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An Analysis of Selected Economic and Methodological Issues Relating to Time Series Research in Accounting

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ABSTRACT

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In recent years there has been a rapid growth of time series research in accounting. This has led to applications in several areas including those of auditing, financial reporting and management accounting. These studies have provided insight into the stochastic properties of key variables within the accounting environment. Yet, at the same time, they have raised a large number of issues of both substantive and methodological natures.

The present paper focuses on identification, synthesis and integration of what the authors consider to be some of the main economic and methodological issues that have emerged within the last several years. This discussion considers different trends which might occur within this area of research in the short and intermediate term futures.
INTRODUCTION

In recent years there has been a rapid growth of time series research in accountancy. This has led to applications in several areas including those of auditing, financial reporting and management accounting. These studies have provided insight into the stochastic properties of key variables within the accounting environment. Yet, at the same time, they have raised a large number of issues of both substantive and methodological nature. The purpose of this paper is to focus on some of what the authors consider to be the main issues relating to time series research in accounting.

In the next section we provide an overview of time series research in accounting (henceforth TSRA). Section 3 discusses economic issues, Section 4 discusses methodological issues and Section 5 considers future research.

OVERVIEW OF TSRA

The purpose of this section is to provide a brief survey of some of the major applications of time series research in accounting (for a detailed survey see Abdel-Khalik (1977-78), and Hopwood and Newbold (1981)). Subsequent sections build on the discussion presented here.

Factors Motivating TSRA

Since accounting is concerned with providing information for making decisions, it is not surprising that it is concerned with time series. This is because many types of decisions in the business environment involve the use of forecasts. For example, Norby (1973) found that a large percentage of financial analysts use earnings forecasts in their
decision making process. In addition, Ball and Brown (1968) found that advance knowledge of annual corporate earning would enable an investor to earn 'abnormally' high returns (as measured by the capital asset pricing model of Sharpe (1964), Lintner (1965) and Mossin (1966)). Such a possibility has led the Securities and Exchange Commission to favor the concept of urging and/or requiring the disclosure of earnings forecasts. (For a detailed discussion see: Dopuch and Penman (1976), Penman (1980), Prakash and Rappaport (1974) and the Wall Street Journal (1978)). Their reasoning in part has been that, in the name of fairness, all potential investors should have equal access to the best forecast available, especially in the case where the forecast is based on inside information.

The use of forecasts by investors has been recognized in the accounting literature. For example, Beaver, et. al. (1968) considered "predictability" as a possible criterion for assessing the usefulness of alternative reported financial numbers. Under this view different numbers can be compared on the basis of how well they predict some variable of interest. For example, the Financial Accounting Standard Board (1976, p. 55) has stated:

Earnings from an enterprise for a period measured by accrual accounting are generally considered to the most relevant indicator of relative success or failure of the earnings process of an enterprise in bringing in needed cash.

From this statement it can be seen that the "variable of interest" has been considered, at least by the Financial Accounting Standards Board, to be some form of cash measure. More debatable, however, is the notion of using past earnings to predict future earnings. While this type of approach has been operationalized (see, for example, Simmons
and Gray (1969)), both Revsine (1971) and Greenball (1971) have presented convincing arguments that it is not acceptable for use as a basis for comparing alternative accounting methods.

Another motivating factor for TSRA has been information content/capital market research. In testing the information content of accounting numbers, researchers have hypothesized that the capital market reacts to new or 'unexpected' information about a particular company. This has led to the computation of an expectation or prediction of the accounting number. The predicted number is then subtracted from the actual and the difference is then hypothesized to convey either 'good' or 'bad' news to the market. If this hypothesis is correct then the sign of the difference will be associated with abnormal returns as defined by the capital pricing model of Sharpe (1964), Lintner (1965) and Mossin (1966). This methodology was introduced by Ball and Brown (1968) and has been applied by many, including Foster (1977), Brown and Kennelly (1972) and Joy, et. al. (1977). For example, Foster (1977) used an autoregressive model on the seasonal difference of earnings per share to generate a prediction of earnings.

There have been many other applications of TSRA which are too numerous to discuss in detail here. One such application is univariate and multivariate modeling in auditing (see, for example, Stringer (1975), Kinney (1978) and Albrecht and McKeown (1977)). Another is spectral analysis (Praetz, 1979) and correlogram analysis (Lookabill and McKeown, 1976) of security dividend-price returns. Fama (1965, 1970) showed that under certain conditions these returns should be white noise if prices reflect all publically available
information. Therefore, this research has been concerned with testing for a flat spectrum. Finally, Foster (1977) gives a list of several other areas of applications, including cost of capital research, dividend policy and income smoothing.

Research Findings

This section summarizes the results of a substantial portion of previous time series research in accounting. The focus is on the time series properties of accounting earnings since this has been the area of the largest quantity of research activity. The Financial Accounting Board (FASB) has stated, "The primary focus of financial reporting is information about earnings and its components" (FASB, 1978, p. ix).

Early studies dealing with the time series properties of earnings used simple naive and/or index models due to the lack of tools to deal with formal time series. These include Reilly, et. al. (1972), Little (1962), Little and Rayner (1966), Green (1964), Green and Segal (1967), Copeland and Marioni (1972), Beaver (1970), Craigg and Malkiel (1968), Coates (1972), Ball and Brown (1968) and Brown and Kennelly (1972). These studies used simple 'rule of thumb' models such as average of previous values. Later Dopuch and Watts (1972), Ball and Watts (1972) and others introduced formal time series models into the accounting literature and focused on the time series behavior of annual earnings. Similarly, Collins and Hopwood (1980), Brown and Rozeff (1979), Foster (1977), Griffin (1977), Hopwood and McKeown (1981), Watts (1975) and others focused on the stochastic behavior of quarterly earnings.
The results of the annual studies provide a substantial amount of evidence that annual earnings or earnings per share follow a random walk or a random walk with a drift. Support for this conclusion comes from Ball and Watts (1972), Beaver (1970), Brealy (1969), Little and Rayner (1966), Lookabill (1976) and Salamon and Smith (1977). In addition, Albrecht, et. al. (1977) and Watts and Leftwich (1977) found that full Box-Jenkins analysis of individual series did not provide more accurate forecasts than those of the random walk. Therefore, the use of a single or 'premier' model seems to be the most appropriate procedure, at least in the cases studied.

Research on quarterly earnings has also involved a consideration of a 'premier' versus individual series model approach. Several univariate 'premier' models have been investigated in the past. These include those of (using the notation of Box and Jenkins (1970)):

(i) Foster (1977), who considered the \((1,0,0) \times (0,1,0)_4\) model

\[(1-\phi B) (1-B^4)X_t = a_t, \text{ plus a constant term}\]

(ii) Griffin (1977) and Watts, who considered the \((0,1,1) \times (0,1,1)_4\) model

\[(1-B)(1-B^4)X_t = (1-\theta B)(1-\theta B^4)a_t\]

(iii) Brown and Rozeff (1979), who considered the \((1,0,0) \times (0,1,1)_4\) model

\[(1-\phi B)(1-B^4)X_t = (1-\theta B^4)a_t\]

Note that the Foster model is a special case of the Brown and Rozeff model with \(\theta = 0\). (The Foster model also contains a constant, but Brown and Rozeff (1979) found this parameter to be insignificant.)
Lorek (1979) and Collins and Hopwood (1980) explored the relative predictability of these premier models and found that there was no advantage to performing individual series identification, at least for forecasting horizons within one year. Both of these studies focused on the ability of the models to generate annual forecasts from quarterly earnings. These results also indicated, as originally suggested by Foster (1977), that the Foster model fails to incorporate a seasonal lag.

More recently researchers have begun to explore multiple time series models. For example, Hopwood and McKeown (1981) found the model

\[(y_t - y_{t-4}) = W_0(X_t - X_{t-4}) + \frac{(1-\phi B^4)}{(1-\phi B)} a_t\]

to be useful in predicting annual earnings from quarterly earnings. In this model \(y_t\) denotes quarterly earnings per share and \(X_t\) a market index of earnings.

Also Beaver, at. al. (1980) developed a time series model that used security prices to predict earnings. Their model form is based primarily on a priori reseasoning plus several assumptions. Similarly, Chant (1980) found that the money supply could be used as a single leading indicator of earnings.

ECONOMIC ISSUES

To our knowledge there has been no clear cut distinction made in previous literature between economic and methodological problems. By economic issues we refer to those issues which primarily relate to utilizing underlying circumstances and economic theories for the purpose of system identification and parameter determination or estimation.
On the other hand, we use the term methodological issues to refer to problems which are primarily statistical in nature. There are, of course, issues that are likely to be both statistical and economic in nature.

**System Identification**

Most time series research in accounting has been analytical as opposed to holistic. By this it is meant that the focus has been on individual time series as opposed to a system of dynamically related variables. This no doubt accounts for the poor predictability results of statistical models relative to financial analysts (see, for example, Brown and Rozeff (1977), Collins and Hopwood (1980), and Hopwood, et al. (1981)). The need to develop predictions or expectations from a system standpoint was recognized two decades ago by Muth (1961) who developed what is now referred to as rational expectations 'theory.' He argued that, in an economic environment, individuals cannot be expected to form expectations from only single univariate extrapolation. There is a need to incorporate additional variables according to the relevant economics theory.

A primary reason for the analytical instead of systems approach has been methodological restrictions. The tools for system identification are not well developed. Practically speaking, even simple systems such as those containing several inputs and a single output can be extremely difficult to identify when the inputs are not independent. This is because the specific model form is input determined by a matrix of cross correlation functions between all of the variables, and this includes information about the relationships between the input variables
which must be considered. One possible way to solve this problem might be through 'successive orthogonalization' which would work as follows:

Assume there are three input series \( X_1, t \), \( X_2, t \), \( X_3, t \) and one output series \( Y, t \); then let

\[
\begin{align*}
X_1, t & = U_1, t \\
X_2, t & = T_{12} U_1, t + U_2, t \\
X_3, t & = T_{13} U_1, t + T_{23} U_2, t + U_3, t
\end{align*}
\]

where \( U_i, t \) is a white noise series and \( T_{i,j} \) represents the transfer function (i.e., a polynomial ratio identified and estimated from the data and theory) between white noise series \( U_i, t \) and input series \( X_j, t \). The result is that \( U_1, t, U_2, t \) and \( U_3, t \) are white noise, mutually uncorrelated series where the time vectors \( X \) and \( U \) are related by the following transformation

\[
X = T \cdot U \quad \text{and} \quad T \text{ is of the form:}
\]

\[
\begin{bmatrix}
1 & 0 & 0 \\
T_{12} & 1 & 0 \\
T_{13} & T_{23} & 1
\end{bmatrix}
\]

The three \( U_i, t \) series can then be used to identify three separate single input transfer functions with \( Y, t \) being the output variable in each case. Call each of these transfer functions \( G_1, G_2 \) and \( G_3 \), then a final model would be of the form \( Y, t = G_1 U_1, t + G_2 U_2, t + G_3 U_3, t \). The model could then be reparameterized in terms of the original series
(i.e., \( U = T^{-1}X \)) before forecasting. This example can easily be extended to a larger number of input series.

Note that the successive orthogonalization approach is mathematical as opposed to economic in nature. Whenever possible, economic theory should be given precedence in model identification. However, a difficulty with the economic approach might be that the economic theory might specify only the variables that belong in the system and not the form of the model. In this case successive orthogonalization (SO) could be used in conjunction with economic theory. In addition, SO might be used to provide a simplified representation of the system, even when the exact model form is known.

Most of the research in accounting has not utilized economic arguments in the determination of the specific model form, given that the relevant variables in the system have been selected. For example, most researchers have relied on the data to make the choice of an autoregressive versus moving average model. However, Granger and Newbold (1977, p. 23) argue that such a choice is sometimes possible:

If some economic variable is in equilibrium but is moved from the equilibrium position by a series of buffeting effects from unpredictable events either from or within the economy, such as strikes, or from the outside, and the system is such that the effects are not immediately assimilated, then a moving average model will arise. An example might be a small commodity market that receives a series of news items about the state of crops in producing countries.

Granger and Newbold (1977) base their reasoning on the fact that an infinite order autoregressive model is equivalent to a simple first order moving average model. The same type of reasoning can be applied to transfer function models where an analogous relationship exists between input and output lag models.
Finally, it should be mentioned that the systems approach, while not yet applied much to accounting time series, has been reasonably well developed in science as a whole. In 1954, under the leadership of biologist Ludwig von Bertalanffy, economist Kenneth Boulding, biomathematician Anatol Rapoport, and physiologist Ralph Gerard, the Society for General Systems Theory (now Society for General Systems Research) was formed. Also a general systems theory has evolved. For example, Boulding (1964) has identified five basic principles of systems theory. Also Litterer (1969) identifies some of the characteristics of systems theory. These include interdependency of objects, holism, entropy, goal seeking, inputs and outputs, transformation, regulation, hierarchy, differentiation and equifinality (for a discussion of these see Schoderbek, et. al. (1980)). Within a time series context several of these characteristics correspond very closely with the discussion in Box and Jenkins (1970) of multiple time series. For example, inputs and outputs correspond to input and output series, transformation to transfer functions, and regulation to feedback and feedforward control. Perhaps general systems theory will be useful in providing a framework for future time series research in accounting, particularly in the area of cybernetics 'closed loop' systems. (An example is given below. For a more complete discussion see Schoderbek et al. (1980).) Such systems are very often good representations of economic situations since feedback control is typically a prerequisite of goal achievement (or goal maintenance). For example, a market priced equilibrium can be represented as a feedback system with the goal of supply equaling demand. Consider Figure 1 which contains a supply
Figure 1

A Block Diagram for Market Price Equilibrium

SS
Supply Source Transfer Function

SIP

DIP

DS
Demand Source Transfer Function

reference input) i=0

l=0

D
disturbance (i.e., new information)

revised price equilibrium price

Market Transfer Function M

Supply Source Transfer Function
source (SS), demand source (DS), supply information processor (SIP), demand information processor (DIP), market (M), and disturbance (D). Assume that the system is initially in equilibrium with supply and demand equal. Then allow the introduction of a disturbance (D). This information is transmitted to SIP and DIP which in turn signal SS and DS to adjust the quantities supplied and demanded. The new quantities are passed through the comparer (denoted X) which takes the difference between the two quantities and compares it to the 'ideal' reference input \( l = 0 \). The deviation from the reference input is transmitted to the market which establishes a revised price. The revised price is then transmitted to SS and DS which again adjust the price. The process continues until supply and demand are equal. Note that the square boxes represent transfer functions which would be determined from theory and data.

At the heart of the above example is a goal of zero difference between supply and demand. While the goal in this example is somewhat abstract, many examples exist within the accounting environment where the goals are deliberately selected by managers, creditors or investors. For example, managers might be interested in zero deviations between budgeted and actual amounts, creditors might desire to keep bad debits at some fixed percentage of total loans, and investors might desire to maintain some constant level of risk in an investment portfolio. The common characteristics of these situations is that output of decisions are used as inputs to future decisions.

**Problems of Aggregation**

Accounting and economic variables are very often subjected to either intratemporal or intertemporal aggregation. An example of
intratemporal aggregation is income, which is an aggregate of various expenses and revenues. Intertemporal aggregation occurs, for example, when quarterly income is aggregated to produce annual income.

Both types of aggregation are particularly important since the results of Brewer (1973) and Rose (1977) show the form of the autoregressive integrated moving model is not invariant under either type of aggregation. Therefore, use of the information in the disaggregate series could be very helpful in identifying the correct model form for the aggregated series.

From the standpoint of accounting, aggregation theory has the potential to help in assessing the value of using aggregated versus disaggregated figures. For example, Hopwood, et. al. (1981), (also see Hopwood and Newbold (1981)) showed that there is about a 15 to 20 per cent information gain in reporting accounting income on a quarterly basis versus an annual basis. They also note that the quarterly earnings models of Brown and Rozeff (1979), Griffin (1977) and Watts (1975), upon aggregation, do not theoretically lead to the random walk model found by most researchers cited above.

**Changing Price Levels**

The effect of changing price levels (e.g., inflation) on the time series properties of accounting numbers has received little attention. In an attempt to gain some insight into this problem Hopwood (1979) looked at the ratios of variances for the last half to the first half of 50 series. It was found that regardless of the differencing combinations used, the variance was increasing over time for all of the sample firms. Furthermore, it was found that this problem was mitigated by dividing the series numbers by a price index. This procedure also resulted in improved forecasts.
Another way of dealing with this problem might be the use of the Box and Cox (1964) transformation, which is of the class

\[ Y_t = (X_t^\lambda - 1)/\lambda \quad (\lambda \neq 0) \]

\[ = \log X_t \quad (\lambda = 0) \]

where \( X_t \) is the series to be transformed, \( Y_t \) is the transformed series and \( \lambda \) is the transformation parameter.

Hopwood, et. al. (1981) found \( \lambda \) to be significantly different from 1 for about one half of their sample. For these series there was a marked improvement in forecast accuracy after applying the transformation.

**Intervention Analysis**

Box and Tiao (1975) introduced intervention analysis to allow for the impact of a single event such as a strike on the time series. This procedure involves adding a parameter to the model which is greater than zero when the event occurs and is zero for all other times. (In some cases more than one intervention parameter might be desirable.) These kinds of events are very common in the accounting environment. For example, Collins and Hopwood (1980) found a number of cases (strikes, etc.) where an intervention term could have been used.

To gain an idea of the magnitude of the problem we made a cursory examination of about 250 COMPUSTAT tape companies. We noted that occasionally the earnings of a firm would take a violent swing. For example, during the third quarter of 1974, the earnings of AMF company made a ten-fold drop from the same quarter in the previous year and a five-fold drop from the previous quarter.
A second potential use of intervention analysis is the inclusion of the intervention variable for purposes of assessing the impact of a particular action on some time series of interest. For example, Griffin (1977) used this approach to examine the effect of bond reclassification on conditional security returns. His models included a single input transfer function with an intervention variable. The intervention parameter therefore provided a test for the information content of the reclassification. In a similar vein, Larcker, at. al. (1980) provides convincing arguments for the use of Griffin's methodology. For another intervention application see Deakin (1976).

METHODOLOGICAL ISSUES

Exact Likelihood Estimation

Our analysis of the literature revealed that virtually all research studies have used least squares estimation. It should be noted that this approach is only an approximation of maximum likelihood estimation and Ansley and Newbold (1980) have shown that it produces inferior parameter estimates. The loss in parameter estimation precision is greater for shorter series since the exact likelihood approach provides better estimates of the initial conditions (or 'start up values') than the techniques of Box and Jenkins (1970). The shorter the series the more that the parameter estimates depend on these conditions.

Stationarity-invertability Conditions

As discussed by Box and Jenkins (1970) theory requires that the model parameters satisfy certain stationarity-invertability conditions.
Our examination of tabled models in the accounting literature revealed a large number of models with parameters violating these conditions. These models can lead to extremely large forecast errors. For example, a first order autoregressive model with a parameter equal to 1.5 will produce a forecast function which quickly diverges upward toward infinity.

Newbold and Ansley (1980) show that this problem is aggravated by the use of least squares, as opposed to exact likelihood estimation. If least squares is to be used, the nonlinear regression can easily be constrained to keep the parameters within bounds. We have developed a program which accomplishes this by adding the following term to the sum of the squares during estimation:

$$|B-MR+\delta| \times 10^{-20}$$

where $B$ is the polynomial root boundary described by Box and Jenkins (1970), $MR$ is the minimum polynomial root, and $\delta$ is small constant which is arbitrarily close to zero. This term is only added when the estimation routine tries a parameter value out of bounds. This simple program modification can typically be made with only a small number of statements when the roots are available.

**Correlated Error Structure**

A large portion of accounting time series studies involve model estimation for a sample of firms within a common time interval. Since all firms are more or less subject to common economic influences, these circumstances will lead to contemporaneously correlated errors. In the linear regression case, Zellner (1962, 1963) has referred to this as the
problem of 'seemingly unrelated regression equations (SUR).'. It is well known (see for example, Judge et al. (1980)) that simultaneous modeling of different firms' data can lead to more efficient estimation when this problem occurs (for a SUR literature review see Srivastava and Dwivedi (1979)). Along these lines and those of Nelson (1976), Palm (1977), Reinsel (1979), and Salamon and Moriarty (1980) presented an application of the SUR concept to univariate time series models (henceforth SURARMA).

It is interesting to note that for some firms there might exist non-contemporaneously correlated error disturbances. This is because the affect of some general economic shocks is likely to occur at different times for different firms. For example, it is widely known that sudden increases in interest rates will affect the construction industry before they affect the consumer retail goods industry. In such a situation the multivariate ARIMA methods of Tiao and Box (1979) might prove useful.

One drawback of the SURARMA approach is that it requires estimation (or knowledge) of the \((N^2-N)/2\) covariances between the errors of the \(N\) series being modeled. For 50 firms this would require the estimation of 1,225 numbers. For series of lengths typically found in accounting studies (i.e., 50-75 observations) this would involve considerable estimation risk; that is, the gains from simultaneous estimation might be more than eliminated from the error associated with the estimation of the variance-covariance matrix of disturbance errors.

It should be pointed out that an alternative approach to SURARMA might be the elimination of common disturbances via industry, market
or other indices. This would be accomplished by use of single or multiple input transfer function-noise model. It would be interesting to compare the market index transfer function approach of Hopwood and McKeown (1981) with the SURARMA approach of Salamon and Moriarty (1980). The important thing is that both of these studies take a 'systems approach.' It is of our opinion that this approach will lead not only to better forecasting but to a better understanding of the interrelationships of variables within the accounting environment.

**System Stationarity**

The stationarity of a Gaussian time series requires that the mean, variance and autocovariances be constant over time. A constant mean typically can be achieved by differencing. However, Hopwood et al. (1981) found that quarterly earnings do not exhibit constant variances over time. Their results also showed that this problem can be mitigated by using a power transformation.

The requirement of constant autocovariances, to our knowledge, has not been investigated to any considerable degree in accounting. Also this problem is very plausible since most firms undergo structural and environmental changes over time. Examples of these changes are changing product mixes, industry trends, etc. Some of these changes might be dealt with through simple intervention analysis, but others might require more elaborate measures. Finally note that the same problem can occur with multiple time series if the cross-covariance functions change over time.
FUTURE RESEARCH

The basic thrust of this paper has been to depict time series research in accounting as moving from simple univariate analysis to a more general dynamic systems approach. In our opinion this will lead to future research which combines econometrics, economic theory and time series model building. As discussed above, we feel that whenever possible economic theory should be brought to bear on system modeling, but such an approach can be supplemented by identification based on available data. This view is summarized by Jenkins (1979, pp. 90-91):

The most serious weakness in econometric model building seems to be the absence of a model building methodology. It is argued by many that 'economic theory' should be the sole arbiter as to what structures should be built into a model. ... However, no 'theory' in any subject is sacrosanct. ... ...a more sensible approach would seem to be to use theory and prior knowledge to influence the choice of variables for a particular situation and then to combine this knowledge with empirical investigation in order to arrive at models which are representationally adequate.

Finally, a general dynamic systems approach will require research on interrelationships between variables in the accounting environment. Such interrelationships might be characterized by mutual crosscorrelation, aggregation and feedback. In addition, it will be necessary to deal with problems such as changing variances (and possibly covariances.) These problems will be subject to the additional problem of large outliers.
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