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The Variability of Inflation in Brazil: 1974-1982*

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This paper shows that variability of unanticipated inflation depended positively on the level of the inflation rate in Brazil for the period 1974 to 1982. The model assumes that individuals use all information available in formulating forecasts about future inflation rates. The variance around this forecast is defined as the unanticipated variability of inflation. I estimate the model using monthly data and generate estimates of the one-step-ahead forecasts of the level and variance of monthly inflation rates. This method represents an improvement on previous research on Brazilian inflation variability in that the mean of inflation is modeled explicitly and the variance is estimated around this mean, as opposed to calculating variability around a moving average or simple time trend.

I. Introduction

Does inflation uncertainty increase with the inflation rate? Milton Friedman (1977) maintains that it does, and that this is the predominant danger of inflation. This note tries to determine empirically whether inflation "uncertainty" increases with the inflation rate in Brazil. I use the variance of inflation around its conditional mean as a proxy for inflation "uncertainty." My main objective is to find the conditioning elements of the variance of Brazil's inflation.

Recent work by Engle (1983) shows that a positive relationship between the inflation rate and the variance of inflation suggested by Friedman (1977) does not exist in the United States. Inflation rates in the U.S.,

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however, have been historically low (even those of the 1970's) compared with those of Brazil. A relationship may exist at high levels of inflation.

There are good theoretical reasons to believe that the variability of inflation increases directly with the rate of inflation. If prices are adjusted at set discrete intervals because of costs of price adjustment, as in Sheshinski and Weiss (1977), or because inflation is "inertial," as in Lopes (1976), (1984), Bacha and Lopes (1983) and Arida and Lara-Resende (1985), it is easy to show that inflation variability will increase with an increase in inflation.[1] Further, if the government has used price controls to contain inflation, the probability of large readjustments in these prices increases with an acceleration of inflation as fiscal balance tends to deteriorate under such circumstances.

The accelerationist and rational expectationist views of inflation where increases in inflation and inflation variability stem from suboptimal monetary policy are also compatible with this viewpoint.[2] Hence, the findings of this paper are not intended to resolve debate concerning the nature of inflation but only to see if the relationship exists. It is assumed, however, that individuals form expectations about future inflation in a partially rational way as defined in Pagan, Hall, and Trivedi (1983) in that they use all possible information available.

I estimate a reduced form inflation equation which is compatible with many visions of the inflation process and test the structure of the process which generates inflation variance.[3] Section II discusses the shortcomings of using variance as a proxy for uncertainty. Section III develops tests of whether the variance of inflation depends upon the inflation rate or if it follows Engle's (1982) "Autoregressive Conditional Heteroscedasticity" process. Section IV presents the results and section V provides some applications.

II. Measuring Inflation Uncertainty

One of many problems with models of inflation uncertainty which use inflation variance as its measure is that agents are assumed to know the underlying probability distribution of inflation (or the probability distribution of deviations of inflation around its expected rate). In this context, one is referring to inflation risk and not uncertainty. Uncerainty

1 If the period of adjustment shrinks, however, the variability should decline.

2 See Sargent and Wallace (1976) among many.

3 For a discussion of how reduced-form equations may be generated from a variety of structural equations, see Sargent (1976).

deals with ignorance and not with a game of chance where all possible outcomes are known and assigned probability measures of occurrence. Weintraub (1975) delineates the difference between risk and uncertainty when discussing Keynes' treatment of the relationship between uncertainty and probability theory in the following passage:

> In modern parlance, it was Keynes' viewpoint that a major leap of faith is involved in treating situations characterized by uncertainty as situations involving only risk. Any choice now among future alternatives is thus fundamentally uncertain, since the future is logically unknowable. No sampling from the future is feasible to ascertain probabilities for future alternatives, so there is no way uncertainty problems can be reduced to problems of risk.[4]

Hence, inflation variability can best be used to model inflation risk and not uncertainty. In spite of this problem, it will be assumed that individuals act as if they assign a subjective probability distribution to possible future values of inflation. More specifically, when expectations are formed about the future value of a random variable, one must form expectations about the full probability distribution of the variable in question. Ideally, one would like to model expectations on the entire probability distribution of inflation. This, however, is beyond the scope of this note. Instead, the paper will focus on a two parameter (location-scale) conditional distribution function for the inflation rate.

Following Engle (1983), the random variable inflation will have a nonstochastic unconditional mean and variance at each point in time. Economic agents, however, are concerned with the conditional distribution of inflation given all past information and its conditional moments may be defined as being dependent on this information set. Let $\tilde{p}_t$ be the inflation rate at time t, Φ_{t-1} the information set including all information through time t–1, π_t be the conditional mean of $\tilde{p}_t$, and v_t be the conditional variance of $\tilde{p}_t$ around π_t. Formally, we are interested in estimating π_t and v_t where:

$$(1) \quad E(\tilde{p}_t \,|\, \Phi_{t-1}) = \pi_t$$

$$(2) \quad E\,((\tilde{p}_t - \pi_t)^2 \,|\, \Phi_{t-1}) = v_t$$

This model is an improvement on methods which assume either a constant variance over time (such as, for example, Lucas (1973)) or those which estimate v_t around a moving average of the inflation rate (such as, for example, Klein (1977), Pindyck (1984) and, for the Brazilian case in

[4] See Weintraub (1975, p. 532), Shackle (1967) and Kregel (1976).

terms of relative prices, Kadota and Moura da Silva (1982)).[5] In the former, the possibility of a heteroscedastic variance structure is simply assumed away. In the latter, the mean of inflation is modelled as a moving average instead of assuming some underlying structure. The improvement lies in the fact that, based upon findings shown here, variables other than past inflation rates improve inflation rate forecasts.[6] If an inflation level/variance relationship exists even when individuals form inflation expectations using all information available to them, then the assertion that inflation imposes large costs in the form of increased risk gains stronger empirical confirmation.

III. Tests on the Variance of Inflation

We will test to see if inflation variance is dependent on the conditional mean or if it follows the ARCH process of Engle (1982). Both of these tests are based upon the simple test for heteroscedasticity developed by Breusch and Pagan (1979).

The reduced-form inflation regression model is assumed to take the following form:

(3) $\tilde{P}_t = \Gamma(B)\tilde{P}_{t-1} + \beta(B)\tilde{m}_{t-1} + \varepsilon_t$

Where $\tilde{P}_t$ is the inflation rate at time t, $\tilde{m}_{t-1}$ is the percentage change in some monetary aggregate (to be determined by experimentation), ε_t is an error term with mean zero, B is the backshift operator, $\Gamma(B) = \Gamma_1 + \Gamma_2 B + \Gamma_3 B^2 + \cdots + \Gamma_p B^{p-1}$, and $\beta(B) = \beta_1 + \beta_2 B + \beta_3 B^2 + \cdots \beta_p B^{p-1}$. Clearly,

(4) $\pi_t = \Gamma(B)\tilde{P}_{t-1} + \beta(B)\tilde{m}_{t-1}$

Suppose the variance of inflation is dependent on the level of inflation in the following way.

(5) $v_t = \delta_0 + \delta_1 \pi^2{}_t$

A simple test to see if the variance of ε_t is a function of π_t is to regress (including an intercept) the squared residuals from the OLS estimate of

5 For a comparison of different methods of testing whether inflation variability depends upon the level, see Pagan, Hall, and Trivedi (1983).

6 See the results of causality tests presented in footnote 9.

equation (3) (which assumes homoscedastic ε_t), e_t^2, on the predicted values of inflation. The test statistic TR^2, where the R^2 is from this auxiliary regression, is distributed as a $X^2(1)$ under the null hypothesis of homoscedastic ε_t. If this null hypothesis is rejected, inflation variance depends upon the level of inflation.

The ARCH model of Engle (1982) assumes that the variance of inflation at time t is a function of past variances.

$$(6) \quad v_t = \alpha_0 + \alpha(B)\varepsilon^2_{t-1}$$

Where $\alpha(B) = \alpha_1 + \alpha_2 B + \alpha_3 B^2 + \quad \cdots \quad + \alpha_q B^{q-1}$. Under the null hypothesis that $\alpha_1 = \alpha_2 = \cdots = \alpha_q = 0$, the test statistic TR^2 formed by taking the R^2 from the regression (including intercept) of the squared residuals, e^2_t, on the lagged values of the squared residuals $e^2_{t-1}, e^2_{t-2}, \cdots, e^2_{t-q}$ is distributed as a $X^2_{(q)}$.[7]

IV. The Results

After some experimentation with different monetary aggregates, the OLS estimate of equation (3) using seasonally adjusted monthly data[8] from 1974 to 1982 is:[9]

[7] Both these tests are discussed in Engel, R.F. (1983). The first test, however, is a modified version of the one Engle uses.

[8] The data appear in Martone (1983). Mudanças Estruturais no Mercado Monetário e Suas Implicaçoes, Working Paper No. 24, University of Sao Paulo, seasonally adjusted by ratio to moving trend methods. The data was seasonally adjusted by using the U.S. Bureau of the Census X-11 program. Seasonality was not constant for all variables.

[9] Equations using the monetary base, M_1, M_2, M_3, and total credit to the private sector were estimated and causality tests were used to determine which monetary aggregate was the most appropriate. The $F_{(12, 68)}$ statistics for the test of whether the above variables aggregate cause inflation appear below.

	$\bar{P}$
Monetary Base	1.894***
M_1	1.908**
M_2	0.675
M_3	1.042
Bank Credit to Private Sector	1.171

Only the monetary base and M_1 significantly cause inflation. I chose to work only with M_1 as its significance level was lowest for simplicity. It should be noted that the heteroscedastic structure of inflation around its conditional mean was exactly the same for both aggregates, and hence, using the monetary base in addition to M_1 adds nothing to the analysis. The causality results presented above agree with Martone's (1983) results on the demand for money. They also agree in general with causality tests reported in Cardoso (1977), Contador (1978), Carneiro Netto and Fraga Neto (1984), and Bastos Marques (1983).

$$\text{(7)}\quad \tilde{p}_t = 0.389\tilde{p}_{t-1} + -0.146\tilde{p}_{t-12} + 0.065\tilde{m}_{1t-3} + 0.1152\tilde{m}_{1t-6}$$
$$(-1.947^{***}) \qquad (1.949^{***}) \qquad (1.727^{***}) \qquad (2.959^{*})$$
$$+ 0.138\tilde{m}_{1t-7} + 0.116\tilde{m}_{1t-8} + 0.094\tilde{m}_{1t-10} + 0.0114D_{1979}$$
$$(3.187^{*}) \qquad (2.428^{**}) \qquad (1.927^{***}) \qquad (2.720^{*})$$
$$F_{(26,68)} = 14.526^{*} \qquad R^2 = 0.8474$$

Where $\tilde{p}_t$ is the one period difference in the logs of wholesale price index (IGP-DI), $\tilde{m}_{1t}$ is the one period difference in the logs of M_1, and D_{1979} is a dummy taking a value of one from 1979 to 1982 to capture the supply price shocks occurring in 1979 (e.g. the second oil shock, the change to semi-annual adjustment of wages for inflation as opposed to annual, and bad harvests). T statistics appear in parentheses where a * signifies significance at the 1% level, ** signifies significance at the 5% level, and *** signifies significance at the 10% level. Insignificant lags of inflation and monetary growth as well as a time trend component which proved insignificant are not shown, but are included in all calculations below.[10] I also included the difference in the logs of the average wage in the transformation industry and the *Conjuntura Economica* index of import prices in one set of regressions.[11] Neither caused inflation using standard causality tests and equations which included them displayed the same heteroscedastic structure as those that did not include them.[12] These results, therefore, do not appear here but are available upon request.

I regressed the squared residuals from equation (7) on the predicted inflation rates. The test statistic TR^2 from this regression is 6.65 which rejects the null hypothesis of homoscedasticity in favor of the alternative hypothesis of dependence of inflation variability on the level of inflation (at a 2.5% significance level).[13]

The squared residuals were regressed on a variety of lag structures for the squared residuals. An ARCH process of order three was determined.

10 Two recent articles discourage "screening" regressions by throwing away insignificant variables. See Schwartz (1978), pp. 461-464, and Freedman (1983). Therefore, all variables, significant and insignificant, are used in the following calculations although the parameter estimates of the insignificant variables are not reported here.

11 All data were obtained from Conjuntura Economica, the Banco Central do Brasil: Boletim, the Brazilian Institute of Geography and Statistics (IBGE) Indicadores.

12 The $F_{(12,\ 44)}$ for the test for wage inflation causing inflation was 0.6426 and for import price inflation causing inflation was 0.8321. The $F_{(24,\ 44)}$ for the joint causation of inflation by wage and import price inflation was 0.6546.

13 The critical value for a $X^2_{(1)}$ at $\alpha = 0.025$ is 5.02.

The joint inclusion of predicted inflaiton and lagged values of the squared residuals did not reject the null hypothesis that all parameters were equal to zero. This is explained by the very high collinearity of the squared residuals and the predicted value of inflation. In order to keep the analysis as simple as possible, the remainder of this paper assumes that the level of inflation is the main determinant of its variance. This assumption seems reasonable as lagged values of the squared residuals failed to cause inflation variance using standard causality tests while the predicted values did significantly cause inflation variance.

Finally, a simple correction for the heteroscedasticity found above proved extremely satisfactory. I divided the dependent and independent variables in (3) by the predicted values from equation (7). This procedure was iterated until conergence was achieved within four iterations. The final inflation equation is as follows.

$$(8)\quad \tilde{p}_t = 0.495\tilde{p}_{t-1} - 0.224\tilde{p}_{t-4} - 0.101\tilde{p}_{t-12} + 0.100\tilde{m}_{1t-3}$$

$$(4.441^{*})\quad (-1.718^{***})\quad (-1.930^{***})\quad (2.981^{*})$$

$$+ 0.060\tilde{m}_{1t-5} + 0.090\tilde{m}_{1t-6} + 0.125\tilde{m}_{1t-7} + 0.102\tilde{m}_{1t-8}$$

$$(1.705^{***})\quad (2.509^{**})\quad (3.247^{*})\quad (2.465^{**})$$

$$+ 0.139\tilde{m}_{1t-10} + 0.95\tilde{m}_{1t-12} + 0.0100D_{1979}$$

$$(3.244^{*})\quad (2.400^{**})\quad (3.259^{*})$$

$$F_{(27,68)} = 110.414^{*}\qquad R^2 = 0.9777$$

The large improvement in the performance of the equation reinforces the assertion that inflation variability increases with inflation. After some experimentation with different functional forms, I regressed the squared residuals from (8) on the squared predicted values of inflation from (8) to generate an estimate of inflation variance equation. An unrestricted equation produced an insignificant negative intercept. The following equation constrains the intercept to be zero to ensure non-negative variances.

$$(9)\quad v_t = 0.0274\tilde{p}_t^2 \qquad F_{(1,\,94)} = 45.289^{*}$$

$$(4.386^{*})$$

$$R^2 = 0.3251 \quad TR^2 = 31.21^{*}$$

Clear, $dv_t/d\tilde{p}_t > 0$ for positive inflation rates, and, hence, inflation variance varies directly with the level of inflation. It should be noted that there were no negative inflation rates over this period. Estimates of the monthly errors, predicted inflation rates and inflation variances appear in Appendix 1. These represent one-month-ahead forecasts of the monthly inflation rate and the monthly inflation variance from equations (8) and (9).

V. Concluding Remarks and Extensions

The variability of inflation has been shown to be a positive function of the level of the inflation rate in Brazil for the period 1974-1982. The model used to determine this assumes that individuals form expectations in a (partially) rational way by using all information available to them. The results agree with those of Kadota and Moura da Silva (1982), who, as mentioned earlier, used a different technique.

The implications of this result are many. Even in a highly indexed economy such as Brazil's, the fact that inflation variability increases with the inflation rate implies that inflation has definite costs. Furthermore, the importance of this relationship concerning an aggregate price index may not appear important at first. Since many contracts are indexed to this index, especially those of indexed bonds, increasing inflation variability will have important macroeconomic implications. Specifically, Moura da Silva (1979) and Baer and Beckerman (1980) explain the large portfolio shfits from nominal ("prefixed" indexed assets) into ex post indexed assets between 1974 and 1976 by asserting that inflation risk increases with the inflation rate. Likewise, the existence of a variance/level relationship may also go far in explaining structural changes in the demand for money function as in Martone (1982) and Cysne (1985).

One possible problem with the analysis is that the one-month-ahead forecasts of the inflation rate and variance were calculated using a model estimated over the entire sample period. Individuals at the time these forecasts were presumably made did not have this full information set and were basing their predictions on "models" estimated using past data. Further, the parameters of the inflation generating process may have changed over the period. In order to account for this, a series of "rolling" regressions could be estimated as in Engle (1983), moving forward one month at a time and calculating one-step-ahead forecasts of the inflation rate and variance. Such a project is outside the scope of this note and is left to future research.

Further, a general ARCH technique as in Weiss (1915) could be used to generate estimates of the variance of inflation instead of assuming that the variance depends only upon the expected inflation rate. It should be noted that equation (9) is stable along the lines of Weiss (1985).

Finally, an application of the technique used in this paper to the variability of relative prices seems in order. The dependence of the variability of relative prices around a conditional mean of relative prices on the general rate of inflation has yet to be established.[14]

14 As mentioned above, Kadota and Moura da Silva (1982) establish that a relationship between the variance of relative prices around a moving average of relative prices and inflation exists.

Appendix 1

ONE STEP-AHEAD-FORECASTS OF INFLATION AND INFLATION VARIANCE

		Error	Expected Inflation	Expected Variance
1975	F	−0.00042	0.0174	0.000008
	M	−0.00079	0.0128	0.000005
	A	−0.00703	0.0141	0.000005
	M	0.00150	0.0172	0.000008
	J	0.00379	0.0193	0.000010
	J	−0.00287	0.0234	0.000015
	A	0.00241	0.0245	0.000017
	S	0.00052	0.0261	0.000019
	O	0.00208	0.0234	0.000015
	N	−0.00061	0.0292	0.000023
	D	0.00092	0.0248	0.000017
1976	J	−0.00109	0.0283	0.000022
	F	0.00331	0.0338	0.000031
	M	−0.01001	0.0397	0.000043
	A	−0.00016	0.0325	0.000029
	M	−0.00055	0.0344	0.000033
	J	−0.00636	0.0345	0.000031
	L	0.00305	0.0327	0.000029
	A	0.00406	0.0368	0.000037
	S	−0.00191	0.0361	0.000036
	O	−0.00045	0.0286	0.000023
	N	−0.00558	0.0293	0.000024
	D	−0.00288	0.0263	0.000019
1977	J	0.00278	0.0312	0.000027
	F	−0.00117	0.0292	0.000023
	M	0.00649	0.0252	0.000017
	A	0.00707	0.0293	0.000024
	M	0.00619	0.0293	0.000024
	J	−0.00745	0.0295	0.000024
	J	−0.00083	0.0214	0.000013
	A	−0.00640	0.0195	0.000011
	S	−0.00009	0.0191	0.000030
	O	−0.00371	0.0329	0.000030
	N	0.00351	0.0321	0.000028
	D	−0.00049	0.0292	0.000027

Appendix 1 (continued)

		Error	Expected Inflation	Expected Variance
1978	J	-0.00429	0.0281	0.000022
	F	0.00365	0.0242	0.000016
	M	-0.00235	0.0263	0.000019
	A	0.00303	0.0280	0.000022
	M	0.00453	0.0285	0.000022
	J	0.00283	0.0352	0.000034
	J	0.00214	0.0242	0.000016
	A	-0.00085	0.0292	0.000023
	S	-0.00517	0.0310	0.000026
	O	0.00006	0.0297	0.000024
	N	0.00238	0.0291	0.000023
	D	-0.00229	0.0241	0.000016
1979	J	-0.01108	0.0452	0.000056
	F	-0.00354	0.0343	0.000032
	M	0.00363	0.0432	0.000051
	A	-0.00511	0.0417	0.000048
	M	-0.01120	0.0364	0.000036
	J	0.00353	0.0332	0.000030
	J	0.00099	0.0423	0.000049
	A	0.00735	0.0478	0.000063
	S	0.01628	0.0573	0.000090
	O	-0.00263	0.0575	0.000091
	N	0.00845	0.0454	0.000056
	D	0.02440	0.0561	0.000086
1980	J	-0.00547	0.0638	0.000112
	F	-0.02138	0.0559	0.000086
	M	0.00142	0.0516	0.000073
	A	-0.00020	0.0580	0.000092
	M	-0.00206	0.0663	0.000120
	J	-0.01783	0.0776	0.000165
	J	0.01039	0.0714	0.000140
	A	-0.00496	0.0690	0.000131
	S	-0.00488	0.0589	0.000095
	O	0.01131	0.0647	0.000115
	N	0.00080	0.0705	0.000136
	D	0.00325	0.0630	0.000109

Appendix 1 (continued)

		Error	Expected Inflation	Expected Variance
1981	J	-0.00326	0.0676	0.000125
	F	0.01012	0.0634	0.000110
	M	-0.00470	0.0646	0.000114
	A	0.00117	0.0559	0.000086
	M	0.00736	0.0548	0.000082
	J	-0.00500	0.0513	0.000072
	J	0.00332	0.0464	0.000059
	A	0.00737	0.0540	0.000080
	S	-0.00158	0.0550	0.000083
	O	-0.00453	0.0497	0.000068
	N	0.00466	0.0523	0.000075
	D	-0.00470	0.0525	0.000076
1982	J	0.01055	0.0516	0.000073
	F	-0.00863	0.0665	0.000121
	M	0.00218	0.0566	0.000088
	A	-0.00819	0.0650	0.000116
	M	0.00402	0.0570	0.000089
	J	0.01855	0.0613	0.000103
	J	-0.00884	0.0675	0.000125
	A	-0.00431	0.0566	0.000088
	S	-0.02312	0.0639	0.000112
	O	0.00523	0.0443	0.000054
	N	-0.00988	0.0569	0.000089
	D	0.01412	0.0534	0.000078

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