5.0	2.77	2.25	4.89

Column:
- I: lagged X_t, Cochrane-Orcutt--actual lagged values and errors
- II: Cochrane-Orcutt--actual errors
- III: no lagged values, no error corrections
- IV: lagged X_t, Cochrane-Orcutt--estimated lagged values and errors
- V: Cochrane-Orcutt--estimated lagged values
- VI: lagged X_t, Cochrane-Orcutt--estimated lagged values and errors

  UM = UF = 0 for all t > 1975:1

For prediction purposes, assumptions about the persistence effects are quite crucial. Table III presents forecasts for 1975:2, 1975:3, 1975:4 and gives the percentage error in forecasting X_t. The first three columns give the forecast errors for the equation with lagged X_t and an error correction; the equation with just an error correction; and the third equation has neither lagged X_t nor an error correction. The first two equations use actual errors and lagged values of X_t. Columns four and five present the endogenous simulations for the first two columns, i.e., estimated errors and lagged X_t are used for forecasts. Finally, the last column gives forecasts using the equation in column one, estimated errors and lagged X_t and with UM = UF = 0 for all forecast periods. This, of course, is what would be the policy makers preferred equation.

The results show that the equation with just an error correction slightly outperforms the equation with lagged X_t in the regular and endogenous simulations. But both are much superior to not allowing for any persistence effects at all. Finally, the last column shows the value of knowing ex post the value of unanticipated money and fiscal growth. These prediction results confirm the impression that these models are only as accurate as their estimation of persistence effects. Table III also gives the percentage error in predicting real GNP for all the models for forecasts one, two and three quarters ahead. The best models compare favorably with the performance of the large econometric models as summarized by McNees [1973].[13] This suggests that with the persistence effects included, the model should be taken quite seriously.

A recent study by Barro [1977] was not troubled by persistence effects.[14]

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13. See McNees [1973], p. 16.

14. His study was done on unemployment, not cyclical output.

However, there were some differences in the approach which account for the differing results. First, Barro used yearly data for his study and thereby assumed that economic actors take a year to change their expectations of the money growth rate. Second, he let lagged unemployment be an explanatory variable in predicting money growth--thus, he was actually letting lagged unemployment (one and two years back) affect current unemployment. Coupled with the time span of the study, this enabled Barro to avoid the problem of the persistence of unemployment.

There is some evidence that the proper periodicity may be quarterly. In a study of the stock market and money growth, Richard Cooper [1974] found that stock prices led money growth by one to three weeks suggesting that anticipations of money growth were formed on the basis of a quarter or less. His study did use a seasonally unadjusted series for money growth but it is doubtful that using a seasonally adjusted series would increase the relevant forecasting period to a year.

A strong claim of the rational expectations models is that anticipated money growth has no effect on output. It would be tempting to enter a series for anticipated money growth and test the hypothesis that it was zero. However, this is not possible in the study because of all the lags. Essentially, a second-order autoregressive form is being utilized to predict money growth. Only if there were two lags would it be possible to test the hypothesis by entering the anticipated series.[15]

Summarizing the results of this paper, a model was developed in which short run fluctuations in output arose only from informational inadequacies on the part of economic agents. Unlike other models of this type, this model

15. This point, essentially a proposition about identification, was brought to my attention by Robert Barro in private correspondence.

was characterized by short run price fixity and thus there would be no correlation between output fluctuations and unanticipated inflation. Rather, it was necessary to look directly at unanticipated money growth and fiscal policy. Expectations were formed with a flexible ARMA process that avoided using future values of a variable from affecting current estimates of the stochastic process.

The empirical evidence suggested that unanticipated monetary and fiscal growth does have a strong impact on cyclical output--for money, the effect of a typical mistake amounted to about 10% of cyclical output in a quarter. Nonetheless, this does not give a complete picture of short term business fluctuations--the persistence effects, which are not called for by the theory, dominate the estimation and forecasting results. This finding poses the strongest challenge to the acceptability of rational expectation models of business fluctuations.

One final note: according to the theory developed in the paper, inventories wee held to buffer the <u>expected</u> fluctuations arising from randomness in aggregate demand. Further work can be done examining the behavior of inventories and their relationship to unanticipated changes in aggregate demand.

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Appendix

Series for Unanticipated Money at Quarterly Rates

UM		I	II	III	IV
1953	1	-0.005323	0.002723	-0.005128	-0.001769
1954	1	0.000988	-0.001149	0.006529	0.001617
1955	1	0.002531	-0.004293	-0.001594	-0.002351
1956	1	0.000781	-0.0036	-0.004683	0.00193
1957	1	-0.00517	-0.003142	-0.002518	-0.007986
1958	1	0.00173	0.009078	-0.003355	0.004083
1959	1	0.002920	-0.002904	-0.00159	-0.011204
1960	1	-2.346933E-00	-0.002108	0.005814	-0.007912
1961	1	0.001616	0.002846	-0.002005	0.004477
1962	1	-0.003254	-0.000728	-0.00680	0.006038
1963	1	0.0001845	0.001401	0.00127	0.002354
1964	1	-0.002734	0.004325	0.007925	-0.001207
1965	1	-0.002205	0.00238	0.003922	0.006649
1966	1	0.003025	-0.00364	-0.019301	0.002199
1967	1	0.005378	0.003889	0.010779	-0.003582
1968	1	0.004524	0.009056	0.004312	0.00485
1969	1	0.001165	-0.002652	-0.002217	0.000383
1970	1	0.002129	0.003908	0.000348	0.002310
1971	1	0.005008	0.010345	-0.005057	-0.095030
1972	1	0.013538	0.003783	0.004392	0.005404
1973	1	3.258115E-05	0.001403	0.000627	0.000691
1974	1	0.003509	0.000348	-0.001718	0.000557
1975	1	-0.008425	0.018157	-0.000385	-0.008629