THE EFFECT OF TIME-SERIES PROPERTIES ON THE PREDICTIVE VALUE OF QUARTERLY EARNINGS FOR FORECASTING ANNUAL EARNINGS

by

Kyung Joo Lee

A Dissertation Submitted to the Faculty of the

COMMITTEE ON BUSINESS ADMINISTRATION

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

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As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Kyung Joo Lee

entitled The Effect of Time-Series Properties on the Predictive Value of Quarterly Earnings for Forecasting Annual Earnings

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Dan S. Dhaliwal — Date 11/16/90

Kenneth F. Kroner — Date 11/16/90

Allen B. Atkins — Date 11/16/90

Date

Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Dissertation Director — Date 11/16/90
Dan S. Dhaliwal

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SIGNED: Kyung Joo Lee

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ABSTRACT

This study provides further evidence regarding the predictive value of quarterly earnings for improving the forecasts of annual earnings. Using an analytical model, it is shown that for a specific class of time-series models, the predictive values are determined by the time-series properties, as measured by parameter value, of quarterly earnings. In particular, the model demonstrates that the accuracy of annual earnings forecasts increases as additional quarterly reports become available, and that the time-series model parameter value is positively related to both total improvement and the first quarter's relative improvement in annual earnings forecasts.

These theoretical predictions are empirically tested using a sample of 235 firms over five year period from 1980 to 1984. Empirical results are consistent with the theoretical predictions. First, annual earnings forecasts become increasingly accurate as additional quarterly reports are available, suggesting that quarterly earnings are useful for improving the forecasts of annual earnings. Second, there are cross-sectional variations in the degree of the improved accuracy in forecasts. More importantly, time-series properties (parameter value) of quarterly earnings are an important determinant of the variations in both total and relative predictive values. This result is robust with respect to different time-series models, forecast error metrics, and statistical methods.

CHAPTER 1

INTRODUCTION

Since the controversial work by Green and Segall [1966,1967], numerous researchers in accounting have examined the predictive value of quarterly earnings for forecasting annual earnings.[1] In particular, they investigated the effects of quarterly reports on the revision (Abdel-Khalik and Espejo [1978] and Brown, Hughes, Rozeff and Vanderweide [1980]) and on the improved accuracy (Lorek [1979], Collins and Hopwood [1980], and Brown and Rozeff [1979b] and Hopwood, McKeown and Newbold [1982]) in the forecasts of annual earnings. Using various time-series models, all of these studies have provided evidence which indicates that the incorporation of quarterly earnings leads to the revisions as well as improvements in annual earnings forecasts.

There is, however, little analytical work as to how the quarterly earnings reports improve the forecasts of annual earnings. As noted by Ball and Foster [1982, p. 213], most of the previous studies have addressed this issue "almost exclusively at an empirical level with limited analysis of the conditions under which improvement in forecasting would (or would not) be expected". In this study, I demonstrate analytically that the degree of improvement is determined by the time-series properties (parameter value) of quarterly earnings. In addition, this study examines the issue of how much each quarterly report

[1] The term 'predictive value' is defined in this paper as the improvement in the forecasts of annual earnings from incorporating the first, second and/or the third quarter's realized earnings over the forecasts made at the beginning of the year. Thus, the 'predictive value' and 'improvement' are used interchangeably.

contributes to the improvement and what factor(s) affect the relative importance of each quarter's earnings to the improvement in the accuracy of annual earnings forecasts.

Since annual earnings are temporal aggregation of four quarterly earnings, the release of quarterly earnings will improve the forecasts of annual earnings in two ways. First, some portion of uncertainty will be reduced by substituting the realized earnings for the predicted ones ('substitution effect'). Second, to the extent that the current quarter's forecast errors are related to future earnings, the quarterly reports will revise the forecasts by providing additional information about the forthcoming quarters' earnings ('revision effect').[2]

The above reasoning suggests that except under unusual conditions where the 'revision effect' more than offsets the 'substitution effect', quarterly reports will improve the forecasts of annual earnings. Furthermore, the 'revision effect' may differ across firms depending on, among other things, the time-series properties of quarterly earnings. This implies that the time-series properties of quarterly earnings would be a potential determinant of cross-sectional differences in the improved accuracy of annual earnings forecasts.

The purpose of this study is to investigate analytically and empirically the effect of time-series behavior of quarterly earnings on their predictive value for improving the forecasts of annual earnings. Overall improvement during a year (total predictive value) as well as the importance of each quarter to total improvement (relative predictive value) are examined. The analytical results suggest that for a specific class of time-series models, quarterly earnings reports always improve the accuracy of annual earnings

[2] This idea has been formalized in an adaptive model of financial analysts' forecasts by Abdel-Khalik and Espejo [1978]. Brown and Rozeff [1979b] provide empirical evidence suggesting that the improved annual earnings forecasts are due to both 'substitution effect' and 'revision effect'.

forecasts and that the degree of improved accuracy varies systematically with the parameter values of the quarterly earnings models.

The motivation for this study comes from the recent empirical finding that systematic differences exist across firms in the time-series properties (parameter values) of quarterly earnings (Bathke, Lorek and Willinger [1989]). While they provide evidence on the positive relationship between firm size and one-quarter-ahead forecast accuracy, the effect of the time-series model parameter on the forecast accuracy was not examined. Given their evidence on the positive relation between firm size and the time-series properties of quarterly earnings, the observed differences in forecast accuracy across firm size strata may be due to differences in the properties of quarterly earnings series. This study extends their work by examining whether the time-series properties, after controlling for firm size, affect the predictive value of quarterly earnings for forecasting annual earnings.

Additional motivation for this study is provided by recent attention to 'information environment' as an explanation for cross-sectional differences in the relationship between accounting earnings and stock returns. Atiase [1987] found that stock price reactions to annual earnings announcements are significantly larger for small firms than for large firms. Freeman [1987] also found that abnormal stock returns associated with annual earnings changes occur earlier for large firms than for small firms. They attribute these results to the differences in the availability of non-earnings information between small and large firms. However, if the time-series behavior of quarterly earnings is systematically related to the importance of earlier quarters in forecasting annual earnings, it may provide an alternative explanation to their results.

The analytical results of this study will also help identify the "best" time-series model of quarterly earnings by providing theoretical predictive values against which different time-series models can be evaluated. Previous studies compared different time-series models in terms of their forecast accuracy and/or the association of their forecast errors with abnormal stock returns (e.g., Collins and Hopwood [1980] and Bathke and Lorek [1984]; among others). The inconsistent results in these studies may be due to the lack of explicit consideration into the conditions under which one model is favored against the others.

Empirical tests are based on the sample of 235 firms over 5 year period from 1980 to 1984. Consistent with the theoretical predictions, the results indicate that both total and relative predictive values are positively related to the time-series properties (parameter value) of quarterly earnings. An attempt to control for the effect of other variables by using firm size which is related to parameter value (Bathke, Lorek and Willinger [1989]) does not affect the inferences regarding parameter value as a determinant of variations in predictive values. These results are also robust across time-series models, forecast error metrics, and statistical methods used.

Utilizing theoretical predictive values, additional test is conducted on the relative superiority among three univariate time-series models of the Foster [1977], the Griffin [1977] and Watts [1975], and the Brown and Rozeff [1979a]. Basically, we compare differences between theoretical predictive values and empirical predictive values across three models because the difference can be viewed as a measure of model misspecification. The result suggests that the Brown and Rozeff model is better than the other models, which is consistent with the evidence based on the 'fitting test' (Brown and Rozeff [1979a]) and the 'predictability test' (Collins and Hopwood [1980] and Bathke and

Lorek [1984]). However, the ranking of the models is clearer under our criterion than the other methods.

Empirical tests were repeated using the Value Line analysts' forecast data. The results are generally consistent with those based on earnings forecasts and parameter values from the three time-series models. Furthermore, the use of an adaptive expectations model enables us to draw some inference as to how analysts revise their forecasts conditional on quarterly reports. The results suggest that the one-quarter ahead forecast error of the most recent quarter explains significant portion of analysts' forecast revisions, and that the autoregressive model, especially the Brown and Rozeff model, is most consistent with analysts' forecasts.

The remainder of the dissertation is organized as follows. The next chapter provides a brief review of the extant literature on the time-series properties and the predictive value of quarterly earnings. Chapter 3 describes a simple analytical model which provides the relationship between time-series properties and the predictive value of quarterly earnings for improving the forecasts of annual earnings. Chapter 4 discusses the hypotheses to be tested, sample selection, and methodology for testing the hypotheses. The empirical results of testing the hypotheses are presented in Chapter 5. Some concluding remarks appear in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

This study investigates the effect of time-series properties on the predictive value of quarterly earnings for improving the forecasts of annual earnings. This chapter provides the review of relevant literature. The surveyed literature is divided into the studies related to three issues: (1) time-series properties of quarterly earnings, (2) determinants of the time-series properties of accounting earnings, and (3) predictive value of quarterly earnings for forecasting annual earnings.

2.1 Time-Series Properties of Quarterly Earnings

It has been well established in the literature that the firm's quarterly earnings process may be parsimoniously described as a multiplicative combination of two systematic patterns: an adjacent quarter-to-quarter movement (regular component) and a quarter-by-quarter movement (seasonal component). Another finding which is of particular importance to the current study is that a single model applicable to all firms (a 'premier' model) is at least as good as the firm-specific models identified by the Box and Jenkins [1976] (hereafter BJ) methodology in forecasting future quarterly earnings. Three premier models suggested in the literature are those of Foster [1977], Griffin [1977], Watts [1975], and Brown and Rozeff [1979a].[3]

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[3] For a detailed survey, see Bao, Lewis, Lin, and Manegold [1983] and Hopwood and McKeown [1986].

Foster [1977] proposed a seasonally differenced first-order autoregressive model with a constant drift (hereafter F model):

$$(1-\phi B)(1-B^4)Q_t = \theta_0 + a_t ,$$

where Q_t is quarterly earnings series; ϕ is an autoregressive parameter; θ_0 is a constant term; B is a backward shift operator such that $B^kQ_t=Q_{t-k}$; and a_t is an independently and identically distributed 'white noise' process with mean zero and constant variance.

Griffin [1977] and Watts [1975] proposed a consecutively and seasonally differenced first-order regular and seasonal moving average model (hereafter GW model):

$$(1-B)(1-B^4)Q_t = (1-\theta B)(1-\theta_s B^4)a_t ,$$

where θ and θ_s are regular and seasonal moving average parameter, respectively.

Brown and Rozeff [1979a] proposed a seasonally differenced first-order autoregressive and seasonal moving average model (hereafter BR model):

$$(1-\phi B)(1-B^4)Q_t = (1-\theta_s B^4)a_t$$

In the BJ notation of (pdq)x(PDQ), the F, GW, and BR models are designated as (100)x(010), (011)x(011), and (100)x(011), respectively.[4] Note that the F model is a special case of the BR model with $\theta_s=0$.

Empirical studies which compared the relative predictive accuracy of these three premier models have provided mixed results.[5] For example, Collins and Hopwood [1980] and Bathke and Lorek [1984] have documented evidence supporting the BR model. In contrast, Benston and Watts [1978] and Lorek [1979] have provided results in favor of the

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[4] The p, d, and q refer to the number of regular autoregressive terms, differencing and moving average terms, respectively. The P, D, and Q are the respective seasonal counterparts of these.

[5] The three premier models were also evaluated in terms of (i) the ability to fit the data (Brown and Rozeff [1979a] and Lorek [1979]) and (ii) the contemporaneous association of forecast errors with abnormal stock price movements (Bathke and Lorek [1984]).

F model and the GW model, respectively. While the comparison among univariate time-series models has been unsuccessful in identifying the best one, recent studies show that bivariate models (Hopwood and McKeown [1981]) and financial analysts (e.g., Collins and Hopwood [1980] and Brown, Hagerman, Griffin and Zmijewski [1987]; among others) generate more accurate forecasts than those by univariate models.

These studies, however, have not employed a benchmark against which the relative accuracy of several time-series models can be compared. For a given time-series model and parameter values, the analytical results of the current study provide theoretical predictive values which can be used to evaluate different time-series models. For example, the "best" model can be identified by comparing the theoretical predictive values with the actual ones across the three premier models.

2.2 Determinants of the Time-Series Properties of Earnings

Most of the early work in the time-series research focused on the identification of parsimonious model(s) that describe the process generating accounting earnings. Little attention has been paid to economic and other explanations for the observed time-series properties of earnings. Given that a firm's accounting earnings depend on the economic environment, the firm's production-investment-financing decisions, and accounting techniques, the time-series properties of a firm's accounting earnings will be affected by the attributes of its operating and accounting decisions (Gonedes and Dopuch [1979]).

There are a few studies that examine the determinants of the time-series properties of annual earnings. van Breda [1981] developed a partial adjustment model of accounting rates of return and hypothesized that the degree of barriers to entry is negatively related to the adjustment parameter because high barriers are associated with high rates of return *ceteris paribus*. The empirical results, based on 29 firms, do not provide strong support for the hypothesis.

Lev [1983] identified a list of factors which may affect the time-series properties of accounting earnings. These factors, derived mainly from the industrial organization literature in economics, include the type of product, barriers to entry, capital intensity and firm size. Using a sample of 385 firms, he found that these variables affect the time-series properties (autocorrelations and variances) of annual earnings. In particular, the results indicate that the time-series properties of annual earnings are related positively to product type (durable goods) and capital intensity, but negatively to barriers to entry and firm size.

More recently, researchers began investigating the existence of differences across firms in the time-series properties of quarterly earnings. Lorek and Bathke [1984] found that more than 12% of their 240 sample firms do not exhibit seasonal behavior and that a first-order autoregressive model dominates the seasonal ARIMA models for these nonseasonal firms. Although these results do not add much to our knowledge as to why certain time-series models are found for quarterly earnings, they provide evidence that for some firms, quarterly earnings processes are different from those suggested by the premier models.

Bathke, Lorek and Willinger [1989] (BLW) examined whether systematic differences exist across firms in the model structure, parameter values and predictive ability of quarterly earnings. They evaluated firm size as a factor that affects the cross-sectional differences in the time-series properties of quarterly earnings. Using extensive sample of 358 firms and classifying them into three size groups (large, medium and small), they found that firm size is positively related to (1) the autoregressive parameters of the F and BR model, and (2) the predictive ability of one-quarter-ahead forecasts. However, no systematic relationship was observed between firm size and the time-series model structure.

The findings by BLW are of most relevance to this study as follows. First, the observed inter-firm differences in the time-series properties (parameter values) of quarterly earnings suggest that the predictive value of quarterly earnings would be different across firms. This follows from the analytical result of positive relationship between the predictive value and the parameter value of a given quarterly earnings model. Second, the positive relation of firm size with the parameter values suggests that at least, firm size should be controlled for in testing the effect of time-series properties on the predictive value of quarterly earnings for forecasting annual earnings.

2.3 Predictive Value of Quarterly Earnings

The first empirical investigation into the predictive value of quarterly earnings for forecasting annual earnings was done by Green and Segall [1966, 1967]. They tested the null hypothesis that models which incorporate first quarter earnings are not superior to those which do not use first quarter earnings in forecasting annual earnings. Their results supported the null hypothesis, indicating that quarterly earnings have little or no predictive value for improving forecasts of annual earnings. In contrast, the follow-up studies (e.g., Coates [1972] and Barnea, Dyckman and Magee [1972]; among others) provided strong evidence supporting the predictive value of quarterly earnings. However, these early studies employed naive and mechanistic models as earnings generating process. Utilizing the premier models which have been proposed as the process generating quarterly earnings, several researchers reexamined the predictive value of quarterly reports.

Lorek [1979] examined the effects of incorporating zero, one, two and three quarterly reports into several quarterly earnings models on the forecasts of annual earnings. Although his main interest was in the comparison among various time-series models, the results provide evidence on the predictive value of quarterly earnings for improving annual earnings forecasts. For each of nine quarterly models (five mechanistic models, firm-specific BJ model, and three premier models), the forecast errors of annual earnings decrease as more quarterly earnings are available. However, Lorek did not conduct statistical test on the differences in forecast errors across quarters.

Collins and Hopwood [1980] extended the work of Lorek [1979] by including the Value Line analysts' forecasts and employing a multivariate analysis of variance (MANOVA) design to test their hypothesis. As with Lorek [1979], Collins and Hopwood were mainly interested in comparing quarterly time-series models. They, however, tested the null hypothesis that no difference in annual forecast accuracy exists between the quarters in which the annual forecasts are generated. Their results rejected the null hypothesis, indicating the importance of quarterly earnings in improving the forecasts of annual earnings.

Abdel-Khalik and Espejo [1978] (AE) examined whether financial analysts use quarterly earnings reports to revise the remaining predicted portion of annual earnings. They developed an adaptive model which provides the interaction between quarterly reports and revisions of analysts' forecasts. AE posited three 'revision possibilities' (RP): (1) no revisions (RP1); (2) revisions in the same direction as the forecast error of the current quarter (RP2); and (3) revisions in the opposite direction to the forecast error (RP3). Using a cross-sectional model which regresses the annual earnings forecast error at the beginning of the year on three (first, second and third) quarterly forecast errors, they provided evidence that quarterly reports contribute to the revisions in the remaining portion of predicted annual earnings.

Brown, Hughes, Rozeff and Vanderweide [1980] (BHRV) argued that the research design used by AE is subject to several econometric problems, and suggested an alternative regression model. Using both simulation and regression analysis, BHRV also found evidence consistent with the hypothesis that financial analysts utilize quarterly reports to revise the remaining portion of forecasted annual earnings. However, both AE and BHRV focused on the revisions rather than the improvements in the forecasts of annual earnings triggered by quarterly earnings reports. Further, the implications of three 'revision possibilities' were not explicitly examined.

Brown and Rozeff [1979b] examined whether quarterly earnings are used by financial analysts to revise and improve their forecasts of annual earnings. They argued that quarterly reports can lead to more accurate annual earnings forecasts in two ways: (1) the 'substitution' of the realized quarterly earnings for their predicted values; and (2) the 'revision' in the forecasts of remaining quarterly earnings. Using the Value Line analysts' forecasts data for 50 firms over five years (1972-76), Brown and Rozeff found strong evidence suggesting that each quarterly report has predictive value for improving the accuracy of annual earnings forecasts. Their results also indicate that both 'substitution' and 'revision' effects contribute to the improved forecast accuracy.

Although all of the above-mentioned studies have documented evidence suggesting that quarterly earnings are useful in improving the forecasts of annual earnings, their focus was on either comparison of different time-series models or testing of the null hypothesis that quarterly earnings have no predictive value. The possibility of inter-firm differences in the predictive value of quarterly earnings and their potential determinants have not been examined. Also not addressed is the issue of how much each quarterly report contributes to the improvement in the annual earnings forecasts. The purpose of this study is to investigate these issues by focusing on the time-series properties (parameter values) as a determinant of cross-sectional differences in the predictive value of quarterly earnings.

CHAPTER 3

MODEL

In this Chapter, a model is developed which provides the relationship between the time-series properties and the predictive content of quarterly earnings for improving the forecasts of annual earnings. The basic approach is to calculate and compare the theoretical error variances for forecasts of the forthcoming annual earnings conditional on the available quarterly reports, for any given (and known) quarterly time-series model.[6] Both the total improvement in the accuracy of annual earnings forecasts from incorporating the first, second and third quarter's earnings and the relative improvement contributed by each quarter's report are shown to be a function of the parameter value of a specified time-series model.

3.1 Model Description

Consider five points in time during a year. The time 0 is the beginning of the fiscal year, while time-periods 1, 2, 3 and 4 correspond to the dates when actual earnings are available for the first, second, third and fourth quarter, respectively. Note that time 4 is the end of the fiscal period when annual earnings become known. At each point in time (0,1,2,3), the forecast of a firm's annual earnings (A) conditional on the available quarterly report (Q_τ) is defined as:

$$E(A|Q_\tau) = \Sigma_t E(Q_t|Q_\tau) \quad t=1,2,3,4$$

[6] The model is similar in spirit to that of Barnea, Dyckman and Magee [1972], but differs in the following way: First, they did not employ a time-series model governing the quarterly earnings, and second they examined the predictive content of the first quarter's earnings only.

where E is an expectation operator, ~ denotes random variable, and $Q_t|Q_\tau$ is the earnings for quarter t (=1,2,3,4) conditional on τ (=0,1,2,3) quarter's actual earnings. For example, $E(Q_3|Q_0)$, $E(Q_3|Q_1)$ and $E(Q_3|Q_2)$ are the forecast of the third quarter earnings conditional on zero, one and two quarterly reports, respectively. Note that for $t \leq \tau$, $E(Q_t|Q_\tau)=Q_t$ since actual quarterly earnings are known at these points in time.

To assess the degree of improvement in forecasting annual earnings from incorporating the quarterly reports, the variance of annual forecast error conditional on each quarterly earnings is compared with that generated before the release of the quarter's earnings.[7] Denoting V_τ as the variance of the forecast error for annual earnings conditional on τ quarter's earnings, we have:

$$V_\tau = var\left[A - E(A|Q_\tau)\right]$$

$$= var\left[\Sigma_t(Q_t - E(Q_t|Q_\tau))\right]$$

$$= \Sigma_t\, var[Q_t-E(Q_t|Q_\tau))] + \Sigma_{s\neq t}\Sigma_t\, cov[(Q_s-E(Q_s|Q_\tau)),(Q_t-E(Q_t|Q_\tau))] \quad (3\text{-}1)$$

Equation (3-1) shows that at the beginning of the year, the variance of annual earnings forecast error (V_0) consists of (1) error variances of one, two, three and four quarter ahead forecasts, and (2) their covariances. At the end of the first quarter, the release of actual earnings would lead to reduction in the error variance, i.e., more accurate forecast for the forthcoming annual earnings. The improved forecast is due to (1) the substitution of the realized first quarterly earnings for their predicted values, and (2) the revision in the forecasts of the remaining three quarters.[8] In subsequent time

[7] The selection of forecast error variance to measure the improvement in forecast is based on (1) the popularity of its use in empirical literature as a forecast error metric, and (2) the assumption of quadratic loss function. Barnea, Dyckman and Magee [1972] also used the forecast error variance.

[8] Abdel-Khalik and Espejo [1978] provide an adaptive model which includes both "substitution effect" and "revision affect". See also Brown and Rozeff [1979] for the empirical evidence on separate contribution of both effects to the improvement in forecasting annual earnings.

periods, as additional quarterly earnings become available, the forecast accuracy would increase substantially compared with that at the beginning of the year.

Although it is intuitively appealing and empirically valid that quarterly earnings improve the forecast of annual earnings, the relative importance of each quarter's earnings to the improvement has not been examined. The contribution of the first quarter's report to the increased forecast accuracy can be measured by the difference between the forecast error variances conditional on zero and one quarter's earnings, V_0-V_1. Likewise, the contribution of the second (third) quarter over the first (second) quarter is measured by V_1-V_2 (V_2-V_3). Then, the total improvement (TI), relative to the forecast error at the beginning of the year (V_0), during a year in the forecast of annual earnings from incorporating realized quarterly earnings can be defined as:

$$TI = (V_0 - V_3)/V_0$$

$$= \Sigma_\tau (V_{\tau-1} - V_\tau)/V_0$$

$$= \Sigma_\tau MI(Q_\tau)/V_0$$

where $MI(Q_\tau)$ is the marginal contribution to increased forecast accuracy by τ quarter's earnings. The relative improvement (RI) contributed by each quarter is defined as:

$$RI(Q_\tau) = MI(Q_\tau)/(V_0 - V_3), \qquad \tau = 1,2,3$$

Previous studies (Lorek [1979], Brown and Rozeff [1979] and Collins and Hopwood [1980]; among others) provided evidence suggesting that TI is positive, i.e., quarterly earnings have predictive value for forecasting annual earnings. However, they were empirical in nature, and ignored the potential differences in the degree of TI across firms. In the next section, we demonstrate analytically that for a specific class of time-series models, TI is always positive and, more importantly, that it varies systematically with the time series properties of quarterly earnings. Also shown is the effect of time-series properties on $RI(Q_\tau)$. The essence of our approach is as follows. Suppose that at time 0, the joint distribution of future quarterly earnings $f(Q_1,Q_2,Q_3,Q_4)$, or equivalently the time-series process of quarterly earnings (and its parameters), is known exactly. Since the variances and covariances of forecast errors (and hence V_τ) can be expressed as a function of parameters of the given model, we can establish the relationship between predictive values (TI and $RI(Q_\tau)$) and time-series model parameter values.

3.2 Time-Series Properties and Predictive Value of Quarterly Earnings

To see how the time series behavior of quarterly earnings affects their predictive value for forecasting annual earnings, we begin by noting that any stationary ARIMA process can be written as an infinite weighted sum of current and previous shocks a_j:[9,10]

$$Q_{\tau+l} = a_{\tau+l} + \pi_1 a_{\tau+l-1} + \pi_2 a_{\tau+l-2} + \ldots.$$

where the weight π_j (j=0,1,2,...) is called the transfer function of the linear filter relating $Q_{\tau+l}$ to $a_{\tau+l}$. Accordingly, a forecast $Q_\tau(t)$ of $Q_{\tau+l}$, which is said to be made at origin τ for lead time t, can be expressed as:

$$Q_\tau(t) = \pi_l a_\tau + \pi_{l+1} a_{\tau-1} + \ldots.$$

where a_τ is an independently and identically distributed 'white noise' process with mean zero and constant variance; that is,

$$E(a_\tau) = 0,$$

and $\quad cov(a_s, a_\tau) = \sigma^2$ if $s=\tau$; $cov(a_s, a_\tau) = 0$ if $s \neq \tau$

---

[9] A stochastic process is said to be (strictly) stationary if the joint distribution is invariant with regard to a displacement in time. Specifically, the stationarity condition requires that the infinite series $\Sigma\, \pi_j$ converge (Nelson [1973, p. 31]).

[10] There are alternative forms for the general ARIMA model: (1) a difference equation form and (2) an infinite weighted sum of previous observations, plus a random shock (Box and Jenkins [1976, p. 127]).

The t-step ahead forecast error $e_\tau(t)$ is then defined as:

$$e_\tau(t) = Q_{\tau+t} - Q_\tau(t)$$

$$= \sum_{j=0}^{t-1} \pi_j a_{\tau+t-j}$$

where π_0=1. For the purpose of this study, $e_\tau(t)$ can be interpreted as the error of t-step ahead quarterly earnings forecast conditional on τ quarter's realized earnings, i.e., $e_\tau(t)$ = $[Q_t - E(Q_t|Q_\tau)]$ in terms of previous notation. Note that τ and t are bounded by [0,3] and [1,4], respectively and $t \le 4-\tau$.

Using the above definition of forecast error and rewriting equation (3-1), we get:

$$V_\tau = \text{var}\,[\sum_{t=1}^{4-\tau} e_\tau(t)]$$

$$= \sum_{t=1}^{4-\tau} \text{var}[e_\tau(t)] + 2 \sum_{s=1}^{3-\tau} \sum_{t>s}^{4-\tau} \text{cov}[e_\tau(s), e_\tau(t)] \qquad (3\text{-}2)$$

The variance of and covariance between forecast errors of same origin but different lead times are shown to be as follows (Box and Jenkins [1976], p. 160):

$$\text{var}[e_\tau(t)] = \sigma^2 \sum_{h=1}^{t} \pi^2_{h-1}$$

and

$$\text{cov}[e_\tau(s), e_\tau(t)] = \sigma^2 \sum_{h=1}^{s-1} \pi_i \pi_{i+t-s}$$

where t>s and π_0=1. By substituting these into (3-2), the forecast error variance of annual earnings conditional on τ quarter's earnings can be written as:

$$V_\tau = \Big[\sum_{t=1}^{4-\tau} \sum_{h=1}^{t} \pi^2_{h-1} + 2\sum_{s=1}^{3-\tau} \sum_{t>s}^{4-\tau} \sum_{i=0}^{s-1} \pi_i \pi_{i+t-s}\Big]\sigma^2, \quad \tau=0,1,2,3 \qquad (3\text{-}3)$$

The following two points should be noted from equation (3-3). First, only π_j, j=0,..,3 are relevant because the maximum forecast horizon is 4 quarters within a year. As will be shown below, this allows V_τ to be a function of the regular parameter of the specific quarterly models, making the seasonal component irrelevant to V_τ. Second, error variance of the forecast made after the third quarter's earnings (V_3) is constant (σ^2) and hence not affected by parameter value π_j for any j.

An assumption is made regarding the time-series model. We assume that the time-series process of quarterly earnings is described by single parameter in its regular and seasonal component with maximum of first-order differencing in regular series.[11] Under this assumption, all π_j ($1 \leq j \leq 3$) can be expressed as a function of the parameter Π (either AR or MA) of the regular component. In addition to simplifying the analysis, this assumption will allow the hypotheses to be stated (and tested) with respected to only the parameter value for a given time-series model. The time-series model structure itself is not directly relevant to the hypotheses. To see this, first note that the class of seasonal time-series models assumed may be written in the following general form:

$$\phi(B)\phi_s(B^4)(1-B)^d(1-B^4)^D Q_t = \theta_0 + \theta(B)\theta_s(B^4)a_t ,$$

where $\phi(B)=1-\phi B$, $\phi_s(B^4)=1-\phi_s B^4$, $\theta(B)=1-\theta B$, and $\theta_s(B^4)=1-\theta_s B^4$; ϕ and ϕ_s are regular and seasonal AR parameter, respectively; θ and θ_s are regular and seasonal MA parameter, respectively; θ_0 is a constant term; and B is a backward shift operator such that $B^k Q_t = Q_{t-k}$. By ignoring the constant term, this form can be rewritten as:

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[11] In a box and Jenkins [1976] notation of (pdq)x(PDQ), this assumption requires that quarterly earnings processes belong to the class of the models with (1) $p+q \leq 1$, (2) $P+Q \leq 1$, and (3) $d \leq 1$. Note that no restriction is imposed on the seasonal differencing (D). All the models suggested by Foster [1977] (100)x(010), Griffin [1977] and Watts [1975] (011)x(011), and Brown and Rozeff [1979] (100)x(011) belong to this class. Thus, the assumtion does not appear to be an unrealistic one.

$$(1-B)^d(1-B^4)^D Q_t = \phi(B)^{-1}\phi_s(B^4)^{-1}\theta(B)\theta_s(B^4)a_t$$

$$= (1+\phi B+\phi^2B^2+...)(1+\phi_s B^4+\phi_s^2B^8+...)(1-\theta B)(1-\theta_s B^4)a_t$$

Since the π_j's for this study are relevant up to three periods back (a_{t-3}), we have the following form for the non-differenced series by ignoring the terms associated with π_j for $j\geq4$:

$$(1-B)^d(1-B^4)^D Q_t = a_t + (\phi-\theta)a_{t-1} + \phi(\phi-\theta)a_{t-2} + \phi^2(\phi-\theta)a_{t-3} + ...$$

Depending on (1) the order of regular differencing (d) and (2) whether AR or MA process is considered, we have the following four types of models:[12]

Model 1: when d=0 and θ=0,

$Q_t = a_t + \phi a_{t-1} + \phi^2 a_{t-2} + \phi^3 a_{t-3}$, and $\pi_j=\phi^j$ for j=1,2,3.

Model 2: when d=0 and ϕ=0,

$Q_t = a_t - \theta a_{t-1}$, and $\pi_j=-\theta$ for j=1; $\pi_j=0$ for j=2,3.

Model 3: when d=1 and θ=0,

$Q_t = a_t + (1+\phi)a_{t-1} + (1+\phi+\phi^2)a_{t-2} + (1+\phi^2+\phi^3)a_{t-3}$, and $\pi_j=1+\Sigma_{s=1}^{j}\ \phi^s$ for j=1,2,3.

Model 4: when d=1 and ϕ=0,

$Q_t = a_t + (1-\theta)a_{t-1} + (1-\theta)a_{t-2} + (1-\theta)a_{t-3}$, and $\pi_j=1-\theta$ for j=1,2,3.

It should be emphasized that for all the above models, π_j are expressed as a function of the regular parameter Π (either ϕ or θ) and lag j, i.e., $\pi_j=f(\Pi, j)$. Furthermore, note that Brown and Rozeff [1979] and Foster [1977] models are special cases of Model 1, while Griffin [1977] and Watts [1975] models belong to Model 4.

Two important results arise from equation (3-3). First, *V_τ is a decreasing function of τ*. That is, $V_0>V_1>V_2>V_3$ or $dV_\tau/d\tau<0$. This result is intuitively apparent because the forecasts become more accurate as the forecast horizon ($4-\tau$) decreases. This is also

[12] The orders of seasonal differencing (D) and seasonal component (ϕ_s and θ_s) are irrelevant because they have no impact on a_{t-j} and thus on π_j for $j\varepsilon[0,3]$.

consistent with empirical evidence that the accuracy of annual earnings forecast increases as the end of the year approaches (e.g., Lorek [1979] and Collins and Hopwood [1980]).

Proof: If $\pi_j \geq 0$, it is obvious from equation (3-3) that V_τ is always decreasing in τ. Note that $\pi_j = 1 + \Sigma_{s=1}^{j} \phi^s > 0$ (Model 3) and $\pi_j = 1 - \theta > 0$ (Model 4) because $|\phi| < 1$ and $|\theta| < 1$ from the stationarity and invertability condition, respectively. Hence, $dV_\tau/d\tau < 0$ for the Model 3 and Model 4. Next, consider Model 1 when the AR parameter ϕ is negative so that $\pi_j < 0$ for some j. Using the relation $\pi_j = \phi^j$, we have: $V_0 - V_1 = (1+\phi)^2(1+\phi^2)^2 > 0$; $V_1 - V_2 = \phi^2 + (1+\phi)^2(1+\phi^2) > 0$; and $V_2 - V_3 = (1+\phi)^2 > 0$. Hence, $V_0 > V_1 > V_2 > V_3$. Finally, the comparisons among V_τ's for the Model 2 give $V_0 - V_1 = V_1 - V_2 = V_2 - V_3 = (1-\theta)^2 > 0$, showing $dV_\tau/d\tau < 0$.

Second, *V_τ always increases with the parameter value for the MA models. For the AR models, V_τ is an increasing function of Π if $\Pi > 0$.*[13] That is, $dV_\tau/d\Pi > 0$ for the MA models,and $dV_\tau/d\Pi > 0$ if $\Pi > 0$ for the AR models.

Proof: Consider the MA models. Let $\Pi = 1 - \theta$. For Model 2, differenciation V_τ with respect to Π gives $dV_0/d\Pi = 6(1+\Pi) > 0$; $dV_1/d\Pi = 4(1+\Pi) > 0$; and $dV_2/d\Pi = 2(1+\Pi) > 0$ because $\Pi > 0$. For Model 4, we have $dV_0/d\Pi = 12 + 28\Pi > 0$; $dV_1/d\Pi = 6 + 10\Pi > 0$; and $dV_2/d\Pi = 2(1+\Pi) > 0$. For the AR models (Model 1 and Model 3), $dV_\tau/d\Pi > 0$ if $\Pi = \phi > 0$. However the sign is indeterminate, except for $dV_2/d\Pi$ which is positive, if $\phi < 0$ because the expression includes some terms with odd power of ϕ.

[13] Note that for the MA models, parameter value Π is defined as $(1-\theta)$ rather than θ. Thus, all the directional statements regarding the MA models should be reversed if θ is used. If not stated otherwise, we continue to use $(1-\theta)$ as our definition of MA parameter in empirical analysis as well as theoretical analysis.

The marginal improvement in the forecast accuracy contributed by each quarter's earnings, $MI(Q_\tau)$, can be obtained by substituting τ=0,1,2,3 into equation (3-3) and subtracting them consecutively. The resulting $MI(Q_\tau)$s are:

$$MI(Q_1) = \Big[\sum_{h=1}^{4} \pi^2_{h-1} + 2\sum_{s=1}^{3}\sum_{i=0}^{s-1} \pi_i\pi_{i+4-s}\Big]\sigma^2 \qquad (3\text{-}4a)$$

$$MI(Q_2) = \Big[\sum_{h=1}^{3} \pi^2_{h-1} + 2\sum_{s=1}^{2}\sum_{i=0}^{s-1} \pi_i\pi_{i+3-s}\Big]\sigma^2 \qquad (3\text{-}4b)$$

and

$$MI(Q_3) = \Big[\sum_{h=1}^{2} \pi^2_{h-1} + 2\pi_1\Big]\sigma^2 \qquad (3\text{-}4c)$$

By either summing up (3-4a), (3-4b) and (3-4c) or subtracting V_3 from V_0, we obtain the following expression for the total improvement in annual earnings forecasts during a year:

$$TI = \Big[\sum_{t=2}^{4}\sum_{h=1}^{t} \pi^2_{h-1} + 2\sum_{s=1}^{3}\sum_{b>s}^{4}\sum_{i=0}^{s-1} \pi_i\pi_{i+t-s}\Big]/V_0 \qquad (3\text{-}5)$$

An important feature of equation (3-5) is that TI is a function of time-series parameter Π. More specifically, *TI is always increasing in Π for the MA models while it is an increasing function of Π if $\Pi>0$ for the AR models.*

Proof: By definition, $TI=(V_0-V_3)/V_0=1-V_3/V_0$. Since V_3 is a constant, TI is affected by Π through the relation between V_0 and Π. From the second result, $dTI/d\Pi>0$ for the MA models because $dV_0/d\Pi>0$. Applying the same reasoning, we have $dTI/d\Pi>$ if $\Pi>0$ for the AR models.

Another implication of equation (3-5) is that TI is always positive, which is obvious from the first result and the definition of TI. This result has been well-documented in the empirical literature (e.g., Lorek [1979], Brown and Rozeff [1979] and Collins and Hopwood [1980]; among others).

From (3-4a), (3-4b), (3-4c) and (3-5), the relative contribution of each quarter's actual earnings to the total improvement may be written compactly as follows:

$$RI(Q_\tau) = MI(Q\tau)/(V_0-V_3) = f(\pi|Q_\tau), \quad \tau=1,2,3 \qquad (3\text{-}6)$$

where $f(\pi|Q_\tau)$ indicates that $RI(Q_\tau)$ is a function of time-series parameter π. Since both π and τ affect the numerator ($MI(Q_\tau)$), an unambiguous relationship between π and $RI(Q_\tau)$ cannot be derived. Therefore, the next section of this paper uses empirically suggested time-series models and numerical examples to derive the relationship.

3.3 Some Examples

As discussed in Chapter 2, the representative seasonal ARIMA models which have been suggested as possible generators of quarterly earnings are (1) Foster [1977] (100)x(010) model (F), (2) Griffin [1977] and Watts [1975] (011)x(011) model (GW), and (3) Brown and Rozeff [1979] (100)x(011) model (BR). This section examines how the parameter values of these models affect the TI and $RI(Q_\tau)$.

First, consider the BR model. In the preceding section, it was shown that for this model, $\pi_j=\phi^j$ for $0\leq j\leq 3$, where ϕ is the autoregressive parameter. Note that the seasonal moving average parameter θ_s is irrelevant to the analysis, which indicates that the BR and F models have the same implications for this study. Substituting ϕ^j for π_j in (3-5) and (3-6), we get:

$$TI = (3+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6)/(4+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6)$$

$$RI(Q_1) = (1+2\phi+3\phi^2+4\phi^3+3\phi^4+2\phi^5+\phi^6)/(3+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6)$$

$$RI(Q_2) = (1+2\phi+3\phi^2+2\phi^3+\phi^4)/(3+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6)$$

and

$$RI(Q_3) = (1+2\phi+\phi^2)/(3+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6)$$

Table 1 provides the theoretical TIs and $RI(Q_t)$s for various values of ϕ. The range of [-.90, .90] is chosen because the stationarity condition requires $-1<\phi<1$. It can be seen from the table that TI is always positive and, more importantly, that it increases with the autoregressive parameter ϕ. For example, TI is 95.8% when $\phi=0.90$ while it is only 75% when $\phi=0$. Table 1 also shows that when $\phi>0$, (1) earlier quarter contributes more to TI than later quarter does ($RI(Q_1)>RI(Q_2)>RI(Q_3)$), and (2) the first quarter's contribution is greater, the larger is the parameter value; that is, $RI(Q_1)$ increases with ϕ.[14] For example, the first quarter contributes more than 51% of TI when $\phi=0.90$, but only 34.3% when $\phi=0.20$. It is interesting that when quarterly earnings are generated by the 'seasonal random walk' model ($\phi=0$), each quarter's report is equally important in improving the forecasts of annual earnings.

Now, consider the GW model. It was shown that the parameter π for this model is $\pi_j=1-\theta$ for $1\le j\le 3$, where θ is the moving average parameter. Substituting $\pi=(1-\theta)$ for π_j in (3-5) and (3-6), we obtain:

$$TI = (3+12\pi+14\pi^2)/(4+12\pi+14\pi^2)$$

$$RI(Q_1) = (1+6\pi+9\pi^2)/(3+12\pi+14\pi^2)$$

$$RI(Q_2) = (1+4\pi+4\pi^2)/(3+12\pi+14\pi^2)$$

and

$$RI(Q_3) = (1+2\pi+\pi^2)/(3+12\pi+14\pi^2)$$

[14] While these statements hold only when ϕ is positive, previous empirical finding that ϕ is in fact nonnegative (e.g., Foster [1977] and Bathke, Lorek and Willinger [1989]) suggests their generalizability.

TABLE 1

The Effects of Time-Series Parameter on The Predictive Values of Quarterly Earnings: The BR Model or The F Model [a]

parameter value $\pi = \phi$	TI [b] (%)	RI [c] (%) Q_1	Q_2	Q_3
-.90	46.55	3.76	95.09	1.15
-.80	46.04	12.61	82.70	4.69
-.70	47.75	21.86	68.29	9.85
-.60	50.82	28.63	55.89	15.48
-.50	54.61	32.47	46.75	20.78
-.40	58.71	34.07	40.62	25.32
-.30	62.91	34.32	36.79	28.89
-.20	67.08	33.97	34.63	31.41
-.10	71.13	33.53	33.60	32.87
.00	75.00	33.33	33.33	33.33
.10	78.62	33.57	33.51	32.91
.20	81.93	34.34	33.90	31.75
.30	84.92	35.66	34.32	30.02
.40	87.55	37.51	34.61	27.88
.50	89.83	39.82	34.69	25.49
.60	91.76	42.52	34.50	22.99
.70	93.38	45.50	34.01	20.49
.80	94.71	48.66	33.25	18.09
.90	95.79	51.92	32.24	15.85

[a] The BR model is (100)x(011) and the F model is (100) x(011) with drift. The parameter value used ($\pi = \phi$) is the autoregressive term in each model.

[b] Total predictive value (improvement) of quarterly earnings for forecasting annual earnings.

[c] Relative predictive value (improvement) of the first (Q_1), second (Q_2) and third (Q_3) quarter's earnings for forecasting annual earnings.

Table 2 provides the theoretical TIs and $RI(Q_t)$s for various values of θ. Note that $0<\pi<2$ because the invertiblity condition requires $-1<\theta<1$. Since the parameter value is always positive, the effects of time-series parameter on TI and $RI(Q_t)$ are clearer for the GW model than for the BR model. It is evident from Table 2 that (1) TI is always positive, (2) TI increases with π $(=1-\theta)$, (3) $RI(Q_1)>RI(Q_2)>RI(Q_3)$, and (4) $RI(Q_1)$ increases with π.

Several points are worth noting from the Table 1 and Table 2. First, the relationship between parameter value and predictive values (both TI and RI) appears to be nonlinear. Second, the variations in the TI and RI appear to be relatively small for a reasonable range of parameter values ($\pi>0$). For example, TI ($RI(Q_1)$) increases from 84.9% (35.7%) to 93.4% (45.5%) when the parameter value increases more than 100% (from 0.30 to 0.70) for the BR model. Obviously, these would work <u>against</u> finding empirically the relationship between parameter value and predictive values.

TABLE 2

The Effects of Time-Series Parameter on The Predictive Values of Quarterly Earnings: The GW Model [a]

parameter value $\pi=1-\theta$	TI [b] (%)	RI [c] (%) Q_1	Q_2	Q_3
1.90	98.71	58.80	30.18	11.02
1.80	98.59	58.55	30.25	11.21
1.70	98.46	58.27	30.32	11.42
1.60	98.31	57.96	30.39	11.65
1.50	98.13	57.62	30.48	11.90
1.40	97.93	57.24	30.57	12.19
1.30	97.69	56.81	30.67	12.52
1.20	97.41	56.34	30.78	12.89
1.10	97.07	55.79	30.90	13.31
1.00	96.67	55.17	31.03	13.79
.90	96.17	54.46	31.19	14.36
.80	95.57	53.62	31.35	15.03
.70	94.81	52.63	31.54	15.83
.60	93.84	51.44	31.76	16.80
.50	92.59	50.00	32.00	18.00
.40	90.94	48.21	32.27	19.52
.30	88.71	45.93	32.57	21.50
.20	85.63	42.95	32.89	24.16
.10	81.27	38.94	33.18	27.88

[a] The GW model is (011)x(011) model. The parameter value used θ in ($\pi = 1-\theta$) is the moving average term in the model.

[b] Total predictive value (improvement) of quarterly earnings for forecasting annual earnings.

[c] Relative predictive value (improvement) of the first (Q_1), second (Q_2) and third (Q_3) quarter's earnings for forecasting annual earnings.

CHAPTER 4

HYPOTHESES AND RESEARCH DESIGN

This chapter uses the analytical results from the model in Chapter 2 and develops two hypotheses to test empiriricallywhether the time-series properties as measured by the parameter values have any systematic impact on the predictive values (both total and relative) of quarterly earnings. This chapter also describes sample selection, empirical measures of predictive values and time-series parameters, and statistical methodology used to test the hypotheses.

4.1 Research Hypotheses

The analysis in Chapter 3 demonstrates that for a specific class of quarterly earnings time-series model, (1) error variance of annual earnings forecasts (V_τ) is always a decreasing function of forecast horizon (4-τ), and (2) total predictive value of quarterly earnings is increasing in the (positive) parameter values. The first result indicates that quarterly earnings have predictive value for improving the forecasts of annual earnings, which has been documented in many of previous empirical studies (Lorek [1979], Brown and Rozeff [1979b], and Collins and Hopwood [1980]; among others).

Of particular interest to this study is the second result, which is given by:

$$\frac{dTI}{d\Pi} > 0$$

where Π represents $(1-\theta)$ for the MA model, and ϕ (>0) for the AR model. We empirically test this theoretical result. Specifically, the first hypothesis (in alternative form) to be tested is:

H1: The *total* predictive value of quarterly earnings for improving the forecasts of annual earnings is positively related to the parameter value of a quarterly earnings time-series model.

As indicated in Chapter 3, an unambiguous relationship between parameter value (Π) and relative predictive values ($RI(Q_\tau)$, τ=1,2,3) cannot be derived for the general class of time-series models assumed. However, the numerical examples in Section 3.3 show that the relative predictive value of the first quarter's earnings ($RI(Q_1)$) is positively related to the non-negative parameter values of three 'premier' quarterly models (the BR, F, and GW models). This can also be seen from the following results of differentiating $RI(Q_1)$ with respect to the relevant parameter values:

$$\frac{dRI(Q_1)}{d\phi} = \frac{2\phi[2+11\phi+22\phi^2+30\phi^3+31\phi^4+23\phi^5+12\phi^6+4\phi^7+\phi^8]}{[3+6\phi+7\phi^2+6\phi^3+4\phi^4+2\phi^5+\phi^6]^2}$$

for the BR and F models, and

$$\frac{dRI(Q_1)}{d(1-\theta)} = \frac{2[3+13(1-\theta)+12(1-\theta)^2]}{[3+12(1-\theta)+14(1-\theta)^2]^2}$$

for the GW model.

It is clear from the above results that (1) $dRI(Q_1)/d\phi > 0$ if $\phi > 0$, and (2) $dRI(Q_1)/d(1-\theta) > 0$ since $(1-\theta) > 0$. However, the relation of parameter values to $RI(Q_2)$ and $RI(Q_3)$ is not obvious and depends on the ranges of parameter values, as can be seen from Table 1 and Table 2. Therefore, our empirical analyses on the relative predictive value focus on $RI(Q_1)$ and test the following hypothesis:

H2: The *relative* predictive value of the first quarter's earnings for improving the forecasts of annual earnings is positively related to the parameter value of a quarterly earnings time-series model.

These hypotheses are derived from the analytical results in Chapter 3, where it was assumed that the firm's quarterly earnings are generated by a specific class of time-series processes such as the BR, F and GW models. Thus, both hypotheses are a joint test of the effects of time-series model structure and parameter value. Further, the power of testing the above hypotheses will critically depend on the time-series model used because it affects the measurements of both improvements in forecasts and parameter values.

While some empirical validity regarding the class of models assumed to derive the hypotheses has been documented, recent studies have provided evidence indicating the superiority of bivariate model (Hopwood and McKeown [1981]) and financial analysts (e.g., Collins and Hopwood [1980] and Brown et. al. [1987]; among others) over univariate time-series models in forecasting future earnings. Therefore, the financial analysts' forecasts are also used along with the three 'premier' univariate time-series models in this study (Section 5.5).

Since the hypotheses are derived from the theoretical analysis, potential factor(s) which may affect the predictive value of quarterly earnings are assumed away. In order to maintain the internal validity, therefore, consideration must be given to the factor(s) when testing the hypotheses. Firm size is used as a controlling variable for the following reasons. First, the superiority of financial analysts' forecasts over those by univariate time-series models suggests that the information other than publicly available earnings data is useful for forecasting earnings. In fact, several studies have used firm size as a proxy for the availability of other information sources and found that firm size is positively related to the accuracy of earnings forecasts (e.g., Brown, Richardson and Schwager [1987] and Collins, Kothari and Rayburn [1987]; among others). Second, recent evidence by Bathke, Lorek and Willinger [1989] suggests that firm size is positively related to both parameter values and the accuracy of one-quarter-ahead earnings forecasts. Thus, by controlling for firm size, the net effect of time-series model parameter value on the predictive value of quarterly earnings can be examined.[15]

4.2 Sample Selection

Each firm included in this study should satisfy the following selection criteria: (1) quarterly earnings per share (EPS) data is available in the Value Line Investment Survey over the period 1967-1984; (2) quarterly earnings forecasts are available in the Value Line during the period 1969-1984; (3) sufficient daily return data is available on the CRSP tape; (4) each firm must be included in the COMPUSTAT tapes; (5) each firm has a fiscal year ending on December throughout the period 1967-1984; and (6) each firm must be in the manufacturing industry with two-digit SIC code between 10 and 39.

The first criterion is used to have enough EPS data for estimating the time-series models by the BJ methodology. The second criterion is introduced (i) to use analysts'

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[15] By specifying a time-series model which includes firm size as an additional variable in a panel model (e.g., the F model), it is possible to derive the relationship between firm size and the predictive value of quarterly earnings. This approach was not taken because (1) empirical validity of this type of time-series model has not been established, and (2) main focus of this paper is on the impact of time-series model parameter.

forecasts as an alternative to those generated by time-series models, and (ii) to estimate parameter values of the time-series model implied by analysts' forecasts. The criteria (3) and (4) are required to obtain the measures of the availability of other information. The fifth and sixth criteria are imposed to ensure the comparability of earnings series across firms. The firms in the regulated industries such as Banking, Utilities and Tranportation are excluded because they may have earnings processes quite different from the manufacturing firms. As is typical with time-series research in accounting, the familiar 'survivorship bias' applies to the sample because it includes only those firms that have existed for at least 18 years.

The above selection criteria yielded a sample of 235 firms. Table 3 shows the breakdown of the sample firms by industry (two-digit SIC code). Twenty three industries are represented in the sample. There is clustering in particular industries, notably Chemicals (SIC=28) and Electric Machinery (SIC=36), which account for 15.7% and 13.6% respectively, of the sample firms. Appendix A presents the list of 235 sample firms including CUSIP number, four-digit SIC code and company name.

4.3 Methodology

4.3.1 Measuring Predictive Values of Quarterly Earnings

The term 'predictive value' is defined here as the improvement in the forecasts of annual earnings from incorporating the first, second and third quarter's earnings over the forecasts made at the beginning of the year. The improvement in the forecasts is measured by the reduction in forecast errors. Two forecast error metrics are used; absolute forecast error (AFE) and squared forecast error (SFE) which are specified as:

TABLE 3

Industry Classifications of Sample Firms

Two-Digit SIC Code	Industry Description	Number of Firms
10	Metal Mining	9
12	Coal Mining	3
13	Oil and Gas Extraction	5
14	Nonmetal Mineral	1
16	Heavy Construction	2
20	Food and Kindred	10
21	Tobacco	3
22	Textile Mill	3
24	Lumber and Wood	2
25	Furniture and Fixtures	2
26	Paper	11
27	Printing and Publishing	7
28	Chemicals	37
29	Petroleum Refining	18
30	Rubber	7
32	Stone, Clay and Glass	11
33	Primary Metal	15
34	Fabricated Metal	9
35	Industrial Machinery	21
36	Electric Machinery	32
37	Transportation Equipment	19
38	Instruments	7
39	Miscellaneous Goods	1
	Total	235

$$AFE(Q_\tau)_{iy} = | A_{iy} - E(A|Q_\tau)_{iy} |$$

and

$$SFE(Q_\tau)_{iy} = (A_{iy} - E(A|Q_\tau)_{iy})^2$$

where A_{iy} = actual annual earnings for firm i and year y, and

$E(A|Q_\tau)_{iy}$ = forecasted annual earnings conditional on τ quarter's earnings for firm i and year y, τ=0,1,2,3.

Although the analytical results in Chapter 3 are based on $SFE(Q_\tau)$, $AFE(Q_\tau)$ will also be used (1) to examine the sensitivity of the results to different measures of forecast error, and (2) to be comparable with previous studies which employed this measure.[16] Hereafter, $SFE(Q_\tau)$ will be used for exposition purposes.

Closely following the definitions in Chapter 3, the total improvement (TI) during a year relative to the beginning of the year in the accuracy of annual earnings forecasts from incorporating realized quarterly earnings is measured by:

$$TI_{iy} = [SFE(Q_0)_{iy} - SFE(Q_3)_{iy}]/SFE(Q_0)_{iy}$$

Similarly, the relative improvement (RI) in the forecast accuracy contributed by each quarter is measured by:

$$RI(Q_\tau)_{iy} = \frac{SFE(Q_{\tau-1})_{iy} - SFE(Q_\tau)_{iy}}{SFE(Q_0)_{iy} - SFE(Q_3)_{iy}}, \qquad \tau=1,2,3$$

The forecasts of annual earnings at the end of each quarter $E(A|Q_\tau)$ are obtained by summing the remaining quarterly forecasts of the year and the actual earnings of current and previous quarters. The quarterly earnings forecasts (one through up to four-quarter-ahead forecasts) are generated by three time-series models (the F, GW and BR

[16] It should be noted that the forecast error metric, $AFE(Q_\tau)$, is an inconsistent and biased estimate of the theoretical forecast error variance V_τ because $AFE(Q_\tau)$ is a square root of V_τ.

model) and the Value Line analysts' forecasts. Twenty annual forecasts at each quarter, from the beginning of 1980 to the third quarter of 1984, are used to test the hypotheses.

4.3.2 Estimating Time-Series Model and Parameter Value

Each time-series model is estimated initially using 52 quarters' EPS data (1967-1979) in order to obtain one through four-quarter-ahead forecasts for the year 1980. The use of 52 observations is based on the suggestion by Box and Jenkins [1976, p. 18] that at least 50 observations should be used to estimate a preliminary model.[17] The models are reestimated by adding the first quarter's actual earnings to the data base in order to generate one through three-quarter-ahead forecasts for 1980. This reestimation procedure is repeated by sequentially including the most recent actual earnings data until the one-quarter-ahead forecast for the fourth quarter of 1984 is generated.[18] Analysts' annual earnings forecasts conditional on each quarter's report are obtained from the Value Line over the period 1980-1984.

Since the empirical evidence regarding the best 'premier' model of quarterly earnings has been inconclusive, we use each of three models (the F, GW and BR models) to obtain the estimates of parameter values. Initially, each time-series model is estimated using the first 52 quarters data (1967-1979) to obtain parameter value estimates for the

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[17] See Lorek and McKeown [1978] for a preliminary evidence regarding the effect of number of observations on the predictive ability. In general, they found a significant increase in predictive ability as the number of observations increases.

[18] The rational for adopting the reestimation procedure over the simpler adaptive forecasting technique is due to (1) empirical evidence suggesting the superiority of reestimation over adaptive forecasting in predictive ability (McKeown and Lorek [1978]), and (2) presumption that forecasts from the reestimation procedure are more comparable with analysts' forecasts.

year 1980. The reestimation procedure is then used by adding additional four quarters' data to the data base to estimate parameter values for the year 1981 through 1984.

4.3.3 Testing Hypotheses

It was hypothesized that both total (H1) and relative (H2) predictive value of quarterly earnings for improving annual earnings forecasts are positively related to the parameter value of a given quarterly earnings model. To test these hypotheses, the following pooled cross-sectional and time-series regression models are estimated:

$$TI_{iy} = a_0 + a_1 PARA_{iy} + a_2 \ln(SIZE)_{iy} + \varepsilon_{iy} \qquad (4\text{-}1)$$

and

$$RI(Q_1)_{iy} = b_0 + b_1 PARA_{iy} + b_2 \ln(SIZE)_{iy} + \varepsilon_{iy} \qquad (4\text{-}2)$$

where TI = total improvement in the accuracy of annual earnings from incorporating actual quarterly earnings,

PARA = parameter value of a given quarterly earnings time-series model,

ln(SIZE) = natural logarithm of firm size,

$RI(Q_1)$ = relative improvement in the forecast accuracy contributed by the first quarter's earnings,

i, y = firm and year index (1980-1984), respectively.

Under these regression models, the hypotheses can be stated formally:

H1: H_0: $a_1 = 0$, H_a: $a_1 > 0$

H2: H_0: $b_1 = 0$, H_a: $b_1 > 0$

The controlling variable, SIZE, is measured by the market value of equity. The coefficients on this variable, a_2 and b_2, are also predicted to be positive for the following reasons. First, to the extent that it is positively related to parameter value (Bathke, Lorek and Willinger [1989]), firm size will have the same impact on the predictive values as the parameter value. Second, information on future earnings from sources other than publicly available earnings data is more easily available for large firms than for smaller firms (Brown, Richardson and Schwager [1987], Collins, Kothari and Rayburn [1987] and Freeman [1987]). This differential availability of information set will be reflected in smaller forecast errors in later part of the year and larger degree of improved annual forecast accuracy in earlier part of the year for the large firms than the smaller firms, resulting in positive relation between firm size and predictive values of quarterly earnings.

There are several potential problems with the regression models (4-1) and (4-2). First, the theoretical results in Section 3.3 (Table 1 and Table 2) suggest a nonlinear relation of parameter values to both TI and $RI(Q_1)$, and yet linearity is assumed in the regression models. As an attempt to correct this problem, we follow the procedure suggested by Iman and Conover [1979] and estimate the models (4-1) and (4-2) by replacing the variables with corresponding ranks. Second, if SIZE is positively related to PARA, multicollinearity problem may arise, resulting in unreliable estimates of the regression coefficients. Diagnostic tests developed by Belsley, Kuh and Welsch [1980] are perfomed to test for the presence of this problem. Finally, the procedure suggested by White [1980] is used to test for heteroskedasticity problem.

As an additional test of H1 and H2, two-way analysis of variance (ANOVA) design is also employed by dichotomizing sample firms according to (1) the magnitude of parameter value (small(S) versus large(L) parameter firms), and (2) the firm size (small(s) versus large(l) firms). Under this 2x2 factorial design, H1 and H2 can be stated in null form:

$$H1: \quad \begin{vmatrix} TI_{sS} \\ \\ TI_{lS} \end{vmatrix} = \begin{vmatrix} TI_{sL} \\ \\ TI_{lL} \end{vmatrix}$$

and

$$H2: \quad \begin{vmatrix} RI(Q_1)_{sS} \\ \\ RI(Q_1)_{lS} \end{vmatrix} = \begin{vmatrix} RI(Q_1)_{sL} \\ \\ RI(Q_1)_{lL} \end{vmatrix}$$

CHAPTER 5

EMPIRICAL RESULTS

This Chapter presents empirical results of testing the hypotheses based on 235 sample firms over five year period (1980-1984). As an initial step, descriptive statistics of parameter value estimates and test for the predictive value of quarterly earnings are presented. This is followed by the presentation of the results of testing our main hypotheses using three 'premier' quarterly time-series models (the BR, F, and GW models). We then provide the results of comparing the three time-series models by utilizing their theoretical and empirical predictive values. Finally, the analyses are repeated using the Value Line analysts' forecasts data and the results are presented.

5.1 Estimation of Time-Series Models

5.1.1 Estimation Procedure

For each of 235 sample firms, the three "premier" univariate time-series models of the Brown and Rozeff [1979a] (BR), the Foster [1977] (F), and the Griffin [1977] and Watts [1975] (GW) were estimated using initial 52 quarters' EPS data (1967-1979) to obtain model parameter values and one through four-quarter-ahead forecasts for the year 1980.

Each model was reestimated by adding realized quarterly earnings to the data base for the years from 1981 to 1984. Thus, fifty two to sixty eight in increment of four quarters data were used to estimate the time-series models. The maximum likelihood method was used with 100 iteration in the estimation process.[19] In most of the cases, 100 iteration was enough to have estimates converged. When estimates do not converge after 100 iterations, the number of iterations was increased until they converge.

5.1.2 Goodness-of-Fit Statistics

Table 4 provides frequency distributions of three 'goodness-of-fit' measures for each model estimated using initial 52 quarters' earnings data. Panel A reports the mean, standard deviation, and quartile distributions of the goodness-of-fit statistic by Ljung and Box [1978].[20] The F model exhibits the largest statistics at all quartiles. Furthermore, more than 25 percent of the sample firms have the Ljung-Box statistic exceeding the probability of Type-I error greater than 5 percent ($\chi^2_{12,\alpha=.05}$=21.026) for the F model.[21] This suggests that the F model does not fit the data well relative to the BR or the GW model. This is not a suprising result because the F model is the least parameterized one among the three models.

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[19] There are three different methods available for estimation purpose: (1) the conditional least square method (CLS); (2) the unconditional (exact) least square method (ULS); and (3) the maximum likelihood method (ML). The choice of the ML over the others is based on the simulation result by Ansley and Newbold [1980] which suggests that the ML is the most preferable one when seasonal data are used.

[20] The Ljung-Box statistic is defined as:

$$\chi_m = n(n+2) \Sigma r_k/(n-k)$$

where $r_k = \Sigma a_t a_{t+k}/\Sigma a_t$, n is the number of residuals, m is the number of lags, and a_t is the 'white noise' process of residuals. This statistic is approximately chi-square distributed with m degrees of freedom (12 in this study).

[21] The Ljung-Box statistic is basically a serial correlation test. With only 52 observations, this statistic will have virtually no statistical power to test for the twelfth serial correlation. Therfore, it is more appropriate to conduct smaller order test (e.g., 6 lags). However, we used 12 lags to make our results comparable to those in previous studies (e.g., Foster [1977], Griffin [1977] and Bathke, Lorek and Willinger [1989]; among others).

TABLE 4

Frequency Distribution of Goodness-of-Fit Statistics Across Time-Series Models [a]

Panel A. Ljung-Box χ^2 Statistic

Model[b]	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
BR	11.609	7.479	6.650	9.980	14.930
F	17.699	11.043	10.390	15.210	22.080
GW	10.166	6.292	5.920	8.790	12.620

Panel B. Akaike Information Criterion (AIC)

Model	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
BR	-56.49	101.15	-115.80	-58.79	3.12
F	-48.65	105.76	-110.13	-49.08	11.76
GW	-55.32	102.31	-116.17	-56.42	1.85

Panel C. Residual Variance

Model	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
BR	0.177	1.043	0.005	0.015	0.055
F	0.299	1.992	0.005	0.019	0.069
GW	0.193	1.150	0.004	0.015	0.051

[a] The statistics are based on the estimation of three models for each of 235 sample firms using 52 quarters' EPS data (1967-1979).

[b] The BR model is (100)x(011), the F model is (100)x(010) with drift, and the GW model is (011)x(011).

Panel B of Table 4 shows the summary statistics of the Akaike Information Criterion (AIC) for each model.[22] This index, introduced by Akaike [1974], measures how much information in data is used in estimating a model. Akaike has shown that the smaller the AIC, the better is the model in fitting the data.[23] Consistent with the results using the Ljung-Box statistic, the F model has the largest values of AIC at all quartiles, suggesting the lack of fitness of the F model relative to the others.[24] The summary statistics of residual variance in Panel C also show the same result.

The Friedman test was used to investigate whether the differences across three time-series models in the goodness-of-fit measures are statistically significant. The Friedman test is a nonparametric version of ANOVA (Conover [1980]) and has been utilized in the time-series literature (e.g., Bathke and Lorek [1984] and Brown, Hagerman, Griffin and Zmijewski [1987]). A nonparametric test was employed because the distributional properties of the goodness-of-fit measures are unknown.

For a given firm, three time-series models were ranked using the magnitude of each goodness-of-fit statistic: a rank of one was assigned to the model yielding the smallest statistic, while a rank of three was assigned to the model yielding the largest statistic. If the Friedman test rejects the null hypothesis of no difference in the goodness-of-fit measure across three time-series models, a matched pair t-test based on the ranks

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[22] The AIC is defined as:

$$AIC = -2\ln(L) + 2K$$

where L is the likelihood function and K is the number of parameters.

[23] Dharan's [1983] work is the only study, to the best of my knowledge, in accounting literature that utilizes the AIC measure to identify the best quarterly earnings model. For more detailed description about AIC, see Dharan [1983] and the references therein.

[24] A Baysian criterion proposed by Schwartz [1978], usually referred to as SBC, was also obtained. The results based on SBC are virtually the same as those based on AIC.

was conducted to test the significance of difference in each model pair and to determine which model is the "best" one in terms of its ability to fit the data.

Table 5 reports the results of model comparison based on the 'fitting test'. The Friedman F-statistics (Panel A) indicate that there is a significant difference (α=0.0001) across three time-series models in each of three goodness-of-fit measures: (1) the Ljung-Box χ^2 statistic; (2) the AIC; and (3) the residual variance. The pairwise comparison results (Panel B) suggest that both the BR and GW models are superior to the F model regardless of which measure was used. On the other hand, the BR-GW pair comparisons provide mixed results which depend on the choice of the goodness-of-fit measure. For example, the GW model is better than The BR model when the Ljung-Box statistic was used, while the BR is the better model using either the AIC or the residual variance.

5.1.3 Time-Series Model Parameter Values

Table 6 presents descriptive statistics on the parameter values of each model estimated using initial 52 quarters' EPS data (Panel A, Panel B and Panel C). Also reported are the distributions of the first-order sample autocorrelations of raw earnings series as well as the series with regular and/or seasonal differencing (Panel D). In general, quarterly EPS of the sample firms exhibit significantly positive autocorrelations. For example, the autoregressive parameter of the BR model has mean (median) value of 0.675 (0.710) and only three firms have negative parameter values.

In addition, most of the sample firms have very large parameter values, as can be seen from the lower quartile value of 0.534 for the BR model and 0.377 for the F model. This may be due to our sample selection criteria which favor the inclusion of the successful firms, resulting in the stable (i.e., highly positively correlated) patterns of

TABLE 5

Comparison of Goodness-of-Fit Statistics Across Time-Series Models [a]

Panel A. Summary Statistics and Overall Comparisons [b]

	Ljung-Box χ^2		AIC		Res Variance	
Model	Mean Rank	Mean Value	Mean Rank	Mean Value	Mean Rank	Mean Value
BR	1.785	11.609	1.545	-56.489	1.677	0.177
F	2.657	17.699	2.536	-48.654	2.617	0.299
GW	1.957	10.166	1.919	-55.319	1.706	0.193
Friedman F	179.09		117.42		219.07	
p-value	0.001		0.001		0.001	

Panel B. Pairwise Comparisons [c]

Model Pair	Ljung-Box χ^2	AIC	Res Variance
BR - F	-12.08 (0.001)	-12.39 (0.001)	-15.19 (0.001)
BR - GW	2.82 (0.005)	-4.92 (0.001)	-0.48 (0.634)
GW - F	-15.23 (0.005)	-7.37 (0.001)	-14.38 (0.001)

[a] The three goodness-of-fit statistics are obtained by estimating three time-series models for each of 235 sample firms using 52 quarters' EPS data (1967-1979).

[b] For each firm, a rank of one (three) is assigned to the model yielding the smallest (largest) goodness-of-fit statistic.

[c] The matched-pair t-tests based on the ranks are used. Associated p-values are in parentheses.

TABLE 6

Frequency Distribution of Time-Series Model Parameters and First-Order Autocorrelations [a]

Panel A. Brown and Rozeff Model: (100)x(011)

	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
ϕ	0.675	0.259	0.534	0.710	0.881
θ	0.495	0.354	0.267	0.588	0.740

Panel B. Foster Model: (100)x(010) with Drift

	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
ϕ	0.509	0.235	0.377	0.532	0.681
θ_0	0.051	0.085	0.023	0.047	0.078

Panel C. Griffin and Watts Model: (011)x(011)

	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
θ_1	0.364	0.323	0.177	0.380	0.592
θ_4	0.592	0.353	0.394	0.682	0.849

Panel D. First-Order Autocorrelations

(d,D)[b]	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
(0,0)	0.621	0.258	0.456	0.693	0.839
(0,1)	0.472	0.225	0.330	0.492	0.642
(1,0)	-0.305	0.235	-0.481	-0.289	-0.123
(1,1)	-0.227	0.216	-0.397	-0.261	-0.084

[a] The parameter values are estimated using 52 quarter's EPS data (1967-1979).

[b] The regular (d) and seasonal (D) differencing of the original EPS series.

earnings series for the sample firms. This large parameter values will work against the research hypotheses because (1) the variations in predictive values are smaller for larger parameter values than for smaller ones and (2) the marginal increase in total predictive values is decreasing with the parameter value.

In order to examine whether systematic differences exist across firms in the time-series properties of quarterly earnings, we evaluate firm size as an independent variable which affects the cross-sectional differences in the time-series model parameter values.[25] Firm size was chosen because of the absence of well-articulated theory which identifies other variables as determinants of time-series properties of quarterly earnings.[26]

The use of firm size as a determinant of parameter values raises two issues related to the measurement of the variable. The first one is the choice of an appropriate proxy for firm size. We measured firm size by market value of equity at the beginning of the year because it has been typically used in the accounting literature (e.g., Bathke, Lorek and Willinger [1989] and Collins, Kothari and Rayburn [1987]).[27] The second issue is the selection of the point in time to measure firm size. In this study, firm size was measured by taking a mean value over the period corresponding to the estimation of time-series models. For example, firm size for the year 1980 is the average of market values

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[25] Time-series properties of earnings may include model structure (e.g., three 'premier' models) as well as parameter value. The effect of firm size on the model structure was not considered because (1) an empirical evidence suggests that the model structure is invariant with firm size (Bathke, Lorek and Willinger [1989]) and (2) the variable of most interest in this study is the time-series model parameter value.

[26] Additional variables which have been suggested as potential determinants of time-series properties of annual earnings include product type, degree of competition, and capital intensity (Lev [1983]). Whether these variables also affect the process generating quarterly earnings is unknown. An investigation into this issue is beyond the scope of this study.

[27] To examine the sensitivity of our results to the choice of size measure, we also employed total assets and sales as additional measures of firm size. The results are qualitatively the same as those using market value of equity.

of equity over the period from 1967 to 1979. Following Lev [1983], we also used firm size measured at the mid-point of the period (e.g., 1973 for 1980). The results remain the same.

To investigate the effect of firm size on the time-series model parameter values, the sample firms were trichotomized by market value of equity. Since both parameter value and firm size may vary over time, we restricted the analysis to 1980 data rather than using all the 5 years of data (1980-1984).[28] The middle strata firms were excluded to enhance the power of testing the null hypothesis of no difference in parameter values across firm size strata.[29]

Table 7 provides some evidence regarding the relationship between parameter value and firm size. Panel A presents frequency distributions of parameter values by firm size for each of the three time-series models. The results clearly indicates that large firms exhibit larger parameter values than smaller firms. When the BR model is used, the mean values of the autoregressive parameter are 0.571 and 0.775, respectively for small and large firms. This result also holds for the autoregressive parameter in the F model (0.439 versus 0.587) and for the moving average parameter in the GW model (0.590 versus 0.729).[30]

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[28] The use of either year-by-year analysis or pooled data does not affect the results in any significant way.

[29] Following the approach used by Bathke, Lorek and Willinger [1989], we retained the middle strata firms and conducted three-sample median test. The null hypothesis was rejected at any conventional significance level. However, this was contributed by the significant difference between small and large firm size strata.

[30] For the GW model, the parameter value was measured by $1-\theta_1$, not by the MA parameter itself (θ_1), because this measure is theoretically related to the predictive value of quarterly earnings (see Chapter 3).

TABLE 7

The Relationship Between Time-Series Parameter Value and Firm Size [a]

Panel A. Summary Statistics of Parameter Values By Firm Size [b]

1. Brown and Rozeff Model: (100)x(011)

Firm Size	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
Small	0.571	0.286	0.434	0.616	0.800
Large	0.775	0.208	0.674	0.837	0.942
Wilcoxon Z	4.780 (p=0.001)				

2. Foster Model: (100)x(010) with Drift

Firm Size	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
Small	0.439	0.232	0.280	0.484	0.614
Large	0.587	0.219	0.446	0.621	0.743
Wilcoxon Z	3.945 (p=0.001)				

3. Griffin and Watts Model: (011)x(011)

Firm Size	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
Small	0.590	0.313	0.391	0.568	0.784
Large	0.729	0.338	0.471	0.743	0.929
Wilcoxon Z	2.699 (p=0.007)				

Panel B. Correlation Between Time-Series Parameters and Firm Size

Model	Pearson Correlation	Spearman Correlation
BR	0.172 (p=0.008)	0.356 (p=0.001)
F	0.118 (p=0.071)	0.260 (p=0.001)
GW	0.165 (p=0.011)	0.209 (p=0.001)

[a] Parameter values are estimated using 52 quarters' EPS data. Firm size is measured by average market value of equity over the period from 1967 to 1979.

[b] Firms in middle size strata are excluded.

To determine whether the difference in parameter values between two size strata is statistically significant, we conducted the Wilcoxon Signed-Ranks tests. The Wilcoxon Z-statistics indicate that the difference is significant at α level less than 0.001 for all of the three time-series models. Panel B of Table 7 presents the correlation coefficient between parameter value and firm size. Both the Pearson correlation and Spearman rank correlation are presented alog with p-values. The results show that the correlation is significantly positive and robust with respect to the correlation measure or the time-series model used. In sum, these results suggest that the time-series model parameter values are positively related to firm size, which is consistent with the evidence in Bathke, Lorek and Willinger [1989].

5.2 Predictive Value of Quarterly Earnings

5.2.1 Quarterly Reports and Annual Earnings Forecasts

As suggested in the review of previous research (Chapter 2), a number of studies have documented empirical evidence which suggests the usefulness of quarterly earnings reports for improving the forecasts of annual earnings (e.g., Brown and Rozeff [1979b] and Collins and Hopwood [1980]). The analytical result in Chapter 3 also shows that the forecast error variance is an increasing function of forecast horizon. In this section, we provide evidence on the existence of predictive value of quarterly earnings for forecasting annual earnings. This will serve as an initial step toward addressing the main research issue: the effect of time-series properties on the predictive values of quarterly earnings.

To measure the accuracy of annual earnings forecasts, two forecast error metrics were used: absolute percentage error (APE) and squared percentage error (SPE) which are specified as:

$$APE(Q_\tau)_{iy} = \left| \frac{A_{iy} - E(A|Q_\tau)_{iy}}{A_{iy}} \right|$$

and

$$SPE(Q_\tau)_{iy} = \left(\frac{A_{iy} - E(A|Q_\tau)_{iy}}{A_{iy}} \right)^2$$

where A_{iy} = realized annual earnings,

$E(A|Q_\tau)_{iy}$ = forecasted annual earnings conditional on τ quarter's earnings,[31]

i, y = firm index (i=1,..,235) and year index (y=1980,..,1984), respectively.

Note that both metrics are deflated by actual annual earnings. The reason for this is to ensure relative comparability of forecast errors among firms because earnings numbers in absolute scale are different across firms. The APE assumes a linear loss function while the SPE is based on a quadratic loss function which is consistent with the assumption used in the theoretical analysis in Chapter 3. However, both metrics were used to be consistent with previous studies and to see the sensitivity of the results to the choice of error metrics. In an attempt to avoid the problem of outliers, all forecast errors greater than 300 percent were truncated to 300 percent.[32]

Table 8 presents some evidence about the usefulness of quarterly earnings for improving the forecasts of annual earnings. The mean, standard deviation, and quartile distribution of forecast errors as measured by APE are reported for each conditioning quarter and for the three time-series models. The summary statistics are based on

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[31] At the end of each quarter τ, annual earnings forecasts were obtained by summing the remaining quarter's forecasts of the year and the realized earnings of current and previous quarters.

[32] The 300 percent rule of truncation is an arbitrary procedure. As a sensitivity analysis, the 100 percent truncation scheme was also used with similar results.

TABLE 8

Descriptive Statistics of *Absolute Percentage Error* of Annual Earnings Forecasts [a, b]

Panel A. Brown and Rozeff Model: (100)x(011)

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.583	0.803	0.090	0.235	0.667
1	0.462	0.715	0.066	0.174	0.460
2	0.351	0.606	0.046	0.124	0.320
3	0.244	0.508	0.022	0.063	0.193

Panel B. Foster Model: (100)x(010) with Drift

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.639	0.880	0.075	0.238	0.758
1	0.514	0.793	0.063	0.173	0.529
2	0.416	0.712	0.042	0.129	0.378
3	0.277	0.566	0.021	0.070	0.233

Panel C. Griffin and Watts Model: (011)x(011)

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.649	0.873	0.080	0.255	0.808
1	0.492	0.755	0.059	0.185	0.530
2	0.373	0.635	0.045	0.124	0.359
3	0.248	0.521	0.022	0.065	0.200

[a] The summary statistics are based on 235 sample firms over 5 year period (1980-1984).

[b] The absolute percentage error (APE) is defined as APE=|(A-E(A))/A|, where A and E(A) are actual and forecasted annual earnings, respectively. APE greater than 3.00 were truncated to 3.00.

pooling across firms and over time: total of 1,175 observations (235 firms x 5 years) for each model.[33]

As predicted by the theoretical result, the accuracy of annual earnings forecasts improves as additional quarterly reports are available. This is evident from the first-order stochastic dominance in the cumulative distribution functions of forecast errors, $APE(Q_0)>APE(Q_1)>APE(Q_2)>APE(Q_3)$, at all quartiles. For example, the median values of APE decline monotonically as additional quarterly earnings become available (0.235, 0.174, 0.124, 0.063) for the BR model. To examine whether the improvements in forecasts are statistically significant, we tested the null hypothesis of no difference in APEs across the quarters in which annual forecasts are generated. The F-statistics were 56.01, 49.40 and 68.43 for the BR, F and GW model respectively, resulting in the rejection of the null hypothesis at $\alpha<0.001$ regardless of which model is used for forecasting.[34]

Another evidence revealed by Table 8 is that the cross-sectional variability of forecast errors decreases as the year-end approaches. For example, when the GW model is used, the standard deviation of APE declines from 0.873 at the beginning of the year to 0.521 after the release of the third quarter's earnings. This result suggests that inter-firm difference in the accuracy of annual earnings forecasts becomes increasingly smaller as the time to the announcement of actual earnings decreases.

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[33] The forecast errors may not be independent over time. To avoid this serial correlation problem, all the analyses were also conducted on year-by-year basis. The results were qualitatively the same.

[34] The non-normality of data, as can be seen from mean forecast errors being always greater than median values, indicates that the parameteric F-tests are not valid. Hence, a nonparametric test, the Kruskal-Wallis test (Connover [1980, pp. 229-237]), was also employed to test the null hypothesis. The χ^2 statistics of 391.45 (BR), 300.52 (F) and 363.98(GW) provide the same inference.

Table 9 provides the results using forecast errors measured by SPE. The results are essentially the same as those using APE. As additional quarterly reports are available, there are (1) increase in the accuracy of annual earnings forecasts and (2) decrease in the variability of forecast errors, regardless of which time-series model is used for forecasting. Once again, the improvements in forecasts are highly significant (α<0.001) using either the F-test or the Kruskal-Wallis test. Overall, these results confirm the evidence documented in previous studies (e.g., Lorek [1979], Brown and Rozeff [1979b] and Collins and Hopwood [1980]), suggesting that quarterly earnings are indeed useful for improving the accuracy of annual earnings forecasts.

5.2.2 Comparison of Time-Series Models Using Annual Earnings Forecast Error

Mixed results have been reported in previous studies which have utilized the accuracy of annual earnings forecasts conditional on quarterly reports to evaluate three time-series models of quarterly earnings (the BR, F, and GW models). For example, evidence in Collins and Hopwood [1980] supports the BR model while Lorek [1979] has provided results in favor of the GW model.[35] In this section, we provide further evidence regarding the relative superiority among three univariate time-series models. As with model comparison based on the goodness-of-fit measure in section 5.1.2, the Friedman test and the matched-paired t-test were used.

Table 10 provides the results of evaluating three time-series models based on the relative accuracy of forecasting annual earnings, using absolute percentage errors (APE).

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[35] Evidence in recent studies suggests that bivariate models (Hopwood and McKeown [1981]) and financial analysts (Collins and Hopwood [1980] and Brown, Hagerman, Griffin and Zmijewski [1987]) generate more accurate forecasts than univariate models. Results using the Value Line analysts' forecasts appear in section 5.5.

TABLE 9

Descriptive Statistics of *Squared Percentage Error* of Annual Earnings Forecasts [a, b]

Panel A. Brown and Rozeff Model: (100)x(011)

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.546	0.968	0.008	0.055	0.445
1	0.406	0.860	0.004	0.030	0.212
2	0.294	0.718	0.002	0.015	0.103
3	0.198	0.606	0.000	0.004	0.037

Panel B. Foster Model: (100)x(010) with Drift

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.607	1.031	0.006	0.057	0.574
1	0.467	0.933	0.004	0.030	0.280
2	0.368	0.838	0.002	0.017	0.143
3	0.229	0.663	0.000	0.005	0.054

Panel C. Griffin and Watts Model: (011)x(011)

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.619	1.030	0.006	0.065	0.653
1	0.438	0.886	0.004	0.034	0.281
2	0.323	0.769	0.002	0.015	0.129
3	0.199	0.617	0.000	0.004	0.040

[a] The summary statistics are based on 235 sample firms over 5 year period (1980-1984).

[b] The squared percentage error (SPE) is defined as $SPE=((A-E(A))/A)^2$, where A and E(A) are actual and forecasted annual earnings, respectively. SPE greater than 3.00 were truncated to 3.00.

TABLE 10

Comparisons of Time-Series Models Based on Annual Earnings Forecast Errors: Using APE [a]

Panel A. Summary Statistics and Overall Comparisons [b]

	Q_0		Q_1		Q_2		Q_3	
Model	Mean Rank	Mean APE	Mean Rank	Mean APE	Mean Rank	Mean APE	Mean Rank	Mean APE
BR	1.934	0.583	1.961	0.462	1.917	0.351	1.974	0.244
F	1.991	0.634	2.043	0.514	2.097	0.416	2.046	0.277
GW	2.075	0.649	1.996	0.492	1.986	0.373	1.980	0.248
Friedman F	9.47		3.04		14.92		2.92	
p-value	0.001		0.048		0.001		0.054	

Panel B. Pairwise Comparisons [c]

Model Pair	Q_0	Q_1	Q_2	Q_3
BR - F	-1.40	-1.97	-4.33	-2.27
	(0.161)	(0.049)	(0.001)	(0.024)
BR - GW	-3.41	-0.86	-1.74	-0.55
	(0.001)	(0.392)	(0.082)	(0.582)
GW - F	2.23	-1.18	-2.70	-1.86
	(0.024)	(0.240)	(0.007)	(0.063)

[a] The statistics are based on pooling data across 235 sample firms and over 5 years (1,175 observations).

[b] For each firm-year, a rank of one (three) is assigned to the model yielding the smallest (largest) APE.

[c] The matched-pair t-tests based on ranks are used. Associated p-values are in parentheses.

Panel A of Table 10 summarizes the average ranks and APEs at each conditioning quarter for each time-series model. The Friedman F-statistics reveal that the null hypothesis of no difference in annual earnings forecast errors across three time-series models can be rejected at α level less than or equal to 0.055 regardless of conditioning quarters in which annual forecasts are made. This result suggests that there is a significant difference in the predictability across three time-series models.

It is clear from Panel A that the BR model has the smallest mean ranks and APEs for all conditioning quarters. Panel B of Table 10 provides the t-statistics and the associated levels of significance for the multiple comparisons of three models. The t-statistics for the comparisons of (BR,F) pair indicate that forecast errors are significantly (α<0.05) smaller for the BR model than for the F model except the forecast at Q_0. The BR model also exhibits smaller forecast errorsthan the GW model, and the differences are significant at Q_0 and Q_2. However, the results of (GW,F) pair comparison depend on forecast horizon; the F model is superior to the GW model at Q_0, but the reverse holds at other conditioning quarters.

Table 11 presents the model comparison results using squared percentage error (SPE). The Friedman F-statistics are similar to those from using APE, indicating again that three time-series models are significantly different in terms of their ability to forecast annual earnings. The summary statistics of mean ranks and APEs (Panel A) and the pairwise comparison results (Panel B) clearly suggest the dominance of the BR model over the F model or the GW model.

In sum, the results show that the BR model is superior to the F or GW model in terms of the 'predictability test' and this finding is robust with respect to different forecast error metrics and forecast horizons. This result is consistent with the evidence in previous

TABLE 11

Comparisons of Time-Series Models Based on Annual Earnings Forecast Errors: Using SPE [a]

Panel A. Summary Statistics and Overall Comparisons [b]

Model	Q_0 Mean Rank	Q_0 Mean SPE	Q_1 Mean Rank	Q_1 Mean SPE	Q_2 Mean Rank	Q_2 Mean SPE	Q_3 Mean Rank	Q_3 Mean SPE
BR	1.950	0.546	1.970	0.406	1.920	0.294	1.975	0.198
F	1.986	0.607	2.035	0.467	2.084	0.368	2.040	0.229
GW	2.064	0.619	1.995	0.438	1.996	0.323	1.985	0.199
Friedman F	6.65		2.02		12.46		2.22	
p-value	0.001		0.133		0.001		0.109	

Panel B. Pairwise Comparisons [c]

Model Pair	Q_0	Q_1	Q_2	Q_3
BR - F	-0.90	-1.59	-4.00	-1.88
	(0.368)	(0.112)	(0.001)	(0.060)
BR - GW	-2.81	-0.62	-1.96	-0.43
	(0.005)	(0.537)	(0.050)	(0.668)
GW - F	2.13	-1.03	-2.15	-1.51
	(0.034)	(0.302)	(0.032)	(0.131)

[a] The statistics are based on pooling data across 235 sample firms and over 5 years (1,175 observations).

[b] For each firm-year, a rank of one (three) is assigned to the model yielding the smallest (largest) SPE.

[c] The matched-pair t-tests based on ranks are used. Associated p-values are in parentheses.

studies (Collins and Hopwood [1980] and Bathke and Lorek [1984]) and also consistent with the result based on the 'fitting test' in section 5.1.2.

5.3 Effects of Parameter Value on Predictive Values of Quarterly Earnings

5.3.1 Summary Statistics on Predictive Values of Quarterly Earnings

Table 12 shows descriptive statistics of the predictive values of quarterly earnings. The mean, standard deviation, and quartile distributions of both total (TI) and relative predictive values (RI) as defined in section 4.3.1 using absolute forecast errors are reported for three time-series models.[36] Since, by definition, predictive values should not exceed 100 percent, observations with predictive values greater than 100 percent were excluded from the analyses.[37] The results are based on the aggregation of data over 235 sample firms and 5 years.[38]

The results in Table 12 indicate that on average, TIs are 79.1%, 77.7% and 79.0% for the BR, F and GW model, respectively. Two points are worth noting from summary statistics. First, TIs are smaller than the theoretical ones as indicated in Table 1 and Table 2, but larger than those implied by the forecast errors in Table 8.[39] Second, cross-sectional variations in TIs are small and skewed to the right, as can be seen from the

[36] Note that forecast error metrics used to measure the predictive values are not deflated by actual earnings. Mathematically, however, the use of either deflated or undeflated forecast errors does not affect the measurement of the predictive values.

[37] Predictive values greater than 100 percent may occur due to the misspecification of time-series models used. The extent of model misspecification can be measured by the difference between empirical and theoretical predictive values. This issue will be discussed in section 5.4.

[38] The results based on year-by-year analyses are quite similar to those reported.

[39] For example, consider the BR model. Since the mean parameter value is 0.675, corresponding theoretical TI is about 92% as can be seen from Table 1. However, from Table 8, average TI is 58.1%; (0.583-0.244)/0.583.

TABLE 12

Descriptive Statistics of *Predictive Values* of Quarterly Earnings: Using Absolute Forecast Errors [a, b]

Panel A. Brown and Rozeff Model: (100)x(011)

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.791	0.215	0.705	0.855	0.931
$RI(Q_1)$	0.434	0.329	0.220	0.447	0.677
$RI(Q_2)$	0.299	0.311	0.100	0.307	0.507
$RI(Q_3)$	0.267	0.281	0.065	0.257	0.454

Panel B. Foster Model: (100)x(010) with Drift

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.777	0.222	0.703	0.825	0.923
$RI(Q_1)$	0.418	0.327	0.199	0.439	0.670
$RI(Q_2)$	0.298	0.322	0.113	0.298	0.503
$RI(Q_3)$	0.283	0.299	0.086	0.278	0.470

Panel C. Griffin and Watts Model: (011)x(011)

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.790	0.246	0.727	0.854	0.936
$RI(Q_1)$	0.468	0.327	0.251	0.497	0.718
$RI(Q_2)$	0.280	0.309	0.096	0.281	0.482
$RI(Q_3)$	0.251	0.281	0.058	0.223	0.423

[a] The statistics are based on pooling data across 235 sample firms and over 5 years.

[b] Predictive values greater than 100% are truncated to 100%.

lower quartile values of 70.5%, 70.3% and 72.7% for the BR, F and GW model, respectively. Along with highly skewed distribution of parameter values (Table 6), this will work against the research hypothesis 1 (H1).

Average contribution by the first quarter's earnings to TI (RI(Q_1)) are 43.4%, 41.8% and 46.8% for the BR, F and GW model, respectively. As with TIs, RI(Q_1)s have (1) mean values smaller than theoretical ones and (2) small cross-sectional variations for all time-series models. An important result is the monotonic decline in the values of RI as additional quarterly reports become available; RI(Q_1)>RI(Q_2)>RI(Q_3) for all quartiles. This suggests that earlier quarters contribute more to TI than later quarters and is consistent with the prediction from the analytical result in section 3.2.

Table 13 presents descriptive statistics of predictive values using squared forecast errors. TIs are not only larger, but also closer to theoretical values than those using absolute forecast errors. For example, average TIs are 92.3% for the BR and F models and 92.2% for the GW model. The reason for this is our use of squared forecast error in deriving theoretical results. Once again, the results exhibit small cross-sectional variations in both TIs and RIs, and the importance of earlier quarters for improving the forecasts of annual earnings.

5.3.2 Univariate Analysis

As an initial step, one-way analysis of variance (ANOVA) and the Wilcoxon Signed-Ranks test were conducted to provide a univariate test of the hypotheses (H1 and H2). The sample firms were trichotomized by the estimated parameter values for each time-series model. In light of small cross-sectional variation in parameter values, the middle

TABLE 13

Descriptive Statistics of *Predictive Values* of Quarterly Earnings: Using Squared Forecast Errors [a, b]

Panel A. Brown and Rozeff Model: (100)x(011)

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.923	0.167	0.909	0.979	0.995
RI(Q_1)	0.583	0.324	0.365	0.640	0.854
RI(Q_2)	0.253	0.296	0.060	0.225	0.425
RI(Q_3)	0.164	0.230	0.009	0.095	0.264

Panel B. Foster Model: (100)x(010) with Drift

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.923	0.127	0.911	0.969	0.994
RI(Q_1)	0.559	0.330	0.339	0.629	0.826
RI(Q_2)	0.255	0.304	0.072	0.231	0.432
RI(Q_3)	0.185	0.249	0.019	0.113	0.291

Panel C. Griffin and Watts Model: (011)x(011)

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.922	0.196	0.927	0.979	0.996
RI(Q_1)	0.609	0.335	0.414	0.698	0.878
RI(Q_2)	0.235	0.296	0.056	0.201	0.402
RI(Q_3)	0.156	0.226	0.011	0.087	0.245

[a] The statistics are based on pooling data across 235 sample firms and over 5 years.

[b] Predictive values greater than 100% are truncated to 100%.

strata firms were excluded to enhance the power of testing the hypotheses. TIs and RI(Q_1)s were then compared between small and large parameter firms.

Table 14 provide some evidence about the effect of time-series parameter values on the predictive values of quarterly earnings. The mean and standard deviation of both TI and RI(Q_1) are reported for each parameter strata and for each time-series model using both absolute (AFE) and squared forecast errors (SFE). The results show that large parameter firms have larger TIs as well as RI(Q_1)s than for small parameter firms. Except for TI using SFE and the BR model, the differences are statistically significant (α<0.001) using either the F-tests or the Wilcoxon tests. This result holds up across different combinations of time-series models and forecast error metrics. In sum, these results strongly support the hypotheses (both H1 and H2), suggesting that the time-series properties of quarterly earnings as measured by parameter values are positively related to their predictive values of improving annual earnings forecasts.

It has been documented in the literature that firm size is positively related to (1) parameter values of quarterly earnings models (Bathke, Lorek and Willinger [1989] and also see Table 7) and (2) the accuracy of earnings forecasts (Brown, Richardson and Schwager [1987] and Collins, Kothari and Rayburn [1987]). Hence, firm size may have direct or indirect impact on the predictive values of quarterly earnings. To examine this issue, we compared TIs and RI(Q_1)s between small and large firm size strata.[40]

Table 15 reports the results of testing whether firm size is systematically related to the predictive values of quarterly earnings. Although both TIs and RI(Q_1)s are consistently larger for large firms than for small firms, the differeces are statistically

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[40] Average market value of equity was used as a measure of firm size. Similar to the case of parameter value, middle strata firms were excluded from the analysis.

TABLE 14

Effect of *Time-Series Parameter* on the Predictive Values of Quarterly Earnings: One-Way ANOVA [a]

Panel A. Brown and Rozeff Model: (100)x(011)

	Absolute Forecast Error		Squared Forecast Error	
Parameter	TI	$RI(Q_1)$	TI	$RI(Q_1)$
Small	0.746(0.226)	0.333(0.290)	0.901(0.181)	0.451(0.324)
Large	0.834(0.202)	0.513(0.347)	0.929(0.206)	0.680(0.299)
F-value	17.02**	31.81**	2.14ξ	52.98**
Wilcoxon Z	5.43**	6.11**	5.16**	7.31**

Panel B. Foster Model: (100)x(010) with Drift

	Absolute Forecast Error		Squared Forecast Error	
Parameter	TI	$RI(Q_1)$	TI	$RI(Q_1)$
Small	0.740(0.234)	0.352(0.284)	0.898(0.160)	0.474(0.308)
Large	0.832(0.201)	0.472(0.333)	0.955(0.086)	0.634(0.318)
F-value	18.80**	15.94**	19.94**	26.64**
Wilcoxon Z	5.65**	4.35**	5.71**	5.69**

Panel C. Griffin and Watts Model: (011)x(011)

	Absolute Forecast Error		Squared Forecast Error	
Parameter	TI	$RI(Q_1)$	TI	$RI(Q_1)$
Small	0.738(0.269)	0.380(0.286)	0.888(0.254)	0.515(0.312)
Large	0.823(0.251)	0.570(0.330)	0.946(0.144)	0.706(0.324)
F-value	11.08**	38.87**	7.92**	35.98**
Wilcoxon Z	5.91**	6.67**	5.97**	7.54**

[a] Analyses are based on pooling data across 235 sample firms and over 5 years. Observations in middle parameter group are excluded.

** Significant at $\alpha<0.01$; * Significant at $\alpha<0.05$.
ξ Significant at $\alpha<0.10$.

TABLE 15

Effect of *Firm Size* on the Predictive Values of Quarterly Earnings: One-Way ANOVA [a]

Panel A. Brown and Rozeff Model: (100)x(011)

Firm Size	Absolute Forecast Error TI	Absolute Forecast Error RI(Q_1)	Squared Forecast Error TI	Squared Forecast Error RI(Q_1)
Small	0.780(0.210)	0.401(0.314)	0.921(0.134)	0.548(0.310)
Large	0.801(0.208)	0.472(0.340)	0.927(0.171)	0.616(0.335)
F-value	1.10	4.61*	0.14	4.26*
Wilcoxon Z	1.25	2.48**	1.33	2.68**

Panel B. Foster Model: (100)x(010) with Drift

Firm Size	Absolute Forecast Error TI	Absolute Forecast Error RI(Q_1)	Squared Forecast Error TI	Squared Forecast Error RI(Q_1)
Small	0.772(0.211)	0.394(0.333)	0.915(0.142)	0.535(0.342)
Large	0.788(0.214)	0.451(0.327)	0.931(0.109)	0.596(0.323)
F-value	0.65	3.07*	1.55	3.40*
Wilcoxon Z	1.15	1.77ξ	1.21	1.92ξ

Panel C. Griffin and Watts Model: (011)x(011)

Firm Size	Absolute Forecast Error TI	Absolute Forecast Error RI(Q_1)	Squared Forecast Error TI	Squared Forecast Error RI(Q_1)
Small	0.786(0.244)	0.456(0.317)	0.915(0.233)	0.587(0.333)
Large	0.798(0.213)	0.487(0.336)	0.928(0.168)	0.632(0.340)
F-value	0.28	0.94	0.42	1.80ξ
Wilcoxon Z	0.02	1.59	0.17	1.78ξ

[a] Analyses are based on pooling data across 235 firms and over 5 years. Observations in middle size strata are excluded.

** Significant at $\alpha<0.01$.
* Significant at $\alpha<0.05$.
ξ Significant at $\alpha<0.10$.

insignificant for TIs. In contrast, significant differences ($\alpha<0.10$) exist in $RI(Q_1)$s across firm size strata with an exception of the GW model using AFE. This finding is robust with respect to the test statistics, time-series models and forecast error metrics. Overall, these results indicate that the first quarter's earnings are more important for larger firms than for smaller firms in providing information about forthcoming annual earnings.

5.3.3 Multivariate Analysis

Univariate tests in previous section indicate that predictive values of quarterly earnings are positively related to parameter value and, although weak, firm size. In order to enhance the efficiency and validity of hypothesis testing, two-way ANOVA design was employed as an additional test of the hypotheses. Table 16 provides ANOVA results using total predictive value (TI) as a dependent variable (H1). Sums of squares, F-statistics, p-values and R^2s are reported for three time-series models and two forecast error metrics.[41]

The following four points emerge from the examination of the table. First, with one exception for the BR model using SFE, parameter value has significant main effect ($p<0.001$). This result lends strong support to H1 and is consistent with the univariate result. Second, firm size has no significant effect on TI, which also confirms the univariate result. Third, the strong main effect of parameter value is not sensitive to the choice of time-series model or forecast error metric. Finally, however, a substantial portion of the

[41] The effects of interaction between parameter value and firm size on predictive values were also investigated. Since the interaction effects were not significant, only the main effects were reported.

TABLE 16

Effect of Time-Series Parameter and Firm Size on the *Total Predictive Value* of Quarterly Earnings: ANOVA

Panel A. Brown and Rozeff Model: (100)x(011)

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	0.732	16.78	0.0001	0.054	1.83	0.1771
Size	0.000	0.01	0.9226	0.000	0.00	0.9600
Error	12.395			8.254		
R-square	0.036			0.007		

Panel B. Foster Model: (100)x(010) with Drift

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	0.744	17.53	0.0001	0.117	6.95	0.0088
Size	0.005	0.11	0.7361	0.008	0.50	0.4790
Error	11.975			4.561		
R-square	0.059			0.027		

Panel C. Griffin and Watts Model: (011)x(011)

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	0.970	16.80	0.0001	0.429	10.11	0.0016
Size	0.001	0.02	0.8866	0.002	0.05	0.8247
Error	15.930			11.469		
R-square	0.057			0.036		

variation in TI remains unexplained as can be seen from the R^2s of 3.6%, 5.9% and 5.7% using AFE for the BR, F and GW model, respectively.[42]

Table 17 shows the results of 2x2 ANOVA using $RI(Q_1)$ as a dependent variable. Consistent with the univariate result, average $RI(Q_1)$s are significantly different across two parameter value strata ($p<0.001$) regardless of which combination of time-series model and forecast error metric is used. However, firm size variable has significantly ($p<0.05$) positive impact on $RI(Q_1)$ for the F model only. This result strongly supports H2, suggesting that the first quarter's earnings are more important for the firms with large parameter values than for those with small parameter values in improving the forecasts of annual earnings.

5.3.4 Regression Analysis

The results presented so far indicate that the predictive values (both TI and RI) of quarterly earnings are positively related to time-series model parameter values. Moreover, such a relation was found to be robust with respect to the choice of either time-series model or forecast error metric. However, these results are based on the independent variables which are measured on binary basis; large versus small parameter value and firm size. The theoretical analyses in Chapter 3 show that the predictive values are an increasing function of parameter values. Accordingly, regression analyses were

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[42] This may be due to either (1) the misspecification of three univariate time-series models or (2) the estimation error in applying the Box-Jenkins approach to obtain parameter values.

TABLE 17

Effect of Time-Series Parameter and Firm Size on the *Relative Predictive Value* of Quarterly Earnings: ANOVA

Panel A. Brown and Rozeff Model: (100)x(011)

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	3.029	30.62	0.0001	4.002	38.92	0.0001
Size	0.017	0.17	0.6762	0.002	0.02	0.8994
Error	28.099			28.687		
R-square	0.098			0.122		

Panel B. Foster Model: (100)x(010) with Drift

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	1.342	14.04	0.0002	1.946	20.84	0.0001
Size	0.383	4.06	0.0448	0.419	4.49	0.0351
Error	26.957			25.406		
R-square	0.060			0.085		

Panel C. Griffin and Watts Model: (011)x(011)

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	2.843	28.21	0.0001	2.608	25.00	0.0001
Size	0.053	0.52	0.4702	0.003	0.03	0.8674
Error	27.815			28.173		
R-square	0.094			0.085		

conducted to provide further evidence about the effect of parameter value on the predictive values of quarterly earnings.[43]

Table 18 presents the estimates of the regression model (4-1) using both AFE (Panel A) and SFE (Panel B). In each panel, three sets of estimates corresponding to the BR, F and GW model are shown. For an exposition purpose, consider the case of the BR model. The coefficient (a_1) of the parameter value variable has the hypothesized positive sign and is statistically significant at the α level of 0.01 for AFE and 0.05 for SFE. This result is consistent with the theoretical prediction that total predictive value is an increasing function of parameter values. The coefficient (a_2) of the firm size variable also has the predicted sign (positive) but it is statistically insignificant.[44] These results hold up for the F and GW models and for AFE and SFE. In sum, these results provide strong support for H1.

The overall F-statistics are 9.306, 11.221 and 4.463 for the BR, F and GW model respectively, when AFE is used. This reveals that the null hypothesis of no statistical relationship between the dependent variable (TI) and the independent variables (parameter value and firm size) can be rejected at the 0.001 level of significance. Although somewhat weak, the use of SFE provides similar results. However, the R^2s are quite small indicating that the substantial portion of the variation in TI is unexplained by parameter value and firm size variables. This may be due to the characteristics of the data; small variation in the distributions of the independent variables, in particular,

[43] All the results reported are based on pooling data cross-sectionally and over time. This may yield biased estimates of standard errors and, therefore, lead to incorrect inferences regarding the significance levels of the estimated coefficients due to the potential problem of cross-sectional dependence. To avoid this problem, we repeated the analyses for each year (1980-1984). Essential feature of the results remains the same.

[44] The use of original measure of firm size, rather than the transformed one by taking logarithm, does not affect either the sign or the significance level of the coefficient (a_2).

TABLE 18

Effect of Time-Series Parameter and Firm Size on the *Total Predictive Value* of Quarterly Earnings: Regression Analysis [a]

$$TI_{iy} = a_0 + a_1 PARA_{iy} + a_2 \ln(SIZE)_{iy} + \varepsilon_{iy} \; ^{b}$$

Panel A. Using Absolute Forecast Errors

Variables	BR	F	GW
Intercept	0.680	0.698	0.721
	(15.999)**	(16.409)**	(15.062)**
PARA	0.127	0.156	0.088
	(4.083)**	(4.727)**	(2.912)**
ln(SIZE)	0.509	0.099	0.253
	(0.857)	(0.168)	(0.375)
R^2 (%)	3.02	3.43	1.44
F-value	9.306**	11.221**	4.463**

Panel B. Using Squared Forecast Errors

Variables	BR	F	GW
Intercept	0.866	0.881	0.864
	(25.661)**	(35.220)**	(22.356)**
PARA	0.054	0.089	0.054
	(2.218)*	(4.675)**	(2.221)*
ln(SIZE)	0.361	0.009	0.384
	(0.762)	(0.026)	(0.705)
R^2 (%)	1.03	3.46	0.96
F-value	3.038*	10.940**	2.890$^{\xi}$

[a] Analyses are based on pooling data across 235 sample firms and over 5 years.

[b] TI= total predictive value; PARA= parameter value; ln(SIZE)= natural logarithm of firm size.

** Significant at $\alpha<0.01$.
* Significant at $\alpha<0.05$.
ξ Significant at $\alpha<0.01$

parameter value (see Table 6). Another possibilities include the misspecification of time-series models and the estimation error associated with parameter values (see footnote 42).

In order to examine the effect of parameter value on the relative predictive value of the first quarter's earnings ($RI(Q_1)$), the regression model (4-2) was estimated and the estimation results are reported in Table 19. The following three points are evident from the table. First, the estimated coefficient (b_1), which captures the effect of parameter value, is positive and statistically significant ($\alpha<0.01$) for every combination of time-series model and forecast error metric. Second, while its sign is in the predicted sign (positive), the coefficient (b_2) of the firm size variable is insignificant. Third, although the R^2s are relatively low, the overall F-statistics are large enough to reject the null hypothesis of no association between $RI(Q_1)$ and the independent variables. In summary, these results lend strong support to H2 suggesting that the predictive values contributed by the first quarter's earnings a positive function of time-series model parameter values.

Several diagnostic tests were undertaken to assess the robustness and internal validity of the inferences drawn from the regression analyses. First, the observed positive correlation between firm size and parameter values (Table 7) indicates that multicollinearity may be a problem in the regression models (4-1) and (4-2), resulting in unstable estimates and high standard errors. The approach suggested by Belsley, Kuh and Welsch [1980] was used to test for this problem. Small value of the condition index, the square root of the ratio of the largest eigenvalue to each individual eigenvalue, suggests that multicollinearity is not a severe problem.

Second, a test for heteroskedasticity was conducted following the procedure of White [1980]. Basically, the procedure involves regressing the squared estimated

TABLE 19

Effect of Time-Series Parameter and Firm Size on the *Relative Predictive Value* of Quarterly Earnings: Regression Analysis [a]

$$RI(Q_1)_{iy} = b_0 + b_1 PARA_{iy} + b_2 \ln(SIZE)_{iy} + \varepsilon_{iy} \quad ^{b}$$

Panel A. Using Absolute Forecast Errors

Variables	BR	F	GW
Intercept	0.232	0.275	0.383
	(3.619)**	(4.391)**	(6.142)**
PARA	0.291	0.215	0.236
	(6.230)**	(4.434)**	(5.974)**
ln(SIZE)	0.410	0.662	0.801
	(0.458)	(0.766)	(0.910)
R^2 (%)	6.33	3.14	5.53
F-value	20.215**	10.237**	17.897**

Panel B. Using Squared Forecast Errors

Variables	BR	F	GW
Intercept	0.382	0.367	0.511
	(6.110)**	(5.739)**	(7.894)**
PARA	0.364	0.277	0.221
	(8.018)**	(5.678)**	(5.401)*
ln(SIZE)	0.244	0.973	0.472
	(0.278)	(1.101)	(0.518)
R^2 (%)	10.01	5.25	4.65
F-value	32.485**	16.912**	14.583**

[a] Analyses are based on pooling data across 235 sample firms and over 5 years.

[b] RI= relative predictive value; PARA= paremeter value; ln(SIZE)= natural logarithm of firm size.

** Significant at α<0.01.

residuals from the regression models (4-1) and (4-2) on all second order products and cross-products of the original regressors. The R^2 from this second regression, multiplied by the number of observations, follows approximately a chi-square distribution with 5 degrees of freedom. Table 20 provides the χ^2 statistics for each regression model and time-series model used. The result indicates that heteroskedasticity is not a problem except for the model (4-2) using absolute forecast error.

Finally, although the results presented so far provide strong support for the hypotheses (H1 and H2), it appears that the linear regression models used do not fit the data well. One of such indication is the low R^2 values. In addition to the characteristics of data as discussed earlier, this may be due to the inappropriateness of the linear regression model in testing the theoretical result in Chapter 3 which suggests that the predictive values (both TI and RI) ar a monotonic but nonlinear function of parameter values. In an attempt to investigate this issue and the sensitivity of the results, we repeated the regression analyses by replacing the data with their corresponding ranks.

The rank transformation approach has been shown to be effective when the dependent variable is a monotonic function of the independent variable(s) and this monotonic relationship is nonlinear in nature (Iman and Conover [1979]), which is the case of our data. Specifically, the following two 'rank regression' models were estimated:

$$R(TI)_{iy} = \alpha_0 + \alpha_1 R(PARA)_{iy} + \alpha_2 R(SIZE)_{iy} + \varepsilon_{iy}, \qquad (5\text{-}1)$$

and

$$R(RI)_{iy} = \beta_0 + \beta_1 R(PARA)_{iy} + \beta_2 R(SIZE)_{iy} + \varepsilon_{iy}, \qquad (5\text{-}2)$$

where $R(TI)$ = the rank of total predictive value (TI),

$R(RI)$ = the rank of relative predictive value contributed by the first quarter's earnings ($RI(Q_1)$),

TABLE 20

Test for Heteroskedasticity: White's χ^2 Statistics [a]

Panel A. $TI_{iy} = a_0 + a_1 PARA_{iy} + a_2 \ln(SIZE)_{iy} + \varepsilon_{iy}$

Model	Absolute Forecast Error	Squared Forecast Error
BR	1.442	2.935
F	3.804	8.582
GW	1.784	3.666

Panel B. $RI(Q_1)_{iy} = b_0 + b_1 PARA_{iy} + b_2 \ln(SIZE)_{iy} + \varepsilon_{iy}$

Model	Absolute Forecast Error	Squared Forecast Error
BR	10.698[ξ]	3.581
F	14.075*	3.555
GW	9.594[ξ]	2.284

[a] The χ^2 statistics were obtained from the following procedure as suggested in White [1980]. First, obtain residuals from the OLS regression of model (4-1) or (4-2). Second, run the following regression:

$$\varepsilon^2 = \alpha_0+\alpha_1 PARA+\alpha_2 PARA^2+\alpha_3 \ln(SIZE)+\alpha_4[\ln(SIZE)]^2 +\alpha_5 PARA x \ln(SIZE)+e,$$

where ε is regression residuals from the first step. Finally, multiply the R^2 from the second regression by the number of observations (N) to get $\chi^2 = NxR^2$.

* Significant at $\alpha<0.05$;
ξ Significant at $\alpha<0.10$.

R(PARA) = the rank of parameter value from a given time-series model,

R(SIZE) = the rank of firm size as measured by market value of equity,

i,y = firm and year index (1980-1984), respectively.

Panel A (Panel B) of Table 21 presents the results of estimating the above regression model (5-1) using AFE (SFE). Insofar as the inferences about the coefficient estimates are concerened, the results from the rank regression essentially conform to those using the linear regression approach. The parameter value has positive effect on TI and its coefficient estimate (α_1) is siginificant at the α level less than 0.01 for all combinations of time-series model and forecast error metric, indicating strong support for H1. Except for the GW model, the firm size variable has positive sign but still remains statistically insignificant.

A noticeable feature from Table 21 is the increase in the values of R^2. For example, R^2 increases from (3.02%, 3.43%, 1.44%) to (7.75%, 5.55%, 4.63%) for the (BR, F, GW) models when AFE is used. Similar increases are observed for SFE. This suggests that the rank regression approach has achieved mild success in capturing the monotonically nonlinear nature of the relationship between TI and parameter value.

The estimates of the regression model (5-2) are presented in Table 22 for AFE (Panel A) and for SFE (Panel B). Consistent with the results using the linear regression approach, the coefficient (β_1) of parameter value is positive and statistically significant (α<0.01). With the exception of the GW model, the coefficient (β_2) of the firm size variable is again in the predicted sign (positive) but statistically insignificant. As expected, there are mild increases in R^2s. In summary, these results provide strong support for H2, suggesting that parameter value is positively related to RI(Q_1) even after controlling for the effect of firm size.

TABLE 21

Effect of Time-Series Parameter and Firm Size on the *Total Predictive Value* of Quarterly Earnings: Rank Regression Analysis [a]

$$R(TI)_{iy} = \alpha_0 + \alpha_1 R(PARA)_{iy} + \alpha_2 R(SIZE)_{iy} + \varepsilon_{iy} \ ^{b}$$

Panel A. Using Absolute Forecast Errors

Variables	BR	F	GW
Intercept	210.433	240.139	247.723
	(12.267)**	(12.910)**	(13.752)**
R(PARA)	0.274	0.235	0.216
	(6.909)**	(6.083)**	(5.451)**
R(SIZE)	2.727	0.828	-2.006
	(0.689)	(0.214)	(0.507)
R^2 (%)	7.75	5.55	4.63
F-value	25.124**	18.555**	14.861**

Panel B. Using Squared Forecast Errors

Variables	BR	F	GW
Intercept	219.395	233.012	243.633
	(12.841)**	(12.707)**	(13.667)**
R(PARA)	0.240	0.227	0.221
	(5.915)**	(5.755)**	(5.535)**
R(SIZE)	1.407	1.408	-3.066
	(0.347)	(0.357)	(0.767)
R^2 (%)	5.86	5.18	4.90
F-value	18.161**	16.667**	15.396**

[a] Analyses are based on pooling data across 235 sample firms and over 5 years.

[b] R(TI)= rank of total predictive value; R(PARA)= rank of parameter value; R(SIZE)= rank of firm size.

** Significant at α<0.01.

TABLE 22

Effect of Time-Series Parameter and Firm Size on the *Relative Predictive Value* of Quarterly Earnings: Rank Regression Analysis [a]

$$R(RI)_{iy} = \beta_0 + \beta_1 R(PARA)_{iy} + \beta_2 R(SIZE)_{iy} + \varepsilon_{iy} \ ^{b}$$

Panel A. Using Absolute Forecast Errors

Variables	BR	F	GW
Intercept	225.793	246.262	230.536
	(13.034)**	(13.139)**	(12.958)**
R(PARA)	0.243	0.201	0.265
	(6.066)**	(5.148)**	(6.772)**
R(SIZE)	0.728	2.364	-1.323
	(0.182)	(0.606)	(0.338)
R^2 (%)	6.63	4.10	6.97
F-value	18.864**	13.503**	22.941**

Panel B. Using Squared Forecast Errors

Variables	BR	F	GW
Intercept	192.690	220.383	212.484
	(11.600)**	(12.129)**	(12.167)**
R(PARA)	0.329	0.261	0.296
	(8.362)**	(6.690)**	(7.547)**
R(SIZE)	1.518	2.073	-0.144
	(0.385)	(0.530)	(0.037)
R^2 (%)	11.01	6.90	8.73
F-value	36.124**	22.595**	28.588**

[a] Analyses are based on pooling data across 235 sample firms and over 5 years.

[b] R(RI)= rank of relative predictive value contributed by the first quarter's earnings; R(PARA)= rank of parameter value; R(SIZE)= rank of firm size.

** Significant at $\alpha<0.01$.

5.4 Comparisons of Time-Series Models Using Predictive Values

A number of studies have evaluated three premier time-series models of quarterly earnings (the BR, F, and GW models) in an attempt to identify the "best" model. Typically, the model evaluation procedure is based on one or some of the following criteria: (1) the ability to fit the earnings data ('fitting test'); (2) the accuracy in the forecasts of future earnings ('predictability test'); and (3) the correlation between stock returns and earnings forecast errors ('association test').

Empirical studies which employed some of these criteria have provided mixed results. For example, the 'predictability tests' in Collins and Hopwood [1980] and Bathke and Lorek [1984] suggest an evidence supporting the BR model. In contrast, Benston and Watts [1978] and Lorek [1979] have provided results in favor of the F model and the GW model, respectively.

The results presented in previous sections provide strong evidence which suggests (1) there are cross-sectional variations in the predictive values of quarterly earnings, and (2) time-series model parameter value is an important determinant of these cross-sectional variations. In this section, we utilize the implication of these findings to provide additional evidence regarding the relative superiority among three premier quarterly time-series models. The approach used in this section is different from that in previous studies because, rather than employing some of the above-mentioned criteria, the models are evaluated in terms of their relative differences between theoretical and empirical predictive values of quarterly earnings for forecasting annual earnings.

It was shown in Chapter 3 that under certain assumptions, both total and relative predictive values are determined by the time-series properties (parameter values) of quarterly earnings for a specific class of time-series models. Thus, for any given quarterly model, it is straightforward to calculate the theoretical measure as well as the empirical measure of predictive values. Since any discrepancy in these two measures represents the extent of model misspecification, this approach can be applied to the comparison of different quarterly earnings models.

For a given time-series model (the BR, F, or GW model), the estimated parameter values will determine the predictive values. Theoretical predictive values were obtained by substituting the estimated parameter values for the true parameter values (ϕ or π) in the functional forms specified in section 3.3. This procedure was applied to each model, each firm in the sample, and each year over the period from 1980 to 1984. Empirical (actual) predictive values were measured using annual earnings forecast errors conditional on the available quarterly reports as defined in section 4.3.1.

The theoretical (TPV) and empirical (EPV) predictive values were then averaged over 5 year period to get corresponding mean values for each firm and each model:

$$MTPV_{im} = 1/5 \; \Sigma_y \; TPV_{imy}$$

and

$$MEPV_{im} = 1/5 \; \Sigma_y \; EPV_{imy}$$

where $MTPV_{im}$ = mean theoretical predictive values,

$MEPV_{im}$ = mean empirical predictive values,

i = firm index, i=1,...,235,

m = time-series model index, i=BR, F, or GW, and

y = year index, y=1980,...,1984.

The absolute deviation (DPV_{im}) of the theoretical predictive values from corresponding empirical values was used to measure how close the empirical predictive values are to the theoretical values:

$$DPV_{im} = |MTPV_{im} - MEPV_{im}|$$

The magnitude of DPV_{im} represents the extent of misspecification of model m for firm i; the model is more misspecified, the larger is the magnitude of DPV_{im}. Therefore, this measure can be used to evaluate different time-series models. Specifically, the null and alternative hypotheses to be tested in this section can be stated as:

$$H_0: \; E(DPV_{BR}) = E(DPV_F) = E(DPV_{GW})$$

$$H_a: \; E(DPV_j) \neq E(DPV_k) \text{ for any } j \neq k \; \varepsilon \; BR, F, \text{ or } GW$$

where E( ) denotes an expectation operator.

The Friedman test was used to test the hypothesis because (1) the hypothesis testing involves comparison of DPVs from different time-series model for the same firms (related sample) and (2) the distributional properties of the variable DPV are unknown. For a given firm, three time-series models were ranked using the magnitude of DPV: a rank of one was assigned to the model yielding the smallest DPV, while a rank of three to the model yielding the largest DPV. If the Friedman test rejects the null hypothesis, the matched-paired t-test based on the ranks was conducted to test the significance of difference in each model pair and to determine which model is the "best" one in terms of its specification.

Table 23 presents the results of evaluating three quarterly earnings models based on their predictive values using squared forecast errors. Panel A of Table 23 summarizes the average rank and mean DPV for each model and for both total (TI) and relative (RI) predictive values. The F-statistics from the Friedman test reveal that the null hypothesis

TABLE 23

Comparisons of Time-Series Models Based on Predictive Values Using Squared Forecast Errors [a]

Panel A. Summary Statistics and Overall Comparisons [b]

	TI		$RI(Q_1)$		$RI(Q_2)$		$RI(Q_3)$	
Model	Mean Rank	Mean DPV	Mean Rank	Mean DPV	Mean Rank	Mean DPV	Mean Rank	Mean DPV
BR	1.785	0.093	1.928	0.259	1.902	0.223	1.719	0.164
F	2.330	0.112	2.013	0.273	2.026	0.240	2.255	0.211
GW	2.021	0.111	2.060	0.267	2.072	0.243	2.026	0.190
Friedman F	21.67		1.58		2.74		27.38	
p-value	0.001		0.207		0.066		0.001	

Panel B. Pairwise Comparisons [c]

Model Pair	TI	$RI(Q_1)$	$RI(Q_2)$	$RI(Q_3)$
BR - F	-5.21	-0.90	-1.31	-4.05
	(0.001)	(0.370)	(0.192)	(0.001)
BR - GW	-3.19	-1.42	-1.85	-1.24
	(0.002)	(0.158)	(0.066)	(0.215)
GW - F	-2.28	0.53	0.52	-0.16
	(0.023)	(0.598)	(0.603)	(0.871)

[a] The statistics are based on 235 sample firms using average predictive values over 5 years.

[b] For each firm, a rank of one (three) is assigned to the model yielding the smallest (largest) value of absolute deviation between average theoretical predictive value and average empirical predictive value (DPV).

[c] The matched-pair t-tests based on ranks are used. Associated p-values are in parentheses.

can be rejected in favor of the alternative hypothesis at the α level of 0.001 when TI was used. Except for $RI(Q_1)$, the null hypothesis was also rejected for $RI(Q_2)$ and $RI(Q_3)$ with α level of 0.10 and 0.001, respectively. This result suggests that there is a significant difference across three premier models.

Panel B of Table 23 provides the t-statistics and the associated levels of significance for the multiple comparisons of three time-series models. For TI, all the pairwise comparisons were statistically significant. The significance levels of two-tail tests for (BR, F), (BR, GW) and (GW, F) pairs were 0.001, 0.002 and 0.023, respectively. This result indicates that the BR model has the smallest specification error, while the F model has the largest specification error. Although the significance levels are not high, the BR model is still better than the F or GW models when the comparisons are based on RIs. Overall, these results indicate that the BR model is the best one (i.e., the least misspecified model).

Table 24 provides the model comparison results using absolute forecast errors to measure the predictive values. The Friedman F-statistics are almost the same as those from using squared forecast errors, indicating again that three time-series models are significantly different in terms of their extent of misspecification. While less consistent across different predictive values, the general conclusion which can be drawn from the pairwise comparison remains the same: the BR model is the better one of three quarterly time-series models.

In summary, the results show that the BR model dominates the F or GW model, and this finding is robust with respect to different forecast error metrics and predictive values. These results are generally consistent with the evidence presented in previous sections (see sections 5.1.2 and 5.2.2) and previous studies, which is based on the 'fitting

TABLE 24

Comparisons of Time-Series Models Based on Predictive Values Using Absolute Forecast Errors [a]

Panel A. Summary Statistics and Overall Comparisons [b]

	TI		$RI(Q_1)$		$RI(Q_2)$		$RI(Q_3)$	
Model	Mean Rank	Mean DPV	Mean Rank	Mean DPV	Mean Rank	Mean DPV	Mean Rank	Mean DPV
BR	1.902	0.231	2.060	0.255	1.885	0.213	1.962	0.215
F	1.949	0.238	1.957	0.249	1.996	0.214	2.111	0.228
GW	2.149	0.248	1.983	0.249	2.119	0.235	1.928	0.217
Friedman F	6.14		0.99		4.88		3.36	
p-value	0.002		0.371		0.008		0.035	

Panel B. Pairwise Comparisons [c]

Model Pair	TI	$RI(Q_1)$	$RI(Q_2)$	$RI(Q_3)$
BR - F	-0.51	1.08	-1.19	-0.64
	(0.617)	(0.282)	(0.235)	(0.524)
BR - GW	-2.78	0.83	-2.57	1.60
	(0.006)	(0.409)	(0.011)	(0.112)
GW - F	2.16	0.28	1.35	-0.40
	(0.032)	(0.776)	(0.178)	(0.687)

[a] The statistics are based on 235 sample firms using average predictive values over 5 years.

[b] For each firm, a rank of one (three) is assigned to the model yielding the smallest (largest) value of absolute deviation between average theoretical predictive value and average empirical predictive value (DPV).

[c] The matched-pair t-tests based on ranks are used. Associated p-values are in parentheses.

test' (Brown and Rozeff [1979a] and also see Table 5) and the 'predictability test' (Collins and Hopwood [1980], Bathke and Lorek [1984] and also see Table 10 and Table 11). However, our approach provides clearer rankings among three models than the other methods: the dominance of the BR model.

5.5 Further Analysis Using Analysts' Forecasts

5.5.1 Estimation of Parameter Values Implied by Analysts' Forecasts

Recent studies have provided empirical evidence suggesting the superiority of financial analysts over the three 'premier' time-series models in forecasting future earnings (e.g., Collins and Hopwood [1980] and Brown, Hagerman, Griffin and Zmijewski [1987]). Therefore, it would be more appropriate to use (1) forecasts data by financial analysts and (2) parameter values of the model that is supposed to be utilized by analysts in forming their earnings forecasts. Analysts' forecast data from the Value Line Investment Survey were used in this study.

To obtain parameter values of the quarterly earnings model implied by analysts' forecasts, the following regression model was estimated:[45]

$$REV_\tau(t) = \alpha + \beta(t)FE_\tau + e \qquad (5\text{-}3)$$

where $REV_\tau(t)$ = the revision of t-quarter ahead Value Line forecast at quarter τ, and

FE_τ = the forecast error for quarter τ; actual earnings minus the most recent Value Line forecast of quarter τ.

[45] Brown and Rozeff [1979c] also used this model to examine whether analysts' forecasts are concordant with the univariate time-series models. However, they estimated the model using cross-sectional data (i.e., single estimate of $\beta(1)$ and $\beta(2)$ at each quarter). In this study, a time-series analysis was used by estimating the model for each sample firm.

This 'adaptive expectations model' was used for the following reasons. First, the process by which analysts form their forecasts has not been established in the literature. The model has been used in previous studies to investigate analysts' revision process of annual earnings forecasts (Givoly [1985]) as well as quarterly earnings forecasts (Abdel-Khalik and Espejo [1978] and Brown and Rozeff [1979c]). Finally, it can be shown (Box and Jenkins [1976] and Brown and Rozeff [1979c]) that the coefficient $\beta(t)$ (hereafter, revision coefficients) represent an AR parameter (ϕ) if $\beta(2)=\beta(1)^2$, but the MA parameter ($1-\theta$) if $\beta(2)=\beta(1)$. This would allow us to interprete the revision coefficients as time-series model parameter values.

Equation (5-3) was estimated for each firm using initial 10 years' forecasts data (1970-1979) to obtain the revision coefficient $\beta(t)$ for the year 1980. The same procedure was repeated by adding another year's forecasts to the data base for the years from 1981 to 1984. Both one-quarter and two-quarter ahead forecast revisions were used as dependent variables, resulting in $\beta(1)$ and $\beta(2)$ for each of 235 sample firms over five year period (total of 2,350 estimates: 2x235x2).

Table 25 presents summary statistics on the estimation results of equation (5-3) using initial 10 years' forecast data. Panel A reports the mean, standard deviation, and quartile distributions of intercept and slope coefficients, their t-statistics, and R^2s using one-quarter ahead forecast revisions as dependent variable. The results suggest that in most of the sample firms, the adaptive expectations model adequately represents analysts' forecast revision process. First, the mean R^2 value of 0.221 indicates that significant portion of forecast revision is explained by the most recent one-quarter ahead forecast error. Second, the estimated intercepts are small and insignificantly different from zero. Third, average slope coefficient is 0.329 and it is significant in 190 of the 235 regressions.

TABLE 25

Descriptive Statistics of Adaptive Expectations Model Estimates Using Analysts' Forecasts [a]

$$REV_{\tau}(t) = \alpha + \beta(t)FE_{\tau} + \varepsilon$$ [b]

Panel A. One-Quarter Ahead Forecast Revisions

Estimates	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
α	-0.015	0.049	-0.021	-0.006	0.003
$t(\alpha)$	-0.478	1.243	-1.352	-0.652	0.328
β	0.329	0.257	0.171	0.326	0.465
$t(\beta)$	2.926	2.850	1.539	2.782	4.421
R^2	0.221	0.186	0.068	0.177	0.359

Panel B. Two-Quarter Ahead Forecast Revisions

Estimates	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
α	0.001	0.039	-0.006	0.003	0.014
$t(\alpha)$	0.291	1.308	-0.599	0.409	1.235
β	0.148	0.246	0.011	0.116	0.236
$t(\beta)$	1.194	1.509	0.124	1.177	2.118
R^2	0.101	0.121	0.009	0.055	0.146

[a] The summary statistics are based on 235 sample firms.

[b] $REV_{\tau}(t)$ = the revision of t-quarter ahead Value Line forecast at quarter τ.
FE_{τ} = the forecast error for quarter τ; actual EPS minus the most recent Value Line forecast for quarter τ.

Furthermore, except for nine firms, the revision coefficients are positive and most of them lie between zero and one except for three firms.

Panel B of Table 25 shows the summary statistics on the estimates of equation (5-3) using two-quarter ahead forecast revisions. As expected, there is a decrease in R^2 (an average value of 0.101). Although the descriptive statistics on the revision coefficients using two-quarter ahead forecasts are less informative, they can be used to draw an inference as to which time-series model is most concordant with analysts' forecast revision process. Specifically, we test the following two null hypotheses:

H_{01}: $\beta(1) = \beta(2)^2$

H_{02}: $\beta(1) = \beta(2)$

The acceptance of H_{01} suggests that the revision mechanism by analysts is consistent with an AR model (the BR or the F model) while the acceptance of H_{02} suggests a MA model (the GW model). The t-values from the matched-paired t-tests are 1.382 and 9.483 for the H_{01} and H_{02}, respectively. From this, we can infer that analysts' forecast revision process is more concordant with either the BR or the F model than with the GW model. This result is also consistent with that of Brown and Rozeff [1979c].

Table 26 reports the correlations among revision coefficients ($\beta(1)$), time-series model parameter estimates, and firm size. First, there is a positive correlation between revision coefficients and parameter value estimates regardless of which time-series model is used. This suggests that analysts utilize the time-series properties of earnings series (e.g., Crichfield, Dyckman and Lakonishok [1978], Cragg and Malkiel [1982] and Givoly [1985]). Second, the correlation is not significant for the F model. Along with the above t-test result, this suggests that analysts' forecast revision process is consistent with the BR model, not with the F model. Finally, the revision coefficients have significantly

TABLE 26

Correlations Among Revision Coefficients, Time-Series Parameter Values, and Firm Size [a]

Variables [b]	Pearson Correlation	Spearman Correlation
$Corr(\beta,\Pi_{BR})$	0.290 (p=0.001)	0.302 (p=0.001)
$Corr(\beta,\Pi_{F})$	0.052 (p=0.425)	0.085 (p=0.192)
$Corr(\beta,\Pi_{GW})$	0.487 (p=0.001)	0.508 (p=0.001)
$Corr(\beta,SIZE)$	0.177 (p=0.007)	0.098 (p=0.135)

[a] The correlation coefficients are based on 235 sample firms using the variables at year 1980.

[b] β = the slope coefficient of the regression model (5-3).
Π_{BR} = the AR parameter estimates (ϕ) of the BR model.
Π_{F} = the AR parameter estimates (ϕ) of the F model.
Π_{GW} = the MA parameter estimates ($1-\theta$) of the GW model.
SIZE = firm size, as measured by the market value of equity.

positive correlation with firm size, indicating the need to control for firm size even if we use analysts' forecast data and revision coefficients to test the hypotheses.

Before proceeding to hypothesis testing, it should be emphasized that the adaptive expectations model (5-3) is misspecified due to the omission of relevant variables which may affect the process of analysts' forecast revisions. For example, Brown, Foster and Noreen [1985] found an evidence which suggests that analysts utilize prior stock price changes in their earnings forecasts, and Easton and Zmijewski [1989] used a variation of model (5-3) which includes past price changes as additional variable. Although the issue of what factors affect the formation of analysts' forecasts is beyond the scope of this study, it should be noted that the estimates of revision coefficients from model (5-3) are downward biased due to the omission of relevant variable(s).

5.5.2 Testing Hypotheses Using Analysts' Forecasts

Table 27 presents some evidence about the predictive value of quarterly earnings using analysts' forecast data. Descriptive statistics of annual earnings forecast errors are reported for each conditioning quarter and for both absolute forecast error (AFE) (Panel A) and squared forecast error (SFE) (Panel B). The results are almost the same as those using forecasts from time-series models (Table 8 and Table 9). First, the accuracy of annual earnings forecasts improves as additional quarterly reports become available. This improvement is statistically significant based on either the F-tests or the Kruskal-Wallis tests.[46] Second, the cross-sectional variability of forecast errors decreases as the year-end approaches. All these results are robust with respect to the choice of forecast error

[46] The F-values are 70.562 and 55.499 for the AFE and SFE, respectively. The corresponding χ^2 statistics from the Kruskal-Wallis tests are 455.50 and 454.94.

TABLE 27

Descriptive Statistics of Annual Earnings Forecast Errors Using Analysts' Forecasts [a]

Panel A. Absolute Percentage Error [b]

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.543	0.803	0.060	0.177	0.624
1	0.430	0.712	0.042	0.127	0.413
2	0.310	0.599	0.029	0.084	0.266
3	0.173	0.419	0.013	0.038	0.130

Panel B. Squared Percentage Error [c]

Quarters Reported	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
0	0.517	0.962	0.004	0.031	0.390
1	0.390	0.848	0.002	0.016	0.171
2	0.258	0.693	0.001	0.007	0.071
3	0.129	0.498	0.000	0.001	0.017

[a] The summary statistics are based on 235 sample firms over 5 year period (1980-1984).

[b] The absolute percentage error (APE) is defined as $APE=|(A-E(A))/A|$, where A and E(A) are actual and forecasted annual earnings, respectively. APE greater than 3.00 were truncated to 3.00.

[c] The squared percentage error (SPE) is defined as $SPE=((A-E(A))/A)^2$. SPE greater than 3.00 were also truncated to 3.00.

metric. Finally, analysts' forecasts consistently exhibit smaller distributions of forecast errors at every quarter than those from time-series models, which is consistent with the evidence by Collins and Hopwood [1980].

Table 28 provides descriptive statistics on the predictive values of quarterly earnings using AFE (Panel A) and SFE (Panel B). On average, TI is 0.684 (0.838) and $RI(Q_1)$ is 0.460 (0.607) when AFE (SFE) is used. Assuming that the revision coefficients approximates the AR parameter (ϕ), its mean value of 0.329 (Table 25) should give theoretical TI of about 0.850 from Table 1.[47] This suggests that SFE measure is more appropriated one than AFE, which is an expected result because AFE is an inconsistent and biased estimate of theoretical forecast error variance.

One-way ANOVA was conducted using analysts' forecasts to provide a univariate test of the hypotheses H1 and H2, and the results are reported in Table 29. Panel A provides an evidence about the effect of parameter values, as measured by the revision coefficients, on the predictive values of quarterly earnings. The result shows that large parameter firms have larger TIs as well as $RI(Q_1)$s than the firms with smaller parameter values. The differences are statistically significant ($\alpha<0.10$) using either the F-tests or the Wilcoxon tests. Also, the result is not sensitive to the choice of forecast error metric. Panel B of Table 29 shows the relationship between firm size and predictive values. As predicted, large firms exhibit consistently larger predictive values (both TI and $RI(Q_1)$) than smaller firms. However, the differences are statistically significant ($\alpha<0.10$) only when AFE was used.

Table 30 presents the results of 2x2 ANOVA to test the effect of parameter values on the total predictive value (Panel A) and the relative predictive value (Panel B) after

[47] This is only an approximation because the estimates of revision coefficients are downward biased due to the omission of relevant variables in equation (5-3).

TABLE 28

Descriptive Statistics of *Predictive Values* of Quarterly Earnings: Using Financial Analysts' Forecasts [a, b]

Panel A. Absolute Forecast Error

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.684	0.379	0.664	0.862	0.949
$RI(Q_1)$	0.460	0.278	0.378	0.526	0.641
$RI(Q_2)$	0.246	0.162	0.085	0.297	0.372
$RI(Q_3)$	0.077	0.090	0.000	0.022	0.148

Panel B. Squared Forecast Error

Predictive Values	Mean	Std Dev.	Quartiles 0.25	0.50	0.75
TI	0.838	0.341	0.940	0.987	0.998
$RI(Q_1)$	0.607	0.279	0.529	0.664	0.801
$RI(Q_2)$	0.214	0.143	0.102	0.219	0.320
$RI(Q_3)$	0.041	0.058	0.000	0.013	0.060

[a] The statistics are based on pooling data across 235 sample firms and over 5 years.

[b] Predictive values greater than 100% are truncated to 100%.

TABLE 29

Effect of Parameter Value and Firm Size on the Predictive Values of Quarterly Earnings: One-Way ANOVA Using Analysts' Forecasts [a, b]

Panel A. The Effect of Parameter Value

	Absolute Forecast Error		Squared Forecast Error	
Parameter	TI	RI(Q_1)	TI	RI(Q_1)
Small	0.622(0.407)	0.408(0.286)	0.793(0.386)	0.556(0.300)
Large	0.782(0.304)	0.526(0.235)	0.908(0.259)	0.667(0.237)
F-value	5.82^{*}	6.31^{*}	5.84^{*}	8.07^{**}
Wilcoxon Z	2.24^{*}	2.12^{*}	1.62^{ξ}	2.69^{**}

Panel B. The Effect of Firm Size

	Absolute Forecast Error		Squared Forecast Error	
Firm Size	TI	RI(Q_1)	TI	RI(Q_1)
Small	0.649(0.393)	0.426(0.278)	0.805(0.379)	0.568(0.299)
Large	0.764(0.337)	0.515(0.259)	0.883(0.291)	0.644(0.251)
F-value	2.91^{ξ}	3.24^{ξ}	2.51	3.63^{ξ}
Wilcoxon Z	2.03^{*}	1.71^{ξ}	0.99	1.57

[a] Analyses are based on pooling data across 235 sample firms and over 5 years. Observations in middle parameter group are excluded.

[b] The numbers reported are mean values with the standard deviation in parentheses. Parameter values are the slope coefficients of the regression model (5-3) and firm size is measured by the market value of equity.

** Significant at $\alpha<0.01$; * Significant at $\alpha<0.05$.
ξ Significant at $\alpha<0.10$.

TABLE 30

Effect of Parameter Value and Firm Size on the Predictive Values of Quarterly Earnings: Two-Way ANOVA Using Analysts' Forecasts

Panel A. Total Predictive Value

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	0.400	3.57	0.0625	0.356	3.69	0.0570
Size	0.247	2.20	0.1420	0.258	2.67	0.1046
Error	8.509			12.258		
R-square	0.071			0.047		

Panel B. Relative Predictive Value

	Absolute Forecast Error			Squared Forecast Error		
Source	SS	F	p	SS	F	p
Parameter	0.224	3.61	0.0611	0.234	3.44	0.0660
Size	0.233	3.76	0.0561	0.347	5.09	0.0258
Error	4.703			8.650		
R-square	0.088			0.061		

controlling for firm size. Consistent with the univariate results, parameter value has significantly positive effect on both TI and RI(Q_1). Although the significance level is somewhat low (α<0.10), this result lends support to the hypotheses (H1 and H2) even after controlling for the effect of firm size.

Table 31 reports the results of regression analyses using analysts' forecast data and the revision coefficients. Panel A shows the estimates of regression models (4-1) and (4-2). The coefficients, a_1 and b_1, of the parameter value variable have the hypothesized sign (positive) and are statistically significant at the α level of 0.05 for AFE and 0.01 for SFE. The coefficients, a_2 and b_2, of the firm size variable also have the predicted positive sign but they are statistically insignificant except for the RI(Q_1) when SFE was used. Following the same procedure as in Section 5.3.4, rank regression models of (5-1) and (5-2) were also estimated, and the results are reported in Panel B of Table 31.[48] The general tenor of conclusion remains the same; significantly positive relation of parameter value to both total and relative predictive values.

Overall, the results using the Value Line analysts' forecast data and the estimates of parameter values implied by analysts' forecasts are consistent with those using three 'premier' time-series models. In summary, empirical results strongly support for the hypotheses (H1 and H2), and these results are robust with respect to the choice of forecast error metric, statistical methodology, forecast data and parameter values used.

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[48] Diagnostic tests for multicollinearity and heteroskedasticity were also conducted using the procedure by Belsley, Kuh and Welsch [1980] and White [1980], respectively. Test result indicates that neither of these problems is present in our data.

TABLE 31

Effect of Parameter Value and Firm Size on the Predictive Values of Quarterly Earnings: Regression Analysis Using Analysts' Forecasts [a]

$$PV_{iy} = a_0 + a_1PARA_{iy} + a_2\ln(SIZE)_{iy} + \varepsilon_{iy} \ ^{b}$$

Panel A. Ordinary Regression Analysis

	Absolute Forecast Error		Squared Forecast Error	
Variables	TI	RI(Q_1)	TI	RI(Q_1)
Intercept	0.769	0.543	0.899	0.691
	(6.298)**	(6.076)**	(10.404)**	(9.856)**
PARA	0.215	0.151	0.173	0.168
	(2.511)*	(2.402)*	(2.723)**	(3.262)**
ln(SIZE)	0.024	0.021	0.019	0.022
	(1.323)	(1.544)	(1.444)	(2.094)*
R^2 (%)	3.42	4.58	3.22	4.99
F-value	4.135*	4.195*	4.702**	7.432**

Panel B. Rank Regression Analysis [c]

	Absolute Forecast Error		Squared Forecast Error	
Variables	TI	RI(Q_1)	TI	RI(Q_1)
Intercept	84.022	85.128	138.977	135.472
	(8.264)**	(8.351)**	(10.764)**	(10.657)**
PARA	0.189	0.177	0.102	0.176
	(2.589)**	(2.408)*	(1.732)ξ	(3.037)**
ln(SIZE)	0.128	0.128	0.071	0.120
	(1.752)ξ	(1.742)ξ	(1.197)	(2.072)*
R^2 (%)	5.49	5.00	1.54	4.56
F-value	5.086**	4.602**	2.220ξ	6.767**

[a] Analyses are based on pooling 235 sample firms and over 5 years.

[b] PV= predictive values (either TI or RI(Q_1)); PARA= parameter value implied by analysts' forecasts; ln(SIZE)= natural log of firm size.

[c] Ranks of both dependent and independent variables are used.

** Significant at $\alpha<0.01$; * Significant at $\alpha<0.05$;
ξ Significant at $\alpha<0.10$.

CHAPTER 6

CONCLUSIONS

The purpose of this study is to provide further evidence regarding the predictive value of quarterly earnings for improving the forecasts of annual earnings. More specifically, this study examines analytically and empirically the effect of time-series behavior of quarterly earnings on their predictive value. A simple analytical model developed in Chapter 3 shows, among others, that for a specific class of time-series models, (1) the accuracy of annual earnings forecasts increases as additional quarterly reports become available, and (2) the time-series model parameter value is positively related to both total improvement and the first quarter's relative improvement in annual earnings forecasts.

These theoretical predictions were empirically tested using a sample of 235 firms over five year period (1980-1984). Empirical results are consistent with the theoretical predictions. First, annual earnings forecasts become increasingly accurate as additional quarterly reports are available, suggesting that quarterly earnings are useful for improving the forecasts of annual earnings. Second, there are cross-sectional variations in the degree of the improved accuracy in forecasts. More importantly, time-series properties (parameter value) of quarterly earnings are an important determinant of the variations in both total and relative predictive values. This result is robust with respect to different time-series models, forecast error metrics, and statistical methods.

Empirical tests were also conducted using the Value Line analysts' forecast data. The results are generally consistent with those using earnings forecasts and parameter values from the three 'premier' time-series models (the BR, F, and GW models). Furthermore, the use of simple adaptive expectations model enables us to draw some inference as to (1) how analysts revise their forecasts conditional on quarterly reports, and (2) which univariate time-series model is most concordant with analysts' forecasts. The results suggest that (1) the one-quarter ahead forecast error explains significant portion of analysts' forecast revisions, and (2) the autoregressive model, especially the BR model, is most consistent with analysts' forecats.

The theoretical results were also applied to the comparison of three time-series models. Absolute deviation between theoretical predictive values and empirical predictive values was used as a criterion by which to evaluate a model. Empirical results indicate that the BR model has the smallest misspecification error of the three models. Although similar result was obtained using other criteria such as the 'fitting test' and the 'predictability test', the rankings of the models are clearer under our criterion.

This study provides the following contributions to the accounting literature. First, while most of previous studies on the predictive value of quarterly earnings have been empirical in nature, this study demonstrates analytically that quarterly reports always improve the forecasts of annual earnings if quarterly earnings are described by either first-order autoregressive or moving average process such as the three 'premier' models. Second, it has been analytically shown and empirically observed that the degree of improvements in annual forecasts from incorporating quarterly earnings varies systematically with parameter values of underlying time-series model. This result can be applied to additional explanation of 'information environment hypothesis' of earnings-returns relationship. Finally, this study also examines the relative importance of the first quarter's earnings to the improved accuracy in annual forecasts, which has not been investigated in previous studies.

A natural extension of this study would be to examine the impact of several factors, which affect the time-series properties of quarterly earnings, on their predictive value in improving the accuracy of annual earnings forecasts. Investigation into this issue requires the identification of some determinants of quarterly earnings process. Another related issue is to investigate the effect of quarterly earnings model parameter value on the intra-year relationship between accounting earnings and security returns. For example, the differential stock price reactions to earlier versus later quarters' earnings announcements may be explained by the differences in the time-series properties of quarterly earnings. In light of the analytical results of this paper, it is expected that the firms with larger parameter values will exhibit larger price changes and stronger earnings-returns relationship during the earlier months of the year.

Finally, the issue of how financial analysts form their earnings expectations can be further investigated by including in the adaptive expectations model other variables which are related to the information set utilized by analysts. For example, the variables such as past price changes, parameter values of time-series models, and firm size may be included as additional variables.

APPENDIX A

LIST OF SAMPLE FIRMS

CUSIP	SIC	COMPANY NAME
00282410	2834	Abbot Laboratories
00628410	2250	Adams-Millis Corp
01371610	3330	Alcan Aluminium Ltd
01737210	3630	Allegheny International Inc
01941110	3460	Allied Products
10964510	3530	Allis-Chalmers Corp
02224910	3330	Aluminium Co of America
02312710	1211	Amax Inc
02470310	2111	American Brands Inc
02532110	2800	American Cyanamid Co
02660910	2830	American Home Products Corp
02971710	3580	American Standard Inc
03110510	3620	Ametek Inc
03190510	2911	Amoco Corp
03189710	3679	Amp Inc
03203710	3560	Ampco-Pittsburgh Corp
03304710	3221	Anchor Hocking Corp
04217010	3310	Armco Inc
04247610	3079	Armstrong World Industries Inc
04333910	3714	Arvin Industries Inc
04341310	3330	Asarco Inc
04882510	2911	Atlantic Richfield Co
05430310	2844	Avon Products
06780610	3499	Barnes Group Inc
07170710	2834	Bausch & Lomb Inc
07189210	2834	Baxter Travenol Laboratories
07587310	3530	Becor Western Inc
07749110	2200	Belding Heminway
07785110	3688	Bell & Howell Co
08185120	1040	Benguet Corp
08750910	3310	Bethlehem Steel Corp
09702310	3721	Boeing Co
09959910	2020	Borden Inc
09972510	3714	Borg-Warner Corp
11009710	2834	Bristol-Myers Co
11704310	3510	Brunswick Corp
12220510	3679	Burndy Corp
13106910	1040	Callahan Mining Corp
13441110	1040	Campbell Red Lake Mines
13985910	3830	Capital Cities Inc
14233910	3000	Carlisle Cos Inc
14912310	3531	Caterpillar Inc

15687910	3290	Certain-Teed Corp
15852510	2600	Champion International Corp
15866310	3699	Champion Spark Plug
16515910	2600	Chesapeake Corp
16675110	2911	Chevron Corp
17119610	3711	Chrysler Corp
17217210	3540	Cincinnati Milacron Inc
18139610	3537	Clark Equipment Co
18589610	1000	Cleveland-Cliffs Inc
19121610	2086	Coca-Cola Co
19355810	3940	Coleman Co Inc
19416210	2841	Colgate-Palmolive Co
19686470	3714	Colt Industries Inc
20027310	3560	Combustion Engineering Inc
20043510	3330	Cominco Ltd
20829110	3600	Conrac Corp
21666910	3610	Cooper Industries Inc
21683110	3000	Cooper Tire & Rubber
21768710	3310	Copperweld Corp
21932710	3221	Corning Glass Works
12614910	2000	CPC International Inc
22439910	3494	Crane Co
22711110	2860	Crompton & Knowles Corp
22825510	3410	Crown Cork & Seal Co Inc
12650110	3679	CTS Corp
23102110	3510	Cummins Engine
23156110	3720	Curtis-Wright Corp
23252510	3310	Cyclops Corp
25059510	2850	De Soto Inc
24863110	2649	Dennison Manufacturing Co
25365110	3683	Diebold Inc
25707510	1040	Dome Mines Ltd
25786710	2750	Donnelley (R.R.) & Sons Co
26000310	3530	Dover Corp
26054310	2800	Dow Chemical
26353410	2800	Du Pont (E.I.) De Nemours
27746110	3861	Eastman Kodak Co
27805810	3714	Eaton Corp
28555110	3682	Electronic Associates Inc
29121010	3550	Emhart Corp
30229010	2911	Exxon Corp
30371110	3721	Fairchild Industries Inc
31369310	2600	Federal Paper Board Co
31354910	3714	Federal-Mogul Corp
31540510	2890	Ferro Corp
30249130	2800	FMC Corp
34537010	3711	Ford Motor Corp

35024410	1600	Foster Wheeler Corp
35160410	3823	Foxboro Co
36955010	3721	General Dynamics Corp
36960410	3600	General Electric Co
37044210	3711	General Motors Corp
37062210	3290	General Refractories Co
37083810	3825	General Signal Corp
37329810	2400	Georgia-Pacific Corp
36161410	2520	GF Corp
37450310	3241	Giant Group Ltd
37576610	3429	Gillette Co
38238810	3000	Goodrich (B.F.) Co
38255010	3000	Goodyear Tire & Rubber Co
38388310	2800	Grace (W.R.) & Co
40018110	3721	Grumman Corp
40218L10	2600	Gulf Canada Corp
40621610	1389	Halliburton Co
41163110	2731	Harcourt Brace Jovanovich
41586410	3440	Harsco Corp
42270410	1040	Hecla Mining Co
42705610	2800	Hercules Inc
42786610	2065	Hershey Foods Corp
42981210	3640	High Voltage Engineering
43761410	1040	Homestake Mining
43850610	3664	Honeywell Inc
44926810	2000	IC Industries Inc
45154210	3241	Ideal Basic Industries Inc
45303820	2911	Imperial Oil Ltd
45325840	1000	Inco Ltd
45686610	3560	Ingersoll-Rand Co
45747210	3310	Inland Steel Industries Inc
45765910	3460	Insilco Corp
45870210	3560	Interlake Corp
45920010	3680	IBM Corp
45950610	2844	International Flavors & Fragrances
46014610	2600	International Paper Co
45067910	3714	ITT Corp
47816010	2834	Johnson & Johnson
48300810	3330	Kaiser Aluminum & Chemical Corp
48783610	2000	Kellogg Co
49238610	2911	Kerr-McGee Corp
49378210	3460	Kidde Inc
49436810	2600	Kimberly-Clark Corp
50060210	1499	Koppers Co
53982110	3760	Lockheed Corp
54229010	3241	Lone Star Industries
54626810	1311	Louisiana Land & Exploration

54986610	3310	Lukens Inc
55479010	2731	Macmillan Inc
56502010	3290	Manville Corp
57327510	3760	Martin Marietta Corp
57859210	3630	Maytag Corp
58016910	3721	McDonnell Douglas Corp
58064510	2731	McGraw-Hill Inc
58123810	1211	Mcintyre Mines Ltd
58283410	2600	Mead Corp
58933110	2830	Merck & Co
60405910	2649	Minnesota Mining & Manufacturing Co
60705910	2911	Mobil Corp
60803010	2510	Mohasco Corp
60915010	3540	Monarch Machine Tool Co
61166210	2800	Monsanto Co
62007610	3663	Motorola Inc
62632010	2250	Munsingwear Inc
62671710	2911	Murphy Oil Corp
62957910	1211	Nacco Industries
62985310	2890	Nalco Chemical Co
63565510	2800	National Distillers & Chemical
62886210	3680	NCR Corp
65163910	1040	Newmont Mining Corp
62915610	2890	NL Industries
65704510	3600	North American Philips Corp
66860510	3290	Norton Co
67459910	1311	Occidental Petroleum Corp
68066520	2800	Olin Corp
69073420	3290	Owens-Corning Fiberglass Corp
70931710	2800	Pennwalt Corp
70990310	2911	Pennzoil Co
71344810	2086	Pepsico Inc
71708110	2834	Pfizer Inc
71726510	3330	Phelps Dodge Corp
71815410	2111	Philip Morris Cos Inc
71850710	2911	Phillips Petroleum Co
72447910	3570	Pitney-Bowes Inc
72570110	1211	Pittston Co
73109510	3861	Polaroid Corp
73620210	3531	Portec Inc
69350610	2800	PPG Industries Inc
74741910	2911	Quaker State Oil Refining
75510310	3714	Raytech Corp
75511110	3664	Raytheon Co
75920010	2820	Reichhold Chemicals Inc
76176310	3330	Reynolds Metals Co
74960L10	2000	RJR Nabisco Inc

77537110	2800	Rohm & Haas Co
77675510	2834	Rorer Group
78025760	2911	Royal Dutch Petroleum
78108810	3079	Rubbermaid Inc
80660510	2830	Schering-Plough
80685710	1389	Schlumberger Ltd
80987710	2600	Scott Paper Co
82930210	3664	Singer Co
83117510	1600	Slattery Group Inc
83186510	3714	Smith (A.O.) Corp
83237710	2834	Smithkline Beckman Corp
78462610	3452	SPS Technologies Inc
85220610	3610	Square D Co
85373410	2911	Standard Oil Co
85926410	2834	Sterling Drug Inc
86048610	3664	Stewart-Warner Corp
86158910	2600	Stone Container Corp
86676210	2911	Sun Co Inc
86732310	3720	Sundstrand Corp
86783310	1311	Sunshine Mining Co
88169410	2911	Texaco Inc
88250810	3674	Texas Instruments Inc
88320310	3721	Textron Inc
88431510	3679	Thomas & Betts Corp
88722410	2721	Time Inc
88736010	2711	Times Mirror Co
88738910	3560	Timken Co
89051610	2065	Tootsie Roll Industries Inc
89586110	3410	Triangle Industries
89667810	3590	Trinova Corp
87264910	3663	TRW Inc
91277510	2121	U S Tobacco Co
90553010	2600	Union Camp Corp
90558110	2800	Union Carbide Corp
90921410	3680	Unisys Corp
91067110	3665	United Industrial Corp
91301710	3720	United Technologies Corp
91528910	2911	Unocal Corp
91530210	2834	Upjohn Co
90329310	3270	USG Corp
90290510	2911	USX Corp
92261210	3580	Vendo Co
92916010	1499	Vulcan Materials Co
93448810	2830	Warner-Lambert Co
96040210	3600	Westinghouse Electric Corp
96216610	2400	Weyerhaeuser Co
96315010	3310	Wheeling-Pittsburgh Steel

96332010	3630	Whirlpool Corp
97738510	2911	Witco Corp
98252610	2065	Wrigley (W.M.) Jr Co
98412110	3861	Xerox Corp
98934910	3651	Zenith Electronics Corp

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