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The information content of earnings announcements with varying return parameters

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OF EARNINGS ANNOUNCEMENTS
WITH VARYING RETURN PARAMETERS

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of

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by

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In Partial Fulfillment of the

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TO MY PARENTS

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ABSTRACT

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Changes in beta (systematic risk of a firm) over time have received increasing attention in the accounting and finance literatures. However, few studies on the information content of earnings announcements have considered the possibility of changing betas. It is well known that betas vary due to various macroeconomic and microeconomic events. Among the various economic events, this study concentrates on earnings announcements. We also consider alpha changes in this information content study. This study is to re-examine some issues regarding the information content of quarterly earnings announcements with the possible variability of parameters in the market model. Before proceeding to the empirical tests theoretical positive linkages between earnings changes (unexpected earnings) and beta changes is provided. We then test mainly: (1) the significance of parameter (alpha and beta) shifts during earnings announcement period, (2) the directional relationship between parameter changes and earnings changes, (3) the significance of abnormal returns when abnormal returns are measured based on varying parameters, and (4) the directional relationship between varying-parameters-based abnormal returns and unexpected earnings.

The tests are conducted using the BERAB (Bayesian Estimators for Random Alpha and Beta) approach which is devised for the purpose of estimating varying parameters. That is, parameters in the RCMM (Random Coefficient Market Model) are estimated using GLS (Generalized Least Squares) technique and quadratic programming

within the framework of Bayesian approach. The BERAB estimates are dynamic with regard to time and economic events. Empirical results in this study report that changes in betas are positively and significantly related to changes in earnings and that alphas vary during event period of earnings announcement. They also show that, when parameter changes are considered in measuring expected rate of returns within the framework of the market model, the expected returns are closer to actual realized returns at the portfolio and individual firm levels comparing to the expected returns estimated with OLS parameters. As a result, BERAB-based abnormal returns, which is the difference between realized returns and expected returns, reduce toward zero at the levels of portfolio and individual firm. Another result shows that the directional relationship between BERAB-based abnormal returns and unexpected earnings is weaker than the directional relationship between OLS-based abnormal returns and unexpected earnings. The above results are mainly due to the fact that BERAB-based expected returns contain the information from earnings changes, while OLS-based expected returns do not. This difference between the two types of expected returns causes BERAB-based abnormal returns and OLS-based abnormal returns to behave differently.

CHAPTER 1

INTRODUCTION

The purpose of this study is to introduce the concept of time-varying betas to the study of information content of earnings announcements. Since the seminal work by Ball and Brown [1968], numerous studies have been conducted on the information content of earnings announcements over the last twenty years. There is overwhelming evidence that changes in stock returns are positively associated with earnings changes (the terms 'earnings changes' and 'unexpected earnings' are interchangeable throughout this study) at times of earnings releases (Beaver [1968], Beaver, Clarke, and Wright [1979], Beaver, Lambert, and Morse [1980], Kross and Schroeder [1984], and Hagerman, Zmijewski and Shah [1984], among others). Another set of studies has investigated the variability of systematic risk. King [1966] is the first that finds a firm's systematic risk varies over time. His result suggests that a firm's systematic risk could be altered by changes in the various economic factors although he does not list economic factors in detail. Evidence from a large number of subsequent studies also suggests that a firm's systematic risk (beta) varies cross-sectionally and over time due to various economic events such as inflation, bull and bear markets, capital-structure-related events, dividend changes, earnings changes, and so forth (Ibbotson [1975], Fabozzi and Francis [1978], Chen and Martin [1980], Sunder [1980], Conine [1982], Dejong and Collins [1985], Brown, Harlow, and Tinic [1988], Ball and Kothari [1989], and Clarkson and Thompson [1990], among others).

Although many studies have dealt with various aspects of the information content of earnings reports, while others have examined varying betas, few researchers have explicitly considered possible beta changes related to earnings changes (unexpected earnings) in investigating the information content of earnings announcements. This ignorance of beta changes may lead to a model misspecification problem in measuring abnormal returns. Patell and Wolfson [1984] point out that "apparent anomalies may indicate model misspecification rather than market inefficiency." Ball, Kothari, and Watts [1988] argue that "observed anomalies could be due to inadequate control for CAPM variables." To illustrate this inadequate control for CAPM variables, Ball, Kothari, and Watts analyze changes in beta in relation to earnings changes in measuring abnormal returns. Their empirical results show that beta changes are positively related to earnings changes and that post-earnings announcement drifts disappear at the level of portfolio if changes in beta are reflected in measuring abnormal returns. In the study of serial correlations in returns, Ball and Kothari [1989] empirically show that beta shifts according to the return performance in a positive way. Considering the positive earnings/return relation, their results indicate the positive earnings/beta relation. They also report that the absolute values of abnormal returns reduce toward zero at the portfolio level after beta shifts are introduced into measuring abnormal returns. Although the above studies do not directly deal with the behavior of abnormal returns during earnings announcement period (e.g., 2 trading days, 3 trading days, or a week around earnings announcement date), they imply that (at least) some portion of abnormal returns during earnings announcement period can disappear when considering beta changes in estimating abnormal returns.

There has been meager analytical explanations and empirical evidence about alpha changes that are due to macroeconomic or microeconomic events. Francis and Fabozzi [1979] empirically show that alpha in the market model is varying according to the macroeconomic factors such as business cycles. Although their study empirically shows alpha changes, their alpha changes deal only with business cycles not earnings announcements. However, we cannot eliminate the possibility of alpha shifts that are due to earnings announcements. We therefore consider alpha changes in the market model in measuring abnormal returns around earnings announcements.

In this study, theoretical linkages between earnings changes and changes in alpha and beta are provided and empirically examined. The significance of beta shifts and alpha shifts at times of earnings reports is tested. This study tests if there still exist significant nonzero abnormal returns, at the portfolio as well as individual firm levels, around earnings releases when abnormal returns are measured based on changing parameters (Total sample is grouped into three portfolios according to the sign of unexpected earnings. See Chapter 3 and Section 6.2 for the details and reasons of grouping portfolios). This study also examines the directional relationship between unexpected earnings and abnormal returns measured based on changing parameters. Finally the expectation that abnormal returns measured based on changing parameters (alpha and beta) behave differently from abnormal returns measured based on fixed parameters is empirically examined.

1.1. Relationship Between Earnings Changes and Beta Changes

Beta changes can be geared to earnings changes via (i) capital-structure-related financial policies, (ii) dividend policies, and (iii) investment policies.

Earnings/beta relationship via capital-structure-related financial policies: The earnings/beta relation through capital-structure-related events can be derived under the incentive signalling hypothesis (Ross [1977]). Examples which this hypothesis can be applied to are issuer tender offers and convertible debt-call policies.[1] The incentive signalling hypothesis can be explained as follows: Assume that information is asymmetric between managers and outside investors and that managers are compensated by an incentive plan. The incentive plan is an increasing function of the firm's performance (stock price) and a decreasing function of the bankruptcy penalty. It is also assumed that the managers' compensation plan is publicly known to outside investors. If the managers of an unsuccessful firm choose a financial policy which increases debt above a certain level (F^*) beyond which bankruptcy can occur, managers' compensation decreases due to the bankruptcy penalty. Since the managers' compensation plan is known to outside investors, investors can deduce that managers of the unsuccessful firm cannot rationally increase debt above F^*. Therefore, if a firm chooses a debt-increasing financial policy (above F^*), the market can deduce that the firm will be successful in the future. Accordingly, debt-increasing financial policies are followed by stock price increases. Consequently, if managers know that their firm is going to be successful in the future, they choose debt-increasing financial policies in order to enhance stock prices without the risk of bankruptcy thereby increasing their compensation. For the above reasons, debt level (or capital-structure-related financial polices) can serve as a signal about earnings prospects to the market (Ross [1977], and Leland and Pyle [1977]).

The information about earnings prospects-re signalled by debt level-related financial policies is not fully perceived by the market at times of financial policies announcements. Empirical results show that positive unexpected earnings and negative unexpected earnings exist at times of earnings releases (even for several years) after debt increasing financial policies and debt decreasing financial policies, respectively (e.g., Vermaelen [1981], Ofer and Natarajan [1987], and Dann, Masulis, and Mayers [1989]). In short, a positive relationship exists between earnings changes at times of earnings announcements and leverage changes.

The positive relationship between leverage changes and beta changes is well documented (Hamada [1969, 1972], Rubinstein [1973], Bowman [1979], and Mandelker and Rhee [1984]). Therefore, we can conjecture that earnings changes are positively related to beta changes through capital-structure-related financial polices.[2]

Earnings/beta relation via dividend policies: Dividend policy is also related to a firm's capital structure. An increase in dividends represents an increase in a firm's financial leverage[3] when the dividend increase is financed externally and even internally as well. Debt-financed dividend increases transfer wealth from bondholders to stockholders.[4] John and Kalay [1982] analytically show that highly levered firms are more likely than low levered firms to pay out the maximum allowed dividends because the greater the amount of debt, the more the wealth that can be transferred away from bondholders.[5] Stockholders therefore prefer debt-financed dividend to other type of dividends (e.g., equity-financed dividend and investment-financed dividend) If so, dividend changes are positively related to leverage changes and, consequently, to beta changes.

The signalling hypothesis is easily applied to dividend policy. A firm that increases dividend payments signals that it has expected future cash flows that are sufficiently large to meet debt payments and dividend payments without an increase in the probability of bankruptcy. If investors believe that firms which pay greater dividends expect an optimistic future, unexpected dividend increases will be perceived as a favorable sign by the market. Miller and Rock [1985] show that dividend changes are positively related to earnings changes (model (11) in Miller and Rock). Furthermore, empirical studies show that earnings changes are positively related to dividend changes (e.g., Healy and Palepu [1988]). Based on the positive relations between beta changes and dividend changes on the one hand, and between dividend changes and earnings changes on the other, we can presume that earnings changes are positively related to beta changes.[6]

Earnings/beta relation via investment policies: Beta changes can be positively related to earnings changes through investment policies (Ball, Kothari, and Watts [1988]). If a firm enters a new, higher risk line of business, its risk increases and product price will tend to increase to reflect the higher cost of capital. Hence, the firm's revenue increases. But to the extent that the investment is equity-financed, the firm's expenses do not increase. For this reason, earnings changes are positively related to the firm's risk (beta) changes through investment policies. Ball, Kothari, and Watts empirically show that unexpected earnings changes are positively related to beta changes through investment policies.[7]

Summary of earnings/beta relation: Beta changes are positively related to capital-structure-related financial policies, dividend policies, and investment policies, which are in turn positively related to earnings changes.[8] Hence, beta changes are related to earnings changes in a positive way. The summary of all possible earnings/beta relations discussed is shown in Figure 1 at the end of Chapter 2.

1.2. Purposes of the Study

This study is to to re-examine some issues regarding the information content of quarterly earnings announcements with the possible positive association between beta changes and accounting earnings changes. The purposes of this study are as follows:

(1) We scrutinize theoretical linkages between earnings changes (unexpected earnings) and beta changes.

(2) We derive a estimator, within the framework of Bayesian approach, to estimate varying alphas and betas. For convenience, from now on, the Bayesian estimator is denoted as BERAB which is the abbreviation of "Bayesian Estimator for Random Alpha and Beta." If parameter changes after earnings announcement are permanent, OLS (ordinary least squares) approach can still be applied to the parameter estimation during event period. Several empirical studies indicate that (at least some portion of) parameter changes are temporary (e.g., Brown, Harlow, and Tinic [1988], Bernard and Thomas [1989] among others). Parameter changes therefore are assumed to be temporary in this study. The BERAB approach is derived based on the concept of temporary parameter changes.

(3) We test for the significance of beta shifts (changes), at the portfolio level, based on a difference between beta estimates obtained from the BERAB approach and beta estimates from the conventional OLS approach (see Section 6.2 for the details and reasons of grouping portfolios). This test is also carried out based on a difference between beta estimates obtained from the BERAB approach and beta estimates from the GLS (Generalized Least Squares) approach.

(4) We examine the directional relationship between beta changes and earnings changes by regressing beta changes on unexpected earnings.

(5) We test for significance of alpha shifts at the portfolio level based on a difference between alpha estimates obtained from the BERAB approach and alpha estimates from the conventional OLS approach. This test is also carried out based on a difference between alpha estimates obtained from the BERAB approach and alpha estimates from the GLS approach.

(6) We compare portfolio-level abnormal returns estimated using the BERAB approach with portfolio-level-abnormal returns estimated using the OLS (or GLS) approach in order to examine if BERAB-based abnormal returns are significantly different from traditional OLS-based (or GLS-based) abnormal returns.

(7) We test if there exist nonzero abnormal returns when abnormal returns are measured based on BERAB approach. This test is done at the portfolio level.

(8) We regress the abnormal returns computed using the BERAB approach on unexpected earnings to examine the directional relationship between BERAB-based abnormal returns and unexpected earnings.

1.3. Summary of the Results

In our study, beta changes (around earnings announcements) are theoretically linked to earnings changes in a positive way. Results show that BERAB-based betas (which reflect the effects of earnings reports) are significantly different from OLS-based betas (which do not reflect the effects of earnings reports) at the portfolio level and beta changes are positively related to earnings changes. With this result, we can interpret that earnings reports have information contents on firms' betas as well as firms' rates of return. This study assumes that alphas (intercept terms) as well as betas are varying in the market model. The significance of alpha shifts around earnings releases are tested at the portfolio level. Empirical result reports that alpha shifts are significantly different from zero.

The behavior of abnormal returns measured based on fixed parameters (OLS or GLS parameters) are similar to that of abnormal returns reported in prior information content studies. When introducing the parameter (alpha and beta) changes into the measurement of abnormal returns, nonzero abnormal returns still exist during event period (of earnings announcement). However, BERAB-based abnormal returns are significantly less (this significance is somewhat marginal) than OLS- (or GLS-) based abnormal returns in a portfolio which consists of positive unexpected earnings and BERAB-based abnormal returns are significantly higher than OLS- (or GLS-) based abnormal returns in a portfolio which consists of negative unexpected earnings. In case of a portfolio with zero unexpected earnings, both types of abnormal returns are not significantly different from zero. At the individual firm level, the deviations of BERAB-based expected earnings from actual returns are far less than the deviations of OLS- (or GLS-) based expected earnings from actual returns. Consequently, BERAB-based abnormal returns have a tendency of moving toward zero comparing to OLS- (or GLS-) based abnormal returns at the both portfolio and individual firm levels. The last empirical result reports that there still exists a positive relationship between BERAB-based abnormal returns and unexpected earnings.

It is reasonably anticipated that abnormal returns during event period disappear under the strong EMH (efficient market hypothesis). In this sense, significant nonzero abnormal returns during earnings announcement period, when using OLS approach within the framework of the market model, may be due to the several flaws such as the misestimation of model parameters, omitted variables, and so forth. We therefore expect that (most or at least some portion of) abnormal returns during earnings announcement period disappear when parameter changes due to earnings changes are considered in measuring abnormal returns. This expectation is supported by our empirical results that BERAB-based abnormal returns are closer to zero than OLS-based abnormal returns at the portfolio and individual firm levels and that the relationship between BERAB-based abnormal returns and unexpected earnings is weaker than the relationship between OLS-based abnormal returns and unexpected earnings.

1.4. Organization of the Study

Chapter 2 reviews previous studies and provides the theoretical background for the current study. Chapter 3 develops the hypotheses to be tested. Chapter 4 derives the new method, BERAB, used to estimate varying alphas and betas and discusses the properties of the BERAB estimator. Chapter 5 describes the research methodology used and Chapter 6 presents the empirical results. This is followed by a final chapter which provides the summary and conclusions. Appendices show the derivation of the BERAB estimator and prove their MVUE (minimum variance unbiased estimator) property.

CHAPTER 2

THEORETICAL BACKGROUND

This chapter surveys prior studies on the relationship between earnings changes and beta changes, thereby providing the theoretical background of the study. The results of discussions in this chapter can be summarized as follows: Changes in earnings are positively related to beta changes via capital-structure-related financial policies, dividend policies, and investment policies.

The first section discusses earnings/beta relation through capital-structure-related financial policies. In the second section, earnings/beta relation through dividend policies is discussed. The third section considers earnings/beta relation via investment policies. In the last section, earnings/beta relation discussed in this chapter is summarized and the summary is exhibited in Figure 1.

2.1. Earnings/Beta Relation via Capital-Structure-Related Financial Policies

The first subsection considers the earnings/leverage relation through capital-structure-related financial policies. In the second subsection, the leverage/beta relation is discussed. The third subsection discusses the earnings/beta relationship by combining earnings/leverage relation (discussed in the first subsection) and leverage/beta relation (discussed in the second subsection).

2.1.1. Earnings/Leverage Relation

A body of theoretical literature predicts that capital-structure changes should be related to changes in expected earnings. Some studies have reported empirical evidence supporting this prediction. In this subsection, we discuss both theory and empirical evidence.

(1) Earnings/Leverage Relation Under the Incentive-Signalling Equilibrium: Ross [1977] applies an incentive-signalling approach to explain the determination of a firm's financial structure. Based on the several assumptions,[9] he establishes a signalling equilibrium.[10] His signalling equilibrium suggests that managers may elect to use financial policy decisions that make financial leverage higher in order to signal an optimistic future for the firm. For example, suppose that the market consists of two types of firms, *A* and *B*. Type *A* firms are successful firms and will have a total return of *a*. Type *B* firms are unsuccessful and will have a total return of *b* with $a>b$. Assume that F^* is the maximum amount of debt a type *B* firm can carry. If a type *B* firm issues new debt so that its total debt exceeds F^*, then the firm will go bankrupt. Managers of a type *B* firm can give a false signal to the market that their firm is type *A*. But, if managers' compensation schedules depend on a bankruptcy penalty, and if the bankruptcy cost is high enough to offset the marginal capital gain obtained through false signalling (model (13)[11] in Ross), managers have no economic incentives to lie. So, if the manager compensation plans are known to outside investors and if the firms' total debt becomes greater than F^*, the market perceives the firm to be successful. Accordingly, the debt-increasing financial policies are followed by stock-price increases. Therefore, managers of Type-*A* firms choose debt-increasing financial policies in order to enhance stock prices which in turn increase their compensation (which is a function of stock prices). As a result, managers make real financial policy decisions as a means of forwarding unambiguous signals to the market

about the firm's future performance. These signals are not fully incorporated into the earnings expectations by the market at the time of financial policy announcement. According to the prior empirical results, changes in expected earnings at times of earnings reports are positive after debt increasing financial policies, and vice versa. (e.g., Vermaelen [1981], Ofer and Natarajan [1987], and Dann, Masulis, and Mayers [1989]). Thus, under the incentive-signalling hypothesis, leverage changes induced by financing policies are positively related to earnings changes at times of earnings releases.

While Ross focuses on the role of managers in establishing equilibrium, Leland and Pyle [1977] focus on the role of entrepreneurs (owners). Leland and Pyle consider an entrepreneur who wants to undertake a firm (or an investment project) and is willing to hold a fraction α of the firm's (or project's) equity. Under the assumption[12] of information heterogeneity, they show that the market value of the firm (or project) perceived by outside investors is an increasing function of α. That is, the size of α can serve as a signal of firm (or project) quality (i.e., future cash flow).[13] Further, they model the relationship between the value of a firm and the level of debt. Their calculation shows that debt level is an increasing function of the fraction (α) of entrepreneurs' equity in the firm.[14] Since debt level is monotonically increasing in α, α and debt level have a one-to-one relation. Thus, market-perceived firm value is an increasing function of debt level, and so, debt level can serve as a signal for the firm's future performance.

(2) Example of Financial Signals - Issuer Tender Offers: Capital-structure-related events such as issuer-tender offers, and convertible-debt-call policies are examples of signalling devices in Ross's incentive-signalling model. Vermaelen [1981] carries out an empirical study on the relationship between issuer-tender offers and earnings changes. He comments: "The signalling hypothesis implies that firms want to correct mispricing of their securities on the basis of favorable inside information. ... As the value of the firm equals the present value of all future net cash-flows, this favorable information should be reflected

in 'abnormal' cash-flow increases subsequent to the repurchase announcement." His model is similar to Ross's signalling model in that high leverage-oriented financing policy is related to firm's optimistic future. He finds that issuer-tender offers are followed by significant positive unexpected earnings. This result supports the positive relationship between leverage changes and earnings changes since issuer-tender offers cause leverage to increase.

Dann, Masulis, and Mayers [1989] examine whether corporate financing decisions contain information regarding a firm's future earnings prospects. For this purpose, they test whether issuer-tender offers have a positive signalling effect on the market perception of the firm's prospect. To do this, they regress abnormal returns at times of earnings reports on unexpected earnings, employing dummy variables (where the dummy equals 1 in the post-offer-period's earnings announcement and 0 otherwise). The result shows that the coefficients for the dummy variables are significantly different from zero, which is consistent with the signalling hypothesis with respect to issuer-tender offers. As a result, empirical support is provided to the proposition that the relationship between issuer-tender offers and unexpected earnings can be explained under the incentive-signalling hypothesis. They find the positive relationship between abnormal returns measured at the tender-offer announcement period and subsequent (4 years) unexpected earnings changes.[15] They also find positive unexpected (quarterly) earnings for most of the five year period following the tender-offer year.[16] This result indicates that there is a positive relationship between earnings changes and issuer-tender offers. Since issuer-tender offers induce leverage increases, earnings changes are positively related to leverage changes.

(3) <u>Example of the Financial Signals - Convertible Debt Call Policies:</u> Ingersoll [1977 a] shows that, to maximize shareholder's wealth, managers should call their convertibles as soon as the market price of callable bonds first reaches the call price. However, an empirical study by Ingersoll [1977 b] finds that actual calls are delayed

relative to the time that the theory predicts. In an attempt to solve this puzzle, Harris and Raviv [1985] provide an incentive-signalling model to explain why calls are delayed. Under the incentive-signalling hypothesis, they show that equilibrium exists in which firms with favorable information choose not to call. This is because of the benefits of increased current stock prices exceeding the future costs of a possible increase in the conversion ratio (the number of stocks into which each bond is converted). Conversely, firms with unfavorable information choose to call because the costs of current decreases in stock prices are less than the future costs of forcing bondholders to convert in the future.[17] So, delay of calls of debt is followed by unexpected earnings increases and calls of debt are followed by unexpected earnings decreases (theorem 6 in Harris and Raviv).

Ofer and Natarajan [1987] test two hypotheses: (i) the call announcement (delay in calls) is associated with a decrease (increase) in the common stock price because investors perceive the call as signalling bad (good) news, and (ii) the bad (good) news is manifested in the firm's performance after the call (delay of call). The first hypothesis states that the relationship exists between call policies and returns while the second hypothesis deals with the relationship between call policies and earnings changes. Empirical results support each of these two hypotheses. Additionally, Ofer and Natarajan's results may imply a direct earnings/beta relation. Their results show significant cumulative abnormal returns (for five years) subsequent to the calls. They explain this phenomena in two ways. First, the information signalled by the calls may not be fully incorporated into stock prices at the time of announcements. Second, the negative abnormal returns may be the outcome of overestimating the expected return. This second reasoning may imply overestimation of beta. The beta used for measuring expected return in the market model is estimated over the sample period before the call. After the call, the beta may actually decline due to the decreases in the leverage ratio that is caused by the call policy. The gap between the beta estimated from the sample period and the true beta after the call can cause expected returns to be overestimated. As a result, the second explanation implies that a positive relationship exists between beta changes and calls of debt. Since negative earnings changes occur subsequent to calls of debt, the second explanation further implies a positive relationship between earnings changes and beta changes.

2.1.2. Leverage/Beta Relation

Our discussion so far has centered on the relation between earnings changes and leverage changes via capital structure-related financial policies. To relate earnings changes to beta changes, we now look at leverage/beta relation.

Intuitively, firms with more debt are riskier than firms with less debt. Hamada [1969] derives the three Modigliani-Miller Propositions [1958] using the Sharpe-Lintner-Mossin [1964, 1965, 1966] equilibrium relationship (CAPM), thereby introducing financing and investment decisions into the model. In his model, Hamada shows that a levered firm's risk is higher than an unlevered firm's risk, and that a firm's risk is positively related to financial leverage. Hamada [1972] shows empirically that approximately 21 to 24 % of the observed average systematic risk of common stocks (from 304 NYSE firms) can be explained by financial leverage which includes debt and preferred stock.

Bowman [1979] provides a theoretical basis for the relationship between systematic risk and financial variables. He demonstrates that beta is an increasing function of financial leverage . The relationship between a levered firm's beta (β_L) and an unlevered firm's beta (β_U) is: $\beta_L=[1+(D_L/S_L)]\beta_U$, where S_L is the market value of the entire equity of a levered firm, and D_L is the debt amount. Considering two different levels of debt D_{L_1} and D_{L_2}, beta (β_{L_1}) of a firm with D_{L_1} is $[1+(D_{L_1}/S_{L_1})]\beta_U$ and beta (β_{L_2}) of a firm with D_{L_2} is $[1+(D_{L_2}/S_{L_2})]\beta_U$. Based on the assumption that all the proceeds from new debt issued by a firm are used for purchasing its common stocks, Hamada [1969] establishes the result: $S_U=S_L+D_L$, where S_U is the market value of the equity of an unlevered firm. Using this result, we get: $\beta_{L_2}= [(S_U-D_{L_1})/(S_U-D_{L_2})]\beta_{L_1}$. Once we let $D_{L_2}>D_{L_1}$, it follows that: $\beta_{L_2}>\beta_{L_1}$. Thus, the beta of a levered firm increases as the level of debt increases.

Mandelker and Rhee [1984] examine the leverage/beta relationship via a regression of systematic risk of common stock on financial leverage and operating leverage. Their empirical results indicate that a significant positive relationship exists between systematic risk and financial leverage.

Based on the above analytical and empirical studies, it is shown that a positive relationship exists between leverage changes and beta changes.

2.1.3. Earnings/Beta Relation

This subsection combines the earnings/leverage relation (discussed in 2.1.1) and leverage/beta relation (discussed in 2.1.2.) to link earnings changes to beta changes.

The positive earnings/leverage relation is explained under the incentive-signalling hypothesis and has been supported by many prior empirical studies. The positive leverage/beta relation has been also supported analytically and empirically. Considering the positive relationship between earnings changes and leverage changes via capital-structure-related financial events, as well as the positive relationship between leverage changes and beta changes, we can conjecture that beta changes are positively associated with earnings changes.

2.2. Earnings/Beta Relation via Dividend Policies

In the first subsection, a positive earnings/dividend relation is discussed. A discussion about positive dividend/leverage relationship follows in the second subsection.

The discussions suggest that a positive relation exists between earnings changes and leverage changes via dividend policies. The third subsection discusses the positive earnings/beta relationship by combining the earnings/dividend relation (discussed in 2.2.1), the dividend/leverage relation (discussed in 2.2.2), and the leverage/beta relation (discussed in 2.1.2).

2.2.1. Earnings/Dividend Relation

Under the assumption of full information,[18] a firm's budget constraint is expressed as X_t-I_t=D_t-B_t (equation (4) in Miller and Rock [1985]), where X_t is the firm's return (cash flow) at time t from the investment at time t-1, I_t is the investment at time t, D_t is dividend at time t, and B_t is the debt at time t. Under the information asymmetry assumption, discrepancies exist between the expected earnings by outside investors and actual earnings that are known to managers. Miller and Rock assume that I_t is determined based on the Fisherian optimality criterion,[19] that is, I_t is given. If the actual dividend is larger than the expected dividend ($E(D_t)$), the market perceives X_t to be more than expected when assuming B_t or $E(B_t)$ to be given. Thus, earnings changes are positively associated with dividend changes. John and Williams [1985] analytically derive the positive relationship between dividend changes and earnings changes under the signalling hypothesis. Healy and Palepu [1988] provide empirical evidence that dividend changes are positively related to earnings changes.

2.2.2. Dividend/Leverage Relation

Black and Scholes [1973] state that dividend liberalization may be indirectly related to capital structure changes. Because a new issue of common stock hurts the wealth of existing stockholders, stockholders try to liberalize dividend policy without issuing new shares (equity-financed dividend). They may finance a higher dividend by selling off a division (investment-financed dividend). Investment financed dividends may not be directly related to leverage changes, but they can increase the variance of a firm's future value, thereby causing a positive relation to occur between dividend changes and beta changes. They can also finance higher dividends by adding to the company's short-term debt (debt-financed dividend). Through debt-financed dividends, dividend increases are positively related to debt increases.

Stockholders could, if permitted, attempt to transfer wealth from bondholders to themselves by debt-financed dividends. Stockholder's equity value increases due to the signalling effect of increased dividends, while value of outstanding old debt decreases because risk of old debt increases due to the new issue of senior debt. This wealth-redistribution hypothesis provides a clue that dividend increases are related to debt increases in a positive way (Kalay [1982], John and Kalay [1982], and Handjinicolaou and Kalay [1984]).[20]

2.2.3. Earnings/Beta Relation via Dividend Policies

Considering the positive earnings/dividends relation, as well as the positive dividends/leverage relation, we arrive at the conclusion that earnings changes are positively associated with leverage changes via dividend policies. In subsection 2.1.2, we discuss the positive relationship between leverage changes and beta changes. By combining this positive relation with the positive earnings/leverage relation, we conclude that earnings changes are associated with beta changes via dividend policies in a positive way.

2.3. Earnings/Beta Relation via Investment Policies

Ball, Kothari, and Watts [1988] discuss the relationship between earnings changes and beta changes. They argue that earnings changes are related to beta changes through investment policies. Their reasoning is that variations in investment risk are linked to earnings changes via the firm's product markets and the fact that accounting earnings are calculated without a charge for the cost of equity capital. For example, consider a firm that enters a new, higher risk line of business. The selling price of products in that line of business reflects the higher supply price of the higher risk capital. The firm's sales revenue reflects the increase in cost of capital,[21] but to the extent that the investment is equity-financed, the firm's expenses do not. Hence, the cost of capital increases are reflected in the firm's earnings in a positive way. The conclusion is that the relationship between earnings changes and beta changes induced by changes in investment risk is positive.[22] Empirical results by Ball et al. support the positive relationship between earnings changes (unexpected earnings) and beta changes.

2.4. Summary of the Earnings/Beta Relation

So far, we have discussed whether beta changes are related to earnings changes. We discuss this relation within the context of (i) capital-structure-related financial policies, (ii) dividend policies, and (iii) investment policies.[23] Based on the results from previous analytical and empirical studies, we can conclude that a positive relationship exists between beta changes and earnings changes. Figure 1 summarizes the possible earnings/beta relations discussed in this section.

CHAPTER 3

HYPOTHESES

Few prior studies consider the beta/earnings relation in examining the information content of earnings announcements. Traditional information content studies that reveal the relationship between abnormal returns and earnings changes (unexpected earnings) assume constant betas which are measured using the OLS approach. We discuss in Chapter 2 that beta can vary in relation to earnings changes and that there exists a positive earnings/beta relation. Hence, beta changes should be considered when measuring abnormal returns in information content studies of earnings releases. To measure varying betas, a BERAB estimator is devised. BERAB denotes "Bayesian Estimators for Random Alpha and Beta." The positive relationship between beta changes and earnings changes is examined based on the BERAB estimator. We also consider the variability in alpha and employ the BERAB approach in estimating varying alphas. The alpha shifts due to earnings changes are tested. We also examine how the earnings/return relation can be different depending on whether the BERAB-based parameters or conventional OLS-based parameters are used for the estimation of abnormal returns. Finally the directional relationship between BERAB-based abnormal returns and unexpected earnings is examined.

BERAB beta is broken into two parts. The first term is the same as the traditional fixed beta, and the second term represents the beta shift that is due to the economic event of earnings announcements (see Chapter 4 and Appendices for the details of BERAB estimators). The same explanation as in the case of BERAB beta is applicable to BERAB alpha. As a result, BERAB estimators for parameters are the estimators which are adjusted to the event of earnings announcement.

OLS beta is a function of a firm's return and market return from the estimation (past) period. BERAB beta is a function of the firm's return and market return for the current (prediction) period as well as the past (estimation) period. It is meaningful to include data from prediction period in estimating varying betas. Since beta changes are affected by earnings changes, varying betas should be measured considering the earnings changes that occur in the prediction period (earnings announcement period). The main difference between the OLS beta and BERAB beta is as follows: OLS beta is static in that OLS estimate for beta remains the same throughout estimation period and prediction period. BERAB beta is dynamic in that BERAB estimate for beta can vary in each beta prediction period.

If BERAB betas are not significantly different from OLS betas, using BERAB betas instead of OLS betas in information content studies of earnings reports may not be meaningful. We anticipate that discrepancies exist between OLS betas and BERAB betas since the BERAB approach deals with beta changes that are due to earnings announcement while the OLS approach ignores such economic events in estimating beta.

In this study, we employ two measures as the magnitudes of beta changes. First, beta changes are measured by the differences between BERAB betas and OLS betas. With this metric, we examine whether there exist shifts from traditional fixed OLS betas to varying BERAB betas. Second, beta changes are defined as the differences between BERAB betas and GLS (generalized least squares) betas (see Chapters 4 and Appendices for the details of GLS betas). Since parameters are assumed to be random in the random coefficient market model (RCMM) in this study, the variance-covariance structure of disturbance terms is heteroscedastic. When there exists heteroscedasticity, OLS technique faces errors in measuring parameters. To solve this problem, we employ GLS technique.

In examining the above differences between OLS betas and BERAB betas, total observations are grouped into three portfolios according to the sign of unexpected earnings; (1) a portfolio with negative unexpected earnings (P^-), (2) a portfolio with zero unexpected earnings (P^o), and (3) a portfolio with positive unexpected earnings (P^+). The reason why total sample is grouped into three portfolios is as follows. Based on the positive earnings/beta relation analyzed in Chapter 2, we expect negative beta shift in P^-, no beta shift in P^o, and positive beta shift in P^+. If we compute the mean of beta shifts of the total sample, the mean may approach zero as positive shift in P^+ is offset by negative beta shift in P^-. As a result, if we test the mean at the level of total sample, the mean may not be significantly different from zero. It can be erroneously interpreted that there do not exist beta shifts around earnings releases although there exist beta shifts. The same portfolio grouping is applied to the cases of testing H_{10},H_{20}, H_{40}, H_{50}, H_{60}, H_{70}, and H_{80}.

To test the beta shifts, the first null hypothesis is stated as follows:

$$H_{10}: \overline{\Delta\beta}_{BL} = 0 \text{ in all three portfolios}$$

$$H_{1A}: \overline{\Delta\beta}_{BL} < 0 \text{ for } P^-, \text{ and/or } \overline{\Delta\beta}_{BL} \neq 0 \text{ for } P^o, \text{ and/or } \overline{\Delta\beta}_{BL} > 0 \text{ for } P^+$$

where

$\overline{\Delta\beta}_{BL}$ = mean of $\Delta\beta_{BLj}$ in a portfolio,

$\Delta\beta_{BLj} = \beta_{Bj} - \beta_{Lj}$,

β_{Lj} = jth beta estimate obtained using traditional OLS approach,

β_{Bj} = jth BERAB beta obtained using equation (A.14.b).

The following null hypothesis is stated for the alternative test for beta shifts:

$$H_{20}: \overline{\Delta\beta}_{BG} = 0 \text{ in all three portfolios}$$

$$H_{2A}: \overline{\Delta\beta}_{BG} < 0 \text{ for } P^-, \text{ and/or } \overline{\Delta\beta}_{BG} \neq 0 \text{ for } P^o, \text{ and/or } \overline{\Delta\beta}_{BG} > 0 \text{ for } P^+$$

where

$\overline{\Delta\beta}_{BG}$ = mean of $\Delta\beta_{BGj}$ in a portfolio,

$\Delta\beta_{BGj} = \beta_{Bj} - \beta_{Gj}$,

β_{Gj} = jth beta estimate obtained using GLS approach,

β_{Bj} = jth BERAB beta obtained using equation (A.14.b).

In testing H_{10} and H_{20}, we use t-statistics.

Since beta changes are positively related to earnings changes, we expect the sign and magnitude of beta changes to be different among firms according to the sign and magnitude of unexpected earnings. To examine this, the following null hypothesis is tested:

H_{30}: Beta changes are not associated with unexpected earnings.

H_{3A}: Beta changes are positively associated with unexpected earnings.

To test this hypothesis, we run a regression of beta changes on unexpected earnings, and examine the significance of the coefficient for unexpected earnings based on t-test. The magnitude of beta changes are measured by $\Delta\beta_{BLj}$ and $\Delta\beta_{BGj}$.

This study considers alpha shifts as well as beta shifts in the market model. Francis and Fabozzi [1979] empirically show that alpha varies due to business cycles. Although empirical evidence which shows alpha changes due to various kinds of economic events including earnings announcement has been meager, we cannot exclude the possibility of alpha changes. To test if there exist shifts from OLS (or GLS) alphas to BERAB alphas, the following null hypotheses are tested:

H_{40}: $\overline{\Delta\alpha}_{BL} = 0$ for all three portfolios

H_{4A}: $\overline{\Delta\alpha}_{BL} \neq 0$ for any of three portfolios

H_{50}: $\overline{\Delta\alpha}_{BG} = 0$ for all three portfolios

H_{5A}: $\overline{\Delta\alpha}_{BG} \neq 0$ for any of three portfolios where

$\overline{\Delta\alpha}_{BL}$ = mean of $\Delta\alpha_{BLj}$ in a portfolio,

$\Delta\alpha_{BLj} = \alpha_{Bj} - \alpha_{Lj}$,

α_{Lj} = jth beta estimate obtained using traditional OLS approach,

α_{Bj} = jth BERAB beta obtained using equation (A.14.b),

$\overline{\Delta\alpha}_{BG}$ = mean of $\Delta\alpha_{BGj}$ in a portfolio,

$\Delta\alpha_{BGj} = \alpha_{Bj} - \alpha_{Gj}$,

α_{Gj} = jth beta estimate obtained using GLS approach.

In testing H_{40} and H_{50} we use t-statistics.

If there are differences between BERAB-based parameters (alpha and beta) estimates and OLS-based (or GLS-based) parameters estimates, they are likely to induce differences between BERAB-based abnormal returns and OLS-based (or GLS-based) abnormal returns. It is reasonably anticipated that abnormal returns during event period disappear under the strong EMH (efficient market hypothesis). In this sense, significant nonzero abnormal returns during earnings announcement period, when using OLS approach within the framework of the market model, may be due to the several flaws such as the misestimation of model parameters, omitted variables, and so forth. We therefore expect that (most or at least some portion of) abnormal returns during earnings announcement period disappear when parameter changes due to earnings changes are considered in measuring abnormal returns. The following null hypotheses are aimed at testing for this possibility:

H_{60}: $\overline{\Delta C}_{BL} = 0$ for all three portfolios

H_{6A}: $\overline{\Delta C}_{BL} > 0$ for P^-, and/or $\overline{\Delta C}_{BL} \neq 0$ for P^O, and/or $\overline{\Delta C}_{BL} < 0$ for P^+

H_{70}: $\overline{\Delta C}_{BG} = 0$ for all three portfolios

$$H_{7A}: \overline{\Delta C}_{BG} > 0 \text{ for } P^-, \text{ and/or } \overline{\Delta C}_{BG} \neq 0 \text{ for } P^O, \text{ and/or } \overline{\Delta C}_{BG} < 0 \text{ for } P^+$$

where

$\overline{\Delta C}_{BL}$ = mean of ΔC_{BLj} in a portfolio,

$\Delta C_{BLj} = C_{Bj} - C_{Lj}$,

C_{Lj} = jth cumulative abnormal returns obtained using traditional OLS approach (see equation (5.3) in Chapter 5),

C_{Bj} = jth cumulative abnormal returns obtained using BERAB approach (see equation (A.14.b)),

$\overline{\Delta C}_{BG}$ = mean of ΔC_{BGj} in a portfolio,

$\Delta C_{BGj} = C_{Bj} - C_{Gj}$,

C_{Gj} = jth cumulative abnormal returns obtained using GLS approach.

Previously reported nonzero abnormal returns measured using OLS approach within the framework of the market model can be due to the problems such as parameter estimation error, omitted variables, and so on. If parameter estimation problem is the only or major contributor to the nonzero abnormal returns, under the EMH, we anticipate that BERAB-based expected returns by the market model are not significantly different from actual realized returns at the portfolio level. In turn, it is anticipated that there does not exist significant nonzero abnormal returns in all three portfolios (P^-, P^O, and P^+) when BERAB approach is employed. To examine this nonzero abnormal returns at the portfolio level, the following null hypothesis is tested:

$$H_{80}: \bar{C}_B = 0 \text{ for all three portfolios}$$

$$H_{8A}: \bar{C}_B < 0 \text{ for } P^-, \text{ and/or } \bar{C}_B \neq 0 \text{ for } P^O, \text{ and/or } \bar{C}_B > 0 \text{ for } P^+$$

where

$\bar{C}_B$ = mean of C_{Bj} in a portfolio,

C_{Bj} = jth cumulative abnormal returns when using BERAB approach.

Finally, we examine the directional relationship between abnormal returns and unexpected earnings when employing the BERAB approach in estimating parameters. If the ignorance of parameter changes due to earnings changes is the major cause of abnormal returns, we expect no significant abnormal returns for all three portfolios under the EMH. It is therefore expected that there does not exist a significant relationship between unexpected earnings and BERAB-based abnormal returns. To test the relationship, the following null hypothesis is stated:

> H_{90}: BERAB-based abnormal returns are not associated with unexpected earnings.
>
> H_{9A}: BERAB-based abnormal returns are positively associated with unexpected earnings.

To examine H_{90}, we run a regression of BERAB abnormal returns on unexpected earnings and test significance of the coefficient for unexpected earnings based on t-statistic.

CHAPTER 4

BAYESIAN ESTIMATORS FOR ALPHA AND BETA (BERAB)

4.1. Prior Studies on Estimation for Alpha and Beta

While theoretical and empirical studies concerning the variability of alpha have been meager, numerous studies have been conducted on the theoretical and empirical aspects of changing betas. First subsection discusses beta variability and beta estimation. Brief discussion concerning the variability in alphas is followed in the second subsection.

4.1.1. Variability of Beta and Beta Estimation

Considerable efforts and resources have been devoted to the estimation of beta in both the academic and the investment communities. Traditionally, beta has been estimated from past return data by the OLS technique. OLS estimates for beta are best linear unbiased estimates (if there does not exist heteroscedasticity in the variance-covariance structure of disturbance term). For this reason, the classical sample-theory estimation procedures are commonly applied to the estimation of the beta of a firm. If the betas of firms were fixed, they could be easily estimated using OLS from historical data. If, on the contrary, betas were unstable over time, their statistical estimation by OLS would not be easy.

Ball and Brown [1969] examine the relation between accounting beta and market-model-based beta. Others (e.g., Beaver, Kettler, and Scholes [1970], Bildersee [1975], and Eskew [1979]) extend the Ball and Brown study by adding other accounting variables[24] as explanatory variables, and find that models based on accounting variables forecast betas more accurately than do market models relying solely on prior return data. However, Elgers [1980] finds that after controlling for measurement errors in OLS betas, and using Bayesian techniques proposed by Vasicek [1973], and Maier, Peterson and Vander Weide [1982], accounting variables do not produce more accurate beta estimates.

Vasicek [1973] argues that Bayesian estimates outperform the classical sampling-theory estimates (OLS estimates) for the following reasons: First, Bayesian procedures provide estimates that minimize loss due to misestimation, while sampling-theory estimates minimize the error of sampling.[25] Second, Bayesian theory incorporates available prior information in addition to the sample information.[26] In Vasicek's study, shrinking factors (prior information about beta) are applied to the OLS betas in a manner that makes the dispersion among the resultant "scaled betas" (Bayes betas) approximately equal to the dispersion among the actual betas that are being forecasted. The scaled betas become forecasts of market beta. Vasicek's Bayesian estimate can be interpreted as an adjustment of the sample estimate (OLS estimate) of beta toward the best prior estimate (e.g., unity) of beta. While Vasicek's Bayesian approach has been well accepted in empirical finance research, it deals with only the measurement error of the OLS estimate but does not consider beta changes due to economic factors (e.g., inflation, bull and bear markets, product changes, earnings releases, and so on).

The traditional OLS estimation procedure assumes that beta is constant over time. Blume [1975] documents the regression tendency of OLS beta estimates towards the cross-sectional mean of all betas over time. He concludes that the reversion of estimated betas toward the mean of 1 is due to both statistical measurement error (order bias)[27] and economic factors (firms taking on new projects with betas closer to 1 than their existing portfolio of projects, or the beta of the existing portfolio of projects moving closer to 1 over time). His empirical results even after adjusting for the measurement error (order bias) disclose a definite regression tendency. This evidence strongly suggests that part of this observed regression tendency represents real variability (due to economic factors) of the betas. Other studies (Levy [1971], Levitz [1974], Altman, Jacquallat and Levasseur [1974], Baesel [1974], Ibbotson [1975], Fabozzi and Francis [1978], Roenfeldt, Griepentrog and Pflaum [1978], Chen and Martin [1980], Sunder [1980], Fisher and Kamin [1985], DeJong and Collins [1985], Kalay and Loewenstein [1985], Simonds, LaMotte and McWhorter [1986], Brown, Harlow, and Tinic [1988], Ball, Kothari, and Watts [1988], Ball and Kothari [1989] and Clarkson and Thompson [1990]) have provided evidence to support the idea that betas are not constant over time.

Fabozzi and Francis [1978] states that changes in beta could be induced by four types of forces: (1) microeconomic variables such as product changes, leverage changes, dividend changes, and numerous other sources, (2) macroeconomic influences such as inflation, price controls, changes in business cycle, and many others, (3) political factors such as labor legislation, pollution control legislation, elections, war, etc.,and (4) market factors such as bull and bear market, disintermediation and credit crunches, and so forth.

Varying parameters of the CAPM or the market model have been estimated using several models such as switching regression model, Kalman filter model, and random-coefficient model. The switching regression model is, for example, used by Eades, Hess and Kim [1985] in a study that examines the timeliness and unbiasedness of the market's response to dividend announcements. This model deals with discontinuities in parameter variation. If the regression parameters change in response to changes in various economic determinants, it is doubtful that the change is abrupt as hypothesized in the simplest form of the switching regression model. Models with continuous variation in parameters seem to be more relevant to real-world situations. The Kalman filter model[28] is used by Fisher and Kamin [1985] to show the improvement of predictive ability of the Kalman filter model estimator over the OLS estimator in terms of mean squared errors. The difficulty in applying the Kalman filter model to beta estimation lies in finding a Markov process (transition matrix) that sequentially varying coefficients obey. Random coefficient model is used by Chen and Keown [1983] in their study of group effects on the process of diversification. Random coefficient model (comparing to switching regression model and Kalman filter model) is considered to better represent varying coefficients of the single-index market model. Chen and Lee [1982] develops a method for estimating varying beta in a random coefficient model using a Bayesian approach. Their Bayesian estimator takes care of the stochastic nature of beta differently from the static Vasicek's Bayesian beta estimator. In their study, the CAPM model without an intercept term is used. In this study, we use the random coefficient market model (RCMM) with an intercept term (which is assumed to be correlated to betas), since the market model is more typical than CAPM in the information content study of earnings announcements.

Others have also proposed beta estimators which deal with variability of beta. For example, Fewings [1975] devises a beta estimator which varies in accordance with the firm's expected growth rate. Chen and Boness [1975] show the relationship between beta changes and the effects of inflation. Chen, Kim, and Kon [1975] propose a beta estimate which reflects investors' aggregate cash demands. Ibbotson [1975] deals with the issue of new common stock in estimating varying beta. However, each of these estimators is confined only to one kind of economic determinant (e.g., growth rate, inflation, investors' aggregate cash demands, and so forth). On the other hand, the Bayesian beta estimator devised by Chen and Lee is able to simultaneously reflect changes in various kinds of economic determinants (e.g., war, stock market-related regulations, inflation, business cycles, financial leverage-related events, dividend changes, product changes, and so on).

4.1.2. Variability of Alpha

Research into the variability of alpha (intercept term) has been meager. Black, Jensen, and Scholes [1972] have shown that alpha is changing, in part, depending on the magnitude of beta. The empirical results of Black, Jensen, and Scholes (BJS), and Miller and Scholes [1972] show that the intercept term in the empirical CAPM or the two factor model is not zero and is highly variable. This means that models other than the standard single-factor or two-factor CAPM can be derived by relaxing some of the standard CAPM's assumptions such as explicit consideration of nonmarketable assets and the existence of differential taxes on capital gains and dividends. BJS, referring to Black and Jensen [1977], argue that "if some assets are omitted from the market portfolio, a model similar in some ways to the two-factor model would result." Roll's [1977] critique is relevant to this issue as well. Empirical results by BJS show that the "intercept term of the two-factor model is highly variable and any alternative hypothesis must be consistent with this phenomenon." They conclude that "it is not sufficient for an alternative model to simply imply a nonzero but constant intercept." Francis and Fabozzi [1979] show that alpha as well as beta varies. They examine alpha changes in the market model that are due to macroeconomic conditions such as bull and bear market. Although empirical evidence which shows alpha changes due to various kinds of macroeconomic and microeconomic events has been meager, we cannot exclude the possibility of alpha changes, not related to beta changes.

4.2. Motivation for New Estimators

Since the introduction of the concept of beta by Markowitz [1959] and Sharpe [1963], much effort has been spent on the problem of estimating beta. Sharpe suggests the OLS procedure for beta estimation which has been widely used. The OLS procedure however faces problems with respect to prediction of future beta such as statistical measurement problems due to sampling errors and failure to consider stochastic nature of beta.

Researchers have suggested several special approaches to accurately estimate beta. One of them is the static Bayesian estimator (Vasicek [1973], and Maier, Peterson and Vander Weide[1982]). Fabozzi and Francis[1978] propose a beta estimator based on a model in which parameters are allowed to be random, but this estimator is also static with regard to future prediction. While these estimation procedures improve the prediction ability for future beta, they do not deal with the stochastic nature of beta. Sarris [1973] devises a time-varying Bayesian estimator assuming that coefficients follow a Markov process. Although Sarris' model can be applied to stock market studies, it does not directly deal with the stock market-related model. Later, Chen and Lee [1982] propose a Bayesian estimator which deals with the stochastic nature of beta in the CAPM. Others (Fewings [1975], Chen and Lee [1975], Chen, Kim, and Kon [1975], Ibbotson [1975], Ball, Kothari, and Watts [1988], and Clarkson and Thompson[1988]) have also devised estimators for varying betas. These estimation procedures deal with only a specific economic event such as inflation, new issue of common stocks, and so forth; none of these deals with the estimation of betas which are varying at the time of earnings releases. On the other hand, various kinds of economic events including earnings releases can be reflected simultaneously in the Bayesian estimator proposed by Chen and Lee. However, Chen and Lee's estimator deals with beta changes in CAPM. The market model is more typical than CAPM in market-based accounting research. We therefore employ market model in this study. We devise BERAB (Bayesian Estimators for Random Alpha and Beta) procedure to estimate varying alphas as well as varying betas in the market model.

In addition, several authors find evidence that alpha and beta are correlated (Black,Jensen and Scholes [1972], Miller and Scholes [1972], and Maier, Peterson, and

Vander Weide [1977,1982]). We therefore believe that, in the market model, alpha as well as beta varies over time and that they are correlated to each other. We propose Bayesian estimators for random alpha and beta (BERAB) in the hope that these time-varying estimators improve their future predictability.

4.3. The Proposed Estimators for Random Alpha and Beta (BERAB)

Estimation procedures for changing regression coefficients are developed by Sarris [1973] and Chen and Lee [1982]. Both use a Bayesian approach. Sarris' basic model is the Kalman-filter model which has multiple coefficients including an intercept term and imposes a Markov structure on the varying coefficients. Chen and Lee use a random coefficient model with one coefficient, beta. This study follows the Bayesian approach using the RCMM (Random Coefficient Market Model) of two correlated varying parameters of which one is an intercept term.

The RCMM can be written as:

$$R_{jt} = \alpha_{jt} + \beta_{jt}R_{mt} + \varepsilon_{jt}, \quad t = 1,\ldots,n; \; j = 1,\ldots,N \qquad (4.1)$$

where

$\alpha_{jt} = \alpha_{jo} + u_{jt}$

$\beta_{jt} = \beta_{jo} + v_{jt}$

R_{jt} = rate of return on asset j at time t,

R_{mt} = rate of return on market portfolio at time t,

α_{jt} = intercept term of asset j at time t,

α_{jo} = mean of α_{jt} (=E(α_{jt})),

β_{jt} = market sensitivity of asset j at time t,

β_{jo} = mean of β_{jt} (=E(β_{jt})),

ε_{jt} = disturbance term which is i.i.d. normal with mean zero and variance $\sigma^2_{\varepsilon j}$,

u_{jt} = disturbance term for alpha which is i.i.d. normal with mean zero and variance σ^2_{uj},

v_{jt} = disturbance term for beta which is i.i.d. normal with mean zero and variance σ^2_{vj},

$E(\varepsilon_{jt}\varepsilon_{js}) = 0, \quad E(u_{jt}u_{js}) = 0, \quad E(v_{jt}v_{js}) = 0,$

$E(v_{jt}\varepsilon_{jt}) = 0, \quad E(u_{jt}\varepsilon_{jt}) = 0,$

$E(u_{jt}v_{jt}) = \sigma_{uvj}, \quad E(u_{jt}v_{js}) = 0, \quad s \neq t$, all s,t.

The Bayesian estimators for random α and β (BERAB) at time t are (see Appendix A for the derivation of BERAB):

$$\alpha_{Bt} = \alpha_o + \frac{(R_t-\alpha_o-\beta_o R_{mt})(\sigma^2_u+\sigma_{uv}R_{mt})}{(\sigma^2_\varepsilon+\sigma^2_u+\sigma^2_v R^2_{mt}+2\sigma_{uv}R_{mt})}, \tag{A.14.a}$$

$$\beta_{Bt} = \beta_o + \frac{(R_t-\alpha_o-\beta_o R_{mt})(\sigma^2_v R_{mt}+\sigma_{uv})}{(\sigma^2_\varepsilon+\sigma^2_u+\sigma^2_v R^2_{mt}+2\sigma_{uv}R_{mt})}. \tag{A.14.b}$$

Here, the subscript j is omitted to simplify the notations. α_o and β_o are estimated using the GLS technique from the past sample period considering the variability of α and β during the sample period. The second term on the right-hand side of equations (A.14.a) and (A.14.b) represents the α changes and β changes, respectively, during the prediction period. Therefore, α_{Bt} and β_{Bt} become the estimates which are adjusted for firm-specific (e.g., earnings releases) as well as economy-wide events (e.g., inflation, and business cycles) that occur during the prediction period through prediction period's R_t and R_{mt}.

Estimators α_{Bt} and β_{Bt} require prior knowledge of α_o, β_o, σ_ε^2, σ_u^2, σ_v^2, and σ_{uv}. In the estimation of priors, we employ empirical Bayes analysis.[29] That is, data from the estimation (sample) period is used (excluding prediction period's data). Sarris, and Chen and Lee estimate priors (e.g., α_o, β_o, σ_ε^2, σ_u^2, and σ_v^2) employing maximum likelihood estimation (MLE) procedures. In this study, we employ the generalized least-squares (GLS) estimator, which is the same as MLE, for α_o and β_o, and use restricted least squares procedure (quadratic programming) for the estimation of σ_ε^2, σ_u^2, σ_v^2 and σ_{uv}. We estimate variance and covariance terms (σ_ε^2, σ_u^2, σ_v^2 and σ_{uv}) within the framework of linear regression model as in equation (C.9). The problem in this estimation procedure is that estimates for regression coefficients can be negative although they should be greater than or equal to zero. To solve this problem, we gibe some nonnegativity restrictions on the linear regression model. It is called the restricted least squares procedure and the actual solving procedure turns out to be quadratic programming. The reason why we use restricted least squares procedure instead of MLE is that Froehlich [1973] shows that restricted least squares procedure is better than MLE in terms of MSE (mean squared errors). Estimators for α_o and β_o by GLS are as follows (see Appendix B):

$$\alpha_G = \left[\frac{1}{(\Sigma K_t^{-1})(\Sigma R_{mt}^2 K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})^2}\right] \cdot [(\Sigma R_{mt}^2 K_t^{-1})(\Sigma R_t K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})(\Sigma R_{mt} R_t K_t^{-1})], \quad \textbf{(B.8.a)}$$

$$\beta_G = \left[\frac{1}{(\Sigma K_t^{-1})(\Sigma R_{mt}^2 K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})^2}\right] \cdot [(\Sigma K_t^{-1})(\Sigma R_{mt} R_t K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})(\Sigma R_t K_t^{-1})], \quad \textbf{(B.8.b)}$$

where (ΣK_t^{-1}) denotes $(\sum_{t=1}^{n} K_t^{-1})$, and

$$K_t = \sigma_u^2 + R_{mt}^2\sigma_v^2 + \sigma_\varepsilon^2 + 2R_{mt}\sigma_{uv}. \qquad \text{(B.3)}$$

Estimators α_{Bt}, β_{Bt}, α_G and β_G require estimates of variances ($\Psi = [\sigma_u^2 \;\; \sigma_v^2 \;\; \sigma_\varepsilon^2 \;\; \sigma_{uv}]'$). To estimate Ψ, we employ a two-step quadratic programming approach to deal with nonnegativity of σ_u^2, σ_v^2 and σ_ε^2 (see Appendix C). From the first-step of the quadratic programming which does not employ the variance-covariance matrix, we get estimates $\hat{\Psi}$ for Ψ. Then we obtain the final estimate Ψ for Ψ by substituting $\hat{\Psi}$ into the variance-covariance matrix of the second-step quadratic programming. The restricted least squares estimator, Ψ, obtained by the two-step quadratic programming is used to get estimates for α_G and β_G. The estimates of α_G, β_G, and Ψ are used to obtain estimates of α_{Bt} and β_{Bt}.

4.4. Properties of the BERAB

The Bayesian estimators, $\mathbf{b}_{Bt}$(α_{Bt} and β_{Bt}), are minimum variance unbiased estimators (MVUE) when $\mathbf{B}_0$ (α_0 and β_0) and Ψ (σ_ε^2, σ_u^2, σ_v^2 and σ_{uv}) are known with certainty (see Appendix D). Sarris points out that the Bayesian estimator is consistent if $\mathbf{B}_0$ and Ψ are known since, for large samples, the Bayesian estimate approaches the MLE and the MLE is proved to be consistent by Cooley [1971]. However, since $\mathbf{B}_0$ and Ψ are not known, the errors of $\mathbf{b}_B$ in estimating $\mathbf{B}$ (refer to equations (A.1.a) and (A.2) for $\mathbf{B}$) are compounded. If $\mathbf{B}_0$ and Ψ are estimated using the MLE approach and those estimates are substituted into $\mathbf{b}_B$, then $\mathbf{b}_B$ is still, for large samples, consistent considering the arguments of Sarris, and Chen and Lee that are based on the proof of Cooley. In this study, Ψ is estimated by a restricted least-squares method and these estimates, Ψ, are substituted into the $\mathbf{B}_G$ (α_G and β_G) that are again substituted into $\mathbf{b}_B$. Hildreth and Houck [1968] prove that $\mathbf{B}_G$ are consistent when $\hat{\Psi}$ ($\hat{\sigma}_\varepsilon^2$, $\hat{\sigma}_u^2$, $\hat{\sigma}_v^2$, and $\hat{\sigma}_{uv}$) (obtained from equations (C.16.a) and (C.16.b)) is substituted into $\mathbf{B}_G$. Froehlich [1973] shows that the estimate of $\mathbf{B}_0$, $\mathbf{B}_G$, is more efficient in terms of MSE when using Ψ is used rather than when $\hat{\Psi}$ or MLE-based estimate of Ψ are used. So, considering the fact that Ψ is more efficient in terms of MSE due to a two-stage procedure which utilizes the first stage estimates $\hat{\Psi}$, and that $\mathbf{B}_G$ into which $\hat{\Psi}$ is substituted is consistent, we expect that $\mathbf{B}_G$ into which Ψ is substituted is a better estimator in terms of MSE. So, therefore, is $\mathbf{b}_B$.

From equation (A.12) the variance of $\mathbf{b}_B$ is:

$$VAR(\mathbf{b}_B) = VAR(\mathbf{B}|\mathbf{R}) = ((1/\sigma_\varepsilon^2)X'X + \mathbf{H}^{-1})^{-1}. \quad (A.12)$$

Then

$$VAR(\alpha_{Bt}) = \frac{\sigma_u^2\sigma_v^2R_{mt}^2 + \sigma_\varepsilon^2\sigma_u^2 - (\sigma_{uv})^2R_{mt}^2}{\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2R_{mt}^2 + 2\sigma_{uv}R_{mt}}, \quad (4.2.a)$$

$$VAR(\beta_{Bt}) = \frac{\sigma_u^2\sigma_v^2 + \sigma_\varepsilon^2\sigma_v^2 - (\sigma_{uv})^2}{\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2R_{mt}^2 + 2\sigma_{uv}R_{mt}}, \quad (4.2.b)$$

$$COV(\alpha_{Bt},\beta_{Bt}) = \frac{(\sigma_{uv})^2R_{mt} + \sigma_\varepsilon^2\sigma_{uv} - \sigma_u^2\sigma_v^2R_{mt}}{\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2R_{mt}^2 + 2\sigma_{uv}R_{mt}}. \quad (4.2.c)$$

The Bayesian estimator in equations (A.14.a) and (A.14.b) and its variances in (4.2.a) and (4.2.b) can be compared to the Bayesian estimator of Chen and Lee. If α_o and σ_u^2 go to zero, β_{Bt} and $VAR(\beta_{Bt})$ become exactly the same as the beta estimator and variance of that beta estimator proposed by Chen and Lee.[30]

If α_t and β_t in equation (4.1) are constant, that is $u_t = v_t = 0$, then the prior p.d.f. of $\mathbf{B}$, $f(\mathbf{B})$, does not follow a normal distribution as in equation (A.6). $f(\mathbf{B})$ is 1 if $\mathbf{B} = \mathbf{M}$, and zero if $\mathbf{B} \neq \mathbf{M}$. In addition, the variance-covariance matrix $\mathbf{H}$ in equation (A.3) becomes singular, thereby making it impossible to invert $\mathbf{H}$. We cannot therefore obtain estimates for $\mathbf{B}$ from equations (A.11) or (A.14.a) and (A.14.b). Anyhow, if we let α_t

and β_t be constant (σ_u^2, σ_v^2 and $\sigma_{uv} = 0$) then α_{Bt} and β_{Bt} in equations (A.14.a) and (A.14.b) equal α_o and β_o, respectively. Parameters α_o and β_o are estimated by α_G and β_G in equation (B.7). In this case, K_t also becomes σ_ε^2 and Ω becomes $\sigma_\varepsilon^2 I$. And so $\alpha_G = \alpha_L$ and $\beta_G = \beta_L$ where α_L and β_L are OLS estimates for α and β.[31] On the other hand, the MVUEs in case of constant α_t and β_t are GLS estimators that are the same as the estimators in equation (B.7) except K_t in equation (B.6). Furthermore, K_t becomes σ_ε^2 since σ_u^2, σ_v^2 and σ_{uv} are zero, and so Ω becomes $\sigma_\varepsilon^2 I$, so that the GLS estimates become OLS estimates. Consequently even in cases where α_t and β_t are constant we can use the time-varying Bayesian estimators in equation (A.14.a) and (A.14.b) for α_{Bt} and β_{Bt}.

When α_t alone is constant or β_t alone is constant, then the variance-covariance matrix **H** in equation (A.3) is also singular and **H** can not be inverted. We cannot, therefore, claim the same Bayesian estimator as in equation (A.14.a) and (A.14.b). However we still can use the time-varying Bayesian estimators in equations (A.14.a) and (A.14.b) for α_t and β_t. If α_t alone approaches α_o for all t in equation (A.14.a), then

$$\lim_{\sigma_u^2 \to o} \alpha_{Bt} = \alpha_o \quad , \tag{4.3}$$

and

$$\lim_{\sigma_u^2 \to o} \beta_{Bt} = \beta_o + \frac{(R_t - \alpha_o - \beta_o R_{mt})\, \sigma_v^2 R_{mt}}{\sigma_\varepsilon^2 + \sigma_v^2 R_{mt}^2} . \tag{4.4}$$

If β_t alone approaches β_o for all t in equation (A.14.b), then

$$\lim_{\sigma_v^2 \to o} \alpha_{Bt} = \alpha_o + \frac{(R_t - \alpha_o - \beta_o R_{mt})\, \sigma_u^2}{\sigma_\varepsilon^2 + \sigma_u^2} , \tag{4.5}$$

and

$$\lim_{\sigma_v^2 \to o} \beta_{Bt} = \beta_o \tag{4.6}$$

On the other hand, if only α_t is constant, we make some changes in equation (A.6) (to derive a new β_{Bt}) as follows: $\mathbf{H}=\sigma_v^2\,\mathbf{I}$, $\mathbf{B}=\underline{\mathbf{B}}$, and $(\mathbf{R}-\mathbf{XB})=(\mathbf{R}-\underline{\mathbf{X}}\underline{\mathbf{B}})$ where $\underline{\mathbf{X}} = R_{mt}\,\mathbf{I}$, $\underline{\mathbf{B}}=\beta_t\mathbf{1}$, $\mathbf{I}$ is n×n identity matrix, and $\mathbf{1}$ is column vector consisting of n unit elements. In this case, the new β_{Bt} exactly equals β_{Bt} in equation (4.4). So we can still use β_{Bt} in equation (A.14.b) when σ_u^2 is zero. Due to the same reason, we can use α_{Bt} in equation (A.14.a) when only β_t is constant since α_{Bt} in equation (A.14.a) becomes exactly the same as α_{Bt} in equation (4.5) when β_t is constant.

Where there is no correlation between α_t and β_t (i.e., σ_{uv}=0), the matrix H is still heteroscedastic and invertible. So we can use the estimators in equation (A.14.a) and (A.14.b) in this case.

The estimated $\mathbf{b}_B$ is jointly determined by R_{mt} and R_t (of current and past period), along with $\alpha_o, \beta_o, \sigma_u^2, \sigma_v^2, \sigma_\varepsilon^2$ and σ_{uv}. Estimates for $\alpha_o, \beta_o, \sigma_u^2, \sigma_v^2, \sigma_\varepsilon^2$ and σ_{uv} are obtained based on the information from the sample (past) period. But, information from the prediction period as well as past period is used with regard to R_{mt} and R_t. If we assume that economy-wide and firm-specific events cause beta to change during the prediction period and that these events are reflected in security prices and market returns due to the market efficiency, then, by including R_{mt} and R_t of the test (prediction) period in the beta estimators, we can measure current beta changes that are due to current economic changes in the whole market as well as the individual firm.

CHAPTER 5

RESEARCH DESIGN

5.1. The Sample

Empirical analyses are conducted using the data for a sample of 397 firms. The data sets consists of (1) daily stock returns of firms, (2) market daily-return indices, (3) quarterly earnings per share (EPS), (4) forecasted quarterly EPS, and (5) earnings announcement dates. Initially, 890 firms are selected randomly from those listed in COMPUSTAT files (1988 version). To be included in the sample, the following criteria are applied to the initially selected firms: (1) Daily return data is available from the CRSP tape for the calendar period 1981-1987. (2) Market return data is available from the CRSP tape for the calendar period 1981-1987. (3) Forecasted and actual quarterly EPS data are available from the I/B/E/S summary forecast data tape (Lynch, Jones and Ryan) for the fiscal period 1984-1986. (4) Quarterly earnings announcement dates are available from the COMPUSTAT files or Wall Street Journal Index for the fiscal period 1984-1986 (prediction period). The earnings announcement date is defined as the date at which news of the firm's earnings release first appears in the Wall Street Journal.

In addition to the above four criteria five more restrictions are considered: (1) Firms that go through organizational changes such as mergers or acquisitions are excluded from the sample. (2) Firms that change closing dates of fiscal quarters during the period 1983-1987, are excluded from the sample. These two filters result in 397 remaining firms. (3) In this study, 100 weekly returns are used in the estimation of each beta for each quarter. Weekly data is used in estimating parameters in order to fully incorporate the effects of earnings releases into the parameter estimation. Each weekly return is made up of daily returns of five consecutive trading days. To examine the seriousness of the problems introduced due to multiple weekend effects occurring in some weekly returns (each of which consists of five consecutive daily returns), 5 trading day periods are identified proceeding backwards in time from 31st December, 1985. Only three weeks among 52 weeks (of year 1985) include the weekend effect more than once (twice). This indicates that presence of multiple weekend effects in some weeks is not a serious problem in estimating betas. If all the five consecutive daily returns is missing and/or no trading, the corresponding weekly return is treated as missing data. If the number of weekly returns that are missing exceeds 50, beta is not calculated for the corresponding quarter to maintain the property of the estimation efficiency of a large sample. Those quarters are eliminated from the sample observations. (4) Additionally, to control for confounding effects, an earnings announcement that has other concurrent events (e.g., stock split, stock dividend, cash dividend, and so on) occurred between day -5 and day +3 from the earnings announcement date is not included in the sample.[32] Finally 3199 observations are contained in the sample. (5) Summary statistics in Table 1 report that the dependent and independent variables that are used in several regression models and significance tests deviate from normality substantially. Substantial deviation from normality can result in the drawing of erroneous inferences. We attempt to impose normality by trimming the sample (see Section 6.1 and footnote 37 for the details of trimming). After trimming, 3199 observations are remained.

5.2. Earnings Forecast Error

A firm's unexpected earnings is defined as actual quarterly earnings minus the forecasted quarterly earnings divided by a deflator. The model is expressed as:

$$UE_{iq} = (E_{iq} - FE_{iq}) / P_{iq} \tag{5.1}$$

where:

UE_{iq} = the unexpected component of quarterly EPS for firm i and quarter q;

E_{iq} = the actual EPS for firm i and quarter q;

FE_{iq} = the forecasted EPS from the I/B/E/S tape for firm i and quarter q;

P_{iq} = the deflator (stock price st the end of quarter preceding to the announcement quarter) for firm i and quarter q.

Several studies find that security analysts outperform mechanical time-series models when forecasting quarterly earnings (e.g., Brown and Rozeff [1979], Fried and Givoly [1982], and O'Brien [1988]). We use (mean of) analysts' consensus forecasts from the I/B/E/S data base as a surrogate for market expectations of earnings.

A related issue is the selection of an appropriate deflator. Christie [1987] argues from an economic standpoint that, in return studies, a market value measure such as stock price is the correct deflator. Recent research (e.g., Brown [1987] and Hughes and Ricks [1987]) deflates unexpected earnings (UE) by either the fiscal-period-end share price or the closing share price on the day preceding the period over which the security returns are cumulated. Consistent with these researches, we deflate the UE metric by the stock price at the end of the quarter preceding to the announcement quarter (or at the beginning of the announcement quarter).

5.3. Parameter Estimates

In order to estimate the return parameters, the following RCMM model in equation (4.1) is used (j subscript is omitted):

$$R_t = \alpha_t + \beta_t R_{mt} + \varepsilon_t. \tag{4.1}$$

In estimating parameters, weekly return data are employed (see Figure 2 for graphical exhibition and footnote 33 for the reason of using weekly data).[33] The announcement week is defined as the week which consists of trading days -2, -1, 0, +1, and +2 relative to the announcement date. This announcement week is denoted as week 0. Week -1 consists of days -7, -6, -5, -4, and -3.

We estimate α_t and β_t using three different approaches.

(1) The OLS Approach: The estimates are obtained based on OLS Approach using returns of 100 weeks that fall between the closing date of a quarter prior to earnings release and -100th week prior to the closing date. In this case, parameters α_t and β_t in equation (4.1) are constant.

(2) The GLS Approach : The estimates are obtained based on GLS Approach using return data of 100 weeks from the time period that lie between week -1 and week -100 relative to the earnings announcement week. Parameters α_t and β_t in equation (4.1) are random. The GLS Approach is applied because of heteroscedasticity due to randomness of α and β.

(3) The BERAB Approach: The estimates are obtained based on BERAB Approach using 101 weekly return data sets from weeks -100 through 0. The estimates obtained by GLS Approach are used as priors in the estimation of the BERAB parameters.

One purpose of this study is to test the relationship between earnings changes and beta changes. Beta changes due to earnings changes are measured by the differences between BERAB betas (3) and OLS betas (1), and between BERAB betas (3) and GLS betas (2).

5.4. Abnormal Returns

The parameter estimates obtained in Section 5.3 are used to compute abnormal returns. Abnormal returns during earnings announcement week is measured based on weekly returns. The weekly abnormal return of jth observation is:

$$e_j = R_j - (\hat{\alpha}_j + \hat{\beta}_t R_{mj}), \tag{5.2}$$

where $\hat{\alpha}_j$ and $\hat{\beta}_j$ are estimates for α_j and β_j (in equation (4.1)) measured by OLS, GLS, and BERAB approaches.

Average (cumulative) abnormal returns in a portfolio is computed as follows:

$$\bar{C} = \frac{1}{N} \sum_{j=1}^{N} e_j \tag{5.3}$$

where N is the number of observations (announcements).

Patell [1976] suggests a normalization procedure in estimating abnormal returns computed using OLS approach to deal with the increase in variance due to prediction outside the estimation period. However, we do not employ normalization procedure because of the lack of comparability between OLS-based-abnormal-returns and the Bayesian-based-abnormal-returns employed in this study when using the normalization procedure.[34] Additionally, Patell's empirical result shows that "the average value of

1.0081 for C_{it} (increase in variance of abnormal return due to prediction outside the sample) indicates that its omission would have added less than a 1 percent average upward bias to the test statistics."

5.5. Testing Procedures

To test hypotheses H_{10}, a t-test is employed. When the observations in the two samples are paired (e.g., β_B and β_L), we use the differences:

$$\Delta\beta_{BLj} = \beta_{Bj} - \beta_{Lj} \qquad\qquad j = 1, \ldots\ldots, N$$

in the fashion of a sample from a single population. β_{Bj} is the jth beta estimate by BERAB approach and β_{Lj} is the jth beta estimate by OLS approach. Thus, assuming that $\Delta\beta_{BLj}$ is normally distributed, we can use t-statistic, $(\overline{\Delta\beta}_{BL} \,/\, s(\overline{\Delta\beta}_{BL}))$, with N-1 degrees of freedom where $\overline{\Delta\beta}_{BL} = \sum_{j=1}^{N} \Delta\beta_{BLj} \,/\, N$ and $s^2(\overline{\Delta\beta}_{BL}) = \sum_{j=1}^{N} (\Delta\beta_{BLj} - \overline{\Delta\beta}_{BL})^2 \,/\, N(N-1)$. For the test of H_{20}, the same t-statistic as in H_{10} is used. The total sample is grouped into three portfolios according to the sign of unexpected earnings and the same t-statistics are used for each of the three portfolios except that the sample size N changes (see Chapter 3 for the details of grouping portfolios).

In this study, beta changes are hypothesized to be positively related to unexpected earnings. To test this relationship (H_{30}), we regress beta changes on unexpected earnings, and examine the significance of the slope coefficient based on t-statistic. The regression model is:

$$\Delta\beta_{iq} = a + b\, UE_{iq} + \phi_{iq} \qquad (5.4)$$

where $\Delta\beta_{iq}$ is the beta change of firm i in test quarter q and is defined as $(\beta_{Biq} - \beta_{Liq})$ or $(\beta_{Biq} - \beta_{Giq})$, β_{Biq} is the BERAB estimate for β of firm i in quarter q, β_{Liq} is the OLS beta estimate (by the OLS Approach in section 5.3) of firm i in quarter q, β_{Giq} is the GLS beta estimate (by the GLS Approach in section 5.3) of firm i in quarter q, UE_{iq} is the analyst's earnings forecast error of firm i in quarter q defined in equation (5.1), a is the intercept term, b is the slope coefficient, and ϕ_{iq} is i.i.d with mean zero and variance σ_{ϕ}^{2}.

This study hypothesizes alpha changes as well as beta changes. We therefore test alpha shifts (H_{40} and H_{50}) in each of three portfolios. We also test if there exists any directional relationship between alpha changes and unexpected earnings. The test procedures are the same as those for beta changes.

To test if there exist differences between BERAB-based abnormal returns and traditional OLS-based (or GLS-based) abnormal returns (hypotheses; H_{60} and H_{70}), we follow the same procedure as in testing H_{10}. Next, we test if the abnormal returns are still significantly different from zero at the portfolio level in the case of the BERAB approach (H_{80}). That is, we test if $\bar{C}_B = 0$, where $\bar{C}_B$ is $\bar{C}$ by BERAB approach. $\bar{C}$ is the mean of cumulative abnormal returns defined in equation (5.3). At the same time we also test if $\bar{C}_L = 0$ or $\bar{C}_G = 0$, where $\bar{C}_L$ and $\bar{C}_G$ are $\bar{C}$ by OLS and GLS (by the GLS Approach in section 5.3) approaches, respectively. The tests for $\bar{C}_L = 0$ and $\bar{C}_G = 0$ are done to see if the test results are consistent with traditional empirical results. These tests are done for each of the three portfolios. For the test, t-tests are used. The t-statistic for the test of mean value ($\bar{C}$) relative to zero is equal to $\bar{C}/\sqrt{S^2/N}$, where N is the number of announcements in a portfolio, and S is the sample standard deviation of C_j.[35]

Assuming the validity of the market model and market efficiency hypothesis, we expect that expected returns measured based on BERAB approach are, at the portfolio level, equal to actual realized returns regardless of the sign and magnitude of unexpected earnings. We therefore expect that there does not exist a significant relationship between BERAB-based abnormal returns and unexpected earnings. The directional relationship (H_{90}) between BERAB-based abnormal returns and unexpected earnings is examined based on the regression approach. We regress abnormal returns on unexpected earnings. The regression model is:

$$C_{iq} = a + b \ UE_{iq} + \varpi_{iq} \tag{5.5}$$

where C_{iq} is the weekly abnormal return of firm i in quarter q, a is the intercept term, b is the slope coefficient, and ϖ_{iq} is assumed to be i.i.d with mean zero and variance σ^2_{ϖ}. The significance of the slope coefficient is examined using t-statistic.

CHAPTER 6

EMPIRICAL RESULTS

6.1 Summary Statistics

To see the profiles of the variables in the sample, we compute some descriptive statistics. Panel A in Table 1 shows the summary statistics of the independent and dependent variables that are used in several regression models and significance tests. Most variables indicate substantial deviations from normality which can result in the drawing of erroneous inferences. We first consider transformation of data. Commonly used transformations are the natural logarithmic transformation and the square root transformation. Firms with negative (or zero) observations cause problems in transforming the data. All the variables listed in table 1 have negative values. Alternatively, we attempt to impose normality by trimming the sample[36]. The top and bottom 1% and 5% are successively trimmed. Summary statistics of the variables after trimming are shown in Panels B and C in Table 1. Trimming substantially reduce the observed departures from normality. Results after trimming are shown in Table 2. Concerning the 11 variables listed on the Table 1 except UE, α_L, and β_L, the top and bottom 1% are trimmed. In case of UE, the top and bottom 5% are trimmed. After trimming simultaneously with regard to 12 variables except α_L, and β_L, 2714 observations are remained (see the footnote 37 for the explanation of sample size 2714).[37] We trimmed 12 variables simultaneously to secure the comparability among several tests. Thus, all the test results are reported using the trimmed values of variables.

6.2. Relationship Between Beta Changes and Unexpected Earnings

This study measures beta changes in two ways; (1) shifts from OLS-based betas to BERAB-based betas ($\Delta\beta_{BL}$), and (2) shifts from GLS-based betas to BERAB-based betas ($\Delta\beta_{BG}$). Panel A in Table 3 reports the differences between BERAB betas and OLS betas. As the total sample level, there does not exist a significant difference (t-value is -0.686) between the mean of BERAB betas and the mean of OLS betas. This result may be due to the fact that incremental (or decremental) shifts from OLS betas to BERAB betas that are related to positive unexpected earnings are offset by decremental (or incremental) shifts from OLS betas to BERAB betas that are related to negative unexpected earnings. In Chapter 2, beta changes positively associated with earnings changes are theoretically predicted. So, we expect the differences between OLS betas and BERAB betas in grouped portfolios if grouping is done according to the sign of changes in earnings. Total sample is classified into three portfolios based on the sign of unexpected earnings; (1) a portfolio with negative unexpected earnings (P^-), (2) a portfolio with zero unexpected earnings (P^o), and (3) a portfolio with positive unexpected earnings (P^+).

With regard to P^-, the mean of BERAB betas is significantly lower than the mean of OLS betas (t-value is -2.484). In case of P^+, the mean of BERAB betas is significantly higher than the mean of OLS betas (t-value is +2.200). For these two cases, the first null hypothesis, H_{10}, is rejected. But, there does not exist a significant difference between the two means in P^o (t-value is -0.293). That is, BERAB betas decrease when actual earnings are less than expected earnings and BERAB betas increase when actual earnings are more than expected earnings.

It is anticipated that beta changes are positively related to earnings changes based on discussions in Chapter 2. To test this directional relationship, the magnitudes of beta changes ($\Delta\beta_{BL}$) are regressed on the magnitudes of earnings changes (UE). Regression result is shown in Panel B of Table 3. t-value of 3.317 for the coefficient of unexpected earnings (UE) is significant at the level of 1%. That is beta changes are significantly and positively associated with earnings changes. H_{30} is rejected based on the result in Panel B of Table 3 when beta changes are defined as $\Delta\beta_{BL}$. Regression result in Panel B of Table 3 is consistent with the test results in Panel A of Table 3.

Changes in betas are also measured by the difference ($\Delta\beta_{BG}$) between BERAB betas and GLS betas. Panel A in Table 4 shows the results for the differences between the mean of BERAB betas and the mean of GLS betas. Results in Panel A of Table 4 are almost the same as the results in Panel A of Table 3. $\Delta\beta_{BG}$ is significantly negative at the level of 5% in P^-, and positive at the level of 1% in P^+. $\Delta\beta_{BG}$ is not significantly different from zero in P^o. As a result, we reject second null hypothesis, H_{20}. $\Delta\beta_{BG}$ is regressed on UE and the result is shown in Panel B of Table 4. The regression result (t-value is 3.248) shown in Panel B of Table 4 is similar to that (t-value is 3.317) shown in Panel B of Table 3. H_{30} is rejected again when beta changes are measured by $\Delta\beta_{BG}$.

The conclusion is that, regardless of whether beta changes are measured by $\Delta\beta_{BL}$ or $\Delta\beta_{BG}$, there exists a significant positive relationship between beta changes and earnings changes. It can be interpreted that earnings changes have information content on beta changes as well as on stock price changes. It is also concluded that BERAB betas increase if earnings increase and BERAB betas decrease if earnings decrease when comparing to OLS betas. In their study of serial correlation in returns, Ball and Kothari [1989] recently document that the realized returns are positively associated with betas at the portfolio level. Considering the fact that return performance is positively related to earnings results, their empirical results indicate positive earnings/beta relationship. In this sense, our results are consistent with the results by Ball and Kothari.

This study assumes variability in alphas as well as variability in betas. Tables 5 and 6 report the empirical results of alpha changes. Alpha changes are positively related to unexpected earnings regardless of whether alpha changes are defined as the shifts ($\Delta\alpha_{BL}$) from OLS alpha to BERAB alpha or the shifts ($\Delta\alpha_{BG}$) from GLS alpha to BERAB alpha. In P^-, the mean of BERAB alphas is lower than the mean of OLS alphas and the mean of GLS alphas. With regard to P^+, the mean of BERAB alphas is higher than the mean of OLS alphas and the mean of GLS alphas. As a result, H_{40} and H_{50} are rejected.

6.3. Differences in Abnormal Returns

If there exist shifts in parameters from OLS (or GLS) parameters estimates to BERAB parameters estimates, there are likely to exist significant differences between OLS-based (or GLS-based) abnormal returns and BERAB-based abnormal returns. Hence, we are interested in testing if and how much BERAB-based abnormal returns are different from OLS-based (or GLS-based) abnormal returns. Table 7 reports the results. As expected, the mean of C_B (BERAB-based abnormal returns) is significantly higher than the means of C_L (OLS-based abnormal returns) and C_G (GLS-based abnormal returns) in P^- (t-values are 7.920 and 7.555, respectively). On the other hand, the mean of C_B is significantly lower (although the significance is marginal) than the means of C_L and C_G in P^+ (t-values are -1.482 and -1.575, respectively). In case of P^O, the mean of C_B is not significantly different from the means of C_L and C_G. That is, BERAB-based abnormal returns, at the portfolio level, has a tendency of moving toward zero when comparing to the abnormal returns measured based on OLS and GLS parameter estimates. Based on the results in Table 7, H_{60} and H_{70} are rejected.

Along with the tests about whether the mean of C_B is significantly different from zero at the portfolio level, we test whether the behaviors of C_L and C_G are consistent with the previous empirical results. Panel As of Tables 8, 9, and 10 reports the test results. For the total sample, the means of C_L and C_G are significantly negative (t-values are -3.163 and

-2.966, respectively). It may be due to the fact that, in our sample, the number of observations related to negative unexpected earnings is more than the number of observations related to positive unexpected earnings. But, the mean of C_B in Table 10 is not significantly different from zero (t-value is -0.523). With regard to grouped portfolios, the means of C_L and C_G are significantly negative (t-values are -8.767 and -8.558, respectively) in P^-, and significantly positive (t-values are 5.104 and 5.148, respectively) in P^+. The behaviors of abnormal returns by OLS and GLS approaches are the same as the results by the previous empirical studies. The means of C_B is also significantly different from zero in both of P^- and P^+ (t-values are -5.903 and -5.728, respectively) although the differences from zero are less than the differences by OLS (or GLS) approach. All the means of C_L, C_G, and C_B are not significantly different from zero in P^O. Based on these results, H_{80} is rejected.

Abnormal returns are measured by the differences between actual realized returns and expected returns (estimated in the market model). Under the EMH, abnormal returns disappear if the market model is valid and parameter estimation is correct since expected returns equal actual realized returns. Hence, significant nonzero abnormal returns indicate that there exists flaws with regard to parameter estimation and/or the market model itself (e.g., omitted variables). This study deals only with parameter estimation problem. If ignorance of parameter changes due to unexpected earnings is the dominating major problem and other factors which induce nonzero abnormal returns are trivial, we can expect zero abnormal returns during earnings announcement period (a week around earnings reporting date in this study). The empirical results in Table 10 report that there still exist significant abnormal returns in P^- and P^+ when abnormal returns are measured based on BERAB approach. As a result, ignorance of parameter changes is not the only or dominating problem in measuring abnormal returns. However, the results in Table 7 show that BERAB-based abnormal returns are significantly less than OLS- (or GLS-) based abnormal returns in P^+ and vice versa in P^-. BERAB-based abnormal returns have a tendency of moving toward zero. That is, BERAB based expected returns are closer to the actual realized returns than OLS- (or GLS-) based abnormal returns. This is because the effects of unexpected earnings are already reflected in BERAB-based expected returns through parameter estimation, while the effects of unexpected earnings are not considered in estimating expected returns when using OLS (or GLS) approach. By subtracting expected returns affected by unexpected earnings from actual returns, some portion of actual returns which are due to unexpected earnings can be eliminated when computing abnormal returns based on BERAB approach. The portion of remained abnormal returns may be due to other problems such as omitted variables in the market model. The conclusion is that the BERAB approach contributes to the improvement of correct estimation of expected returns and this contribution is significant. The means of BERAB-based abnormal returns decrease by 50 % (=0.00443÷0.00883) and 15 % (=0.00086÷0.00562) in P^- and P^+, respectively, comparing to the means of OLS-based abnormal returns (see Panel A in Table 7). When comparing to GLS-based abnormal returns, the result is similar (the result is not shown in this study). Reporting the empirical results of beta shifts on return measures, Ball and Kothari [1989] report that portfolio-level-abnormal-returns after risk adjustment reduce toward zero. Although their portfolios are formed by ranking stocks on returns, considering the well known positive earnings/return relationship, the direction of the movement of abnormal returns in their study is consistent to the direction in our study (portfolios are formed based on unexpected earnings in this study).

6.4. BERAB-Based Abnormal Returns at the Individual Firm Level

IN Section 6.3, we discuss the behaviors of abnormal returns at the portfolio level. Our results show that BERAB-based expected returns by the market model are significantly closer to actual realized returns at the portfolio level comparing to OLS and GLS approaches. However, we cannot be sure that this result can be applicable at the individual firm level. For example, the positive mean of OLS-based abnormal returns in a portfolio with positive unexpected earnings does not guarantee that all the observations (abnormal returns) in that portfolio are positive. They are, on average, positive and some of them can be negative. Also, the zero mean of OLS-based abnormal returns in a portfolio with zero unexpected earnings does not imply that all the observations (abnormal returns) have zero values. Similarly, the zero means of BERAB-based abnormal returns in portfolios do not indicate that all the abnormal returns have zero values at the individual firm level.

The test employs two loss functions, squared error loss function and absolute error loss function. Table 11 reports the results. With regard to squared loss function, the mean deviation of total sample by BERAB approach is less than the mean deviation of total sample by OLS approach by 43% ((0.0014-0.0008)÷0.0014). With absolute loss function, the mean deviation of total sample by BERAB approach is less than the mean deviation of total sample by OLS approach by 37% ((0.030-0.019)÷0.030). Since squared loss function gives more weight on the observations which deviate more, and considering the fact that significance of abnormal returns are tested based on the arithmetic mean in a portfolio in this study, use of absolute loss function rather than squared loss function provides insight. With the absolute loss function, there still exists 39% of difference between OLS approach and BERAB approach. As a result, even at the individual firm level, BERAB-based market model tends to generate less deviation from actual realized returns than the OLS-based market model. This result of low deviation by BERAB approach at the individual firm level is consistent to the result of BERAB-based abnormal returns at the portfolio level. Table 12 shows that the absolute values of mean BERAB-based abnormal returns in all portfolios (except portfolios 7 and 10) are less than the absolute values of mean OLS-based abnormal returns. The result shown in Table 11 is consistent to the result shown in Table 12.

Of course, if the prior result by any estimation procedure is exactly the same as the actual posterior result at each observation level, that estimation procedure is the best in terms of EMH. Although both OLS and BERAB approaches generate errors in measuring expected returns, BERAB approach can be regarded as a better one than OLS approach at the portfolio and firm levels. OLS-based expected returns do not reflect changes in economic factors such as earnings changes. But, actual returns reflect such economic changes. Thus the differences (abnormal returns) between actual returns and OLS-based expected returns still contain the portion of return shifts due to economic changes (earnings changes). So, abnormal returns due to unexpected earnings cannot be eliminated at the portfolio and firm levels when using OLS approach. On the other hand, BERAB-based abnormal returns at the firm level are less related to economic changes proxied in earnings changes because BERAB-based expected earnings already reflect earnings changes and this reflected portion is eliminated in computing abnormal returns.

6.5. Directional Relationship Between Abnormal Returns and Unexpected Earnings

With the discussion at the end of Section 6.3, we expect weaker relationship between BERAB-based abnormal returns and unexpected earnings comparing to OLS (and GLS) approach. Finally, we test the directional relationship between abnormal returns and unexpected earnings. Panel Bs in Table 8, 9, and 10 show that both of C_L and C_G are significantly and positively associated with unexpected earnings (t-values are 6.591 and

6.468, respectively). This results are the same as the results obtained from the traditional empirical studies. There does still exist a significant relationship between C_B and unexpected earnings (t-value is 5.274). However, the relationship is weaker when using BERAB approach than the relationship when using OLS (or GLS) approach. This weaker relationship implies that BERAB-based abnormal returns are less affected by the sign and magnitude of changes in earnings.

6.6. Summary

The results from Tables 3,4,5, and 6 suggest that parameters shift upward during earnings report period if actual earnings are higher than expected and parameters shift downward during earnings report period if actual earnings are lower than expected. That is, during event (earnings release) period, OLS (and GLS) parameters are upward biased when unexpected earnings are negative and downward biased when unexpected earnings are positive. Traditional information content studies have ignored this biasedness in estimating market model parameters.

When the parameter changes are introduced in measuring abnormal returns, the abnormal returns reduce toward zero at the portfolio and individual firm levels (Panel A in Table 10, Table 11, and Table 12)). This result is consistent with the result of Panel B in Table 10 that the directional relationship between abnormal returns and unexpected earnings become weaker when using BERAB approach instead of OLS (or GLS) approach. OLS-based expected returns do not reflect changes in economic factors such as earnings changes. But, actual returns reflect such economic changes. Thus the differences (abnormal returns) between actual returns and OLS-based expected returns still contain the portion of return shifts due to earnings changes. So, abnormal returns due to unexpected earnings cannot be eliminated at the portfolio and firm levels when using OLS approach. On the other hand, BERAB-based abnormal returns at the firm level are less related to economic changes proxied in earnings changes because BERAB-based expected earnings already reflect earnings changes and this reflected portion is eliminated in computing abnormal returns.

CHAPTER 7

SUMMARY AND CONCLUSION

Many of traditional information content studies have employed the market model to estimate parameters and abnormal returns. In estimating parameters, OLS approach has been generally used. This OLS approach assumes that parameters are fixed throughout both of nonevent and event periods. Numerous stock-market-related studies have argued and showed empirically that beta is not constant and changing according to various kinds of economic events (e.g., war, inflation, business cycles, leverage-related events, dividend changes, earnings releases, and so forth). Several studies show that alpha is also varying although accumulated empirical results are meager comparing to beta-related empirical results. If parameter shifts due to economic events are the case, measurement of abnormal returns based on the concept of fixed parameters may have a serious flaw. Our empirical results report the positive beta/earnings and alpha/earnings relations. Consequently, (at least) some portion of significant nonzero portfolio-level-abnormal-returns and firm-level-abnormal-returns during event period may indicate parameter misspecification due to information asymmetry (between prior and posterior event period).

When assuming the market efficiency, parameter estimation revised by posterior information may induce expected returns (by the market model) to approach actual returns during event period at the portfolio and firm levels. In this sense, we derive BERAB estimators for alpha and beta that reflect the effect of earnings releases on parameter changes. Our empirical results show that BERAB-based expected returns by the market model come nearer to the actual returns at the portfolio and firm levels than OLS- (or GLS-

) based expected returns. That is, there exists a less significant nonzero abnormal returns when using BERAB approach. This results can be explained by the following reasonings: Abnormal returns are differences between actual realized returns and expected returns. BERAB-based expected returns reflect the effect of earnings changes while OLS-based expected returns do not. So, OLS-based abnormal returns contain all the portion of actual returns which are related to earnings changes. Some or all of this portion can be eliminated from abnormal returns by computing abnormal returns based on the differences between actual returns and BERAB-based expected returns which already contain the information from earnings changes.

Repeated empirical studies can be a good way of proving the characteristics of an estimator. In this study, the BERAB approach is used with only one sample of data. Further empirical research is suggested for the information content study with other samples. Further on, it is suggested that the BERAB approach is applied to various related topics other than information content studies, since the BERAB approach can be employed in many other event studies just as the market model has been used in those topics.

NOTES

NOTES

1. An issuer tender offer is one of the frequent capital structure-related events. Quoting Vermaelen [1981], "every year hundreds of firms repurchase shares for a variety of reasons and the annual dollar volume of repurchasing has been fluctuating between 3.5 and 13 billion dollars in the last seven years."

2. Leverage-increasing financial policies such as issuer tender offers are followed by stock price increases due to expected earnings increases. The stock price increases cause financial leverage to decrease which, in turn, cause betas to decrease. Vermaelen [1981] points out post-event stock-price effect on leverage. Vermaelen discusses that a firm which repurchases its shares increases its debt-equity ratio. However, stock price increases due to issuer tender offers compensate for the decrease in number of shares outstanding. So, if we consider only the stock price increasing effect, earnings changes are negatively related to beta changes. This negative earnings/beta relation counteracts the positive earnings/beta relation to a certain extent. For example, in his empirical study, repurchasing 15 percent of the shares results in a 1.65 percent decrease in the value of equity. In his empirical example, the relationship between financial leverage changes (or beta changes) and issuer tender offers is positive. The same reasoning is applied to the case of leverage-decreasing financial policies such as calls of convertible debts.

3. Payment of dividends can be met without outside financing, or with debt financing, investment financing (e.g., selling off a division), or equity financing (issuing new equity). Equityholders tend not to issue new equity towards payment of dividends because wealth is then transferred to bondholders from stockholders. Leverage changes can be induced by dividend payments with debt financing and investment financing.

4. For example, if dividend payments are financed by raising debt at higher seniority than outstanding old debts, the market value of debt owned by old bondholders decreases due to the increased risk of the firm. Conversely, stockholders' equity value increases because of increases in stock prices that follow announcement of increased dividends. Additionally, part of the wealth transfer from bondholders to stockholders is due to the tax advantage of debt since interest paid on debt is tax deductible. Kim, McConnell, and Greenwood [1977] discuss the wealth transfer. According to their argument, if the "me-first" rule (defined as a prior arrangement to protect bondholders from uncompensated shifts of wealth from bondholders to stockholders through a change in the capital structure of the firm) is violated (without explicitly violating debt covenants), then (i) a windfall gain is yielded to the stockholders at the expense of original bondholders in case of debt financing and no tax, (ii) a windfall loss of bondholders is transferred to stockholders and government in case of corporate tax, new debt issue, and of old debt retired, and (iii) stockholders gain at the expense of the government and old bondholders in the case of corporate tax, issue of new debt, and retirement of common stock. If this increased debt financing is used for increased dividend payout, then dividend policy can be related to the

firm's financial leverage and the wealth transfer problem between stockholders and bondholders.

5. The empirical study by Handjinicolaou and Kalay [1984] shows that wealth transfer form bondholders to stockholders is maximized for highly levered firms rather than for low levered firms with regard to increased dividend announcement. Firm risk increases as debt increases. This debt increase causes the risk of the outstanding old debt to increase. So, bondholders' risk and firm risk move together. On the other hand, Black and Scholes [1973] point out that the equity of a levered firm can be viewed as an European call option on the firm. According to call option pricing theory, equity value (option price) increases when the variances of future possible values of the firm (stock) increases. As a result, bond risk increases as equity value increases. In other words, bond value decreases as equity value increases. And, the higher the bond risk the larger is the increase in equity value, since the higher the variance of firm value the larger is the increase in equity value.

6. Dividend increasing policies are followed by stock price increases (Handjinicolaou and Kalay [1984], Miller and Rock [1985], John and Williams [1985], and Healy and Palepu [1988]) that cause financial leverage to decrease. Therefore, dividend policies have a negative as well as positive effect on financial leverage and, hence, on beta. This negative effect on financial leverage counteracts, to a certain extent, the positive effect on financial leverage.

7. On the other hand, stock prices increase due to earnings increases. Stock price increases induce a decline in financial leverage, which in turn induces beta reductions. This post-investment stock price effect causes earnings changes to be negatively related to beta changes. Thus, the negative earnings/beta relation that results from a post-investment stock-price effect counters, to a certain extent, the positive earnings/beta relation that results from investment policies. Empirical evidence suggests that the effect of investment policies on the earnings/beta relation dominates the effects of post-investment stock-price changes on the earnings/beta relation (Ball, Kothari, and Watts [1988]).

8. Earnings changes can also be linked to beta changes via cash flow characteristics such as operating leverage, product demand, product price, interest expenses and revenue. Pettit and Westerfield [1972] show in their analytical model that a firm's beta is the function of covariability between its unexpected cash flows and market returns. Some other studies analytically link betas to earnings through cash-flow characteristics. Conine [1982] and Gahlon and Gentry [1982] derive analytical models in which beta is a function of cash flow characteristics. These studies do not show the direction of the relationship between beta changes and earnings changes. However, considering the fact that earnings are a proxy for cash flows and are a function of cash flow characteristics, beta changes are affected by earnings changes.

9. In his signalling model, Ross [1977] assumes that (i) there is information asymmetry between managers and outside investors, (ii) managers are compensated by an incentive schedule (model (5) in Ross), (iii) this compensation schedule is known to the public by a disclosure rule, and (iv) investors use the face value of debt to assess whether a firm is successful.

10. The issue of equilibrium (optimal) capital structure at which shareholders' wealth (firm value) is maximized has been one of the most complex problems. The Modigliani-Miller [1958] irrelevancy proposition states that capital structure has no effect on the value

of the firm under the very restricting assumptions of no taxes (except corporate income tax levied by government), no risky debt, no bankruptcy costs, no signalling opportunities, and so forth. Miller [1977] shows that there is an equilibrium capital structure that is determined by relative corporate and personal tax rates. Stiglitz [1969] proves that existence of risky debt does not affect firm values as long as there are no bankruptcy costs paid to third parties such as trustees and law firms. Kraus and Litzenberger [1973] show mathematically that optimal capital structure is determined by taking an increasing amount of debt until the marginal gain from leverage is equal to the marginal expected loss from bankruptcy costs when a nontrivial bankruptcy cost is introduced. Ross [1977] discusses optimal capital structure by relaxing the no bankruptcy-cost assumption and assuming information asymmetry. He discusses the optimal level of financing in terms of maximizing managers' compensation, while Modigliani and Miller, Miller, Stiglitz, and Kraus and Litzenberger discuss optimal capital structure in terms of maximizing firm value. Thus, here, signalling equilibrium is the optimal capital structure at which managers' compensation is maximized when allowing for signalling opportunities. Myers and Majluf [1984] also discuss optimal financing decisions based on the signalling hypothesis.

11. Based on models (8), (9), and (13) in Ross [1977], there are many equilibrium levels of capital structure (see figure 1 in Ross). Model (8) and (9) consider the manager's compensation for a successful firm and an unsuccessful firm, respectively. Model (13) considers the bankruptcy cost-related constraint when an unsuccessful firm masquerades as a successful firm. Ross suggests more complex models in which managers' expected compensation equals manager's opportunity costs (wages) determined in a perfect market, firm's future return is uncertain (but the distribution of return is known), and there is a continuum of firm types. In this model, a unique optimum level of financing is determined for each firm type based on equation (28) in Ross.

12. Other assumptions in addition to information heterogeneity are (i) that both the firm and the entrepreneur (on personal account) are able to issue debt at the riskless rate, (ii) that the entrepreneur can invest his or her own wealth in the market portfolio as well as in the firm's projects, and (iii) that markets are competitive so that the project is small relative to the whole market and the project has a negligible effect on the return of the entrepreneur's share of the market portfolio.

13. The underlying reasoning is that it is in the owners' interest to invest a greater fraction of his or her wealth in a successful firm (or project).

14. The budget constraint considered by Leland and Pyle is $W_0+D+(1-\alpha)[V(\alpha)-D]-K-\beta V_M-Y=0$, where W_0 is the entrepreneur's initial wealth, D is the amount of debt, $V(\alpha)$ is the market value of the firm (or project) perceived by the market as a function of α, K is the amount of investment in the project, β is the fraction of the market portfolio held by the entrepreneur, V_M is the value of the market portfolio (see assumption (ii) in the footnote 12), and Y is the entrepreneur's private holdings of the riskless asset. The term $(1-\alpha)[V(\alpha)-D]$ is the amount received by the entrepreneur as he sells a portion $(1-\alpha)$ of his equity. Leland and Pyle calculate $\partial D/\partial\alpha$ from their budget constraint. Their calculation shows that $\partial D/\partial\alpha>0$ for all levels of α whenever the entrepreneur's financial contribution to the investment in the firm or project is at least 18.6 percent. The financial contribution to the investment is expressed in the form $(W_0-\beta V_M)/K$ when assuming Y=0 for the

simplicity. Leland and Pyle also argue that in most cases debt is an increasing function of α even when entrepreneurs' financial contributions are considerably less than 18.6 percent.

15. They add some explanations to this relationship. A firm's future prospects cannot be the only potential explanation for these positive abnormal returns. For example, unexpected leverage increases by capital structure changes cause wealth transfers from senior bondholders to stockholders (Fama and Miller [1972], and Galai and Masulis [1976]). Another example is that stock repurchases (as a form of dividend) yield personal tax savings which enhance stock price but have no relation with earnings.

16. Vermaelen [1981] also finds annual earnings increases over the five years subsequent to the issuer tender offers.

17. If earnings decrease unexpectedly in the future, stock prices decrease. Accordingly, the conversion ratio (the number of stocks into which each bond is converted) increases in the future when unexpected negative earnings are realized. This increased conversion ratio contributes to the decrease in earnings per share in addition to the earnings decrease itself. There may therefore be a large decrease in stock prices. The decreased stock prices cause decreases in managers' compensation that depends on stock prices. In the case of inside favorable information, the probability of unexpected negative earnings in the future is low. Thus, if the expected conversion ratio is weighted by the probability of good news and the probability of bad news, the future expected conversion ratio will not be high. As a result, the expected costs of delaying calls and forcing conversion in the future is low. Thus, the benefits of increased present stock prices by delaying calls, in probability, exceeds the future costs in terms of manager's compensation.

18. Full information means that the market is perfect so that there is no information asymmetry.

19. The Fisherian optimum investment policy is to choose the optimal production decision by taking on projects until the marginal rate of return on the investment equals the objective market rate of return. In addition, the Fisher separation theorem shows that, given perfect and complete capital markets, the production decision is governed solely by an objective market criterion (represented by maximizing attained wealth) without regard to individuals' subjective preferences that enter into their consumption decisions.

20. Handjinicolaou and Kalay [1984] explain bond price behavior based on two hypotheses. The information-content hypothesis predicts a positive bond-price response to unexpectedly large dividends, while the wealth transfer hypothesis predicts the opposite. Empirical results show that the wealth-transfer effect dominates the information content effect.

21. "Some variation in investment risk is infra-marginal and specific to the firm, so that the resulting variation in cost of capital is not passed along to the firm's customers. But, in competitive markets some variation in risk that causes a change in the firm's cost of capital is passed on (at least in part) to the firm's customers and so is reflected in a change in earnings" (Ball, Kothari, and Watts [1988]).

22. Ball, Kothari, and Watts [1988] also argue that earnings changes are negatively related to beta changes through the financial structure link. Their reasoning is that a lack of continuous adjustment (or no adjustment) of financial policy can directly cause earnings changes to be negatively associated with equity risk changes. If there is a lag in adjustment

(or no adjustment) of financial policy to unexpected increases in equity values that are due to unexpected earnings increases, then increases in equity values can decrease financial leverage. Increased equity value decreases the ratio of the market value of debt to the market value of equity, thereby decreasing financial leverage. It is known that leverage decreases are related to beta decreases. Therefore unexpected increases in earnings are associated with decreases in beta. This negative earnings/beta relationship counteracts the positive earnings/beta relationship to a certain extent. The empirical results in Ball, Kothari, and Watts show that the positive earnings/beta relation from the investment policies dominates the negative earnings/beta relation that are due to the post-investment stock-price increases.

23. Earnings/beta relation can also be explained through cash flow characteristics. See footnote 8 for the brief discussion.

24. Instrumental variables can be dividend payout, asset growth, leverage, liquidity, asset size, earnings variability, and accounting beta. A complete statement of the instrumental variables rationale is provided in Beaver, Kettler and Scholes [1970].

25. Because of the error due to sampling, the dispersion among the OLS beta estimates of a set of securities is likely to be larger than the dispersion among the population of regression coefficients for the historical period and, consequently, for the period to be forecast.

26. Bayesian theory weights the expected losses by a posterior distribution of the parameters which is the product of the prior distribution and likelihood function, thus incorporating prior information which is available in addition to the sample information.

27. See Blume [1975, pp. 786-788] for the details.

28. The Kalman filter model is originally suggested by Kalman [1960]. Kalman does not take account of heteroscedasticity in his model. Fisher and Kamin [1985] developed the Kalman filter formula to take care of heteroscedasticity. But, both of the above Kalman filter estimates are static.

29. In many cases, the unknown priors have no concrete reality in terms of physical quantities. There are several possible sources of information about the priors. First, the phenomenon under study may be quite familiar to the investigator, allowing him to quantify subjective information about the priors. A second source of possible information about the priors is the (past) data itself. This case is formally the empirical Bayes problem (see Berger [1985]).

30. If the intercept term α_{jt} in equation (4.1) goes to zero, then β_{Bt} in equation (A.14.b) becomes;

$$\lim_{\alpha_o \to o\ \sigma_u^2 \to o} \beta_{Bt} = \lim_{\alpha_o \to o\ \sigma_u^2 \to o} \beta_o + \frac{(R_t - \alpha_o - \beta_o R_{mt})(\sigma_v^2 R_{mt} + \sigma_{uv})}{(\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2 R_{mt}^2 + 2\sigma_{uv} R_{mt})} .$$

$$= \frac{\sigma_\varepsilon^2\beta_o + \sigma_v^2 R_{mt}R_t}{\sigma_\varepsilon^2 + \sigma_v^2 R_{mt}^2} \tag{F.1}$$

Dividing both the denominator and numerator of equation (F.1) by $\sigma_\varepsilon^2\sigma_v^2$, we get

$$\frac{\sigma_\varepsilon^2\beta_o + \sigma_v^2 R_{mt}R_t}{\sigma_\varepsilon^2 + \sigma_v^2 R_{mt}^2} = \left(\frac{\beta_o}{\sigma_v^2} + \frac{R_{mt}R_t}{\sigma_\varepsilon^2}\right) \Big/ \left(\frac{1}{\sigma_v^2} + \frac{R_{mt}^2}{\sigma_\varepsilon^2}\right) \tag{F.2}$$

Equation (F.2) is exactly the same as the estimator proposed by Chen and Lee. Again if the intercept term α_{jt} in equation (4.1) goes to zero, then VAR(β_{Bt}) in equation (4.2.b) becomes:

$$\lim_{\sigma_u^2 \to o} \mathrm{VAR}(\beta_{Bt}) = \lim_{\sigma_u^2 \to o} \frac{\sigma_u^2\sigma_v^2 + \sigma_\varepsilon^2 + \sigma_v^2 - (\sigma_{uv})^2}{\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2 R_{mt}^2 + 2\sigma_{uv}R_{mt}}$$

$$= \frac{\sigma_\varepsilon^2\sigma_v^2}{\sigma_\varepsilon^2 + \sigma_v^2 R_{mt}^2} = \left(\frac{\sigma_\varepsilon^2 + \sigma_v^2 R_{mt}^2}{\sigma_\varepsilon^2\sigma_v^2}\right)^{-1} = \left(\frac{1}{\sigma_\varepsilon^2} + \frac{R_{mt}^2}{\sigma_\varepsilon^2}\right)^{-1} \tag{F.3}$$

Equation (F.3) exactly equals the variance of the beta estimator proposed by Chen and Lee.

31. If $\Omega = \sigma_\varepsilon^2 I$, then

$$\beta_G = \left[\frac{1}{\Sigma K_t^{-1}\Sigma R_{mt}^2 K_t^{-1} - (\Sigma R_{mt}K_t^{-1})^2}\right]$$

$$\cdot[(\Sigma K_t^{-1})(\Sigma R_{mt}R_tK_t^{-1}) - (\Sigma R_{mt}K_t^{-1})(\Sigma R_tK_t^{-1})]$$

$$= \left[\frac{1}{(n/\sigma_\varepsilon^2)(1/\sigma_\varepsilon^2)\Sigma R_{mt}^2 - (1/\sigma_\varepsilon^2)^2(\Sigma R_{mt})^2}\right]$$

$$\cdot[(n/\sigma_\varepsilon^2)(1/\sigma_\varepsilon^2)\Sigma R_{mt}R_t - (1/\sigma_\varepsilon^2)^2\Sigma R_{mt}\Sigma R_t]$$

$$= \frac{n\Sigma R_{mt}R_t - \Sigma R_{mt}\Sigma R_t}{n\Sigma R_{mt}^2 - (\Sigma R_{mt})^2} = \hat{\beta} \text{ by OLS},$$

and,

$$\alpha_G = \frac{\Sigma R_{mt}^2 \Sigma R_t - \Sigma R_{mt}\Sigma R_{mt}R_t}{n\Sigma R_{mt}^2 - (\Sigma R_{mt})^2} = \hat{\alpha} \text{ by OLS}.$$

32. There are two reasons for controlling for confounding effects that arise when economic events other than release of earnings occur around the earnings announcement. In this case, (1) beta changes represented by the second term on the right-hand side of equation (A.14.b) is affected by other economic events as well as the earnings release, and (2) the measured abnormal returns reflect not only the effect of earnings release but the effect of the other economic events as well. To sufficiently control for the confounding effects described above, we exclude from our data set all earnings announcements where a stock split, a stock dividend, a cash dividend, or a trading suspension has occurred in the period [-5,+3] relative to the earnings announcement date.

33. BERAB estimator consists of two parts: fixed term (α_o and β_o; first part of equations (A.14.a) and (A.14.b)) and adjustment term (second part of equation (A.14.a) and (A.14.b)). To fully reflect the effect of earnings announcement on parameters (alpha and beta) changes in the adjustment term, weekly data rather than daily data are used in estimating parameters. For the purpose of consistency, we also use weekly data in estimating OLS and GLS parameters.

34. When forecasting expected return at R_{mh} outside the sample, variance of forecasted return increases in proportion to the difference between R_{mh} and $\bar{R}_m$ where subscript h means that R_m is outside the sample and $\bar{R}_m$ is the sample mean of R_m (See section 3.4 in Neter, Wasserman, and Kutner [1985]). Consequently, the variance of abnormal return (e_t) also increases in proportion to the difference ($R_{mh} - \bar{R}_m$). Patell [1976], Givoly and Palmon [1982], and Collins and Dent [1984] devise a normalization procedure to deal with this problem. But their procedure is based on the parameter estimation by OLS. This study employs a Bayesian approach as well as the OLS approach in estimating parameters. When using BERAB beta for estimating e_t, the computation of variance of e_t is very complicated. Further, normalized e_t's based on BERAB betas and normalized e_t's based on OLS betas are not comparable.

35. In this case, $S^2 = \sum_{j=1}^{n}(C_j - \bar{C})/(N-1)$.

36. Frecka and Hopwood [1983] show that the presence of outliers has a tremendous influence on the parameter estimates. Their study illustrates the use of the trimming technique for eleven financial ratios.

37. The reason why the sample size is 2714 is as follows. For example, when the top and bottom 2% of α_G and β_G are trimmed separately, the total remained observations are 3071, respectively. But, when the top and bottom 2% of α_G and β_G are trimmed simultaneously, the remained observations can be less than 3071. Let's assume that there are 100 observations for each of α_G and β_G, and that 2nd, 6th, 7th, and 9th observations of α_G and 1st, 6th, 7th, and 10th observations of β_G are deleted respectively when the top and bottom 2% of α_G and β_G are trimmed separately. Then, when trimming α_G and β_G simultaneously by 2%, 6 observations (1st, 2nd, 6th, 7th, 9th, and 10th) are deleted from the sample and this 6 observations are more than 4% (2% $\times$ 2) of the total observations. As a result, the remained sample size is 94 which is less than 96 (100-10$\times$4%). With this reasoning, the total sample size remained after trimming 12 variables simultaneously becomes 2714.

FIGURE 1

Relationship Between Beta Changes and Earnings Changes

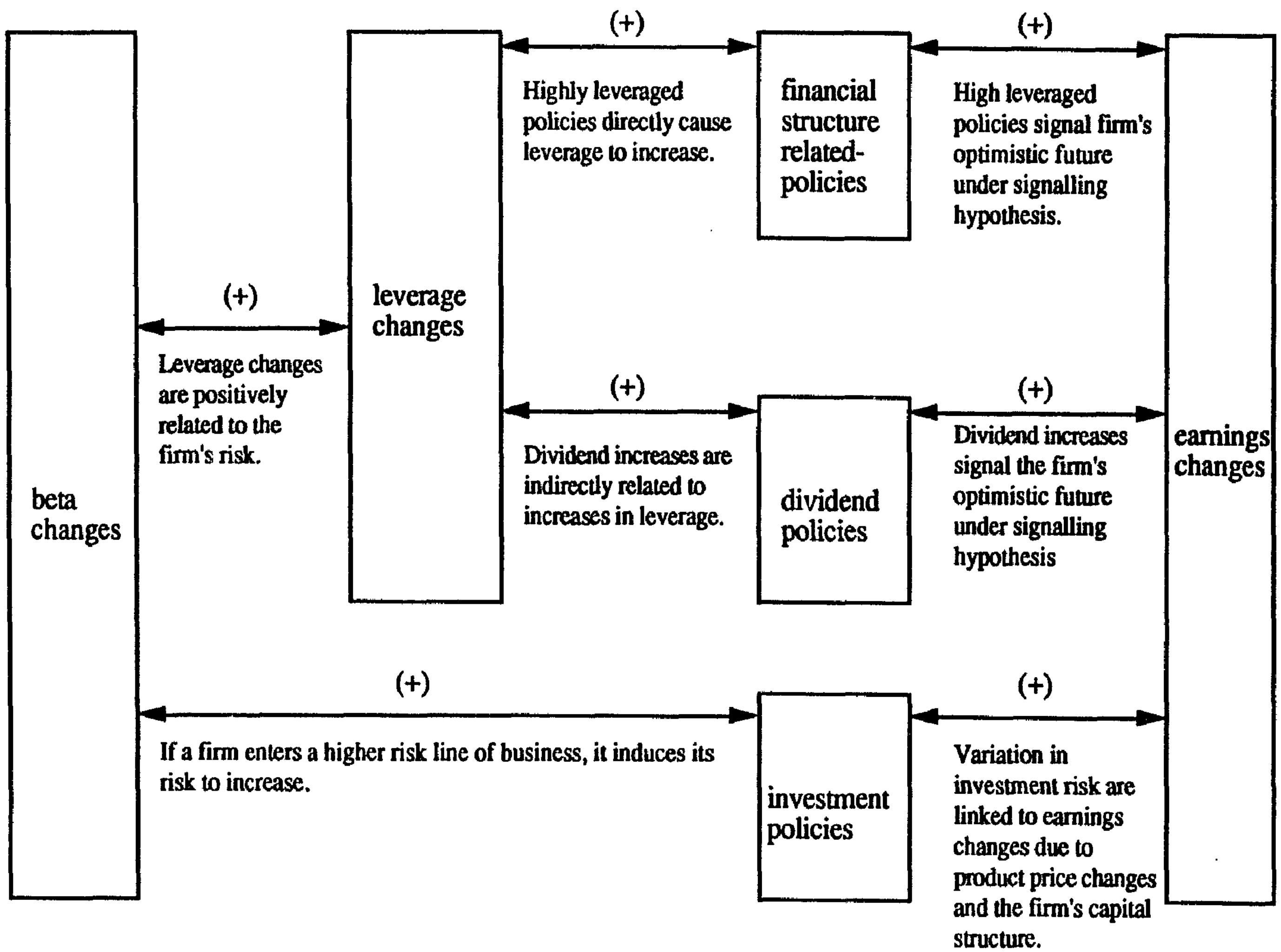


Figure 1, continued.

* (+) denotes positive relationship.

** Related studies

for earnings/leverage relation via financial structure-related financial events are Ross [1977], Leland and Pyle [1981], Harris and Raviv [1985], Ofer and Natarajan [1987], and Dann, Masulis, and Mayers [1989],

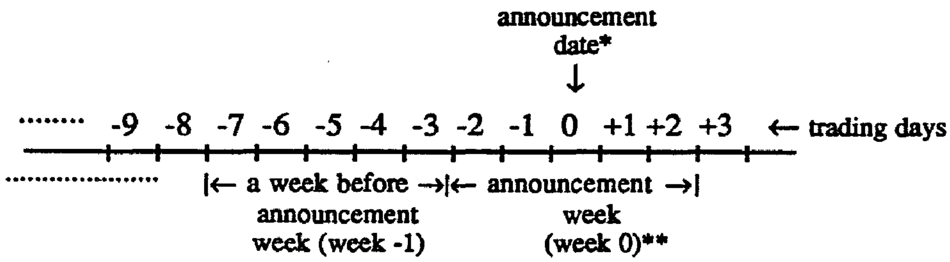
for earnings/leverage relation via dividend policies are Black and Scholes [1973], Kalay [1982], John and Kalay [1982], Handjinicolaou and Kalay [1984], Miller and Rock [1985], John and Williams [1985], and Healy and Palepu [1988],

for leverage/beta relation are Hamada [1962, 1972], Bowman [1972], Mandelker and Rhee [1984], and

for earnings/beta relation via investment policies are Ball, Kothari, and Watts [1988].

FIGURE 2

Aggregation of Daily Returns into Weekly Returns



* Day 0 is the date of earnings announcement.

** Week 0 is the announcement week and consists of days -2, -1, 0, +1, and +2.

TABLE 1

Summary Statistics of the Selected Variables[a]

Panel A: Summary statistics with the whole sample (N = 3199)[b]

variables	median	mean	standard deviation	t-value	skewness	kurtosis
UE	-0.00028	-0.01698	0.3567	-2.6921	-34.23	1305.59
α_L	0.00083	0.00076	0.0046	9.4401	0.24	5.39
α_G	0.00079	0.00106	0.0121	4.9367	22.90	692.20
α_B	0.00021	-0.00169	0.0896	-1.0704	-36.82	1836.13
$\Delta\alpha_{BL}$	-0.00035	-0.00246	0.0896	-1.5521	-37.00	1848.44
$\Delta\alpha_{BG}$	-0.00010	-0.00276	0.0894	-1.7430	-37.35	1866.19
β_L	0.94045	0.96311	0.4707	115.7200	0.62	1.77
β_G	0.94023	0.96073	0.8379	64.8521	7.27	257.35
β_B	0.94977	0.98794	2.4035	23.2484	22.82	812.13
$\Delta\beta_{BL}$	-0.00253	0.02482	2.3724	0.5918	23.37	843.42
$\Delta\beta_{BG}$	0.00066	0.02721	2.1787	0.7063	22.47	863.07
C_L	-0.00368	-0.00148	0.0535	-1.5689	4.00	93.39
C_G	-0.00156	-0.00355	0.0560	-1.5753	3.07	82.22
C_B	0.00000	0.00214	0.1196	1.0131	41.06	1079.02

Table 1, continued

Panel B: Summary statistics after top and bottom 1% are trimmed (N = 3137)[b]

variables	median	mean	standard deviation	t-value	skewness	kurtosis
UE	-0.00028	-0.00444	0.0230	-10.7868	-4.55	29.15
α_L	0.00083	0.00075	0.0039	10.7517	-0.19	0.61
α_G	0.00079	0.00065	0.0041	9.0132	-0.13	0.99
α_B	0.00021	-0.00041	0.0204	-1.1397	-0.12	4.05
$\Delta\alpha_{BL}$	-0.00035	-0.00119	0.0896	-3.3293	-0.06	4.33
$\Delta\alpha_{BG}$	-0.00010	-0.00133	0.0200	-3.7159	-0.17	4.41
β_L	0.94045	0.95703	0.4254	126.0180	0.38	0.04
β_G	0.94023	0.95512	0.4354	122.8670	0.38	0.15
β_B	0.94977	0.95083	0.5443	97.8368	0.20	0.65
$\Delta\beta_{BL}$	-0.00253	-0.00854	0.3595	-1.3302	-0.35	5.42
$\Delta\beta_{BG}$	0.00066	0.00207	0.3250	0.3561	-0.18	5.05
C_L	-0.00368	-0.00183	0.0413	-2.4790	0.18	0.61
C_G	-0.00355	-0.00175	0.0421	-2.3324	0.17	0.72
C_B	0.00000	0.00004	0.0296	0.0746	0.26	2.45

Table 1, continued

Panel C: Summary statistics after top and bottom 5% are trimmed (N = 2881)[b]

variables	median	mean	standard deviation	t-value	skewness	kurtosis
UE	-0.00028	-0.00191	0.0070	-14.7091	-2.06	6.83
α_L	0.00083	0.00078	0.0030	13.9902	-0.15	-0.60
α_G	0.00079	0.00069	0.0031	11.9233	-0.18	-0.55
α_B	0.00021	-0.00036	0.0125	-1.5552	-0.18	1.50
$\Delta\alpha_{BL}$	-0.00035	-0.00115	0.0122	-5.0677	-0.15	1.86
$\Delta\alpha_{BG}$	-0.00010	-0.00125	0.0121	-5.5620	-0.25	1.89
β_L	0.94045	0.94568	0.3498	145.1260	0.10	-0.78
β_G	0.94023	0.94398	0.3544	142.9640	0.10	-0.82
β_B	0.94977	0.94388	0.4250	119.1940	0.11	0.68
$\Delta\beta_{BL}$	-0.00253	-0.00503	0.2182	-1.2365	-0.06	0.58
$\Delta\beta_{BG}$	0.00066	0.00053	0.2017	-0.1413	-0.02	0.76
C_L	-0.00368	-0.00222	0.0322	0.0325	0.12	-0.49
C_G	-0.00358	-0.00220	0.0421	-2.3324	0.17	0.72
C_B	0.00000	0.00029	0.0205	-0.7705	0.10	0.51

a) UE stands for the unexpected earnings scaled by stock price. α_L, α_G, and α_B are the intecept terms of a market model estimated based on OLS, GLS, and BERAB approaches respectively. $\Delta\alpha_{BL}$, and $\Delta\alpha_{BG}$ are (α_B - α_L) and (α_B - α_G) respectively. β_L, β_G, and β_B are systematic risks estimated based on OLS, GLS, and BERAB approaches respectively. $D\beta_{BL}$, and $D\beta_{BG}$ are (β_B - β_L) and (β_B - β_G) respectively. C_L, C_G, and C_B represent cumulative abnormal returns measured based on OLS-, GLS-, and BERAB-based parameters respectively.

b) N is the number of observations in the whole sample.

TABLE 2

Skewness and Kurtosis After Trimming Extreme Observations

variables[a]		full sample (N=3199)[b]	top and bottom 1% trimmed (N=3137)	top and bottom 5% trimmed (N=2881)	simultaneous trimming (N=2714)[c]
UE	skewness	-34.23	-4.55	-2.06	-2.12
	kurtosis	1305.59	29.15	6.83	7.47
α_L	skewness	0.24	-0.19	-0.15	-0.01
	kurtosis	5.39	0.61	-0.60	1.34
α_G	skewness	22.90	-0.13	-0.18	-0.09
	kurtosis	692.20	0.99	0.55	1.03
α_B	skewness	-36.82	-0.12	-0.18	-0.34
	kurtosis	1836.13	4.05	1.50	4.41
$\Delta\alpha_{BL}$	skewness	-37.00	-0.06	-0.15	-0.30
	kurtosis	1846.44	4.33	1.86	4.59
$\Delta\alpha_{BG}$	skewness	-37.35	-0.17	-0.25	-0.32
	kurtosis	1866.19	4.41	1.89	4.64
β_L	skewness	0.62	0.38	0.10	0.39
	kurtosis	1.77	0.04	-0.78	0.33
β_G	skewness	7.27	0.38	0.10	0.35
	kurtosis	257.35	0.15	-0.82	-0.12
β_B	skewness	22.82	0.20	0.11	0.18
	kurtosis	812.13	0.65	-0.68	0.35
$\Delta\beta_{BL}$	skewness	23.37	-0.35	-0.06	-0.27
	kurtosis	843.32	5.42	0.58	4.95
$\Delta\beta_{BG}$	skewness	22.47	-0.18	-0.02	-0.17
	kurtosis	863.07	5.05	0.76	5.04
C_L	skewness	4.00	0.18	0.13	0.13
	kurtosis	93.39	0.61	-0.51	-0.41
C_G	skewness	3.07	0.17	0.12	0.13
	kurtosis	82.22	0.72	-0.49	-0.42
C_B	skewness	41.06	0.26	0.10	0.16
	kurtosis	1079.02	2.45	0.51	2.26

a) For the definition of variables, see a) in Table 1.

b) N is the number of observations remained after trimming. For example, if 5% of observations of the variable, UE, is trimmed, the remained observations are 2881.

c) Simultanous trimming is explained in Section 6.1 and footnote 37.

TABLE 3

Differences Between BERAB Betas and OLS Betas

Panel A: Significance tests for beta shifts ($\Delta\beta_{BL_j}$)[a]

portfolios[c]	mean of BERAB betas(β_B)	mean of OLS betas(β_L)	difference ($\overline{\Delta\beta_{BL}}$)[b]	standard deviation	t-value	number of observations[d]
total sample	0.94829	0.95240	-0.00411	0.00599	-0.686	2714
(-)	0.93923	0.96053	-0.02131	0.00858	-2.484***	1436
(0)	1.04668	1.05192	-0.00524	0.01787	-0.293	191
(+)	0.94202	0.92187	0.02015	0.00916	2.200**	1087

Panel B: Regression-based test for $\Delta\beta_{BL_j}$/UE relation (N = 2714)

$$\Delta\beta_{BL_j} = a + b\ UE_j + e_j$$

independent variable	a	b	
coefficient	0.00172	2.96908	
standard deviation	0.00618	0.89518	
t-value	0.279	3.317**	
R^2 (%)			0.404
adjusted R^2			0.367
F-value			11.001**

a) $\Delta\beta_{BL_j} = \beta_{B_j} - \beta_{L_j}$, where β_{B_j} is the jth BERAB beta estimate and β_{L_j} is the jth OLS beta estimate.

b) $\overline{\Delta\beta_{BL}}$ = mean of $\Delta\beta_{BL_j}$ (or $\beta_B - \beta_L$).

c) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

d) The reason why the total sample size is 2714 is explained in Section 6.1 and footnote 37.

**) Significant at the 0.05 probability level.

***) Significant at the 0.01 probability level.

TABLE 4

Differences Between BERAB Betas and GLS Betas

Panel A: Significance tests for beta shifts ($\Delta\beta_{BGj}$)[a]

portfolios[c]	mean of BERAB betas($\bar{\beta}_B$)	mean of GLS betas($\bar{\beta}_G$)	difference ($\overline{\Delta\beta}_{BG}$)[b]	standard deviation	t-value	number of observations[d]
total sample	0.94829	0.94973	-0.00144	0.00556	-0.259	2714
(-)	0.93923	0.95965	-0.02043	0.00784	-2.606***	1436
(0)	1.04668	1.05793	-0.01125	0.01771	-0.635	191
(+)	0.94202	0.91586	0.02615	0.00862	3.033***	1087

Panel B: Regression-based test for $\Delta\beta_{BGj}$/UE relation (N = 2714)

	$\Delta\beta_{BGj} = a + b\ UE_j + e_j$		
independent variable	a	b	
coefficient	0.00369	2.70068	
standard deviation	0.00574	0.83148	
t-value	0.643	3.248***	
R^2 (%)			0.387
adjusted R^2			0.351
F-value			10.550***

a) $\Delta\beta_{BGj} = \beta_{Bj} - \beta_{Gj}$, where β_{Bj} is the jth BERAB beta estimate and β_{Gj} is the jth GLS beta estimate.

b) $\overline{\Delta\beta}_{BG}$ = mean of $\Delta\beta_{BGj}$ (or $\bar{\beta}_B - \bar{\beta}_G$).

c) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

d) The reason why the total sample size is 2714 is explained in Section 6.1 and footnote 37.

***) Significant at the 0.01 probability level.

TABLE 5

Differences Between BERAB Alphas and OLS Alphas

Panel A: Significance tests for alpha shifts ($\Delta\alpha_{BLj}$)[a]

portfolios[c]	mean of BERAB alphas($\bar{\alpha}_B$)	mean of OLS alphas($\bar{\alpha}_L$)	difference ($\overline{\Delta\alpha}_{BL}$)[b]	standard deviation	t-value	number of observations[d]
total sample	0.00063	0.00100	-0.00163	0.000354	-4.615***	2714
(-)	-0.00323	0.00043	-0.00366	0.000505	-7.246***	1436
(0)	0.00155	0.00121	0.00034	0.001235	0.277	191
(+)	0.00243	0.00172	0.00071	0.000520	1.369*	1087

Panel B: Regression-based test for $\Delta\alpha_{BLj}$/UE relation (N = 2714)

	$\Delta\alpha_{BLj} = a + b\,UE_j + e_j$		
independent variable	a	b	
coefficient	-0.00125	0.20958	
standard deviation	0.00036	0.05263	
t-value	-3.44790	3.98208***	
R^2 (%)			0.581
adjusted R^2			0.545
F-value			15.857***

a) $\Delta\alpha_{BLj} = \alpha_{Bj} - \alpha_{Lj}$, where α_{Bj} is the jth BERAB beta estimate and α_{Lj} is the jth OLS beta estimate.

b) $\overline{\Delta\alpha}_{BL}$ = mean of $\Delta\alpha_{BLj}$ (or $\bar{\alpha}_B - \bar{\alpha}_L$).

c) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

d) The reason why the total sample size is 2714 is explained in Section 6.1 and footnote 37.

*) Significant at the 0.10 probability level.

***) Significant at the 0.01 probability level.

TABLE 6

Differences Between BERAB Alphas and GLS Alphas

Panel A: Significance tests for alpha shifts ($\Delta\alpha_{BGj}$)[a]

portfolios[c]	mean of BERAB alphas($\bar{\alpha}_B$)	mean of GLS alphas($\bar{\alpha}_G$)	difference ($\overline{\Delta\alpha}_{BG}$)[b]	standard deviation	t-value	number of observations[d]
total sample	-0.00063	0.00092	0.00155	0.000354	-4.376***	2714
(-)	-0.00323	0.00031	-0.00353	0.000506	-6.985***	1436
(0)	0.00155	0.00103	0.00052	0.001238	0.417	191
(+)	0.00243	0.00170	0.00072	0.000519	1.396	1087

Panel B: Regression-based test for $\Delta\alpha_{BGj}$/UE relation (N = 2714)

	$\Delta\alpha_{BGj} = a + b\,UE_j + e_j$		
independent variable	a	b	
coefficient	-0.00119	0.19932	
standard deviation	0.00036	0.05267	
t-value	-3.26335***	3.78420***	
R^2 (%)			0.525
adjusted R^2			0.489
F-value			14.320***

a) $\Delta\alpha_{BGj} = \alpha_{Bj} - \alpha_{Gj}$, where α_{Bj} is the jth BERAB beta estimate and α_{Gj} is the jth GLS beta estimate.

b) $\overline{\Delta\alpha}_{BG}$ = mean of $\Delta\alpha_{BGj}$ (or $\bar{\alpha}_B - \bar{\alpha}_G$).

c) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

d) The reason why the total sample size is 2659 is explained in Section 6.1 and footnote 37.

*) Significant at the 0.10 probability level.

***) Significant at the 0.01 probability level.

TABLE 7

Differences Between BERAB-based ($\bar{C}_B$) and OLS-based Abnormal Returns ($\bar{C}_L$) and Between BERAB-based ($\bar{C}_B$) and GLS-based Abnormal Returns ($\bar{C}_G$)[a]

Panel A: Differences Between $\bar{C}_B$ and $\bar{C}_L$

portfolios[b]	$\bar{C}_B$	$\bar{C}_L$	difference ($\Delta\bar{C}_{BL}$)[c]	standard deviation	t-value	number of observations
total sample	-0.00028	-0.00230	0.00202	0.000357	5.658***	2714
(-)	-0.00439	-0.00883	0.00443	0.000559	7.920***	1436
(0)	0.00285	0.00255	0.00029	0.001336	0.219	191
(+)	0.00476	0.00562	-0.00086	0.000581	-1.482 *	1087

Panel B: Differences Between $\bar{C}_B$ and $\bar{C}_G$

portfolios[b]	$\bar{C}_B$	$\bar{C}_G$	difference ($\Delta\bar{C}_{BG}$)[c]	standard deviation	t-value	number of observations
total sample	-0.00028	-0.00216	0.00188	0.000351	5.356***	2714
(-)	-0.00439	-0.00862	0.00422	0.000559	7.555***	1426
(0)	0.00285	0.00276	0.00009	0.001347	0.067	191
(+)	0.00476	0.00567	-0.00091	0.000579	-1.575 *	1087

a) $\bar{C}_B$, $\bar{C}_L$, and $\bar{C}_G$ are cumulative abnormal returns measured based on BERAB and OLS and GLS approaches, respectively.

b) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

c) $\Delta\bar{C}_{BL} = \bar{C}_B - \bar{C}_L$ and

$\Delta\bar{C}_{BG} = \bar{C}_B - \bar{C}_G$

*) Significant at the 0.10 probability level.

***) Significant at the 0.01 probability level.

TABLE 8

Tests for the OLS-Based Abnormal Returns

Panel A: Significance tests for abnormal returns ($\bar{C}_L$)

portfolios[b]	$\bar{C}_L$	standard deviation	t-value	number of observations
total sample	-0.00230	0.000728	-3.163***	2714
(-)	-0.00883	0.001007	-8.767***	1436
(0)	0.00255	0.002544	-1.004	191
(+)	0.00562	0.001100	5.104***	1087

Panel B: Regression-based test for $\bar{C}_L$/UE relation (N = 2714)

	$C_{Lj} = a + b\ UE_j + e_j$		
independent variable	a	b	
coefficient	-0.00097	0.71246	
standard deviation	0.00075	0.10810	
t-value	-1.299 *	6.591***	
R^2 (%)			1.576
adjusted R^2			1.540
F-value			43.438***

a) $\bar{C}_L$ is the mean of cumulative abnormal returns measured based on OLS approach.
b) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.
*) Significant at the 0.10 probability level.
***) Significant at the 0.01 probability level.

TABLE 9

Tests for the GLS-Based Abnormal Returns

Panel A: Significance tests for abnormal returns ($\bar{C}_G$)

portfolios[b]	$\bar{C}_G$	standard deviation	t-value	number of observations
total sample	-0.00216	0.000729	-2.966***	2714
(-)	-0.00862	0.001007	-8.558***	1436
(0)	0.00276	0.002557	1.0781	191
(+)	0.00567	0.001101	5.148***	1087

Panel B: Regression-based test for $\bar{C}_G$/UE relation (N = 2714)

	$C_{Gj} = a + b\ UE_j + e_j$		
independent variable	a	b	
coefficient	-0.00085	0.69956	
standard deviation	0.00075	0.10816	
t-value	-1.135	6.468***	
R^2 (%)			1.519
adjusted R^2			1.483
F-value			41.832***

a) $\bar{C}_G$ is the mean of cumulative abnormal returns measured based on GLS approach.

b) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

***) Significant at the 0.01 probability level.

TABLE 10

Tests for the BERAB-Based Abnormal Returns

Panel A: Significance tests for abnormal returns ($\bar{C}_B$)

portfolios[b]	$\bar{C}_B$	standard deviation	t-value	number of observations
total sample	-0.00028	0.000540	-0.523	2714
(-)	-0.00439	0.000745	-5.903 ***	1436
(0)	0.00285	0.001857	1.433	191
(+)	0.00476	0.000830	5.728 ***	1087

Panel B: Regression-based test for $\bar{C}_B$/UE relation (N = 2714)

	$C_{Bj} = a + b\, UE_j + e_j$		
independent variable	a	b	
coefficient	0.00054	0.42377	
standard deviation	0.00055	0.08035	
t-value	0.966	5.274 ***	
R^2 (%)			1.015
adjusted R^2			0.979
F-value			27.815

a) $\bar{C}_B$ is the mean of cumulative abnormal returns measured based on BERAB approach.

b) Total sample is grouped into three portfolios according to the sign of UE. (-) stands for the portfolio with negative UE, (0) stands for the portfolio with zero UE, and (+) stands for the portfolio with positive UE.

***) Significant at the 0.01 probability level.

TABLE 11

Comparison Between Losses (in Measuring Abnormal Returns) by BERAB approach and OLS Approach

	squared loss function[b]			absolute loss function[c]		
portfolios[a]	OLS	BERAB	observ.	OLS	BERAB	observ.
1	0.0017	0.0009	226	0.033	0.020	226
2	0.0017	0.0009	226	0.032	0.019	226
3	0.0015	0.0009	226	0.031	0.020	226
4	0.0016	0.0009	226	0.031	0.020	226
5	0.0015	0.0007	226	0.030	0.018	226
6	0.0013	0.0007	226	0.029	0.017	226
7	0.0012	0.0007	226	0.027	0.017	226
8	0.0011	0.0007	226	0.026	0.017	226
9	0.0013	0.0007	226	0.027	0.017	226
10	0.0012	0.0008	226	0.028	0.019	226
11	0.0016	0.0009	226	0.030	0.019	226
12	0.0015	0.0008	228	0.030	0.019	228
total	0.0014	0.0008	2714	0.030	0.019	2714

a) Total sample is grouped into 12 portfolios according to the sign and magnitude of unexpected earnings. Portfolio 1 consists of the observations with lowest negative unexpected earnings. Portfolio 12 consists of the observations with highest positive unexpected earnings.

b) When using aquares error loss function, the loss is measured by $\sum_{i=1}^{N}(R_{ia}-R_{ie})^2/N$, where R_{ia} is ith actual return, R_{ie} is ith expected return, and N is the number of observations in a portfolio.

c) When using absolute error loss function, the loss is measured by $\sum_{i=1}^{N}|R_{ia}-R_{ie}|/N$ where $|R_{ia}-R_{ie}|$ is the absolute value of $(R_{ia}-R_{ie})$.

TABLE 12

Comparison Between Abnormal Returns by BERAB Approach and OLS Approach

portfolio[a]	AR by OLS[b]	t-value	observ.	AR by BERAB[c]	t-value
1	-0.00825	-3.03***	226	-0.00315	-1.63 *
2	-0.01132	-4.36***	226	-0.00560	-2.90***
3	-0.00845	-3.34***	226	-0.00419	-2.14**
4	-0.01113	-4.43***	226	-0.00675	-3.50***
5	-0.00810	-3.22**	226	-0.00299	-1.69**
6	-0.00591	-2.47***	226	-0.00346	-1.98**
7	0.00006	0.02	226	-0.00089	0.50
8	0.00153	0.69	226	0.00110	0.62
9	0.00653	2.73***	226	0.00519	2.92***
10	0.00446	1.93**	226	0.00485	2.67***
11	0.00705	2.68***	226	0.00687	3.59***
12	0.00657	2.65***	228	0.00456	2.55***
total	-0.00230	-3.16***	2714	-0.00028	-0.52

a) Total sample is grouped into 12 portfolios according to the sign and magnitude of unexpected earnings. Portfolio 1 consists the observations with lowest negative unexpected earnings. Portfolio 12 consists of the observations with highest positive unexpected earnings.
b) Abnormal returns measured based on OLS approach.
c) Abnormal returns measured based on BERAB approach.
*) Significant at the 0.10 probability level.
**) Significant at the 0.05 probability level.
***) Significant at the 0.01 probability level.

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APPENDICES

Appendix A Derivation of BERAB

For the purpose of estimating time-varying coefficients, for the moment we assume α_{jo}, β_{jo}, $\sigma^2_{\varepsilon j}$, σ^2_{uj}, σ^2_{vj} and σ_{uvj} are exactly known. Consider the model (4.1), (4.1.a) and (4.1.b) in matrix form (j subscript is omitted to simplify the notations)

$$\underset{nx1}{\mathbf{R}} = \underset{nx2n}{\mathbf{X}} \; \underset{2nx1}{\mathbf{B}} + \underset{nx1}{\boldsymbol{\mathcal{E}}} \tag{A.1.a}$$

$$\underset{2nx1}{\mathbf{B}} = \underset{2nx1}{\mathbf{M}} + \underset{2nx1}{\boldsymbol{\Lambda}} \tag{A.1.b}$$

where

$$\mathbf{R} = \begin{pmatrix} R_1 \\ R_2 \\ \cdot \\ \cdot \\ \cdot \\ R_n \end{pmatrix}, \quad \mathbf{X} = \begin{pmatrix} \mathbf{x}_1' & & & & \\ & \mathbf{x}_2' & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & \cdot \\ & & & & & \mathbf{x}_n' \end{pmatrix}, \quad \mathbf{x}_t = \begin{pmatrix} 1 \\ R_{mt} \end{pmatrix}$$

$$\mathbf{B} = \begin{pmatrix} \mathbf{B}_1 \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{B}_n \end{pmatrix}, \quad \mathbf{B}_t = \begin{pmatrix} \alpha_t \\ \beta_t \end{pmatrix}, \quad \boldsymbol{\mathcal{E}} = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_n \end{pmatrix}, \quad \mathrm{VAR}(\boldsymbol{\mathcal{E}}) = \sigma^2_{\varepsilon}\mathbf{I}, \quad \boldsymbol{\Lambda} = \begin{pmatrix} \Lambda_1 \\ \Lambda_2 \\ \cdot \\ \cdot \\ \cdot \\ \Lambda_2 \end{pmatrix}, \quad \Lambda_t = \begin{pmatrix} u_t \\ v_t \end{pmatrix},$$

$$\mathbf{M} = E(\mathbf{B}) = \begin{pmatrix} \mathbf{M}_1 \\ \mathbf{M}_2 \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{M}_n \end{pmatrix} \qquad \mathbf{M}_t = E(\mathbf{B}_t) = \mathbf{B}_o = \begin{pmatrix} \alpha_o \\ \beta_o \end{pmatrix} \tag{A.2}$$

B has a multivariate normal prior density with mean **M** and covariance matrix

$$\mathrm{VAR}(\underset{2nx1}{\mathbf{B}}) = E[(\mathbf{B}-\mathbf{M})(\mathbf{B}-\mathbf{M})'] = \underset{2nx2n}{\mathbf{H}} \tag{A.3}$$

where

$$\mathbf{h}_{ki} = \mathrm{COV}(\mathbf{B}_k\, \mathbf{B}_i)$$

$$= \mathrm{E}\left\{ [\mathbf{B}_k - \mathrm{E}(\mathbf{B}_k)][\mathbf{B}_i - \mathrm{E}(\mathbf{B}_i)]' \right\}$$

$$= \begin{pmatrix} \sigma_u^2 & \sigma_{uv} \\ \sigma_{uv} & \sigma_v^2 \end{pmatrix} = \mathbf{h} \qquad \text{if } k = i \tag{A.4.a}$$

$$= \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} = \mathbf{0} \qquad \text{if } k \neq i, \tag{A.4.b}$$

and so,

$$\mathbf{H} = \begin{pmatrix} \mathbf{h} & \mathbf{0} & . & . & \mathbf{0} \\ \mathbf{0} & \mathbf{h} & & & . \\ . & & . & & . \\ . & & & . & . \\ \mathbf{0} & . & . & . & \mathbf{h} \end{pmatrix} = \mathbf{I} \otimes \mathbf{h} \tag{A.5}$$

where **I** is the n × n unit matrix, and ⊗ denotes the Kronecker product of two matrices. It is assumed that **h** is nonsingular so that **H** is invertible. The covariance matrix **H** is block-diagonal with n diagonal submatrices all equal to the matrix **h**. The off-diagonal submatrices are all zero matrices because their elements are of the type $E(u_k\, u_i)$, $E(u_k\, v_i)$ or $E(v_k\, v_i)$ for k≠i. The inverse of **H** is then block-diagonal with $\mathbf{h}^{-1}$ in the diagonal blocks.

The likelihood of the data **R** given **B** is multivariate normal with mean **XB** and variance $\sigma_\varepsilon^2\mathbf{I}$. The joint p.d.f. of **R** and **B** can thus be found by multiplying the prior p.d.f. of **B** and the likelihood function:

$$\begin{aligned} f(\mathbf{R},\mathbf{B}) &= f(\mathbf{B})f(\mathbf{R} \mid \mathbf{X},\mathbf{B}) \\ &= \left[(2\pi)^n\, |\mathbf{H}|^{1/2}\right]^{-1} \exp\left\{-(1/2)(\mathbf{B} - \mathbf{M})'\, \mathbf{H}^{-1}(\mathbf{B} - \mathbf{M})\right\} \\ &\quad \cdot \left[(2\pi)^{n/2}\, \sigma_\varepsilon^n\right]^{-1} \exp\left\{-(2\sigma_\varepsilon^2)^{-1}(\mathbf{R} - \mathbf{XB})'(\mathbf{R} - \mathbf{XB})\right\} \\ &= \left[(2\pi)^{3n/2} |\mathbf{H}|^{1/2} \sigma_\varepsilon^n\right]^{-1} \end{aligned}$$

$$\cdot\exp\left\{-(1/2)\left[(\mathbf{B}-\mathbf{M})'\mathbf{H}^{-1}(\mathbf{B}-\mathbf{M})+(\sigma_\varepsilon^2)^{-1}(\mathbf{R}-\mathbf{XB})'(\mathbf{R}-\mathbf{XB})\right]\right\}. \qquad (A.6)$$

To obtain the marginal p.d.f. of **R**, we need to integrate the joint p.d.f. $f(\mathbf{R},\mathbf{B})$ over all **B** for a fixed **R**. We complete the squares in **B** in the exponent:

$$\begin{aligned}
&(\mathbf{B}-\mathbf{M})'\mathbf{H}^{-1}(\mathbf{B}-\mathbf{M})+(\sigma_\varepsilon^2)^{-1}(\mathbf{R}-\mathbf{XB})'(\mathbf{R}-\mathbf{XB})\\
&=\mathbf{B}'\mathbf{H}^{-1}\mathbf{B}+\sigma_\varepsilon^{-2}\mathbf{B}'\mathbf{X}'\mathbf{XB}-\mathbf{B}'\mathbf{H}^{-1}\mathbf{M}-\sigma_\varepsilon^{-2}\mathbf{B}'\mathbf{X}'\mathbf{R}-\mathbf{M}'\mathbf{H}^{-1}\mathbf{B}-\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{XB}+\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\\
&=\mathbf{B}'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\mathbf{B}-\mathbf{B}'\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)-\left(\mathbf{M}'\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{X}\right)\mathbf{B}\\
&\quad+\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right)\\
&=\mathbf{B}'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\mathbf{B}-\mathbf{B}'\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)-\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)'\mathbf{B}\\
&\quad+\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right)\\
&=\mathbf{B}'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\mathbf{B}-\mathbf{B}'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\\
&\quad-\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\mathbf{B}+\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right)\\
&=\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\\
&\quad\cdot\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]-\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)'\\
&\qquad\cdot\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\\
&\qquad+\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right)\\
&=\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\\
&\quad\cdot\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]-\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)'\\
&\qquad\cdot\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)+\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right). \qquad (A.7)
\end{aligned}$$

Hence,

$$\begin{aligned}
f(\mathbf{R},\mathbf{B})=&\left[(2\pi)^{3n/2}|\mathbf{H}|^{1/2}\sigma_\varepsilon^{n}\right]^{-1}\exp\left\{-\frac{1}{2}\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]'\right.\\
&\left.\cdot\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)\left[\mathbf{B}-\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)\right]\right\}\\
&\cdot\exp\left\{-\frac{1}{2}\left(\mathbf{M}'\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{R}'\mathbf{R}\right)+\frac{1}{2}\left(\mathbf{H}^{-1}\mathbf{M}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{R}\right)'\left(\mathbf{H}^{-1}+\sigma_\varepsilon^{-2}\mathbf{X}'\mathbf{X}\right)^{-1}\right.
\end{aligned}$$

$$\cdot\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\Big\}, \qquad \text{(A.8)}$$

and the marginal p.d.f. of **R** is

$$f_B(R)=\int_{-\infty}^{\infty} f(R,B)\ dB$$

$$=\left[(2\pi)^{3n/2}|H|^{1/2}\sigma_\varepsilon^{n}\right]^{-1}\exp\left\{-\tfrac{1}{2}\left(M'H^{-1}M+\sigma_\varepsilon^{-2}R'R\right)+\tfrac{1}{2}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)'\right.$$

$$\left.\cdot\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right\}\int_{-\infty}^{\infty}\exp\left\{-\tfrac{1}{2}\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\right.\right.$$

$$\left.\left.\cdot\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]'\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]\right\}dB$$

$$=\left[(2\pi)^{3n/2}|H|^{1/2}\sigma_\varepsilon^{n}\right]^{-1}\exp\left\{-\tfrac{1}{2}\left(M'H^{-1}M+\sigma_\varepsilon^{-2}R'R\right)+\tfrac{1}{2}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)'\right.$$

$$\left.\cdot\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right\}(2\pi)^{2n/2}\left|\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\right|^{+\frac{1}{2}}$$

$$\cdot\int_{-\infty}^{\infty}(2\pi)^{-2n/2}\left|\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\right|^{-\frac{1}{2}}\exp\left\{-\tfrac{1}{2}\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\right.\right.$$

$$\left.\left.\cdot\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]'\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]\right\}dB$$

$$=\left[(2\pi)^{3n/2}|H|^{1/2}\sigma_\varepsilon^{n}\right]^{-1}(2\pi)^{2n/2}\left|\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\right|^{+\frac{1}{2}}\exp\left\{-\tfrac{1}{2}\left[\left(M'H^{-1}M+\sigma_\varepsilon^{-2}R'R\right)\right.\right.$$

$$\left.\left.-\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)'\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]\right\}. \qquad \text{(A.9)}$$

After **B** is integrated out from equation (A.8) to obtain the marginal p.d.f. of **R**, the posterior p.d.f. of **B** given **R** is obtained by dividing the joint p.d.f. defined in equation (A.8) by the marginal p.d.f. of **R**.

$$f(B|R)=\frac{f(R,B)}{f_B(R)}$$

$$=(2\pi)^{-n}\left|H^{-1}+\sigma_\varepsilon^{-2}X'X\right|^{+\frac{1}{2}}\exp\left\{-\tfrac{1}{2}\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]'\right.$$

$$\left.\cdot\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)\left[B-\left(H^{-1}+\sigma_\varepsilon^{-2}X'X\right)^{-1}\left(H^{-1}M+\sigma_\varepsilon^{-2}X'R\right)\right]\right\}. \qquad \text{(A.10)}$$

When a squared error loss function is used, the Bayes estimate for **B**, $\mathbf{b}_B$, is equal to the mean of the posterior p.d.f. The posterior p.d.f. is multivariate normal with mean

$$E(\mathbf{B}|\mathbf{R}) = ((1/\sigma_\varepsilon^2)\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1})^{-1}(\mathbf{H}^{-1}\mathbf{M} + (1/\sigma_\varepsilon^2)\mathbf{X}'\mathbf{R}), \tag{A.11}$$

and variance

$$VAR(\mathbf{B}|\mathbf{R}) = ((1/\sigma_\varepsilon^2)\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1})^{-1}. \tag{A.12}$$

Now, the Bayesian estimators, $\mathbf{b}_B$, for α_{Bt} and β_{Bt} can be written explicitly as

$$\mathbf{b}_{Bt} = \begin{pmatrix} \alpha_{Bt} \\ \beta_{Bt} \end{pmatrix} \tag{A.13}$$

$$\alpha_{Bt} = \alpha_o + \frac{(R_t - \alpha_o - \beta_o R_{mt})(\sigma_u^2 + \sigma_{uv} R_{mt})}{(\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2 R_{mt}^2 + 2\sigma_{uv} R_{mt})}, \tag{A.14.a}$$

$$\beta_{Bt} = \beta_o + \frac{(R_t - \alpha_o - \beta_o R_{mt})(\sigma_v^2 R_{mt} + \sigma_{uv})}{(\sigma_\varepsilon^2 + \sigma_u^2 + \sigma_v^2 R_{mt}^2 + 2\sigma_{uv} R_{mt})}. \tag{A.14.b}$$

This $\mathbf{b}_B$ is the unbiased and minimum variance estimator (see Appendix D).

Appendix B Estimation of Prior Information

The optimal estimator of time-varying parameters in equation (A.14.a) and (A.14.b) requires prior information of α_o, β_o, σ_ε^2, σ_u^2, σ_v^2, and σ_{uv}. Sarris [1973], and Chen and Lee [1982] derive MLEs for β_o (and α_o). Concerning α_o and β_o, MLEs are consistent estimators identical to the least-squares estimators, since normality of the disturbance term is assumed. So, here, we drive estimators of α_o and β_o using the least-squares procedure.

Substituting equations (4.1.a) and (4.1.b) into equation (4.1) and omitting the j subscript again to simplify the notations, equation (4.1) can be written as

$$R_t = \alpha_o + \beta_o R_{mt} + \varepsilon_t^* \tag{B.1}$$

where

$$\varepsilon_t^* = u_t + v_t R_{mt} + \varepsilon_t \tag{B.2}$$

and

$$\begin{aligned} VAR(\varepsilon_t^* | R_{mt}) &= \sigma_u^2 + \sigma_v^2 R_{mt}^2 + \sigma_\varepsilon^2 + 2\sigma_{uv} R_{mt} \\ &= K_t. \end{aligned} \tag{B.3}$$

Consider now the model (B.1) in matrix form

$$\underset{nx1}{R} = \underset{nx2}{Z}\ \underset{2x1}{B_o} + \underset{nx1}{\mathcal{E}^*} \tag{B.4}$$

where

$$Z = \begin{pmatrix} 1 & R_{m1} \\ 1 & R_{m2} \\ \vdots & \vdots \\ 1 & R_{mn} \end{pmatrix} \qquad B_o = \begin{pmatrix} \alpha_o \\ \beta_o \end{pmatrix}, \qquad \mathcal{E}^* \sim N(0, \Omega), \tag{B.5}$$

and

$$\Omega = \begin{pmatrix} K_1 & & & \\ & K_2 & & \\ & & \ddots & \\ & & & K_n \end{pmatrix} \tag{B.6}$$

Since ε_t^*, t=1,...,n, are uncorrelated random variables with zero mean and variances of the form K_t, we are basically in a heteroscedastic situation as far as the estimation of $\mathbf{B}_O$, $\mathbf{B}_G$, is concerned. Aitken's theorem suggests

$$\mathbf{B}_G = \begin{pmatrix} \alpha_G \\ \beta_G \end{pmatrix} = (\mathbf{Z}'\Omega^{-1}\mathbf{Z})^{-1}\mathbf{Z}'\Omega^{-1}\mathbf{R} \quad , \tag{B.7}$$

and so,

$$\alpha_G = \left[\frac{1}{(\Sigma K_t^{-1})(\Sigma R_{mt}^2 K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})^2} \right] \cdot [(\Sigma R_{mt}^2 K_t^{-1})(\Sigma R_t K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})(\Sigma R_{mt} R_t K_t^{-1})], \tag{B.8.a}$$

$$\beta_G = \left[\frac{1}{(\Sigma K_t^{-1})(\Sigma R_{mt}^2 K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})^2} \right] \cdot [(\Sigma K_t^{-1})(\Sigma R_{mt} R_t K_t^{-1}) - (\Sigma R_{mt} K_t^{-1})(\Sigma R_t K_t^{-1})], \tag{B.8.b}$$

where (ΣK_t^{-1}) denotes $(\sum_{t=1}^{n} K_t^{-1})$.

Appendix C Estimation of Variances

The difficulty is obviously that σ_u^2, σ_v^2, σ_ε^2 and σ_{uv} in (B.8.a) and (B.8.b) are unknown. With regard to the estimation of σ_u^2, σ_v^2, σ_ε^2 and σ_{uv}, Chen and Lee [1982] use the MLE approach. Other alternative estimators have been considered by other researchers. They are Hildreth-Houck estimators (See Hildreth and Houck [1968] for details), Theil-Mennes estimators (See Theil and Mennes [1959] for details), and a "MINQUE"[1] estimator (See Rao [1970]). Using a Monte Carlo experiment,[2] Froehlich [1973] examines three of the Hildreth-Houck estimators, "a variant of Hildreth-Houck estimator" that is proposed by Froehlich [1973], a "MINQUE" estimator, and an MLE to find out the better estimator in terms of mean squared errors (MSE).

Froehlich [1973] uses Hildreth-Houck's random coefficient model and sample sizes of 25 and 75 are used. The difference between the two sample sizes should provide hints as to asymptotic properties(e.g., consistency) which might be exhibited. The experiment's result suggests that, for true variances close to zero, the MLE procedure should be avoided even with a relatively large sample size. Even when true variances are close to 1, the MLE procedure does not show the best performance in terms of MSE. Comparison of all the variance estimators reveals that "a variant of Hildreth-Houck estimator" proposed by Froehlich [1973] is, on average, the most efficient.

Now, we start developing estimators for variances in equations (B.8.a) and (B.8.b)

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1 MINQUE is the abbrebiation for Minimum Norm Quadratic Unbiased Estimation. Rao proposes this estimation technique for a linear model with heteroscedastic variances. MINQUE has minimum average variance in the class of quadratic unbiased estimators.

2 Froehlich [1973] uses a Monte Carlo experiment as a test procedure because in most instances analytic attempts prove to be difficult to manipulate.

utilizing the procedures of "a variant of Hildreth-Houck estimator."[3] To estimate variances, we first consider the OLS residuals from the equation (B.4) by replacing B_O and ε^* by $\mathbf{b}$ and ε. Consider the following model to compute the OLS residual:

$$\underset{nx1}{\mathbf{R}} = \underset{nx2}{\mathbf{Z}}\ \underset{2x1}{\mathbf{b}} + \underset{nx1}{\varepsilon} \tag{C.1}$$

where

$$\mathbf{b} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} \tag{C.2}$$

Here **b** is actually random but, to compute the OLS residuals, we regard **b** as being fixed for the moment. ε is the same as ε in equation (A.1.a). Then the OLS estimate of **b** is

$$\mathbf{b}_L = \begin{pmatrix} \alpha_L \\ \beta_L \end{pmatrix} = (\mathbf{Z'Z})^{-1}\mathbf{Z'R}. \tag{C.3}$$

The t th residual is expressed as

$$\begin{aligned} e_t &= R_t - \alpha_{OLS} - \beta_{OLS}R_{mt} \\ &= \alpha_o + \beta_o R_{mt} + \varepsilon_t^* - \alpha_L - \beta_L R_{mt}\,. \end{aligned} \tag{C.4}$$

Consider the variance of, say, the t th residual:

$$\begin{aligned} VAR(e_t) = {} & VAR(\varepsilon_t^*) + VAR(\alpha_L) + VAR(\beta_L R_{mt}) \\ & - 2COV(\varepsilon_t^*, \alpha_L) - 2COV(\varepsilon_t^*, \beta_L R_{mt}) \\ & + 2COV(\alpha_L, \beta_L R_{mt}). \end{aligned} \tag{C.5}$$

---

3 See Hildreth and Houck [1968, pp. 584-588] or J. Johnston [1984, pp. 410-415] for the details. Precisely speaking Hildreth-Houck procedure is not directly available in this case, because of estimation of σ_{uv}. Therefore this study refers to Theil [1971, pp. 622-625]. Anyway the underlying concepts of the Hildreth-Houck and Theil procedures are the same.

If we express $VAR(e_t)$ in equation (C.5) as follows

$$VAR(e_t) = \sigma_u^2 P_t + \sigma_v^2 Q_t + \sigma_\varepsilon^2 S_t + \sigma_{uv} Y_t, \tag{C.6}$$

then

$$P_t = [1+\lambda^2(\Sigma L_t^2 + R_{mt}^2 \Sigma B_t^2 + R_{mt}\Sigma B_t L_t)] - 2\lambda(L_t + R_{mt}B_t), \tag{C.7.a}$$

$$Q_t = R_{mt}^2 + \lambda^2[\Sigma(R_{mt}^2 L_t^2) + R_{mt}^2 \Sigma(R_{mt}^2 B_t^2) + 2R_{mt}(\Sigma R_{mt}^2 B_t L_t)]$$
$$-2\lambda R_{mt}^2(L_t + R_{mt}B_t), \tag{C.7.b}$$

$$S_t = 1 - \lambda(L_t + R_{mt}B_t), \text{ and} \tag{C.7.c}$$

$$Y_t = 2R_{mt} + 2\lambda^2[\Sigma(R_{mt}L_t^2) + 2R_{mt}\Sigma(R_{mt}B_t L_t) + R_{mt}^2 \Sigma(R_{mt}B_t^2]$$
$$-4\lambda R_{mt}(L_t + R_{mt}B_t), \tag{C.7.d}$$

where $$\lambda = 1/\left(n\Sigma R_{mt}^2 - (\Sigma R_{mt})^2\right) \tag{C.8.a}$$

$$B_t = nR_{mt} - \Sigma R_{mt}, \text{ and} \tag{C.8.a}$$

$$L_t = \Sigma R_{mt}^2 - R_{mt}\Sigma R_{mt}. \tag{C.8.b}$$

Since e_t has zero expectation, the left-hand side of equation (C.6) is the expectation of e_t^2, so that we can write equation (C.6) in the form

$$e_t^2 = \sigma_u^2 P_t + \sigma_v^2 Q_t + \sigma_\varepsilon^2 S_t + \sigma_{uv} Y_t + \zeta_t \tag{C.9}$$

where $E(\zeta_t)=0$, and ζ_t is defined as the deviation of e_t^2 from its own expectation.

Given that P_t, Q_t, S_t, and Y_t are known, equation (C.9) suggests that σ_u^2, σ_v^2, σ_ε^2 and σ_{uv} can be estimated by running a regression of e_t^2 on P_t, Q_t, S_t, and Y_t with ζ_t treated as a disturbance. To find out which estimation method is appropriate, we need the covariance matrix of ζ_t, which will now be derived under the condition that the e_t's are normally distributed(since R_{mt} and ε_t are normally distributed). So consider the variance term of ζ_t:

$$\mathrm{VAR}(\zeta_t) = E(e_t^2 - Ee_t^2)^2 = Ee_t^4 - (Ee_t^2)^2$$

$$= 3(Ee_t^2)^2 - (Ee_t^2)^2 = 2(Ee_t^2)^2$$

$$= 2\left(\sigma_u^2 P_t + \sigma_v^2 Q_t + \sigma_\varepsilon^2 S_t + \sigma_{uv} Y_t\right)^2 . \qquad \text{(C.10)}$$

The covariances $E(\zeta_t, \zeta_s)$ for $s \neq t$ are small compared with the variances, so it is asymptotically correct to neglect them (See Theil [1971, pp. 627-628] and Theil and Mennes [1959, pp. 217-218]). Now we are basically in a heteroscedastic situation and an Aitken-type estimator is suggested.

However, Aitken's estimators for σ_u^2, σ_v^2, and σ_ε^2 clearly have an undesirable feature. Sometimes some of its elements are negative. The remedy is to use alternative estimators for Ψ, defined by

$$\min_{\Psi} \; (\underset{n\times 1}{e} - \underset{n\times 4}{A} \; \underset{4\times 1}{\Psi})' \underset{n\times n}{W^{-1}} (e - A \; \Psi) \qquad \text{(C.11.a)}$$

$$\text{s.t.} \quad \sigma_u^2, \; \sigma_v^2, \text{ and } \sigma_\varepsilon^2 \geq 0 \qquad \text{(C.11.b)}$$

where

$$e = \begin{pmatrix} e_1^2 \\ e_2^2 \\ \cdot \\ \cdot \\ \cdot \\ e_n^2 \end{pmatrix} \quad A = \begin{pmatrix} P_1 & Q_1 & S_1 & Y_1 \\ P_2 & Q_2 & S_2 & Y_2 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ P_n & Q_n & S_n & Y_n \end{pmatrix} \quad \Psi = \begin{pmatrix} \sigma_u^2 \\ \sigma_v^2 \\ \sigma_\varepsilon^2 \\ \sigma_{uv} \end{pmatrix} \qquad \text{(C.12)}$$

$$W = \mathrm{VAR}(\zeta) = \begin{pmatrix} 2\varphi_1^2 & & & & \\ & 2\varphi_2^2 & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & 2\varphi_n^2 \end{pmatrix} \qquad \text{(C.13)}$$

$$\underset{1xn}{\zeta'}=[\zeta_1,\ \zeta_2,\cdots\cdots,\zeta_n]\quad \text{, and} \tag{C.14}$$

$$\varphi_t=\sigma_u^2P_t+\sigma_v^2Q_t+\sigma_\varepsilon^2S_t+\sigma_{uv}Y_t\,. \tag{C.15}$$

The purpose of solving the quadratic programming defined by equations (C.11.a) and (C.11.b) is to obtain estimates for $\Psi(\sigma_u^2,\ \sigma_v^2,\ \sigma_\varepsilon^2$ and $\sigma_{uv})$. But to solve equations (C.11.a) and (C.11.b), we should know the elements of covariance matrix **W**. From equations (C.13) and (C.15) we know that the elements of **W** are composed of the elements of Ψ which we are going to estimate. So, a two-step procedure is proposed. The first step is to estimate Ψ $(\sigma_u^2,\ \sigma_v^2,\ \sigma_\varepsilon^2$ and $\sigma_{uv})$ by another quadratic programming defined by

$$\min\ (\,e - A\ \Psi\,)'(\,e - A\ \Psi\,)=\min\ \Sigma(e_t^2-\varphi_t)^2 \tag{C.16.a}$$

$$\text{s.t.}\qquad \sigma_u^2,\ \sigma_v^2,\ \text{and}\ \sigma_\varepsilon^2\ \geq 0 \tag{C.16.b}$$

where Σ denotes the summation from t=1 to t=n. Denote the estimates of Ψ from (C.16.a) and (C.16.b) as $\hat{\Psi}$ then elements of φ_t in equation (C.15) are replaced by elements of $\hat{\Psi}$, and we can get an estimate of **W**, $\hat{\mathbf{W}}$. Now we can start the second step of getting estimates for Ψ, Ψ, from equations (C.11.a) and (C.11.b). The quadratic programming of (C.11.a) and (C.11.b) is rewritten by replacing **W** by $\hat{\mathbf{W}}$

$$\min_{\Psi}\ (\underset{nx1}{e} - \underset{nx4}{A}\ \underset{4x1}{\Psi}\,)'\ \underset{nxn}{\hat{W}^{-1}}(\,e - A\ \Psi\,)$$

$$=\min \sum_{t=1}^{n}\frac{1}{2(\hat{\varphi}_t^2)}(e_t^2-\varphi_t)^2 \tag{C.17.a}$$

$$\text{s.t.}\qquad \sigma_u^2,\ \sigma_v^2,\ \text{and}\ \sigma_\varepsilon^2 \geq 0 \tag{C.17.b}$$

where

$$\hat{\varphi}_t=\hat{\sigma}_u^2\,P_t+\hat{\sigma}_v^2\,Q_t+\hat{\sigma}_\varepsilon^2\,S_t+\hat{\sigma}_{uv}\,Y_t\ . \tag{C.18}$$

The restricted least squares estimator, Ψ, obtained by quadratic programming defined by (C.17.a) and (C.17.b) is used to obtain estimates $\tilde{\alpha}_G$ and $\tilde{\beta}_G$ for α_G and β_G in equation (B.8.a) and (B.8.b). Again $\tilde{\alpha}_G$ and $\tilde{\beta}_G$ in equation (B.8.a) and (B.8.b), and Ψ from (C.17.a) and (C.17.b) are substituted into equations (A.14.a) and (A.14.b) to obtain time-varying coefficients estimates, α_{Bt} and β_{Bt}

Appendix D Proof of MVUE

Returning to equation (A.11), the Bayesian estimator is

$$\mathbf{b_B} = \left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M} + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'R}\right) \quad . \tag{A.11}$$

Then,

$$\mathrm{E}(\mathbf{b_B} - \mathbf{B}) = \mathrm{E}\left\{\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M} + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'R}\right) - \mathbf{B}\right\}$$

$$= \mathrm{E}\left\{\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left(\mathbf{H}^{-1}\mathbf{M} + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'}(\mathbf{XB}+\varepsilon)\right) - \left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)\mathbf{B}\right\}$$

$$= \mathrm{E}\left\{\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left[\mathbf{H}^{-1}\mathbf{M} + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'XB} + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'}\varepsilon - \frac{1}{\sigma_\varepsilon^2}\mathbf{X'XB} - \mathbf{H}^{-1}\mathbf{B}\right]\right\}$$

$$= \mathrm{E}\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + \mathbf{H}^{-1}\right)^{-1}\left[\mathbf{H}^{-1}(\mathbf{M} - \mathbf{B}) + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'}\varepsilon\right] \qquad \text{(from A.1.b)}$$

$$= \mathrm{E}\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X'X} + -\mathbf{H}^{-1}\right)^{-1}\left[\mathbf{H}^{-1}\Lambda + \frac{1}{\sigma_\varepsilon^2}\mathbf{X'}\varepsilon\right] \tag{D.1}$$

$$= \mathbf{O} \tag{D.2}$$

According to the result of (D.2), the Bayesian estimator in equation (A.11) is a linear unbiased estimator in **R** in the sense that $\mathrm{E}(\mathbf{b_B} - \mathbf{B}) = \mathbf{O}$.

Now it can be proved that $\mathbf{b_B}$ has minimum variance in the class of linear unbiased estimators. Let $\mathbf{b_B^*}$ denote any arbitrary linear unbiased estimator in **R**. Write

$$\underset{2n\times1}{\mathbf{b_B^*}} = \underset{2n\times1}{\mathbf{b_B}} + \underset{2n\times n}{\Gamma}\ \underset{n\times1}{\mathbf{R}} + \underset{2n\times1}{\mathbf{q}} \tag{D.3}$$

where elements of Γ and $\mathbf{q}$ are real numbers.

Then,

$$
\begin{aligned}
& E(\mathbf{b}_B^* - \mathbf{B})(\mathbf{b}_B^* - \mathbf{B})' - E(\mathbf{b}_B - \mathbf{B})(\mathbf{b}_B - \mathbf{B})' \\
= \ & E(\mathbf{b}_B + \Gamma\mathbf{R} + \mathbf{q} - \mathbf{B})(\mathbf{b}_B + \Gamma\mathbf{R} + \mathbf{q} - \mathbf{B})' - E(\mathbf{b}_B - \mathbf{B})(\mathbf{b}_B - \mathbf{B})' \\
= \ & E(\mathbf{b}_B - \mathbf{B})(\mathbf{b}_B - \mathbf{B})' + E(\mathbf{b}_B - \mathbf{B})(\Gamma\mathbf{R} + \mathbf{q})' + E(\Gamma\mathbf{R} + \mathbf{q})(\mathbf{b}_B - \mathbf{B})' + E(\Gamma\mathbf{R} + \mathbf{q})(\Gamma\mathbf{R} + \mathbf{q})' \\
& \quad - E(\mathbf{b}_B - \mathbf{B})(\mathbf{b}_B - \mathbf{B})' \\
= \ & E(\mathbf{b}_B - \mathbf{B})(\Gamma\mathbf{R} + \mathbf{q})' + E(\Gamma\mathbf{R} + \mathbf{q})(\mathbf{b}_B - \mathbf{B})' + E(\Gamma\mathbf{R} + \mathbf{q})(\Gamma\mathbf{R} + \mathbf{q})'. \qquad \text{(D.4)}
\end{aligned}
$$

And

$$
\begin{aligned}
& E(\mathbf{b}_B - \mathbf{B})(\Gamma\mathbf{R} + \mathbf{q})' \\
= \ & E(\mathbf{b}_B - \mathbf{B})\mathbf{R}'\Gamma' \\
= \ & \{E(\mathbf{b}_B - \mathbf{B})(\mathbf{B}'\mathbf{X}' + \mathcal{E}')\}\Gamma' \\
= \ & [(E(\mathbf{b}_B - \mathbf{B})\mathbf{B}']\mathbf{X}'\Gamma' + [E(\mathbf{b}_B - \mathbf{B})\mathcal{E}']\Gamma' \\
= \ & \left[E\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1}\right)^{-1}\left(-\mathbf{H}^{-1}\Lambda + \frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathcal{E}\right)\mathbf{B}'\right]\mathbf{X}'\Gamma' \\
& + \left[E\left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1}\right)^{-1}\left(-\mathbf{H}^{-1}\Lambda + \frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathcal{E}\right)\mathcal{E}'\right]\Gamma' \qquad \text{(from (A.1.b))} \\
= \ & \left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1}\right)^{-1}\left[-\mathbf{H}^{-1}E(\Lambda)(\mathbf{M}' + \Lambda') + \frac{1}{\sigma_\varepsilon^2}\mathbf{X}'E(\mathcal{E})(\mathbf{M}' + \Lambda')\right]\mathbf{X}'\Gamma' \\
& + \left(\frac{1}{\sigma_\varepsilon^2}\mathbf{X}'\mathbf{X} + \mathbf{H}^{-1}\right)^{-1}\left[-\mathbf{H}^{-1}E(\Lambda\mathcal{E}') + \frac{1}{\sigma_\varepsilon^2}\mathbf{X}'E(\mathcal{E}\mathcal{E}')\right]\Gamma'
\end{aligned}
$$

$$= \left(\frac{1}{\sigma_{\varepsilon}^{2}} \mathbf{X}'\mathbf{X} + \mathbf{H}^{-1}\right)^{-1} (-\mathbf{X}'\Gamma' + \mathbf{X}'\Gamma'))$$

$$= \mathbf{O} \tag{D.5}$$

Substituting (D.5) into (D.4), we get

$$\mathbf{E}(\mathbf{b}_{\mathbf{B}}^{*} - \mathbf{B})(\mathbf{b}_{\mathbf{B}}^{*} - \mathbf{B})' - \mathbf{E}(\mathbf{b}_{\mathbf{B}} - \mathbf{B})(\mathbf{b}_{\mathbf{B}} - \mathbf{B})'$$

$$= \mathbf{E}(\Gamma\mathbf{R} + \mathbf{q})(\Gamma\mathbf{R} + \mathbf{q})' \tag{D.6}$$

The matrix in (D.6) is non-negative definite. Thus $\mathbf{E}(\mathbf{b}_{\mathbf{B}}^{*} - \mathbf{B})(\mathbf{b}_{\mathbf{B}}^{*} - \mathbf{B})' \geq \Sigma(\mathbf{b}_{\mathbf{B}} - \mathbf{B})(\mathbf{b}_{\mathbf{B}} - \mathbf{B})'$.

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