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A Case Study in Exploring Time Series:

Inflation and the Growth of the Money Supply in Zaire, 1965-1982

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Occasional Paper No. 104

3530

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October 1986
Institute of Social Studies

The views expressed in this publication are those of the authors and not necessarily those of the Institute of Social Studies.

Royal Library, The Hague, Cataloguing in Publication Data

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Subject headings: Zaire; economic history; 1965-1982 inflation; Zaire; history; 1965-1982

ISBN 90-6490-023-X
SISO 345.1 UDC 336.748(675) "1965-1982"

Printed in The Netherlands

TIME SERIES AND EMPIRICAL ANALYSIS

To the economist, time series constitute key data sources for empirical analysis. This is especially true for macroeconomic analysis, which relies virtually exclusively on observations of macroeconomic aggregates as they evolve over time.

Economic time series provide quantitative information about the specific historical evolution of a country, a region, or a sector. As such, they can both inspire economic historians, and allow them to back up their arguments with quantitative data. But time series are not merely of historical interest. Indeed, good economic analyses of current problems require the careful study of historical contexts, and this naturally involves looking at data over time.

Furthermore, time series are used not only to grasp the specifics of the historical process which generated the point under study, but to test the validity of a model against a time series data base. Here the focus is not so much on the specificity of the historical process, but rather on the validity of a general model for which time series data are used as a *sample* of observations. The implicit assumption is that this sample is drawn from a wider population, the characteristics of which we want to know. For example, when a consumption function is estimated using time series data for a given country and period, the general relationship that is supposed to exist between consumption and income is of more interest than the specific evolution of consumption over that period.

Economists do not always distinguish very clearly between the role of time series in empirical analysis and its consequences. For example, in carrying out a case study of the economic situation in one country, they may resort to copying one or another model and estimating it against their data without carefully exploring the data base of the original model, and therefore without a feel for the specificity of the situation under study. Such an analysis cannot become really *concrete*. It evades the necessary process of sharpening one's hypotheses through questioning the available data.

Good exploratory analysis of time series can help to formulate questions about the specificity of the case under study. Furthermore, careful analysis of the features of time series can give economists more confidence in the appropriateness of the specific model and data being tested.

Appropriateness is of special importance in the case of time series. As already mentioned, time series are often used to serve as a sample to estimate a specific model. This assumes that the model is a general, abstract representation of the population from which the sample is drawn. The sample data are then used to estimate the parameters of the population's characteristics. Statistical theory teaches that such inferences are only valid when the sample has been randomly drawn from the population. The question, therefore, is whether time series can in fact be considered as samples of *independently* drawn observations.

For example, to estimate a consumption function in its simplest form, we use consumption and disposable income data over a given period. The pattern of consumption over time, however, can hardly be viewed as a group of randomly drawn observations. In fact, it would be more correct to see a set of time series as *one* observation of a particular historical process proceeding over t years, rather than as a collection of independent observations of unconnected occurrences.

Indeed, the past is the key to understanding the present. The increased indebtedness, reduced utilization of productive capacity of enterprises in import dependent sectors, etc. related to last year's balance of payments crisis will continue to have repercussions today and in the near future. Past investment decisions continue to exert their influence through their impact on the growth of productive capacity. Impacts and repercussions take time to work themselves out.

This paper uses a concrete case study to discuss some of the problems specific to time series. Its main focus is on exploring the patterns inherent in the time series of the case study, in order to uncover more general information about time series analysis. Specifically, the paper is concerned with problems of *trend*, *autocorrelation* and *seasonality* in time series, and their consequences for investigations of the relationships between economic variables.

In addition to illustrating various methods of descriptive analysis using time series, this paper will show that the careful exploratory analysis of time series constitutes an important prerequisite for the formulation and estimation of models, because the danger of estimating *spurious correlations* rather than *causal relationships* is particularly great in the case of time series analysis. It is relatively easy to obtain seemingly good results from regression models estimated with time series data: a high R^2, significant coefficients and a significant overall F statistic are often obtained using extremely shaky models. Time series tend to move together, all influenced by various repercussions which ripple through the economy. Cause and effect are therefore difficult to distinguish merely by looking at two or more series.

THE CASE STUDY: INFLATION IN ZAIRE

Since its independence, Zaire has experienced persistently high rates of inflation. The dominant view has been that the high rate of inflation is due to the high rate of increase in the money supply. According to this view, the money supply is taken to be *endogenous* with respect to the rate of inflation. Consequently, the major instrument to control inflation would then be control over the expansion of the money supply.[1]

The debate on the direction of causality between the money supply and the inflation rate will be set aside until later in this paper. The aim here is to use time series to explore the evolution of the money supply and of the consumer price index in Zaire. This analysis of time series will aid the later formulation of tests on the direction of causality between money and prices. So, while this exploration will throw some light on the issues raised in the debate, the focus here is on methods of empirical analysis. In order to get a better view of their inherent pattern, we shall look at a few time series, knowing that this process may raise questions which encourage thinking or rethinking about economic theory. Again, this is the object of exploratory data analysis: it sharpens our questions about a given problem by looking at the available empirical data in a systematic way.

The time series to be analyzed here are *quarterly* data covering the period 1965 to 1982:

M1: cash in circulation and demand deposits
M2: cash in circulation, demand deposits and time deposits
P: consumer price index

To allow the reader to check results and to experiment further with the data, Appendix A provides the complete data base for this paper.

THE COVARIANCE OF INCREMENT AND LEVEL

Taking a close look at these three series, one finds that they do not increase in a linear fashion, as plotting each variable against time verifies. The resulting patterns look very much like exponential curves. In fact this type of pattern is very common in economic data and reveals a growth process in which *increment covaries with* the *level* previously attained. Why?

A simple example illustrates. In the evolution of the population of a country, the *absolute* increase from year to year will depend upon the *size* of the population. A larger population will increase annually by a larger absolute number than a smaller population, even if the latter grows at a somewhat higher *rate*. In absolute terms, a population of 10,000,000 growing at two percent will increase by 200,000 people, while a population of 1,000,000 growing at three percent will increase by 30,000 in the same period. Size obviously influences the increment from year to year.

In economics this typical growth pattern may result from the fact that the growth of an economy depends on its size. Hence, real and monetary macroeconomic aggregates will generally manifest a growth pattern in which increment covaries with the level previously attained. The fact that increment and level covary does *not*, however, imply that the increment is *proportional* to the level. If such were the case, the growth *rate* would be *constant* over time.

If the increment were *proportional* to the previously attained level, for variable y_t we would get:

$$\Delta y_t = r \cdot y_{t-1} \tag{1}$$

and,

$$\Delta y_t = y_t - y_{t-1}$$
$$r = \text{constant rate of growth.}$$

Equation (1) can be rewritten as follows:

$$y_t = (1 + r) \cdot y_{t-1} \tag{2}$$

and substituting backwards:

$$y_t = y_o \cdot (1 + r)^t \tag{3}$$

Equation (2) gives a *deterministic, auto-regressive* relationship that expresses y_t as a function of itself lagged by one period. Equation (3) on the other hand expresses y_t as a function of a time *trend* variable t.[2]

In reality no economic variable grows at a constant rate over time, and postulating a *deterministic* trend would be very unrealistic. Instead, having noted that a given variable grows along a path that is very similar to an exponential curve, this growth pattern can be *summarized* by estimating its 'average' growth rate. To do so, time series data are compared with a stochastic trend equation that can be formulated by adding a disturbance term to equation (3):

$$y_t = y_o \cdot (1 + r)^t \cdot e_t^u \tag{4}$$

The error term is added as a multiplier because the trend equation is not linear, and needs to be made linear to be suitable for least squares regression. To do so, we take logarithms of both sides of equation (4):

$$\ln y_t = \ln y_o + \ln (1 + r) \cdot t + u_t \tag{5}$$

or to simplify the notation:

$$y'_t = y'_o + r' \cdot t + u_t \tag{6}$$

where $'$ refers to natural logarithms.

Using logarithms to transform data introduces another convenient effect of transformed data on the sample distribution. If the y_t series follows an exponential trend rather closely, then its increment from period to period will inflate over time. That is, the sample distribution of the increment straggles upwards with the trend variable. Transforming the data through logarithms will keep the increment of y'_t more or less constant, fluctuating (due to error terms) around r'. This allows the sample distribution to have a clear centre regardless of the length of the time period covered by the series.

ESTIMATING TRENDS

Before attempting to estimate the average internal compounded growth rate of the time series data for M1, it seems useful to get a sense of the range and distribution of the quarterly rates of growth, by looking at a stem and leaf diagram of the annual growth rates of M1 in Figure 1.[3]

25	*7*
24	
23	*1*
22	8
21	*5*
20	*6*
19	*5*
18	
17	*8723*
16	
15	19*43*
14	
13	0*3*
12	*2*
11	*8*
10	60*43755*
9	
8	962*435*
7	825
6	144*96*
5	254381*3*
4	758009
3	117
2	2
1	327
0	4524
−0	4
−1	4*3*
−2	*3*
−3	7
−4	
−5	2
−6	8
−7	
−8	
⋮	
−28	*8*

1976-1982 in italics
Growth rates in percentages
Stem: 10s and units
Leaves: 10s

Figure 1: Stem and leaf diagram: quarterly growth rates of M1

The five number summary sketches the following pattern:

Upper value	:	25.7%
Upper quartile	:	11.3%
Median	:	6.5%
Lower quartile	:	3.4%
Lowest value	:	–28.8%

from which one can compute:

Midspread	:	7.9%
Step (= 1.5 x midspread)	:	11.8%

and furthermore

Mean	:	7.4%
Standard deviation	:	8.2%

One can deduce from the diagram that the expansion of the money supply has indeed been quite pronounced over the whole period. Furthermore, there has been considerable variation in the growth rate. The bulk of the sample distribution is located between 3 and 11 percent. The median growth rate is 6.5 percent and the arithmetic mean is 7.4 percent, confirming the visual impression that the distribution straggles upwards. There appears to have been more variation in the last seven years of the series (1976 to 1982) and most of the higher growth rates were recorded in this period. For this reason, the growth rates of the last seven years (28 observations) are in italics on the stem and leaf diagram.

Most of the higher growth rates were recorded in 1980 and 1981: 25.7 per cent in the first quarter of 1981, 23.1 per cent in the first quarter of 1980 and 21.5 per cent in the second quarter of 1980. Following the second quarter of 1981 and throughout 1982 the growth rates are generally lower. The steeply negative growth rate of the fourth quarter of 1979 is very striking. It suggests that drastic monetary measures were applied in that period, although these apparently failed to have much effect in subsequent quarters.[4]

Proceeding with the estimation of the trend equation (6) for M1 yields the following results:

$$M1'_t = 3.7355 + 0.0667t \qquad (7)$$
$$\qquad (0.0554) \quad (0.0013)$$

t-stat: *67.5* *50.6*

$R^2 = 0.973$
s.e. $= 0.2325$
F $= 3.888$
DW $= 0.111$
T $= 72$

At first glance the fit appears extremely good: the coefficient of determination is high and the t and F statistics are highly significant. The Durban-Watson statistic, however, indicates the presence of strong, positive autocorrelation. In this particular case, the presence of strong autocorrelation does not affect the bias of the estimator, but it does influence its efficiency. The presence of positive autocorrelation *inflates* the R^2 and the t and F statistics, and hence may lead to an incorrect rejection of the null-hypothesis. A much better sense of the real significance of the trend coefficient is gained when autocorrelation is eliminated from the estimation, as will be shown following the interpretation of (7). We know that:

$$\ln (1 + r) = 0.0667$$

that

$$(1 + r) = 1.07$$

and, therefore, that the internal compounded quarterly growth rate of the monetary base averaged seven per cent. Note that this result is less than the mean of the quarterly growth rates, which equalled 7.4 per cent. The specification of equation (4) concentrates on the internal compounded rate of growth of a series, and hence is more akin to using the *geometric* mean as the principle for defining the average. Above, the *arithmetic* mean of the period by period growth rates is calculated. Now, if the rate of growth is constant over time, the geometric and arithmetic means will be equal. This is not the case here, and in general the geometric mean will be less than the arithmetic mean. The compounded growth rate as calculated from the estimation of equation (6) can also be expected to have a lower value than the average growth rate obtained by calculating the arithmetic mean of the period by period growth rates.

Returning now to the problem of autocorrelation, the Durban-Watson statistic indicates the presence of strong autocorrelation, i.e.:

$$u_t \quad = \rho\, u_{t-1} + e_t$$

where:

$$0 \quad \leqq |\rho| \leqq 1$$

ρ can be estimated from the value of the Durban-Watson statistic using the following equation:

$$\begin{aligned} \rho \quad &\cong 1 - \tfrac{1}{2}\,\mathrm{DW} \\ &\cong 1 - \tfrac{1}{2}\,0.111 \\ &\cong 0.95 \end{aligned}$$

which is very close to one. This suggests an alternative way to estimate equation (6) for M1, because taking first differences yields:

$$\Delta M1_t \quad = r' + u_t - u_{t-1} \tag{8}$$

$$\cong r' + e_t \tag{8'}$$

and hence the estimation of r′ basically involves calculating the mean of the first differences in the logarithms of M1. Note that the arithmetic mean is the least squares estimate of the true mean of the population. In fact, by using a least squares computer package to estimate the equations, (8′) can be estimated by regressing $\Delta M1'_t$ against a constant only. The standard error of this constant and its t value are then simply the standard error of the mean and its t value. The value of the Durban-Watson will then indicate whether e_t is subject to further first order autocorrelation or not.

Before choosing this course, it may be useful to reflect on the meaning of autocorrelation in equation (7). Positive autocorrelation means that successive observations of residuals tend to *string* together. When the residuals are plotted against time, they appear to be connected, rather than scattering erratically as if some random process were operating. This is because factors leading to the expansion of the money supply do not necessarily work their way out in a single period, but may continue to operate over several periods, causing autocorrelation.[5] Given this, is it reasonable to find a strong positive autocorrelation when M_t' is regressed over time?

To investigate this, we turn to the results of estimating r′ from the model specified in equation (8′):

$$\hat{r}' = \underset{(0.00960)}{0.06844} \qquad (8)$$

$$\text{t-stat} : 7.13 \qquad \begin{aligned} \text{s.e.} &= 0.081 \\ \text{DW} &= 2.016 \\ \text{T} &= 71 \end{aligned}$$

Clearly the DW does not indicate any further first-order autocorrelation of the residuals. Note that these residuals are simply the deviations from the mean of the first differences of $M1_t'$. Also, in interpreting these results the reader should remember that:

$$\begin{aligned} \Delta \ln M1_t &= \ln M1_t - \ln M1_{t-1} \\ &= \ln \frac{M1_t}{M1_{t-1}} \\ &\triangleq \text{logarithm of the } \textit{ratio} \text{ of } M1_t \text{ to } M1_{t-1} \\ &= \text{logarithm of } (1 + r_t) \end{aligned}$$

Interestingly, the t-statistic shows that the trend coefficient is significant, but it is much less inflated than the t-statistic obtained by estimating equation (7), i.e. 7.13 versus 50.6! This result emphasizes the extent to which t statistics (and F statistics) can be inflated when strong positive autocorrelation of the residuals is present.

This estimation also allows us to compute the compounded growth rate of M12 as:

$$\ln (1 + r) = 0.06844$$

and hence:

$$(1 + r) = 1.071$$

conforming to the previous result. As was already pointed out, the presence of autocorrelation does not lead to biased estimation in the case of equation (7), but confidence cannot be accorded to the significance levels obtained from it.

The previous estimation of r provided an 'average' growth rate of the money supply over the whole period being considered. But is this average really representative for the period as a whole? The question is not whether there is much variation from quarter to quarter *around* this average, but whether the average itself is meaningful. For example, the stem and leaf diagram given in figure 1 shows that growth rates between 1976 and 1982 tended to be higher than those in the preceding period. One possible reason could be that the growth rate is *accelerating* over the period, indicating that an estimation based on the proposition that the quarterly growth rates fluctuate around a constant rate would be invalid. Alternatively, there could have been a *break* in the pattern, and several distinct periods may have different average growth rates.

The best way to choose between these hypotheses is to look carefully at the pattern of the residuals of equation (8). Figure 2 gives that pattern, divided into two sub-periods. The vertical line gives the position of the mean of $\ln(1 + r)$, and the *distance* between each observation and the line represents the *residual* for that period. The residuals are negative to the left of the line and positive on the right. Consecutive points are connected to give a visual impression of the temporal pattern of the residuals (remember that DWE = 2.02).

In the first period, residuals are generally situated to the left of the line, but they give no impression of an accelerating growth rate. From 1976 to 1982 the residuals cluster on the right of the line, but once more there is little evidence of an accelerating growth rate. It seems therefore more appropriate to estimate separate growth rates for both periods, in order to test whether the growth rate *stepped upwards* in the latter period.

The empirical trend analysis of the variable M2 proceeds very much along the same lines as that for M1, and we shall limit ourselves to merely providing the final estimate of the trend coefficient, leaving the calculations to the interested reader to work out as an exercise.

$$\hat{r}' = \underset{(0.00918)}{0.07012} \qquad (9)$$

$$\text{s.e.} = 0.07739$$

$$\text{t-stat:} \quad 7.6 \qquad \text{DW} = 1.938$$

hence: $(1 + r) = 1.073$

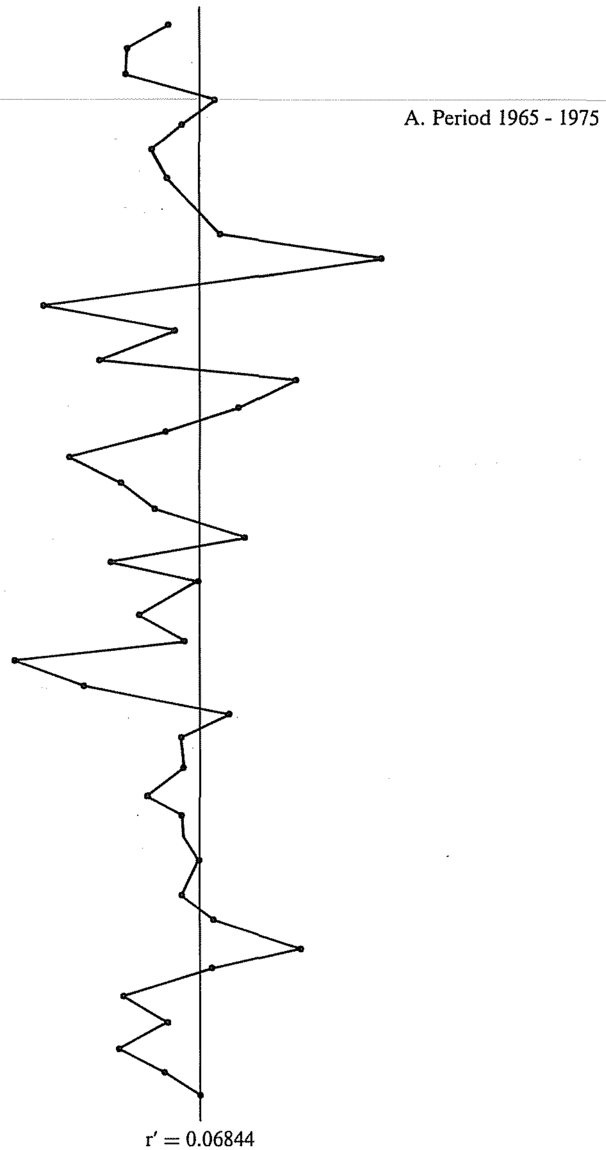


Figure 2: Plot of residuals of equation (8)

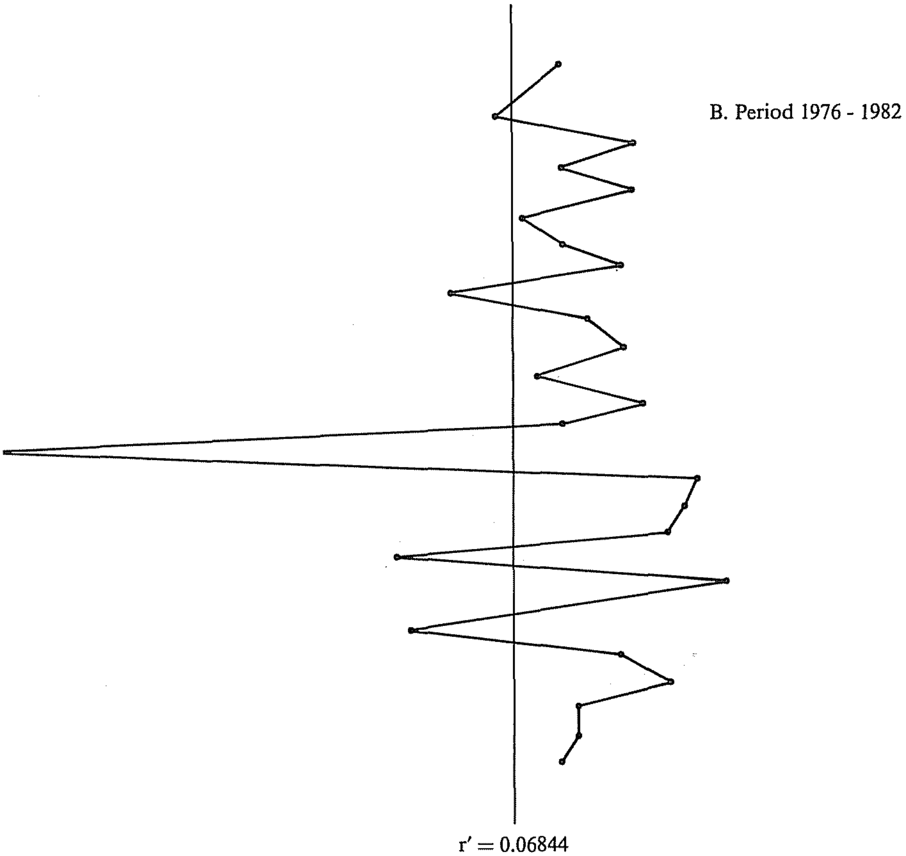


Figure 2 (continued) Plot of residuals of equation (8)

With respect to the consumer price index, figure 3 gives the stem and leaf diagram of the quarterly inflation rate. The pattern can be summarized as follows:

Upper value	:	34.6%
Upper quartile	:	12.3%
Median	:	6.35%
Lower quartile	:	1.3%
Lowest value	:	–7.3%

and:

Midspread	:	11%
Step (= 1.5 × midspread)	:	16.5%

and finally:

Mean	:	8%
standard deviation	:	8.5%

In comparison with the growth rates of M1, the rates of inflation have approximately the same median rate (respectively 6.5 and 6.3 per cent), but the variation is more pronounced with respect to prices. The midspread is 11 per cent (as against 8 per cent for M1) and the distribution straggles upward in a more pronounced fashion. The mean is, therefore, also more divergent from the median than is the case for M1. Considering that these are quarterly rates, we can see that inflation in Zaire has been quite persistent and high. The growth rates of the price level in the last seven years (1976-1982) are in italics to show their position relative to the prior period. They are consistently the highest values of the distribution (plotting the rates of inflation against time confirms this).

Turning now to the estimate of the trend coefficient, it is again clear that estimating the functional form as specified in equation (6) produces strong positively autocorrelated disturbances:

$$P'_t = \underset{(0.096)}{2.952} + \underset{(0.00229)}{0.07498}t \qquad (10)$$

t-stat: 30.8   32.8

$R^2 = 0.939$
s.e. $= 0.403$
$F = 1076$
$T = 72$

Correcting for the presence of autocorrelation gives:

$$r'_t = \underset{(0.00896)}{0.0744} \tag{11}$$

t-stat: 8.3

s.e. = 0.07555
DW = 1.51

The value of the DW in this case suggests that there may still be further autocorrelation of the residuals to be reckoned with, a problem to be taken up in later sections of this paper.

Finally, we can compute the compounded growth rate of the price level from the estimation of r′ in equation (11):

$$(1 + r) = 1.077$$

The fact that this growth rate is higher than the one obtained for M1, although their median rates of growth are similar, is easy to see in the stem and leaf diagrams of their respective quarterly growth rates (figures 1 and 3). The distribution of quarterly rates of inflation straggles upward much more strongly than that of the growth rates of the money supply. Therefore, both the arithmetic and geometric means [the latter produced by the least squares estimation of equation (11)] will be higher.

Plotting the residuals of equation (11) verifies once more that the growth rate of the price index appears to have stepped upwards in the period 1976 to 1982 relative to the previous period. As in the case of M1, however, there is no evidence of a continuous acceleration of the rate of inflation over the whole period.

Finally, readers unfamiliar with the phenomenon of autocorrelation are strongly advised to compare the time patterns of residuals in figures 2 and 4. In figure 2, the residuals behave fairly randomly (remember that DW = 2.02 in this case). In figure 4, however, the residuals are more connected, moving in small *runs*. Here the DW equals 1.51, which is doubtful given the large sample size.

34	6
33	
32	*1*
31	
30	*4*
29	
28	
27	
26	*9*
25	*9*
24	
23	
22	*7*
21	
20	
19	
18	
17	8
16	
15	95*7*
14	*434*
13	*6*
12	*65451*
11	*25899*
10	
9	*53*
8	781*77*
7	538
6	453*13*
5	2
4	48296*9*
3	*839*
2	36*0*
1	7
0	085593229
–0	5197
–1	52
–2	91
–3	
–4	
–5	
–6	
–7	*3*

1976-1982 in italics
Growth rates in percentages
Stem: 10s and units
Leaves: 10s

Figure 3: Stem and Leaf Diagram: quarterly inflation rates

A CASE FOR PERIODIZATION?

Our trend analysis points out that the growth rates of M1, M2 and P seem to have stepped upwards in the period 1976 to 1982. The dividing line is not so precise, but in general the implicit pattern of the latter half of the 1970s and the early 1980s differs from the rest of the sample, with the former witnessing both a higher inflation rate and higher growth rates in M1 and M2.

Before exploring this upward step in the growth rate any further, it is useful to answer a more fundamental question. If some data patterns suggest an interruption in the growth pattern of a variable or set of variables, would it be useful to split the overall period into subperiods?

Doing so automatically would certainly lead us astray in many cases. Misspecification of the nature of a trend could lead to distinguishing subperiods with little or no significance, and, more likely than not, fail to generate questions from the data which could then help to situate the problem in a clearer theoretical framework.

When the data suggest a possible break in a pattern, the best approach is to refer back to the general context in which the problem is set. For example, in Zaire inflation accelerated from the mid-1970s onward. Indeed, we know that the period from the mid-1970s to the present differed from the previous period in many respects.

The outbreak of recession in the world capitalist system in the 1970s and its continuation into the present has drastically altered the economic environment in which Third World countries must function. Zaire is no exception. Hence, even without further knowledge of the specific economic developments in Zaire, the changing pattern which the data suggests for the period starting in the mid-1970s appears to be more than coincidence.

With this in mind, we return to the proposition that the rates of growth seem to have shifted upwards since 1976. To test the proposition that this represents an upward step in the growth rate of M1 rather than a continuous acceleration, we propose the following equation:

$$\frac{M1_t}{M1_{t-1}} = a + b \,.\, D_t + c \,.\, t + w_t \qquad (12)$$

where:

D_t = a dummy variable which = 0 for T = 2 to 44
= 1 for t = 45 to 72

t = trend variable
= 2, 3, 4 . . . 72 (note that one observation is lost by taking the ratio of M1 to $M1_{t-1}$)

The dummy variable is included to test for the significance of a step upwards in the average growth rate of the second period. The trend variable tests for the significance of an accelerating growth rate over the whole period. For M1 this gives the following results:

$$\frac{M1_t}{M1_{t-1}} = \underset{(0.023)}{1.049} + \underset{(0.036)}{0.056D_t} + \underset{(0.000852)}{0.000076t} \qquad (13)$$

t-stat: 45.7 1.57 0.09

R^2 = 0.123
F = 4.77
s.e. = 0.078
DW = 2.23

The coefficient of the trend variable turns out to be totally insignificant, while the coefficient of the dummy variable does indicate some degree of influence. However, there is multicolinearity between D_t and t. Indeed, the simple correlation coefficient between these two explanatory variables equals 0.85, which is superior to their respective correlations with the dependent variable (0.35 for the dummy and 0.30 for t). Deleting the trend variable from the equation yields:

$$\frac{M1_t}{M1_{t-1}} = \underset{(0.012)}{1.051} + \underset{(0.019)}{0.059D_t} \qquad (14)$$

t-stat: *88.6* *3.1*

R^2 = 0.12
F = 9.667
s.e. = 0.0777
DW = 2.228

and confirms the hypothesis that the growth rate of the money supply stepped upwards in the second period. The estimated growth rates for the two periods can be calculated as follows:

$$
\begin{aligned}
r_a &= 0.051 \\
&= 5.1\% \\
r_b &= 0.051 + 0.056 = 0.107 \\
&= 10.7\%
\end{aligned}
$$

to show the quite considerable 5.6 percent step upward in the growth rate.

However paradoxical it may sound, it is nevertheless true that more can be discovered from residual information we fail to explain than from looking only at the goodness of fit. Pausing to carefully consider the pattern of the residuals is crucial to good econometric analysis. If, in the above case, we had tried to fit a trend to see whether the growth rate accelerated over time, without checking for an alternative hypothesis (that there was an upward step in the second period) we would have obtained the following results:

$$
\begin{array}{llll}
\dfrac{M1_t}{M1_{t-1}} = & 1.0295 + & 0.00121t & \qquad (15) \\
 & (0.0194) & (0.000458) & \\
\text{t-stat:} & \mathit{53.1} & \mathit{2.63} & R^2 = 0.091 \\
 & & & F = 6.93 \\
 & & & \text{s.e.} = 0.079 \\
 & & & DW = 2.15
\end{array}
$$

and we would have incorrectly accepted the hypothesis that the trend was present. This error was avoided by taking into account the results presented in (14), where the dummy variable proved to be more significant than the trend variable of equation (15), and the fact that the trend and dummy variables correlate ($r = 0.85$).

The same inferences can be made for M2, and it is again left to the reader to carry out the necessary estimations. Here, only the estimates for the growth rates of the respective period will be given.

$$
\begin{aligned}
r_a &= 5.5\% \\
r_b &= 5.5\% + 5.2\% = 10.7\%
\end{aligned}
$$

The *step* is of the same magnitude as in the case of M1.

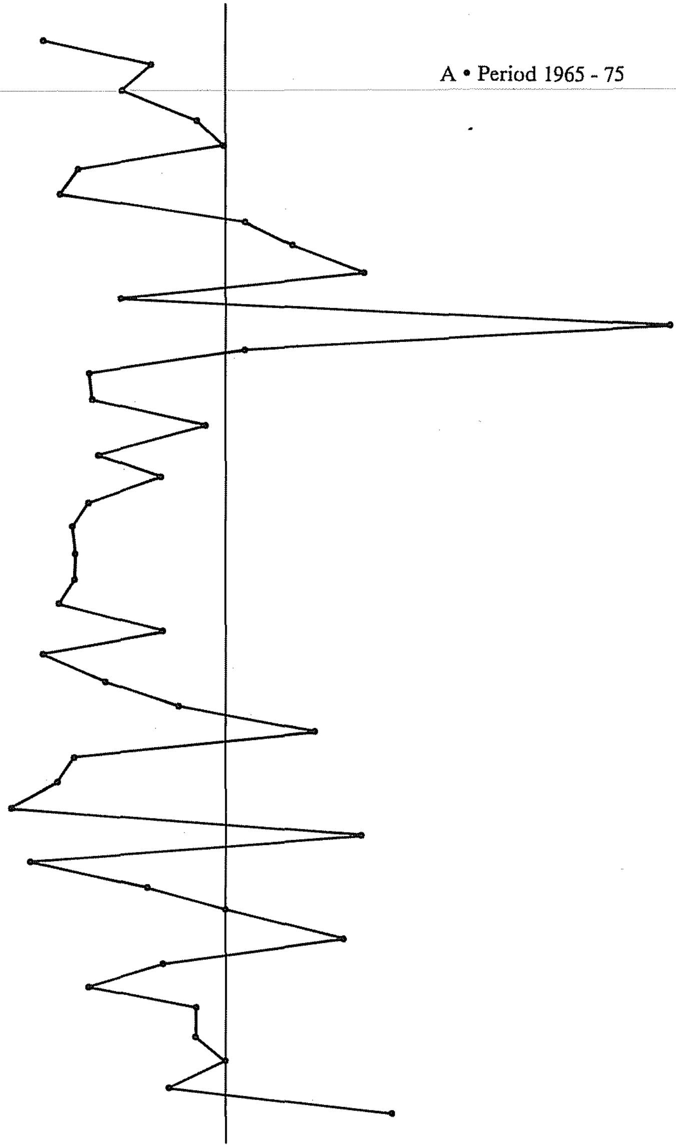
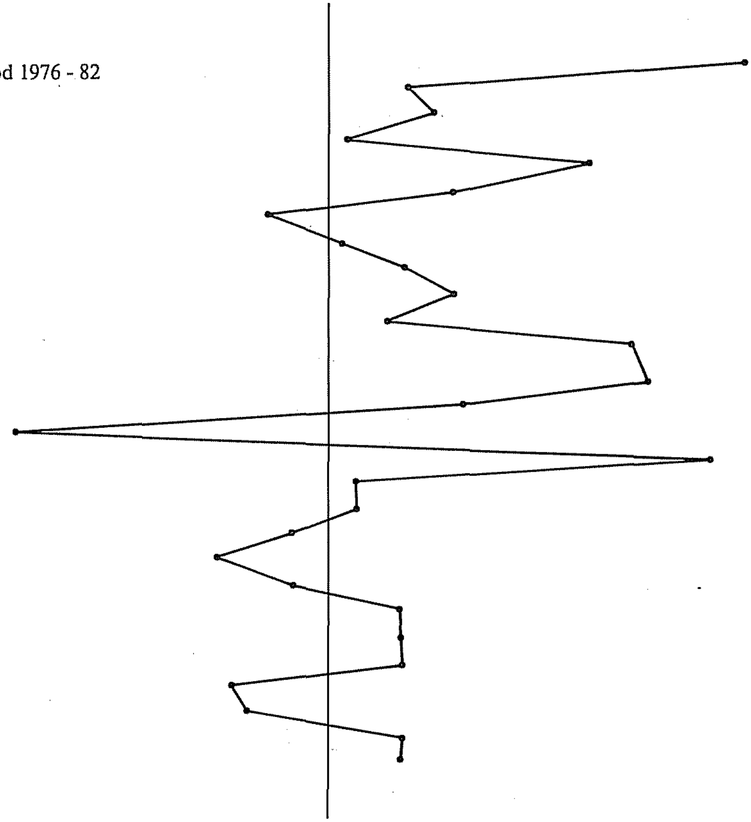


Figure 4: Residuals of equation (11)

B. Period 1976 - 82



r′ = 0.0744

Figure 4 (continued): Residuals of equation (11)

For the consumer price index (P), the estimation of equation (12) yields:

$$\frac{P_t}{P_{t-1}} = \underset{(0.023)}{1.065} + \underset{(0.0353)}{0.0932D_t} - \underset{(0.000843)}{0.00058t} \tag{16}$$

t-stat: 46.9 *2.64* −0.69

$R^2 = 0.184$
$F = 7.69$
s.e. $= 0.0775$
DW $= 1.82$

Interesting indeed! The dummy variable is insignificant despite the presence of multicolinearity, and not only is the time trend variable insignificant, but its coefficient is negative as well. Postulating *only* a trend variable would have yielded the following result:

$$\frac{P_t}{P_{t-1}} = \underset{(0.0197}{1.032} + \underset{(0.00047)}{0.0013t} \tag{17}$$

t-stat: 52.2 2.785

$R^2 = 0.10$
$F = 7.76$
s.e. $= 0.0807$
DW $= 1.69$

falsely suggesting that there is evidence of a continuous trend factor in the growth rate. The results of equation (16) show this to be incorrect.

Deleting the trend variable in the estimation yields:

$$\frac{P_t}{P_{t-1}} = \underset{(0.0118)}{1.052} + \underset{(0.0187)}{0.073D_t} \tag{18}$$

t-stat: 89.4 *3.88*

$R^2 = 0.179$
$F = 15.02$
s.e. $= 0.0772$
DW $= 1.813$

providing much more significant results than those of specification (17).[6]

At this point it becomes possible to specify rates of inflation for both periods:

$$r_a = 5.2\%$$
$$r_b = 5.2\% + 7.3\% = 12.5\%$$

It appears that the step in the rate of inflation from period A to period B was more pronounced than in the case of the growth in the money supply. Thus, while the rate of inflation approximately equalled the growth rate of the money supply between 1962-1975, beginning in the mid-1970s the inflation rate was somewhat higher than the growth rate of the money supply.

The tests carried out in this section indicate that a researcher whose interest lies in analyzing inflation in Zaire is well advised to pay special attention to the changing dynamic in the mid-1970s. Our results show that any attempt to ignore this shift by postulating a continuously accelerating growth rate of the money supply or of inflation will not specify the pattern of interrelationships correctly.

CHECKING FOR SEASONAL VARIATION

When working with quarterly data, it may be useful to check for seasonal patterns. While with some data this may be unimportant, for others, agricultural data for example, such analysis is crucial.

A variety of factors may cause seasonal variation in money and prices. For example, in an economy with a sizeable agricultural sector the behaviour of the money supply may reflect a need for cash balances in the production and marketing of crops. Furthermore, government expenditure often reveals an administrative cycle due to the timing of the fiscal year or the practice of concentrating orders in certain periods. Personal consumption can vary seasonally because certain expenditures are customary at particular times of the year. Investment behaviour can also vary in the course of a year: construction work, for example, may have slack periods during certain seasons.

An easy way to test for seasonal variations in time series data is to summarize the information on quarterly growth rates *for each quarter* over the period. This can be done by using stem and leaf diagrams and their corresponding five-number summaries. A summary of the features revealed by such analysis is presented here, leaving it to the reader to work out each case in more detail.

M1 yields the following pattern of quarterly growth rates for each quarter over the period as a whole:

M1	I	II	III	IV
Median growth rate	8.6	6.4	5.1	5.8
Midspread	5.3	7.0	8.1	12.5
Outliers[7]	3+/1–	–	–	1–
Mean growth rate	9.9	8.7	4.9	5.2
Standard deviation	7.9	5.9	6.5	10.6

which appears to indicate that the growth rate is higher on average in the first quarter. Variation among the average growth rates of the remaining three quarters is more difficult to assess since the midspread varies from quarter to quarter, although quarter III does appear to have the lowest rate.

The growth rates for M2 are as follows:

M2	I	II	III	IV
Median growth rate	10.9	6.5	5.1	6.7
Midspread	12.3	7.7	13.7	9.0
Number of outliers	–	–	–	1–
Mean growth rate	9.9	8.7	6.0	5.8
Standard deviation	7.4	6.1	8.9	9.2

Again, the growth rate is higher on average in the first quarter, and the third quarter shows the lowest rate. The respective midspreads tend to vary quite a bit from quarter to quarter, as was the case with M1 (although not in the same fashion).

Finally, the pattern for P is:

P	I	II	III	IV
Median growth rate	9.5	7.8	4.3	5.9
Midspread	9.2	11.3	10.7	11.2
Outliers	2+	–	–	1+
Mean growth rate	13.2	6.7	4.9	7.8
Standard deviation	10.1	5.9	6.0	9.2

This confirms the pattern already noted for M1 and M2: the inflation rate is higher in the first quarter and lower in the third. The midspreads for P are similar in size.

One method to test the significance of these differences in average growth rates per quarter uses dummy variables for three of the four quarters within the following type of equation:

$$\frac{M1_t}{M1_{t-1}} = a + bD1_t + cD2_t + dD3_t + v_t \qquad (19)$$

where:

$D1_t = 1$ if t refers to the first quarter
$\quad = 0$ otherwise
$D2_t = 1$ if t refers to the second quarter
$\quad = 0$ otherwise
$D3_t = 1$ if t refers to the third quarter
$\quad = 0$ otherwise

and hence:

a = mean of the fourth quarter
$a + b$ = mean of the first quarter
$a + c$ = mean of the second quarter
$a + d$ = mean of the third quarter

Using M1 to estimate equation (19) yields:

	Coefficient	Standard error	t-statistic	(20)
constant	1.052	0.019	54.5	
D1	0.047	0.0278	1.69	
D2	0.034	0.0273	1.25	
D3	0.00796	0.0273	0.29	

$R^2 = 0.053$
$F = 1.258$
s.e. $= 0.082$
DW $= 1.939$

On the whole, seasonal variations appear to be of very little significance. Only D1 has some influence, but this is definitely not very pronounced.

A similar result is obtained for M2:

	Coefficient	Standard error	t-statistic	(21)
constant	1.058	0.0189	56.12	
D1	0.040	0.0271	1.48	
D2	0.029	0.0267	1.08	
D3	0.0015	0.0267	0.057	

$R^2 = 0.047$
F $= 1.1$
s.e. $= 0.08$
DW $= 1.88$

Finally, for P there are somewhat stronger indications of seasonality:

	Coefficient	Standard error	t-statistic	(22)
constant	1.0775	0.0186	56.8	
D1	0.0545	0.0272	2.0	
D2	–0.012	0.0268	–0.43	
D3	–0.0285	0.02681	–1.06	

$R^2 = 0.13$
F $= 3.45$
s.e. $= 0.0804$
DW $= 1.435$

To summarize, although some seasonal variation is apparent in the data, it is insignificant except in the case of P. The variation within each quarter tends to offset whatever inferences one might make about the differences between their respective means.

AUTOCORRELATION IN VARIABLES

The process of estimating the trend to each of the three variables has transformed the original data. Here we look more closely at the reasons for these transformations and relate them to the problem of autocorrelation.

To begin with, we took the logarithms of the original variables, because the growth process of all three variables was characterized by covariance of level and spread. The absolute increment from quarter to quarter tends to inflate over time, producing more variation as time increases. Taking logarithms scales down the inflation of variance caused by covariance of level and increment.

Logarithms transform the original observations from an exponential trend into a linear trend (see equation 5). When estimating with these transformed data we noted the *strong positive* autocorrelation of the variables. This was not surprising, since cause, effect, and feedback take a certain amount of time to work themselves out, and meanwhile produce repercussions through the economy and hence an autocorrelative pattern in descriptive variables.

To cope with this problem, the data is transformed once more by taking the first differences of the log-transformed data. We did so rather mechanically, leaving the reader with only a hint as to why such a transformation makes sense in econometrics. Indeed, the difference between the logarithms of the two values equals the logarithm of the *ratio* of these values. Thus, transforming the data by differencing effectively means working with ratios. The ratio of $M1_t$ to $M1_{t-1}$ is simply $(1 + r_t)$ i.e., one plus the ratio of the quarterly growth rate of quarter t-1 to quarter t.

Since we expect there to be much less autocorrelation in the newly constructed data obtained by differencing the logarithms of the original series, a continued strong presence of autocorrelation would at this point indicate *runs of acceleration* or *deceleration* of the growth rate around the trend line. We saw that M1 lacks first order autocorrelation, while the price level tends to some extent to move in runs of acceleration and deceleration.

When quarterly data reveal seasonal patterns, it is useful to test for higher order autocorrelation, since the autocorrelative pattern may also be influenced by seasonal variations. In such cases it is advisable to check for autocorrelation at least up to the fourth order.

We will begin with M1. Equation (8) estimated the compounded internal growth rate of M1 by using the transformed variable $\Delta M1'_t$.

The residuals of this equation, e_t, are simply the deviations of $\Delta M1'_t$ from its mean. We can use these to check for the autocorrelation pattern of this variable, by regressing e_t on its own past, up to four periods back. The results are:

$\Delta M1'$	Coefficient	Standard error	t-statistic	(23)
e_{t-1}	−0.0239	0.126	−0.189	
e_{t-2}	−0.1121	0.126	−0.887	
e_{t-3}	0.0056	0.126	0.0430	
e_{t-4}	0.1169	0.128	0.9134	
cte.	0.0026	0.010	0.2574	

$R^2 = 0.030$
$F\,(4.62) = 0.4816$
$T = 67$
$DW = 1.9864$

There is no evidence of autocorrelation in the residuals of equation (8). The reader can obtain the same result by regressing M2.

With respect to the money supply series, we may conclude, therefore, that the *transformation* obtained by taking the *logarithms* of the *ratios* of successive observations of the original data produces a time series variable that is no longer autocorrelated. As will be shown, this type of transformation can be very useful in checking for temporal causality sequences without falling into the trap of spurious correlations.

The consumer price index series yields the following result:

$\Delta P'_t$	Coefficient	Standard error	t-statistic	(24)
e_{t-1}	0.1538	0.1212	1.270	
e_{t-2}	0.0582	0.1226	0.474	
e_{t-3}	0.0465	0.1226	0.397	
e_{t-4}	0.3050	0.1205	2.532	
cte.	0.00246	0.0088	0.278	

$R^2 = 0.1598$
$F\,(4.62) = 2.949$
$T = 67$
$DW = 1.9813$

In this case the coefficient of e_{t-4} is significantly different from 0. There is, therefore, a seasonal pattern of autocorrelation in the behaviour of the inflation rate.[8] Notice also that the t value of e_{t-1} is somewhat more significant than the others, a pattern already evident in the visual impression given by the residuals in equation (11).

CAUSALITY AND SPURIOUS CORRELATION

Up to now, we have been concerned with the exploration of a set of three time series in order to get a grip on the patterns inherent in the series: the nature of the trend, its stability over the period, the pattern of seasonality and autocorrelation. The exercise has been limited to relatively simple techniques: looking at distributions by summarizing their main characteristics such as level, spread, shape and outliers, using single equation regressions. Our focus has been on *thinking* about the data and not on the sophistication of the techniques used for making estimations.

This type of questioning appears to be crucial for anyone engaged in concrete, applied economic research. It allows more precise questioning of the concrete context of the problem at hand. Furthermore, it helps one to avoid misspecifying relationships by postulating invalid trend patterns or erroneously regressing a model across different periods with quite distinct, particular features relevant to the problem under study. In short, it allows more confidence in the data base.

Analyzing autocorrelation patterns in variables may also help one avoid engaging in spurious correlations to 'prove' a postulated model. As we know, autocorrelation in the errors of a regression equation implies that the estimator becomes *inefficient*, and in cases where lagged dependent variables are included as explanatory, it becomes not only *inconsistent* but *biased* as well. Positive autocorrelation, therefore, can easily lead one to accept false hypotheses.

Careful analysis of autocorrelation patterns in variables can help to locate the most appropriate ways to transform the original data base to minimize error. For example, our analysis of the time series of the money supply suggests that both M1 and M2 become relatively free from autocorrelation if transformed by taking the first differences of their logarithms. A similar transformation of the price index does not eliminate autocorrelation, although reducing it quite considerably.

Hence, specifying a model by using transformed data may help to avoid the danger of trying to establish a causal relationship between two or more variables which happen to correlate well not because a causal relationship exists, but merely because they are strongly autocorrelated as parts of a more complex interaction of economic and social variables.

There is no substitute for theory in approaching causality in economics. No amount of correlations will by themselves produce a theory about any phenomena. The very purpose of theory consists in abstracting the inner dynamic of the observed phenomena, and hence involves formulating a hierarchy of concepts situated at different levels of abstraction. It is by this process that one moves from merely describing reality to understanding its dynamic motion. With this understanding, one can relate concrete propositions to the behaviour of the interrelationships between *observable* economic variables (whose definitions are themselves products of theory).[9] One can, therefore, test a theory by testing the concrete propositions derived from it which specify the direction of cause, effect and feedback among observable economic variables.

When one is investigating a causal relationship between observable variables, care should be taken that one's statistical tests are not picking up the effect of spurious correlations due to autocorrelated variables.

Granger (1969) suggests a practical method for testing the direction of causality between two variables, based on the premise that cause, effect, and feedback between observable economic variables take time to work themselves out, and therefore operate in temporal sequences.[10] Granger observes that the future cannot cause the past, and that, therefore, one can confirm the hypothesis that Y causes X ($Y \rightarrow X$) if the past and present history of Y helps to explain the present state of X. Since, however, the presence of autocorrelation in Y and X may lead to a spurious correlation in this respect, Granger suggests modifying this criteria. He accepts that Y causes X if the past and present history of Y helps to explain the present state of X *better than X's own past does*. In practice this method involves transforming the Y and X series in order to eliminate the presence of autocorrelation in each variable as much as possible. The transformed series of X, X′ is subsequently regressed against the past, present and future values of the transformed Y series, the Y′, i.e.:

$$X'_t = \sum_{i=1}^{n} a_i Y'_{t-i} + bY'_t + \sum_{=1}^{n} c_j Y'_{t+j} + u_t$$

The significance of the a_i coefficients is tested to discover whether Y → X, while the significance of the c_j coefficients indicates whether X → Y. The significance of the b coefficient indicates a possible contemporary causality, although it does not indicate its direction.[11]

Clearly, the procedure outlined above does not prove causality, since both X and Y could be influenced by a third variable or set of variables that causes them to move in a pattern implying their correlation. Granger's method may, however, be useful in testing the premises of theories postulating a strong causal relationship between two variables along a temporal sequence of cause and effect. Granger's method can then be used to test the postulated direction of causality.

For example, in the case of the data on M1, M2 and P, a dominant view on inflation in Zaire postulates that inflation is the result of excessive expansion in the money supply. This theory considers growth in the money supply to be *exogenous* to the inflation rate and its *main determinant*: its central hypothesis is that M1 (or M2) → P.

Our analysis of the time series data will conclude by applying Granger's methodology to test this hypothesis. First, to cleanse the data of their strong pattern of autocorrelation, they are transformed by taking the first differences of the logarithms of the original values. The transformed data will be called $m1_t$, $m2_t$ and p_t respectively.

Next, variable p_t is regressed against past values of m1 up to four lags back, and against future values of m1 up to four leads ahead. The F value is used to test the joint significance of the lag and lead coefficients, and the results summarized as follows:

	F value	Conclusion
Overall equation	3.671	significant
Lead coefficients	5.542	highly significant
Lag coefficients	1.649	*not* significant

This contradicts the proposition that causality runs from money to prices, and using m2 instead of m1 one must also reject the hypothesis that m2 → p. Test results contradict the hypothesis that the money supply is exogenous to the price level. In fact, they suggest the opposite: the behaviour of the money supply may be largely endogenous and propelled by the process of inflation.

This paper does not intend to enter further into this debate. Its main purpose is to show that the presence of autocorrelation in variables can easily lead one to seek confirmation of causality where in fact the correlation is spurious, and the underlying mechanisms are much more complex than a highly simplified transmission mechanism suggests.

NOTES

1. The interested reader can find references concerning this debate on Zaire in the bibliographical note at the end of this paper.

2. In fact, equation (3) gives the expression for a compound growth process over discrete time periods. It is equivalent to the case of instantaneous growth expressed by:

$$y_t = y_o \cdot e^{r' \cdot t}$$

where r′ is the instantaneous rate of growth, and hence:

$$r' = \ln(1+r)$$

3. For an explanation of the stem and leaf diagram and the use of the five number summary, see Erickson and Nosanchuk (1983).

4. Actually, in December 1979 the monetary authorities in Zaïre carried out a change-over of the ten-Zaïre currency notes, a process which effectively destroyed many existing money balances.

5. This should not give the impression that a stable trend always underlies the growth process of an economy. Growth is never a smooth process. Rather, it hops and skips around a general trend, producing runs of expansion as well as slow-downs along the way. Fundamental changes in an economy will obviously alter the dynamic of its growth process, hence altering the basic trend. Distinguishing between breaks in a trend and variations around a basic pattern can be quite difficult. This is not simply a matter of statistics: it requires an understanding of the wider context of the economy as a whole, and of the political dimensions of economic development.

6. The attentive reader may have noticed that the DW value of equation (17) is slightly lower than that of equation (18) [and also of (16)]. This indeed hints at misspecification.

7. An outlier is defined using Tukey's method (see Erickson and Nosanchuk): An observation is considered to be an outlier if it is situated at a distance of one step or more from its nearest quartile. One step equals 1.5 of the midspread (= interquartile range), a rule of thumb that is very useful when checking whether non-robust estimators (such as mean and standard deviation) are likely to be distorted by outliers.

8. For further tests on this type of autocorrelative pattern see Thomas *An Introduction to Statistical Analysis for Economists*, second edition, Weidenfield and Nicolson, London, 1983, p. 304.

9. e.g. macroeconomic aggregates such as GDP, consumption, investment, etc. are themselves products of Keynesian theory and bear the stamp of that theory. Economists often forget that the collection of facts is itself informed by theory.

10. For references on this article and further developments, see the bibliographic notes at the end of this paper.

11. Clearly, there is the problem of choosing the number of periods to be taken into

consideration. Rather than addressing this here, it suffices to say that u_t will capture the influence of the omitted variables, and that this residual will have to be tested for the presence of autocorrelation.

SUGGESTED READINGS

Two standard works on techniques for exploring time series data are:

Erickson, B.H. and Nosanchuk, T.A. *Understanding Data*, Milton Keynes, The Open University Press, 1983.

Tukey, J. *Exploratory Data Analysis*, New York, Addison Wesley, 1977.

These books do not, however, specifically deal with econometric problems in time series analysis. An excellent introduction to the econometrics of time series analysis is given in:

Pindyck, R. and Rubinfeld, D. *Econometric Models and Economic Forecasts*, International Student Edition, 2nd edn, 1981, especially Part 3.

Thomas, J.J. *An Introduction to Statistical Analysis for Economists*, London, Weidenfeld and Nicolson, 1983, especially ch. 10 and 11.

For readers interested in the debate on inflation in Zaire, a selected bibiography (I) is provided. An extensive bibliography can be found in Mubake Mumeme (1983). Those interested in the more advanced field of testing causality in econometrics will find a selection of basic reference works in section (II).

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– 'La formation des prix au Zaïre et son évolution', *Zaïre-Afrique*. Nr. 125, mai 1978: 261-273.

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– *L'inflation en pays sous-développées, origine, mécanisme et effets des pressions inflationnistes au Congo 1960-1969.*

Vanderlinden, J. (sous la direction). *Du Congo au Zaïre, 1960-1980.* Bruxelles, C.R.I.S.P., 1980.

II. *Causality in Economics and Econometrics*

Granger, C.W.J. 'Investigating Causal Relationships by Econometric Models and Cross Spectral Methods, *Econometrica*, 37, July 1969: 424-438.

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