CORPORATE BOND RISK AND THE ARBITRAGE PRICING THEORY: AN EMPIRICAL STUDY

By

CHIHUANG HERMAN LIN

Bachelor of Science in Agriculture
National Taiwan University
Taipei, Taiwan
1976

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1982

Submitted to the Faculty of the Graduate College
of Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1987

CORPORATE BOND RISK AND THE

ARBITRAGE PRICING THEORY:

AN EMPIRICAL STUDY

Thesis Approved:

W. Gary Simpson
Thesis Advisor

Mary S. Broske

John R. Wingender

Tim C. Ireland

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to all the people who assisted me in this work and during my stay at Oklahoma State University. In particular, I am especially indebted to my major advisor, Dr. Mary S. Broske, for her intelligent guidance, encouragement, and invaluable help.

I am also thankful to the other committee members, Dr. W. Gary Simpson, Dr. John R. Wingender, and Dr. Timothy C. Ireland, for their advisement in the course of this work. Special thanks are due to Dr. Simpson for the guidance he provided to me throughout my doctoral program.

I also appreciate the financial support provided by the Department of Finance, Mr. Paul D. Phillips, and the Office of Business and Economic Research, Oklahoma State University, during the course of this work.

Finally, my parents, my wife, Sujan, my son, Christopher, my brother, and my sisters deserve my deepest appreciation for their constant support, encouragement, sacrifice, and understanding during the long way of my graduate study.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

A. Purpose of the Research

As investment in corporate bonds is not riskless, the required return on such investment should contain a risk premium to compensate the bond-holder for risk incurred by owning the bond. Since corporate bonds are also traded securities, the application of an asset pricing theory to corporate bonds should be straightforward. Unlike the restrictive assumptions of the Capital Asset Pricing Model (CAPM), the Arbitrage Pricing Theory (APT) only assumes that financial markets are perfectly competitive and the returns on risky assets are linearly related to a limited number of common factors. Under such assumptions, a market where no arbitrage opportunity exists would determine a risk premium for risky investment according to the multi-factor model specified by the APT.

The usual perception of corporate bond risk includes inflation risk, interest rate risk, and default risk. Assuming risk aversion, corporate bond investors would require risk premiums commensurate with these risks. Thus, it is reasonable to propose that corporate bond returns may be determined by a multi-factor model such as the APT.

Empirical studies (Percival, 1974; Reilly and Joehnk, 1976; Friend, Westerfield, and Granito, 1978; Alexander, 1980; and Weinstein, 1981) found that the CAPM does not perform well in explaining relevant risk for corporate bonds. Since the APT has been in existence for a relatively short time, it has not been tested with corporate bond data.

Most of the initial APT empirical studies employ factor analysis to endogenously extract the common risk factors and then to test the implications of the APT. An alternative approach in testing the APT is to hypothesize the macroeconomic factors that may affect asset prices and then to verify or reject the hypothesized economic variables using regression analysis. Either approach has its drawbacks. For example, factor analysis cannot obtain unique measures of factor loadings and the selection of risk factors in the regression analysis is somewhat ad hoc.

Based on the above reasons, this research intends to achieve two objectives:

1. To investigate corporate bond risk by applying the APT to corporate bonds, thereby providing evidence that the three commonly perceived sources of corporate bond risk are the main factors affecting corporate bond returns. This research is needed since the CAPM is not a robust model of the risk inherent in corporate bonds. In addition, previous tests of the APT did not include corporate bonds.

2. To propose an alternative way of testing the APT which minimizes the drawbacks and combines the strengths of both the factor analysis and the regression analysis approaches.

B. Statement of Issues

The intuitive appeal of applying the APT to corporate bonds is that the APT allows more than just one factor in the return generating process. However, the APT does not prespecify the underlying risk factors. The presence of a set of unnamed factors in the APT is not better than the existence of an unobservable market portfolio in the CAPM. Several issues need to be investigated before the APT can be used in investment and portfolio management. A survey of the literature resulted in the following issues, which are addressed in this research:

1. The identification (or interpretation) of the common factors extracted by factor analysis;

2. The measurement of the unanticipated changes in risk factors used in the regression analysis;

3. The unique measurement of factor sensitivities which may be used in portfolio management; and

4. The appropriateness of the APT for corporate bonds.

Factor analysis was used in the first part of this study to extract common factors affecting corporate bond returns. An approach which constructs corporate bond portfolios according to bonds' characteristics was proposed to facilitate the interpretation (or identification) of the economic meanings of the extracted common factors.

To verify the significance of the risk factors identified in the first part of this research, and to obtain the unique measures of factor sensitivities, the second part of this study employed the regression analysis to investigate the hypothesized risk-return relationship for corporate bonds. The measures of unanticipated changes in the hypothesized risk factors are also discussed.

C. Significance of the Study

The suggested contributions of this study come from the empirical procedure itself, its results, and its implications. Specifically, the contributions to the literature are suggested to be the following:

1. It proposes an approach which constructs bond portfolios according to bonds' risk characteristics so that the extracted common factors might be identified through the inspection of the rotated factor loadings;

2. It derives measures of unanticipated changes in interest rates and default risk premiums based on the Unbiased Expectation Theory of the term structure of interest rates;

3. It provides evidence that corporate bond default risk is an important factor in determining corporate bond returns (this finding is significant because previous studies, using the CAPM, indicate that the CAPM's beta does not capture the default risk of corporate bonds); and

4. It provides a possible way of putting the APT into practical use. That is, the empirical procedure of this study has significant implications for strategic portfolio management.

D. Organization of the Study

The remainder of this study is organized as follows. Chapter II presents an overview of the literature concerned with the sources of corporate bond risk and with the empirical studies of both the CAPM and the APT which are related to this research. Chapter III provides the theoretical framework of this study. Chapter IV describes the data and methodology employed in this research. It includes a description of the measurement of the three hypothesized risk factors. Chapter V presents the empirical results. Finally, Chapter VI is the summary of this study and the conclusions to be drawn from it.

CHAPTER II

LITERATURE REVIEW

A. Introduction

Corporate bond risk has been a subject of research for many theoretical and empirical studies. Empirical studies applying the CAPM to corporate bonds were implemented in two ways: one is to test the CAPM using corporate bond returns (Percival, 1974; Friend, Westerfield, and Granito, 1978); the other is, assuming the CAPM is correct, to investigate the relationship between the bond beta derived from the CAPM and the usual perception of corporate bond risk such as inflation risk, interest rate risk, and default risk (Reilly and Joehnk, 1976; Weinstein, 1981). Evidence from applying the CAPM to corporate bond data indicates that the CAPM does not perform well in explaining relevant risk for corporate bonds. For example, bond beta was found to be incapable of capturing the default risk of corporate bonds (Percival, 1974; Reilly and Joehnk, 1976; Weinstein, 1981).

The APT is a relatively new theoretical model which specifies the risk-return relationship of capital assets. It requires fewer underlying assumptions and permits more variables in the analysis than does the CAPM. Empirical studies of the APT have been restricted to its application to common stocks with the only exception of Gultekin and Rogalski (1985) which applied the APT to government debt issues. Furthermore, previous empirical work (Merton, 1974; Percival, 1974;

Weinstein, 1981, 1983) suggested that risk for corporate bonds may be multidimensional, i.e., there is more than one type of risk inherent in corporate bonds. Thus, it is appropriate to empirically investigate corporate bond risk by applying the APT to corporate bond returns.

This chapter consists of two parts. The first part presents an overview of the three main sources of corporate bond risk and the literature concerned with the risk-return relationship of corporate bonds. The second part reviews the empirical studies which are related to the issues of applying the APT to corporate bonds.

B. Corporate Bond Risk

1. The Three Main Sources of Corporate Bond Risk

Uncertainty about corporate bond return is usually attributed to three factors: (1) inflation risk, (2) interest rate risk, and (3) default risk. Inflation can erode the ability of bonds, which are denominated in dollars, to buy real physical goods. Interest rate risk arises from the price fluctuation in a bond caused by simultaneous changes in the level of interest rate. Default risk is the risk of defaulting on either the payment of interest or principal. Risk-averse investors would require risk premiums commensurate with these risks. Thus, conceptually, the rate of return for corporate bonds, $\tilde{R}$, can be specified according to the following model:

$$\tilde{R} = r_r + IP + IRP + DRP + \tilde{u} \qquad (2.1)$$

where r_r is the real rate of interest,

IP is the inflation risk premium,

IRP is the interest rate risk premium[1], DRP is the default risk premium, and

$\tilde{u}$ is the random error which has a mean of zero.

Equation (2.1) is not derived from a developed theory of bond pricing; rather, it has been developed conceptually to explain the components of corporate bond returns.

The real rate of interest (r_r) is the pure rate of interest which represents the time preference for money. It is the opportunity cost necessary to compensate individuals for foregoing consumption. Theoretically, the pure rate of interest should be fairly stable in the short run.

Investors need to be compensated for the loss of purchasing power. The inflation premium (IP) is therefore added to the real rate in order to specify a general market based risk-free interest rate r_r + IP. Jaffe and Mandelker (1979) empirically examined the interaction between inflation and the holding-period returns on bonds. They found a positive relationships between the returns to bondholders and concurrent inflation. When inflation was decomposed into anticipated and unanticipated components, their empirical findings suggested that either no relationship or a slight positive correlation existed between the real holding-period returns on fixed income securities and anticipated inflation; and that the holding-period return on a bill or bond was negatively related to unanticipated inflation.

A bond's price is equal to the sum of the present values of future cash flows (i.e., coupons and principal). As interest rates rise (fall), bonds' prices fall (rise). For a given change in interest rates, bonds with different sizes of coupons and maturity dates are exposed to different degrees of interest rate risk. That is, they have different degrees of interest rate sensitivity. Thus, the interest rate risk premium is required in order to compensate for such risk.

Hopewell and Kaufman (1973) showed that a bond's duration, which reflects the amount and timing of every cashflow, is a measure of the bond's interest rate risk because it is closely related to the bond's interest rate sensitivity (or elasticity). Since low-coupon bonds with long terms to maturity tend to have the longest duration, their interest rate risk is the greatest.

As bond's price moves inversely to the level of interest rates, uncertainty about future bond prices is partially attributable to uncertainty about future interest rates. According to the Unbiased Expectations Theory of the term structure of interest rates, the expected spot rate of interest is equal to the forward rate implied in the yield curve. Thus, the term structure of interest rates contains information which may be useful in dealing with interest rate risk. Roll and Ross (1984) described the unanticipated changes in the slope of the term structure of interest rates as an economic factor of the APT. Burmeister and Wall (1986) employed the unexpected change in the term structure, measured as the return on government bonds in period t minus the return on Treasury bills in period t, as one of four macroeconomic factors to test the APT. Their results indicated that the measure has significant influence on stocks' returns.

A bond's default risk is directly related to its probability of default. Bond ratings, published by bond rating agencies such as Moody's and Standard & Poor's, essentially rank bonds in order of their probability of default. To quantify bonds' probabilities of default from market data, Broske (1985a) developed a "delta model" based on stochastic dominance criteria. She also found that the magnitude of the probability of default varies inversely with quality of the bond as indicated by the bond rating. Although default risk is related to bond characteristics, it is also found to be closely related to broad economic conditions. That is, default rates are much larger during periods of economic recession and depression than during normal periods. The default risk premium in Equation (2.1) is to compensate investors for assuming such risk.

In summary, inflation risk, interest rate risk, and default risk are the three main sources of risk faced by any holder of corporate bonds. It is possible, of course, to think of many other potential risk factors, but many of them influence corporate bond returns only through their impact on the above three risk factors. For example, the risk associated with the issuer's earning variability is already captured by the default risk factor. Call risk is issue specific and is not included in a general model specifying assets' risk-return relationship.[2] Tax features also influence bonds' returns. Since tax policy is relatively stable in the short run, this study will not consider it as an important source of corporate bond risk.[3]

2. The CAPM's Beta and Corporate Bond Risk

Theoretically, the linear relationship between risk and return which is expressed by the Capital Asset Pricing Model (CAPM) is applicable to bonds. The initial empirical study applying the CAPM to bonds was done by Percival (1974). He calculated the annual holding-period yields for 175 corporate bonds during the 1953-1967 time period. A portfolio, comprised of all 175 of the corporate bonds equally weighted, was constituted as the market portfolio. His findings suggested that bond betas, derived from the CAPM, are a measure of interest rate risk, but that they must be combined with a nondiversifiable default risk measure in order to explain realized corporate bond returns. Thus, the single beta risk measure of the CAPM does not adequately capture corporate bond risk which is inherently multidimensional.

Reilly and Joehnk (1976) investigated the association between market-determined risk measures for bonds and bond ratings. They assumed that the bond beta derived from the CAPM should be inversely related to bond ratings. Their findings suggested that the expected relationship did not hold because bond ratings are assigned on the basis of the probability of default. In contrast, the bond beta is based on how bond's returns are related to the returns for a market portfolio of risky assets. Therefore, the bond beta is heavily determined by the monthly bond price movements which are influenced by both internal corporate variables and aggregate capital market factors. Since the internal corporate variables are rather stable in the short run, the major factors that influence short run prices are macroeconomic variables, such as changes in aggregate market rates of interest and changes in the expected rate of inflation. This means that bond yields should move together over time because the major influences on interest rate changes are consistent across all bonds. Therefore, the market's influence on all bonds should be similar regardless of agency rating. Their finding is important because it indicates that it would be meaningful to relate the bond returns to the macroeconomic measures such as changes in the level of interest rates and changes in inflation.

The relationship between the CAPM's beta and two types of bond risk—interest rate risk and default risk was further investigated by Weinstein (1981). His findings confirmed Percival's (1974) conclusions that the corporate bond beta is positively related to interest rate risk. It also provided weak support for the hypothesis that default risk and beta are positively related. Thus, empirical studies from Percival (1974), Reilly and Joehnk (1976), and Weinstein (1981) all suggested that the CAPM's beta cannot capture the default risk of corporate bonds.

As criticized by Roll (1977), the greatest difficulty of testing the CAPM comes from the unobservable market portfolio. Alexander (1980) examined the empirical appropriateness of applying the CAPM to long-term corporate bonds. He found that bond betas appear to be sensitive to the market index and concluded that the use of the CAPM to analyze bonds with any index appears to involve both notable violations of regression assumptions and instances of parameter instability.

The application of the CAPM to corporate bonds was also investigated in Friend, Westerfield, and Granito (1978). They tested the CAPM on corporate bond returns as part of a comprehensive retesting of the CAPM by incorporating bonds into the market index. Their study suggested that bond betas derived from the CAPM do not perform well in explaining the relevant risk for bonds.[4]

The CAPM's beta does not adequately explain the relevant risk of corporate bonds mainly because of two reasons: first, the CAPM's beta only captures the market wide variability arising from interest rate risk (Percival, 1974; Weinstein, 1981); second, the "true" beta for a bond is not obtainable since the true market portfolio is not observable; and the use of any proxy for the market portfolio involves statistical problems

(Alexander, 1980). Thus, it is necessary to investigate corporate bond risk by an alternative asset pricing model such as the APT.

C. Empirical Tests of the APT

The APT has attracted the attention of several empirical researchers. Shanken (1982) questioned the testability of the APT as it precludes the very expected return differentials which the theory attempts to explain. Dybvig and Ross (1985) replied that Shanken's critique of the APT rests on fallacies. They demonstrated that the APT is testable on subsets of the assets while the CAPM is not.

Most of the empirical tests of the APT are conducted in two stages. The first stage involves using factor analysis to estimates the factor loadings for each asset (or portfolio). In the second stage, the estimated factor loadings are used to explain the cross-sectional variation of realized returns and to test the implications of the APT.[5]

1. Problems with Empirical Tests of the APT

Factor analysis, as it is used in testing the APT, is subject to criticism arising from the number of factors problem, the nonuniqueness of factor loadings problem, and the identification of common factors problem. These issues are far from resolved and therefore the testing of the APT and the application of the theory to portfolio management becomes more difficult.

The number of factors problem was the main controversy between Roll and Ross (1980, 1984a), Dhrymes, Friend, and Gultekin (1984), and Dhrymes, Friend, Gultekin, and Gultekin (1985a). Roll and Ross (1980) proposed that there are at least three and probably four factors determining common stock returns. Dhrymes, Friend, and Gultekin (1984) and Dhrymes et al. (1985a) argued that the number of factors is not stable because more factors can be found by increasing the size of securities groups and the length of the time series.

Lehmann and Modest (1985) pointed out that the essence of the exchange between Dhrymes, Friend, and Gultekin (1984), Dhrymes et al. (1985a), and Roll and Ross (1984a) is that the statistical factor analysis model with the diagonal covariance matrix for the idiosyncratic disturbances requires that any source of covariation among security returns be classified as a factor while the APT counts as factors only those which are pervasive and affect many security returns. The likelihood ratio statistic cannot distinguish between correlated idiosyncratic risks which are irrelevant for pricing and common factors which help explain expected returns. They also pointed out that there is no statistical test (e.g., Chi-square statistic) that can provide a reliable answer to the question of how many factors are underlying the APT.

The number of factors problem was further addressed in Trzcinka (1986). He stated that assuming that k factors generate security returns is equivalent to assuming that k eigenvalues of the covariance matrix of returns increase as the number of securities increases. Thus, he examined if, in fact, k eigenvalues dominate the covariance matrix of returns as the number of securities increases. He found that at most, one eigenvalue dominates the covariance matrix and that the second through the fifth eigenvalues grew more distinct from each other as the number of securities increases. This was not true of the remaining eigenvalues. He concluded that there is at least one large factor and no obvious way to choose more than one.

Thus, the number of factors problem is far from settled. Perhaps it would be better to develop risk factors that may affect asset prices from economic theory rather than let factor analysis determine the number of factors blindly. This study did not specifically address the number of factors problem. The number of risk factors affecting corporate bond returns was determined based on some combination of the results from the factor analysis and the economic meaningfulness of the extracted common factors.

The factor loadings obtained from factor analysis are unique only up to an orthogonal transformation. In the second stage of testing the APT, the estimated factor loadings are used as independent variables to estimate the constant term (risk free rate or zero-beta return) and regression coefficients (i.e., risk premiums). The nonuniqueness of factor loadings makes the test of the APT more difficult and imprecise since the coefficients are also nonunique. The traditional way to deal with this problem is to use a Chi-square statistic to test the estimated regression coefficients jointly. In this study, regression analysis (rather than the factor analysis) was used to obtain the unique measure of factor sensitivities.

Most empirical studies of the APT did not interpret or identify the common factors extracted by factor analysis. That is, the economic meaning of the common factors is an unsettled problem. The presence of a set of unnamed common factors in the APT is not better than the existence of the unobservable market portfolio in the CAPM for the purpose of the practical application of both theories. This study proposes an approach of constructing corporate bond portfolios to make it easier to interpret (or identify) the common factors extracted from the factor analysis.

2. Previous Tests of the APT

Empirical results of the previous tests of the APT were mixed. Evidence for the APT includes Roll and Ross (1980), Chen (1983), and Pari and Chen (1984). Evidence against the APT includes Reinganum (1981), Dhrymes et al. (1985a), and Lehmann and Modest (1985). Previous empirical work was restricted to the application of the APT to common stock returns, with the only exception of Gultekin and Rogalski (1985). It is equally important to examine the APT using corporate bond returns.

The traditional way of testing the APT (i.e., factor analysis) has its drawbacks as reviewed in Section C.1 of this chapter. A recent study (Burmeister and Wall, 1986) proposed an alternative way of testing the APT through regression analysis. The advantage of the new approach (the regression analysis) is that the drawbacks with the factor analysis can be avoided. However, the new approach has its shortcomings too. For example, the selection of risk factors determining asset returns is not theoretically sound. In addition, the measurement of the selected risk factors is a problem far from settled.

The application of factor analysis in testing the APT has another practical (or technological) limitation. That is, the decomposition of a large variance-covariance matrix (e.g., 500x500) of security returns, if not numerically impossible, would be exorbitantly expensive given current computer technology. Therefore, two feasible alternatives were employed in empirical studies: one is the group approach (Roll and Ross, 1980;

Cho, 1984); the other is the portfolio approach (Lehmann and Modest, 1985; Gultekin and Rogalski, 1985).

The group approach first divides large numbers of securities into several groups of small numbers of securities, then, factor analysis is performed on each group. The portfolio approach first constructs securities portfolios from a large number of securities, and then performs factor analysis on the variance-covariance matrix of portfolio returns. Each approach has its disadvantages. The group approach cannot get exactly the same common factors for each group. For example, the first common factor obtained from group one does not necessarily correspond to the first common factor obtained from group two. The portfolio approach tends to diversify away individual securities' characteristics and therefore reduces the number of common factors extracted.

One advantage of the portfolio approach is that security portfolios can be formed according to the strategy for testing the APT. For example, Lehmann and Modest (1985) formed stocks portfolios on the basis of firm size and dividend yield to examine the ability of the APT to account for the well-documented empirical anomalies of the firm size effect and dividend effect.

Using the portfolio approach, Gultekin and Rogalski (1985) applied the APT to government bonds. They constructed government bond portfolios according to the term to maturity of government bonds. Although they did not intend to identify the extracted common factors, the first common factor was found to be related to maturities of government bonds.

Gultekin and Rogalski's (1985) study raised the following issues: (1) Can more factors, other than the maturity factor, be identified if the strategy of constructing bond portfolios is extended to take into account more bonds' characteristics such as coupon rate and bond grade? (2) Given that the factor loadings obtained from the factor analysis are not unique, how can they be applied to portfolio management? To investigate the first question, the APT should be applied to corporate bond returns. The second question involves testing the APT through a statistical method other than factor analysis.

The APT does not prespecify the common factors determining asset prices. However, given that these common factors are known in advance, it is possible to test the APT by using regression analysis. Burmeister and Wall (1986) hypothesized that, in an APT framework, asset returns are influenced by four macroeconomic factors: (1) unexpected change in risk premiums or default risk measured as the return on corporate bonds in period t minus the return on government bonds in period t, (2) unexpected change in the term structure measured as the return on government bonds in period t minus the return on Treasury bills in period t, (3) unexpected inflation, and (4) unanticipated change in the growth rate of final sales of real goods. Using these macroeconomic factor measures, they showed that estimates of factor sensitivities for both portfolios and individual stocks can be obtained using time series regression.

Burmeiser and Wall's approach avoided the drawbacks of factor analysis in testing the APT. Their estimates of factor sensitivities are unique and therefore have implications for strategic portfolio management. However, the estimates of the hypothesized risk factors should be further discussed since the measurement of independent variables are crucial in a regression analysis. Besides, their selection of risk factors are somewhat ad hoc. It would be better to investigate the common factors through the strategic portfolio approach of factor analysis.

This chapter reviewed the three sources of corporate bond risk which are commonly perceived by bond investors. In this study, bond characteristics related to the three types of risk are the basis for the strategic portfolio construction for extracting common factors. Since the APT is testable on subsets of the assets, it is meaningful to investigate corporate bond risk by the use of the APT. This study proposes a procedure which first extracts common factors through factor analysis and then obtains a set of unique measures of factor sensitivities through regression analysis. The proposed procedure provides a possible way of applying the APT to the management of bond portfolios.

ENDNOTES

[1]Inflation risk and interest rate risk are two different sources of bond risk conceptually. In this study, inflation risk was measured by the percent changes in CPI and interest rate risk was measured by the information contained in the term structure of interest rates. See Chapter IV for details.

[2]Most corporate bonds are callable; however, most government bonds are not callable.

[3]The income from corporate bonds is taxable and there is no longer a separate capital gains tax. Thus, there is no systematic bias within corporate bonds due to different tax features.

[4]There are other studies related to the investigation of corporate bond risk. For example, Fisher (1959) investigated the determinants of the corporate bond risk premium by using internal corporate variables as risk factors. Merton (1974) and Weinstein (1983) examined corporate bond risk by the use of the Black-Scholes Options Pricing Model. Silvers (1973) investigated the determinants of the bond price rather than the risk premium. Detail reviews are not provided since they are less related to the main concern of this study.

[5]See Chapter IV and Appendix A for a detailed description of the two-stage tests of the APT.

CHAPTER III

THEORETICAL FRAMEWORK: THE APT

A. Introduction

The APT is a multifactor model that formulates the risk-return relationship of market assets. However, it does not prespecify the risk factors which affect assets' returns. In order to test the APT, it is necessary to derive the testable implications of the theory. In this chapter, two types of a testable ex post form of the APT were provided. One is to be tested through factor analysis. The other can be tested by using regression analysis.

B. The Arbitrage Pricing Theory

Formulated by Ross (1976), the APT assumes that asset markets are perfectly competitive and individuals believe that returns on assets are generated by a k-factor model as follows:

$$\tilde{R}_i = E_i + b_{i1}\tilde{F}_1 + b_{i2}\tilde{F}_2 + \ldots + b_{ik}\tilde{F}_k + \tilde{\varepsilon}_i \tag{3.1}$$

where $\tilde{R}_i$ is the return on asset i; E_i is the expected return for asset i; $\tilde{F}$'s are the mean zero factors common to all assets; b_{ik} is the sensitivity of the return on asset i to the fluctuations in factor k; $\tilde{\varepsilon}_i$ is an idiosyncratic effect on asset i's return which, by assumption, is completely diversifiable in large portfolios and has a mean of zero.

The economic argument of the APT is that, in the absence of riskless arbitrage profits, the return on a zero-investment, zero-systematic-risk portfolio is zero, as long as the idiosyncratic effects vanish in a large portfolio. An algebraic consequence of this no-arbitrage-opportunity argument is that there exists some constant λ_0, λ_1, λ_2, ..., λ_k such that

$$E_i \approx \lambda_o + \lambda_1 b_{i1} + \lambda_2 b_{i2} + \ldots + \lambda_k b_{ik} \qquad (3.2)$$

If it is possible to construct a portfolio that costs a dollar and has zero total risk, then the intercept λ_0 corresponds to the riskless rate (i.e., $\lambda_0 = R_f$). Otherwise, λ_0 should be zero since the zero beta return is implicit in the linear factor model for security returns. The other parameters λ_1, λ_2, ..., λ_k can be interpreted as risk premiums corresponding to risk factors $\tilde{F}_1$, $\tilde{F}_2$, ..., $\tilde{F}_k$. In other words, λ_k equals $E_k - R_f$, where E_k is the expected return on a portfolio with unit systematic risk on factor k and no risk on any other factor. Therefore, Equation (3.2) can be rewritten as:

$$E_i = R_f + (E_1 - R_f)b_{i1} + (E_2 - R_f)b_{i2} + \ldots + (E_k - R_f)b_{ik} \qquad (3.3)$$

Thus, similar in spirit to the CAPM, Equation (3.3) implies that the expected return on an asset or portfolio will be approximately equal to the risk-free rate (R) plus an overall risk premium $(E_1 - R_f)b_{i1} + (E_2 - R_f)b_{i2} + \ldots + (E_k - R_f)b_{ik}$. The APT does not prespecify the number of factors which may affect securities' returns. Thus, if there should be only one such factor, the CAPM may be reinterpreted as a special case of the APT. The advantage of doing so is that the restrictive assumptions required to validate the CAPM can be avoided and it can be viewed as an arbitrage rather than an equilibrium construct. The absence-of-arbitrage condition is necessary but not sufficient for the economy to be in equilibrium. Thus, the APT is a more fundamental relationship than the CAPM in the sense that a rejection of the APT implies the rejection of the CAPM but not vice versa.

C. Empirical Implications of the APT

As discussed in Roll and Ross (1980), the APT can be generalized into the multi-period context. Thus, Equations (3.1) and (3.3) become respectively

$$\tilde{R}_{it} = E_{it} + b_{i1}\tilde{F}_{1t} + b_{i2}\tilde{F}_{2t} + \dots + b_{ik}\tilde{F}_{kt} + \tilde{\varepsilon}_{it} \tag{3.4}$$

$$E_{it} = R_{ft} + (E_{1t} - R_{ft})b_{i1} + (E_{2t} - R_{ft})b_{i2} + \dots + (E_{kt} - R_{ft})b_{ik} \tag{3.5}$$

Since the common factors ($\tilde{F}$'s) in Equation (3.4) are unspecified and therefore unobservable, it is not possible to test the linear model of Equation (3.4) directly by the use of linear regression. Fortunately, the statistical technique of factor analysis makes it possible to extract common factors ($\tilde{F}$'s) through the analysis of the observable assets' returns ($\tilde{R}$'s). The purpose of factor analysis is to describe the covariance relationships among many variables in terms of a few underlying, but unobservable, random quantities called factors. Given that the observable random vector $\tilde{X}$ has mean μ, then the orthogonal factor model with k common factors is

$$\tilde{X}_i = \mu_i + \ell_{i1}\tilde{F}_1 + \ell_{i2}\tilde{F}_2 + \dots + \ell_{ik}\tilde{F}_k + \tilde{\varepsilon}_i \tag{3.6}$$

where μ_i = mean of variable i;

ℓ_{ik} = factor loadings of the ith variable on the kth factor;

$\tilde{F}_k$ = the kth common factor; and

$\tilde{\varepsilon}_i$ = the ith specific factor.

The unobservable random vectors $\tilde{F}$ and $\tilde{\varepsilon}$ are assumed to satisfy

$\tilde{F}$ and $\tilde{\varepsilon}$ are independent,

$E(\tilde{F}) = 0$, $Cov(\tilde{F}) = Id$, where Id is an identity matrix,

$E(\tilde{\varepsilon}) = 0$, $Cov(\tilde{\varepsilon}) = \Psi$, where Ψ is a diagonal matrix.[6]

Thus, given the similarity of the APT as in Equation (3.4) and the orthogonal factor model as in Equation (3.6), it is possible to obtain those factor sensitivities b_{ik}'s in Equation (3.4) by the use of factor analysis. However, the APT requires that the common factors in Equation (3.4) be priced, i.e., the risk premiums $(E_{kt} - R_{ft})$ in Equation (3.5) should be nonzero. It is possible to obtain a statistical common factor which has no economic influence on assets' returns and therefore is not priced.

To test the APT empirically, it is necessary to perform some mathematical manipulations as follows. First, define factor portfolio j as a well-diversified portfolio with unit systematic risk on factor j and no risk on the other factors.[7] The return on factor portfolio j in period t can be expressed as

$$\tilde{R}_{jt} = R_{ft} + (E_{jt} - R_{ft}) + \tilde{F}_{jt} \tag{3.7}$$

or

$$(E_{jt} - R_{ft}) = \tilde{R}_{jt} - R_{ft} - \tilde{F}_{jt} \tag{3.8}$$

Substituting from Equation (3.8) for $(E_{jt} - R_{ft})$ in Equation (3.5),

$$E_{it} = R_{ft} + \sum_{j=1}^{k} (\tilde{R}_{jt} - R_{ft} - \tilde{F}_{jt}) b_{ij} \tag{3.9}$$

Adding $\sum_{j=1}^{k} b_{ij}\tilde{F}_{jt} + \varepsilon_{it}$ to both sides of Equation (3.9),

$$E_{it} + \sum_{j=1}^{k} b_{ij}\tilde{F}_{jt} + \tilde{\varepsilon}_{it} = R_{ft} + \sum_{j=1}^{k} (R_{jt} - R_{ft} - \tilde{F}_{jt}) b_{ij} + \sum_{j=1}^{k} b_{ij}\tilde{F}_{jt} + \tilde{\varepsilon}_{it} \tag{3.10}$$

Since the left-hand side of Equation (3.10) equals $\tilde{R}_{it}$, Equation (3.10) reduces to

$$\tilde{R}_{it} = R_{ft} + \sum_{j=1}^{k} (\tilde{R}_{jt} - R_{ft}) b_{ij} + \tilde{\varepsilon}_{it} \tag{3.11}$$

Equation (3.11) recasts Equation (3.5) in terms of ex post values. Thus, according to the APT, the realized returns in period t on any security or portfolio ($\tilde{R}_{it}$) can be expressed as a linear function of its systematic risks (b_{ij}), the realized returns on k factor portfolios ($\tilde{R}_{jt}$), the risk-free rate or the return on a zero-beta portfolio (R_{ft}), and a random-error return ($\tilde{\varepsilon}_{it}$) that has an expected value of zero.

The factor sensitivities (b_{ik}'s) in Equation (3.11) can be obtained from factor analysis. To test whether the common factors obtained from factor analysis are priced, the realized returns ($\tilde{R}_{it}$'s) in Equation (3.11) can be cross-sectionally regressed on the factor sensitivities (b_{ij}'s). That is

$$\tilde{R}_i = R_f + (\tilde{R}_1 - R_f)b_{i1} + (\tilde{R}_2 - R_f)b_{i2} + \ldots + (\tilde{R}_k - R_f)b_{ik} + \tilde{\varepsilon}_i \qquad (3.12)$$

There are two testable implications of the APT: first, the intercept term in Equation (3.12) is the risk-free or zero-beta return; and second, cross-sectional returns are linearly related to the factor sensitivities (b_{ik}'s), that is, the coefficients (or risk premiums) in Equation (3.12) are statistically different from zero (or economically priced).

D. An Alternative Way of Testing the APT

The application of factor analysis has its statistical drawbacks as reviewed in Chapter II. The primary economic difficulty with factor analysis is that the factors cannot be directly associated with macroeconomic variables and hence the factor sensitivities do not have direct economic interpretations. An alternative way to test the APT is to run time-series regressions of realized returns on a set of hypothesized risk factors which have economic meanings. To derive such a model, substituting from Equation (3.5) for E_{it} in Equation (3.4), results in

$$\tilde{R}_{it} = R_{ft} + \sum_{j=1}^{k} (E_{jt} - R_{ft})b_{ij} + b_{i1}\tilde{F}_{1t} + \dots + b_{ik}\tilde{F}_{kt} + \tilde{\varepsilon}_{it} \quad (3.13)$$

Assume that the risk free rate is a constant (R_f) through time, and that risk premiums are constants ($\sum_{j=1}^{k} (E_j - R_f)$). Equation (3.13) becomes

$$\tilde{R}_{it} = R_f + \sum_{j=1}^{k} (E_j - R_f)b_{ij} + b_{i1}\tilde{F}_{1t} + b_{i2}\tilde{F}_{2t} + \dots + b_{ik}\tilde{F}_{kt} + \tilde{\varepsilon}_{it} \quad (3.14)$$

or,

$$\tilde{R}_{it} = b_{i0} + b_{i1}\tilde{F}_{1t} + b_{i2}\tilde{F}_{2t} + \dots + b_{ik}\tilde{F}_{kt} + \tilde{\varepsilon}_{it} \quad (3.15)$$

where $b_{i0} = R_f + \sum_{j=1}^{k} (E_j + R_t)b_{ij}$.

According to the APT, each and every risk factor $\tilde{F}$ in Equation (3.15) (or Equation (3.4)) has an expected value of zero. The economic interpretation of these zero-mean risk factors is that they influence assets' returns only through their unanticipated changes. All the anticipated changes have been captured by the expected returns (i.e., the intercept term). Thus, it is possible to test the linear model of Equation (3.15) through time-series regressions. Of course, the unanticipated changes in the hypothesized risk factors should be measured in advance. As discussed in Section IV.D, the three hypothesized risk factors are inflation risk, interest rate risk, and default risk. These three risk factors are similar to those employed by Roll and Ross (1984b) and Burmeister and Wall (1986) except that they used one additional risk factor of industrial production (as in Roll and Ross, 1984b) or the growth rate of real final sales (as in Burmeister and Wall, 1986). The unanticipated measures of the three risk factors will be discussed in Chapter IV.

ENDNOTES

[6]See Johnson and Wichern (1982) and Appendices A and B for detailed illustration of factor analysis.

[7]See Chang and Lewellen (1985) for the estimation of factor portfolios.

CHAPTER IV

METHODOLOGY

A. Introduction

As reviewed in Chapter II, the APT can be tested by using the statistical technique of either factor analysis or regression analysis. Each method has its weaknesses and strengths. This empirical study intended to minimize (or avoid) the drawbacks associated with testing the APT. Therefore, both of the two statistical techniques were employed.

Factor analysis was used in the first part of this study to extract common factors affecting corporate bond returns. An approach which constructs corporate bond portfolios according to a bond's characteristics was proposed to facilitate the interpretation (or identification) of the economic meanings of the extracted common factors. The implications of the APT were also tested.

In the second part of this research, three types of risk which are related to the common factors obtained in the first part were hypothesized to be the risk factors affecting corporate bond returns. Regression analysis was used to test the hypothesized relationship and to estimate the unique measures of factor sensitivities. The measures of the three hypothesized risk factors were also discussed.

This chapter consists of three sections. Section B describes the sources of data. Sections C and D describe the statistical procedures of the first part and the second part of this research respectively.

B. Data

1. Monthly Holding Period Return

The monthly corporate bond data were collected from Moody's Bond Record covering a five-year period, January 1981 through December 1985.[8] Values of the coupon rate, maturity date, month-end price, and yield to maturity were collected from issues which met the following criteria:

1. A rating by Moody's of Aaa, Aa, Baa, Ba, or B;
2. Publicly offered term issues;
3. No more than one bond selected from the same issuer; and
4. Available month-end price data for all issues.[9]

Data on about 400 corporate bond issues were collected as of the end of each month.[10] The monthly holding period returns and bond yields (YTM) were obtained for each bond. The monthly holding period returns (R_t) were calculated as follows:

$$R_t = \frac{P_t - P_{t-1} + C_t}{P_{t-1}} , \tag{4.1}$$

where P_t and P_{t-1} refer to the bond's market prices at the end of month t and t-1 respectively, and C_t is the accrued interest in month t.

2. Other Data

The percent changes in CPI were collected from the CPI Detailed Report published by U.S. Department of Labor. Government bond data were collected from Standard and Poor's Bond Guide. Kalman-filtering estimates of unanticipated inflation were obtained from Burmeister, Wall, and Hamilton (1986).

C. Factor Analysis

The tests of the APT by the use of factor analysis proceeded in the following steps.

1. Twelve corporate bond portfolios were formed on the basis of bond characteristics.

2. The variance-covariance matrix was computed from the time series of portfolio returns.

3. A principal factor analysis was performed on the variance-covariance matrix. This estimated the factor loadings matrix.

4. The estimated factor loadings from the previous step were used to explain the cross-sectional variation of portfolio returns.

5. Estimates from the cross-sectional regression (i.e., Step 4) were used to calculate the Chi-square statistic for testing the joint significance of risk premiums.

The first three steps were referred to as the first stage tests of the APT in this study. Steps four and five were the second stage.

1. The Construction of Bond Portfolios

As reviewed in Chapter II, most empirical tests of the APT by factor analysis employ either the group approach or the portfolio approach. One advantage of using the portfolio approach is that portfolios can be formed according to the purpose of the test. This research intended to identify (or interpret) the common factors determining corporate bond returns. Therefore, bond portfolios were constructed in such a way that the interpretation of the extracted common factors is easier.

Since the factor loadings indicate the correlation between each portfolio and common factor, they can be used to describe the general nature of the common factors. For example, if the factor loadings for the first common factor were in a pattern that speculative-grade-bond-portfolios' first factor loadings were significantly different from investment-grade-bond-portfolios', then the first common factor may be interpreted as a default-risk-factor.

In this study, bond portfolios were constructed according to bond characteristics such as coupons, maturities, and bond grades. Bond grades were used to take into account bonds' default risk. As the coupon and the maturity of a bond are related to the bond's interest rate sensitivity, both coupons and maturities were used to take into account bonds' interest rate risk.[11] Specifically, at the end of each month, bond portfolios were constructed according to the following criteria: (1) investment grade bonds or speculative grade bonds; (2) low coupon bonds or high coupon bonds[12]; (3) term to maturity. The grouping boundaries for term to maturity are (a) less than 10 years; (b) 10 to 19 years; and (c) 20 or more years to maturity. These boundaries are arbitrary. A total of 12 (i.e., 2x2x3) bond portfolios was formed.

2. The Tests of the APT

Each portfolio return was computed as a simple average of the individual bond returns in that portfolio. The empirical variance-covariance matrix was computed from the 12 portfolio returns. The first stage of the tests of the APT was to factor-analyze the estimated variance-covariance matrix. In the factor analysis, the factor loadings were inferred from the estimated variance-covariance matrix. In matrix notation, the estimated variance-covariance matrix, $\hat{V}$, is decomposed into

$$\hat{V} = \hat{B}\hat{B}' + \hat{D} \tag{4.2}$$

where $\hat{B}$ is the matrix of factor loadings, and $\hat{D}$ is the diagonal matrix of own portfolio variances (see Appendix B for details).

To simplify the structure of the common factors, a varimax orthogonal rotation was used to obtain the final factor loadings matrix.[13] This procedure facilitated the economic interpretation of the common factors through a visual inspection of the rotated factor loadings matrix.

The second stage of testing the APT was to regress the cross-sectional portfolio returns on the estimated factor loadings (as independent variables) for each time period. That is,

$$\tilde{R}_i = \lambda_0 + \lambda_1 b_{i1} + \lambda_2 b_{i2} + \ldots + \lambda_k b_{ik} + \tilde{\varepsilon}_i \tag{4.3}$$

The two testable implications of the APT are: (1) intercept term (λ_0) is the risk-free or zero-beta return; (2) the coefficients (or risk premiums, λ's) are jointly different from zero. The two null hypotheses are as follows.

H_1: $\lambda_0 = 0$,

H_2: $\lambda_1 = \lambda_2 = \ldots = \lambda_k = 0$

The test of the intercept term was done by using the t-statistic. Since the estimated factor loadings are unique only up to an orthogonal transformation, no importance can be ascribed to the signs and numerical values of λ's. Therefore, the significance of the risk premiums should be tested jointly. A Chi-square statistic (as described in Appendix A) was used for testing the joint significance of risk premiums. Appendix A gives the statistical details of the tests of the APT.

D. Time Series Regression

The nonuniqueness of the estimated factor loadings makes the tests of the APT imprecise and the application of the APT to portfolio management difficult. Furthermore, the interpretation of common factors through visual inspection of the rotated factor loadings is somewhat subjective. To verify the significance of the risk factors identified in the first part of this study, and to obtain the unique measure of factor sensitivities, Equation (3.15) was hypothesized and tested by using regression analysis in the following manner:

Return = b_0 + b_1(unanticipated inflation risk) + b_2(unanticipated interest rate risk) + b_3(unanticipated default risk) + random error.

The measures of unanticipated changes in inflation, interest rates, and default risk premiums are discussed below.

1. The Unanticipated Change in Inflation

Fama (1975) found that the nominal interest rate for a given month (R_f) minus the average real rate ($\bar{r}_r$) appeared to be the best unbiased estimator of the rate of inflation for that month. This implies that the actual inflation rate (I) minus the anticipated inflation rate (i.e., $I - (R_f - \bar{r}_r)$) might serve as an estimate of unanticipated inflation.

Using the Kalman-filtering technique, Burmeister, Wall, and Hamilton (1986) obtained a monthly series of unbiased, rational, and efficient estimates of unanticipated inflation. Both Fama's estimates and Burmeister, Wall, and Hamilton's estimates were used in this dissertation as measures of unanticipated inflation.

2. The Unanticipated Change in Interest Rates

The term structure of interest rates can be used to measure unanticipated changes in interest rates because interest rate risk arises from the impact of the changes in the level of interest rates on the values of the multiple period cash flows and principals of different maturities. Van Horne (1965) used U.S. Treasury yield curve data and tested certain variations of the error-learning model. The results supported the notion that interest rate expectations are important in explaining the term structure of interest rates and that they are revised systematically when actual rates of interest differ from those that had been anticipated. This finding implies that forward rates are rational expectations of future interest rates. Therefore, the unanticipated changes in interest rates may be measured as the actual interest rate minus the forward rate.

According to the Unbiased Expectation Theory of the term structure of interest rates,

$$(1 + {}_{t-1}RF_{2,t-1})^2 = (1 + {}_{t-1}RF_{1,t-1})(1 + {}_{t}\hat{RF}_{1,t-1}) \qquad (4.4)$$

where RF is the actual treasury debt return (i.e., a spot rate);

$\hat{RF}$ is the forecasted treasury debt return;

the first subscript refers to the time when the rate becomes applicable;

the second subscript refers to the length of the debt; and

the third subscript refers to the point of reference in time.

From Equation (4.4), the forecasted one-period interest rate is

$${}_{t}\hat{RF}_{1,t-1} = \frac{(1 + {}_{t-1}RF_{2,t-1})^2}{(1 + {}_{t-1}RF_{1,t-1})} - 1 \qquad (4.5)$$

Thus, the unanticipated change in interest rate is ${}_{t}RF_{1,t} - {}_{t}\hat{RF}_{1,t-1}$.

Roll and Ross (1984b) described unanticipated changes in the slope of the term structure of interest rates as an APT economic factor. Burmeister and Wall (1986) measured unanticipated changes in the term structure as the return on government bonds in period t minus the return on Treasury bills in period t. Burmeister and Wall did not provide the equation for calculating their measure. However, a duplication of their measure of unanticipated changes in the term structure was calculated for this study as follows:

$$URF_t = LGD_t - SGD_t - EGD_t \tag{4.6}$$

where URF_t are the unanticipated changes in the term structure in period t;

LGD_t is the return on long-term government debt in period t;

SGD_t is the return on short-term government debt in period t;

EGD_t is the difference between the expected returns on long-term and short-term government debts in period t.

Burmeister and Wall's measure was also used in this study.

3. The Unanticipated Change in the Default Risk Premium

The difference between the return on corporate debt and the return on a comparable government debt is generally referred to as the default risk premium.[14] Thus,

$${}_tR_{1,t} = {}_tRF_{1,t} + {}_tDRP_{1,t} \tag{4.7}$$

$${}_tR_{2,t} = {}_tRF_{2,t} + {}_tDRP_{2,t} \tag{4.8}$$

$${}_t\hat{R}_{1,t-1} = {}_t\widehat{RF}_{1,t-1} + {}_t\widehat{DRP}_{1,t-1} \tag{4.9}$$

where DRP is the actual default risk premium;

$\widehat{DRP}$ is the expected default risk premium;

R is the actual corporate debt return; and

$\hat{R}$ is the expected corporate debt return.

Since $(1 + {}_{t-1}R_{2,t-1})^2 = (1 + {}_{t-1}R_{1,t-1})(1 + {}_t\hat{R}_{1,t-1})$, (4.10)

substituting Equation (4.9) into Equation (4.10) for ${}_t\hat{R}_{1,t-1}$, results in

$$(1 + {}_{t-1}R_{2,t-1})^2 = (1 + {}_{t-1}R_{1,t-1})(1 + {}_t\widehat{RF}_{1,t-1} + {}_t\widehat{DRP}_{1,t-1}). \quad (4.11)$$

Solving (4.11) for ${}_t\widehat{DRP}_{1,t-1}$, yields the following expression,

$${}_t\widehat{DRP}_{1,t-1} = \frac{(1 + {}_{t-1}R_{2,t-1})^2}{(1 + {}_{t-1}R_{1,t-1})} - (1 + {}_t\widehat{RF}_{1,t-1}) , \quad (4.12)$$

substituting Equation (4.4) into Equation (4.12) for $(1 + {}_t\widehat{RF}_{1,t-1})$, yields,

$${}_t\widehat{DRP}_{1,t-1} = \frac{(1 + {}_{t-1}R_{2,t-1})^2}{(1 + {}_{t-1}R_{1,t-1})} - \frac{(1 + {}_{t-1}RF_{2,t-1})^2}{(1 + {}_{t-1}RF_{1,t-1})} \quad (4.13)$$

The first term on the right hand side is the expected one-period corporate bond return and the second term is the expected one-period government bond return. Equation (4.13) is exactly the same as Equation (4.9) expressed in terms of observable actual returns. ${}_t\widehat{DRP}_{1,t-1}$ is the expected one-period default risk premium applicable at time t, when the expectation is made at time t-1. From Equation (4.7), the actual one-period default risk premium at time t is

$${}_tDRP_{1,t} = {}_tR_{1,t} - {}_tRF_{1,t} \quad (4.14)$$

Therefore, the unanticipated default risk premium for time period t is

$$({}_tDRP_{1,t} - {}_t\widehat{DRP}_{1,t-1}) = ({}_tR_{1,t} - {}_tRF_{1,t}) - \left[\frac{(1 + {}_{t-1}R_{2,t-1})^2}{(1 + {}_{t-1}R_{1,t-1})} - \frac{(1 + {}_{t-1}RF_{2,t-1})^2}{(1 + {}_{t-1}RF_{1,t-1})}\right] \quad (4.15)$$

Roll and Ross (1984) measured the unanticipated changes in risk premiums by the spread between low grade and high grade bonds. Burmeister and Wall (1986) measured the unexpected change in default risk as the return on corporate bonds minus the return on government bonds. Burmeister and Wall did not provide the equation for calculating their measure. However, a duplication of their measure of unanticipated change in default risk was calculated in this study as follows:

$$UDRP_t = CD_t - GD_t - ED_t \tag{4.16}$$

where $UDRP_t$ is the unanticipated change in default risk;

CD_t is the return on corporate debt in period t;

GD_t is the return on Treasury debt in period t; and

ED_t is the difference between the expected returns on corporate and Treasury debts in period t.

Burmeister and Wall's measure was also used in this study.

4. Estimation of Factor Sensitivities

To test that the three hypothesized risk factors have influences on corporate bond returns, the following time series regressions, using Equation (3.15), were estimated:

$$\tilde{R}_{it} = b_{i0} + b_{i1}\,\widetilde{UI}_t + b_{i2}\,\widetilde{URF}_t + b_{i3}\,\widetilde{UDRP}_t + \tilde{\varepsilon}_{it} \tag{4.17}$$

where $\tilde{R}_{it}$ is the realized return on corporate bond portfolios in period t;

$\widetilde{UI}_t$ is the unanticipated change in inflation in period t;

$\widetilde{URF}_t$ is the unanticipated change in interest rates in period t;

$\widetilde{UDRP}_t$ is the unanticipated change in the default risk premium in period t;

b_{i0} is the expected return of a corporate bond portfolio which is equal to the risk free rate plus the expected risk premiums;

b_{i1}, b_{i2}, and b_{i3} are factor sensitivities; and

$\tilde{\varepsilon}_{it}$ is the residual term.

The null hypotheses were:

H_3: $b_{i0} = 0$, $b_{i1} = 0$, $b_{i2} = 0$, $b_{i3} = 0$.

The estimated regression coefficients b_{i1}, b_{i2}, and b_{i3} are the unique measures of factor sensitivities which can be applied to strategic portfolio planning. There is nothing to prevent a factor sensitivity from being negative. If this were the case, then a rise in the factor would cause this portfolio's return to fall. Intuitively, the signs of b_{i1}, b_{i2}, and b_{i3} are all expected to be positive.

ENDNOTES

[8]Fifty-nine monthly holding period returns were calculated from January 1981 through November 1985.

[9]Bonds with equity features such as warrants or conversion privileges were excluded; most bonds were callable.

[10]This is essentially the population according to the selection criteria.

[11]Duration was not used directly since a corporate bond's YTM, which is one of three inputs in calculating duration, is also related to the bond's default risk.

[12]Low coupon bonds were bonds with a coupon rate lower than 8%, high coupon bonds were bonds with a coupon rate greater than 10%.

[13]The orthogonal rotation leaves the space spanned by the factor loadings unchanged, altering only the directions of the defining basis vectors.

[14]The difference between a corporate debt issue and a comparable government debt issue also includes callability and taxability features. The call feature is negligible if the issues mature in one or two months.

CHAPTER V

EMPIRICAL RESULTS

A. Introduction

This chapter presents the empirical results of this study. Section B provides the results associated with the tests of the APT using factor analysis. Three factors were identified, with the first factor, interpreted as the default risk factor, dominating the other factors. The joint test of the risk premiums did not provide support for the three-factor-model APT at either the ten or five percent level of significance.

The empirical results of the second part of this study are reported in Section C. The findings confirmed that default risk is the dominant factor in corporate bond risk. The evidence did not support either inflation risk or interest rate risk as significant factors of corporate bond risk.

Section D provides an analysis of the empirical results. Both parts of this study revealed that default risk is the most important factor determining corporate bond returns. This finding is encouraging given that previous studies (Percival, 1974; Reilly and Joehnk, 1976; and Weinstein, 1981) found that the CAPM's beta cannot capture bond's default risk. The empirical procedure also has important implications for the application of the APT to the management of corporate bond portfolios.

B. Factor Analysis

1. The First Stage Tests of the APT

Before performing the factor analysis, the statistical characteristics of the returns on the 12 corporate bond portfolios were examined in order to determine whether these bond data are similar to those used in other studies. Table I presents the mean, standard deviation, and skewness of the monthly holding period returns for the 12 corporate bond portfolios. Table I indicates the following: (1) holding coupon and term to maturity constant, mean returns on speculative grade bond portfolios are greater than mean returns on investment grade bond portfolios, (2) holding coupon and bond grade constant, mean returns on long-term bond portfolios are greater than mean returns on short-term bond portfolios, (3) most portfolios are slightly positively skewed with the skewnesses around zero, with only one exception which is 2.137 for the low-coupon, long-term speculative grade bonds' portfolio, and (4) the higher the mean return, the higher the standard deviation, i.e. high return is directly related to high risk.

Table II contains the estimated correlation matrix for corporate bond portfolio monthly returns. A rough investigation of Table II reveals that (1) the returns on the 12 portfolios are highly correlated (except the low-coupon, long-term speculative bond portfolio and (2) returns on the six investment grade bond portfolios are highly correlated, while returns on the six speculative grade bond portfolios are correlated to a lesser degree. This confirms the findings of Broske (1985a) that investment grade bonds (i.e., Moody's ratings of Aaa, Aa, A, and Baa) are close substitutes.

TABLE I

SUMMARY STATISTICS FOR MONTHLY RETURNS ON CORPORATE BOND PORTFOLIOS
(JAN. 81-NOV. 85)

Portfolio	HiCp,[a] ShTm, Inv.	HiCp, ShTm, Spe.	LwCp, ShTm, Inv.	LwCp, ShTm, Spe.	HiCp, MdTm, Inv.	HiCp, MdTm, Spe.	LwCp, MdTm, Inv.	LwCp, MdTm, Spe.	HiCp, LgTm, Inv.	HiCp, LgTm, Spe.	LwCp, LgTm, Inv.	LwCp, LgTm, Spe.
Mean	1.302[b]	1.371	1.256	1.372	1.549	1.595	1.536	1.858	1.499	1.612	1.490	2.438
Standard Deviation	1.573	1.699	1.429	1.566	2.132	2.632	2.464	2.362	2.422	3.199	2.924	5.329
Skewness	.832	.592	.849	-.025	.570	.701	.386	.422	.554	.297	.684	2.137

[a]HiCp = High Coupon; LwCp = Low Coupon; ShTm = Short Term, MdTm = Medium Term; LgTm = Long Term; Inv. = Investment Grade; Spe. = Speculative Grade.

[b]Monthly returns are in percent.

TABLE II

ESTIMATED CORRELATION MATRIX FOR CORPORATE BOND PORTFOLIO MONTHLY RETURNS

Portfolio	HiCp,* ShTm, Inv.	HiCp, ShTm, Spe.	LwCp, ShTm, Inv.	LwCp, ShTm, Spe.	HiCp, MdTm, Inv.	HiCp, MdTm, Spe.	LwCp, MdTm, Inv.	LwCp, MdTm, Spe.	HiCp, LgTm, Inv.	HiCp, LgTm, Spe.	LwCp, LgTm, Inv.	LwCp, LgTm, Spe.
HiCp, ShTm, Inv.	1.000	.699	.874	.639	.869	.855	.854	.664	.853	.726	.899	.329
HiCp, ShTm, Spe.		1.000	.762	.604	.650	.713	.605	.541	.630	.485	.626	.277
LwCp, ShTm, Inv.			1.000	.644	.892	.845	.849	.692	.865	.704	.794	.293
LwCp, ShTm, Spe.				1.000	.645	.698	.644	.596	.594	.602	.576	.262
HiCp, MdTm, Inv.					1.000	.818	.923	.754	.947	.602	.863	.339
HiCp, MdTm, Spe.						1.000	.810	.713	.812	.696	.857	.339
LwCp, MdTm, Inv.							1.000	.732	.930	.619	.888	.300
LwCp, MdTm, Spe.								1.000	.740	.438	.694	.440
HiCp, LgTm, Inv.									1.000	.602	.885	.359
HiCp, LgTm, Spe.										1.000	.633	.283
LwCp, LgTm, Inv.											1.000	.341
LwCp, LgTm, Spe.												1.000

*Refer to Table I for the interpretation of abbreviations.

To factor-analyze the returns on the 12 corporate bond portfolios, the statistical method of principal factor analysis was performed on the variance-covariance matrix of portfolio returns. Table III presents the marginal and cumulative contributions of each factor in explaining the variance-covariance matrix of the 12 portfolio returns. It is quite obvious that the first factor dominates other factors since it explains 71.07 percent of the total variance of portfolio returns. The scree plot[15] of eigenvalues in Figure 1 also reveals that the first common factor is the dominant factor.

TABLE III

VARIANCE EXPLAINED BY EACH FACTOR

Factor	Proportion	Cumulative
1	.7107	.7107
2	.0751	.7858
3	.0561	.8419
4	.0459	.8878
5	.0384	.9262
6	.0214	.9476
7	.0192	.9668
8	.0109	.9777
9	.0090	.9867
10	.0057	.9924
11	.0041	.9965
12	.0035	1.0000

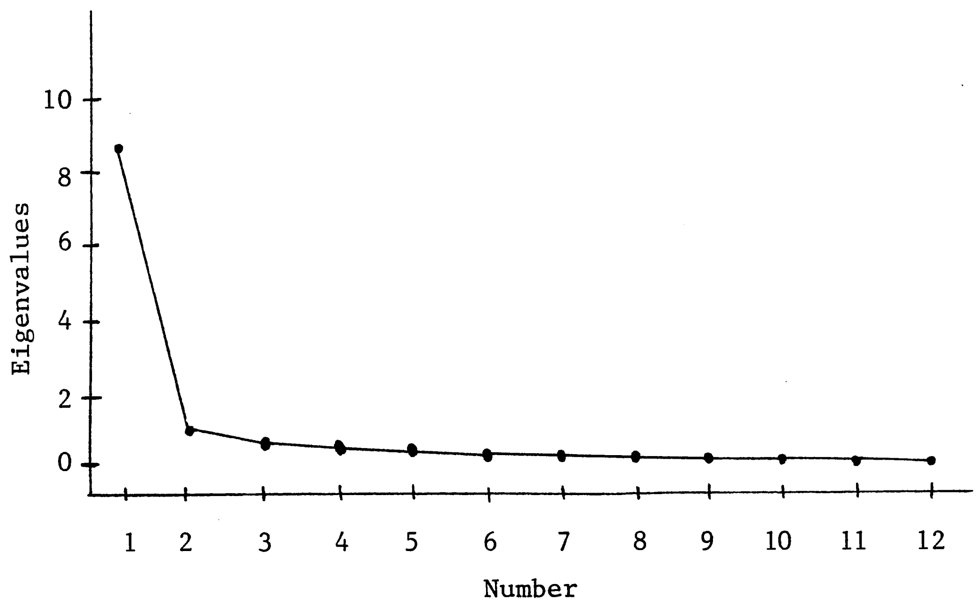

Figure 1. Scree Plot of Eigenvalues

As reviewed in Chapter II, the question of how many factors are underlying the APT is far from settled and that there is no obvious way to choose the number of factors. Nevertheless, Barlett's Chi-square test for the null hypothesis that k factors are sufficient indicates that the Chi-square values for one factor, two factors, and three factors are 117.859, 69.453, and 39.747, respectively. The corresponding probabilities (p-values) are .0001, .0065, and .1947.[16] Therefore, the three-factor-model was chosen based on some combination of (1) the proportion of portfolio variance explained, (2) knowledge of the main sources of corporate bond risk, and (3) the reasonableness of the results.

To simplify the structure of the common factors, a varimax orthogonal rotation is used to obtain the final loadings matrix. Table IV presents the rotated factor loadings for the three-factor model. The three factors presented in Table IV explain 84.19 percent of the total variability in bond portfolio returns. The underlined coefficients in Table IV represent the higher factor loading(s) for the respective common factor. They were used to facilitate the interpretation (or identification) of the three common factors as follows.

Since the factor loadings indicate the correlation between each portfolio and a common factor, they can be used to describe the general nature of the common factors. Table V presents the rotated factor loadings for the first common factor, where the portfolios are classified by bond grade. The six investment grade bond portfolios have the higher factor loadings; and their average is .758. The corresponding average for the six speculative grade bond portfolios is .335. Thus, a significant difference exists between the first factor loadings of the

TABLE IV

ROTATED FACTOR LOADINGS (DATA: MONTHLY RETURNS)

Portfolios	Factor 1	Factor 2	Factor 3
HiCp, LgTm, Inv.*	.85	.26	.26
LwCp, MdTm, Inv.	.83	.28	.22
HiCp, MdTm, Inv.	.82	.25	.28
LwCp, LgTm, Inv.	.76	.31	.26
HiCp, ShTm, Inv.	.66	.42	.35
LwCp, ShTm, Inv.	.63	.40	.45
HiCp, MdTm, Spe.	.54	.37	.36
LwCp, MdTm, Spe.	.47	.13	.20
LwCp, ShTm, Spe.	.29	.27	.26
LwCp, LgTm, Spe.	.13	.10	.09
HiCp, LgTm, Spe.	.28	.90	.17
HiCp, ShTm, Spe.	.30	.18	.88

*Refer to Table I for the interpretation of abbreviations.

TABLE V

ROTATED FACTOR LOADINGS FOR THE FIRST COMMON FACTOR
CLASSIFIED BY BOND GRADE

Investment Grade Bonds		Speculative Grade Bonds	
Portfolio	Factor Loadings for the First Common Factor	Portfolio	Factor Loadings for the First Common Factor
HiCp, LgTm, Inv.*	.85	HiCp, MdTm, Spe.	.54
LwCp, MdTm, Inv.	.83	LwCp, MdTm, Spe.	.47
HiCp, MdTm, Inv.	.82	HiCp, ShTm, Spe.	.30
LwCp, LgTm, Inv.	.76	LwCp, ShTm, Spe.	.29
HiCp, ShTm, Inv.	.66	HiCp, LgTm, Spe.	.28
LwCp, ShTm, Inv.	.63	LwCp, LgTm, Spe.	.13
Average	.758	Average	.335

*Refer to Table I for the interpretation of abbreviations.

two different grade portfolios. Since factor loadings are unique only up to an orthogonal transformation, it does not matter whether the investment grade portfolios or the speculative grade portfolios have the higher factor loadings. That is, the difference between the factor loadings of the two grades is important only in the interpretation of the common factor. Accordingly, the first common factor can be interpreted as a default risk factor.

Table VI presents the rotated factor loadings for the second common factor, where the portfolios are classified by coupon rate. The average of the six factor loadings for the high coupon bond portfolios is .397; while the corresponding average for the six low coupon bond portfolios is .248. The HiCp, LgTm, Spe. (high coupon) portfolio has the highest factor loading of .90; and the LwCp, LgTm, Spe. (low coupon) portfolio has the lowest factor loading of .10. This suggests that the second common factor is related to the coupon rate.

Table VII presents the rotated factor loadings for the third common factor, where the portfolios are classified by term to maturity. The averages of the four factor loadings for the short-term portfolios, the mid-term portfolios, and the long-term portfolios are .485, .265, and .195 respectively. This suggests that the third common factor is related to portfolios' terms to maturity. As reviewed in Chapter II, Gultekin and Rogalski (1985) also found a term-to-maturity factor in the government bond returns. It is also interesting to note that the high coupon, short term, speculative bond portfolio has the highest factor loading of .88; while the low coupon, long term, speculative bond portfolio has the lowest factor loading of .09. Accordingly, the third common factor may be interpreted as an interest-rate-risk factor since, presumably, the high coupon, short term portfolio has the shortest duration and the low coupon, long term portfolio has the longest duration.[17]

TABLE VI

ROTATED FACTOR LOADINGS FOR THE SECOND COMMON FACTOR CLASSIFIED BY COUPON RATE

High Coupon Bonds		Low Coupon Bonds	
Portfolio	Factor Loadings for the Second Common Factor	Portfolio	Factor Loadings for the Second Common Factor
HiCp, LgTm, Spe.*	.90	LwCp, ShTm, Inv.	.40
HiCp, ShTm, Inv.	.42	LwCp, LgTm, Inv.	.31
HiCp, MdTm, Spe.	.37	LwCp, MdTm, Inv.	.28
HiCp, LgTm, Inv.	.26	LwCp, ShTm, Spe.	.27
HiCp, MdTm, Inv.	.25	LwCp, MdTm, Spe.	.13
HiCp, ShTm, Spe.	.18	LwCp, LgTm, Spe.	.10
Average	.397	Average	.248

*Refer to Table I for the interpretation of abbreviations.

TABLE VII

ROTATED FACTOR LOADINGS FOR THE THIRD COMMON FACTOR CLASSIFIED BY TERM TO MATURITY

Short-Term Bonds		Medium-Term Bonds		Long-Term Bonds	
Portfolio	Factor Loadings for the Third Common Factor	Portfolio	Factor Loadings for the Third Common Factor	Portfolio	Factor Loadings for the Third Common Factor
HiCp, ShTm, Spe.*	.88	HiCp, MdTm, Spe.	.36	HiCp, LgTm, Inv.	.26
LwCp, ShTm, Spe.	.45	HiCp, MdTm, Inv.	.28	LwCp, LgTm, Inv.	.26
HiCp, ShTm, Inv.	.35	LwCp, MdTm, Inv.	.22	HiCp, LgTm, Spe.	.17
LwCp, ShTm, Spe.	.26	LwCp, MdTm, Spe.	.20	LwCp, LgTm, Spe.	.09
Average	.485	Average	.265	Average	.195

*Refer to Table I for the interpretation of abbreviations.

2. The Second Stage Tests of the APT

The second stage tests of the APT involved regressing the cross-sectional portfolio returns on the rotated factor loadings for each time period. In this step, the estimated intercept term and coefficients are interpreted as the risk free rate (or zero-beta return) and risk premiums respectively. The nonuniqueness of the factor loadings (i.e., the independent variables) makes the tests of the APT imprecise since the signs and magnitudes of the estimated regression coefficients are not unique either.

Table VIII presents some results of the cross-sectional regressions from January 1981 to November 1985. The t-statistic is for the null hypothesis that the intercept equals zero. The F-statistic is for the null hypothesis that the regression coefficients except the intercept term are jointly equal to zero. The P-value is the observed level of significance. The coefficient of determination (R^2) represents the proportion of variation in the dependent variable which is explained by the independent variables. An examination of Table VIII suggests that the tests are mixed as to the significance of the intercept term and of the regression coefficients as a whole. The interpretation of Table VIII is provided in Table IX.

The findings of Table VIII are summarized in Table IX. (1) Of the 59 cross-sectional regressions, 40 of them indicate that the intercept term is significantly different from zero at the 10 percent level; and 32 of them are significant at the 5 percent level. (2) Thirty regressions indicate that the coefficients of independent variables are not jointly zero at the 10 percent level; and 22 of them are significant at the 5 percent level. (3) Forty-seven of the 59 cross-sectional regressions

TABLE VIII

SECOND STAGE TESTS OF THE APT (THREE-FACTOR MODEL) T-STATISTICS AND F-STATISTICS (P-VALUES IN PARENTHESES)

Month	t[a]	F[b]	R^2	Month	t	F	R^2	Month	t	F	R^2
Jan. 81	4.60	3.23	.5475	Sep. 81	-.73	2.78	.5101	May 82	.78	.28	.0942
	(.001)	(.08)			(.48)	(.11)			(.45)	(.84)	
Feb. 81	3.14	3.04	.5331	Oct. 81	1.84	2.51	.4849	June 82	1.83	10.26	.7937
	(.01)	(.09)			(.10)	(.13)			(.10)	(.004)	
Mar. 81	3.31	3.52	.5685	Nov. 81	1.82	.78	.2263	July 82	1.33	6.32	.7032
	(.01)	(.06)			(.10)	(.53)			(.21)	(.01)	
Apr. 81	-1.97	.67	.1996	Dec. 81	-1.35	3.90	.5941	Aug. 82	1.54	3.05	.5332
	(.08)	(.59)			(.21)	(.05)			(.61)	(.09)	
May 81	1.36	1.49	.3587	Jan. 82	1.68	1.94	.4216	Sep. 82	3.79	1.49	.3590
	(.21)	(.28)			(.13)	(.20)			(.005)	(.28)	
June 81	7.43	10.94	.8040	Feb. 82	2.45	2.13	.4436	Oct. 82	1.31	3.95	.5972
	(.0001)	(.003)			(.04)	(.17)			(.22)	(.05)	
July 81	-.31	1.36	.3375	Mar. 82	.80	4.04	.6026	Nov. 82	-1.88	5.21	.6615
	(.76)	.32)			(.44)	(.05)			(.09)	(.02)	
Aug. 81	-1.50	.20	.0689	Apr. 82	2.26	2.76	.5089	Dec. 82	-.49	2.37	.4703
	(.17)	(.89)			(.05)	(.11)			(.63)	(.14)	

TABLE VIII (CONTINUED)

Month	t	F	R^2	Month	t	F	R^2	Month	t	F	R^2
Jan. 83	6.75	9.36	.7783	Sep. 83	.51	.44	.1418	May 84	-4.11	8.60	.7632
	(.0002)	(.005)			(.62)	(.73)			(.003)	(.007)	
Feb. 83	6.11	16.96	.8642	Oct. 83	1.46	.51	.1603	June 84	-3.31	3.19	.5448
	(.0003)	(.0008)			(.18)	(.68)			(.01)	(.08)	
Mar. 83	4.03	.43	.1389	Nov. 83	4.83	5.95	.6906	July 84	2.96	1.11	.2930
	(.003)	(.73)			(.001)	(.01)			(.01)	(.40)	
Apr. 83	3.52	6.44	.7071	Dec. 83	4.21	4.07	.6041	Aug. 84	4.96	5.77	.6841
	(.007)	(.01)			(.003)	(.04)			(.001)	(.02)	
May 83	-.01	10.12	.7915	Jan. 84	2.11	.39	.1265	Sep. 84	1.95	4.46	.6257
	(.98)	(.004)			(.06)	(.76)			(.08)	(.04)	
June 83	-2.52	1.45	.3515	Feb. 84	-.64	1.46	.3545	Oct. 84	3.58	2.31	.4645
	(.03)	(.30)			(.53)	(.29)			(.007)	(.15)	
July 83	2.58	6.68	.7146	Mar. 84	-1.52	3.32	.5479	Nov. 84	4.77	2.63	.4969
	(.03)	(.01)			(.16)	(.08)			(.001)	(.12)	
Aug. 83	-.53	1.75	.3967	Apr. 84	-2.48	2.41	.4749	Dec. 84	4.40	2.83	.5150
	(.61)	(.23)			(.003)	(.007)			(.002)	(.10)	

TABLE VIII (CONTINUED)

Month	t	F	R^2	Month	t	F	R^2	Month	t	F	R^2
Jan. 85	8.18	1.83	.4064	May 85	4.88	26.23	.9077	Sep. 85	4.04	10.47	.7971
	(.0001)	(.22)			(.001)	(.0002)			(.003)	(.003)	
Feb. 85	1.08	1.10	.2915	June 85	2.16	2.77	.5094	Oct. 85	2.35	2.01	.4293
	(.31)	(.40)			(.06)	(.11)			(.04)	(.19)	
Mar. 85	−6.95	17.98	.8708	July 85	4.49	5.41	.6699	Nov. 85	3.14	5.02	.6532
	(.0001)	(.0006)			(.002)	(.02)			(.01)	(.03)	
Apr. 85	2.87	1.48	.3574	Aug. 85	3.84	2.89	.5200				
	(.02)	(.29)			(.005)	(.10)					

[a]The t-statistic is for the null hypothesis that the intercept equals zero.

[b]The F-statistic is for the null hypothesis that the regression coefficients are all zero.

[c]The P-value is the observed level of significance.

regressions have either a t-statistic or a F-statistic significant at the 10 percent level; and 40 of them have either a t-statistic or F-statistic significant at the 5 percent level.

TABLE IX

SUMMARY OF THE SECOND-STAGE TESTS OF THE APT
(THREE-FACTOR MODEL)

Tests	t^a		F^b		t or F		χ^2_3
Level of significance (α)	10%	5%	10%	5%	10%	5%	3.765
Number of tests significant at the α level	40	32	30	22	47	40	
Number of tests not significant at the α level	19	27	29	37	12	19	
Total	59	59	59	59	59	59	

[a]The t-statistic is for the null hypothesis that the intercept equals zero.

[b]The F-statistic is for the null hypothesis that the regression coefficients are all zero.

A significant F-statistic indicates that at least one of the risk premiums is significantly different from zero for that individual regression (e.g., January 1981). However, for the entire 59 regressions, the decision needs to be made whether the risk premiums are jointly significant. That is, does the evidence provide support for the APT?

A Chi-square statistic (as described in Appendix A) calculated from the 59 sets of regression coefficients was used to test the joint significance of the 59 sets of risk premiums as a whole. The calculated Chi-square statistic, χ^2_3, is 3.765. From the table of percentage points of the χ^2 distribution, $\chi^2_{3,.05}$ is 7.81, $\chi^2_{3,.10}$ is 6.25, and $\chi^2_{3,.50}$ is 2.37. Thus, a χ^2_3 value of 3.765 indicates that the 59 sets of the risk premiums as a whole are not significantly different from zero at the 5 and 10 percent levels. Therefore, the conclusion from the second stage tests of the APT is that the evidence does not provide support for the three-factor-model APT. However, it seems that for some periods of time, the three-factor model is supported by the evidence.

C. Time Series Regression

To investigate the effect of the three hypothesized risk factors (i.e., the unanticipated change in inflation, the unanticipated change in interest rates, and the unanticipated change in the default risk premium) on the returns of the 12 corporate bond portfolios, Equation (4.17) was estimated using monthly data from January 1981 through November 1985. Mainly because of the availability and completeness of the data, the independent variables in Equation (4.17) were measured as follows. Fama's estimate as discussed in Section D.1 of Chapter IV was used to measure the unanticipated change in inflation ($\widetilde{UI}$). Burmeister and Wall's measures as discussed in Sections D.2 and D.3 of Chapter IV were used to estimate the unanticipated change in interest rates ($\widetilde{URF}$) and the unanticipated change in default risk premium ($\widetilde{UDRP}$).

Table X presents the results of the 12 times-series regressions. The findings include the following:

1. The intercept terms, which represent the expected returns in the APT, are highly significant. The average value is 1.43 percent for the six investment grade bond portfolios and is 1.69 percent for the six speculative grade bond portfolios.

2. The 12 regression coefficients for the influence of unanticipated inflation are highly insignificant with only one exception. However, the negative signs of these coefficients are consistent with the findings in Jaffe and Mandelker (1979).

3. The regression coefficients of unanticipated interest rate risk are insignificant at the 5 percent level although the positive signs are consistent with the intuitive expectation.

4. The p-values in column five show that unanticipated change in the default risk premium has a strong positive relationship with returns on corporate bond portfolios. This is consistent with the results of the factor analysis in the first part which showed that default risk is a dominant factor.

5. The R^2 values, ranging from .1866 to .3273, indicate that the unanticipated changes in the three hypothesized risk factors explain a small proportion of the variation of portfolio monthly returns, given that the intercept term has captured the expected return.

6. The Durbin-Watson (DW) values show that the residuals of the regression model are not auto-correlated; although two of them (i.e., HiCp, MdTm, Inv. and HiCp, LwTm, Inv.) indicate slightly positive autocorrelation.

TABLE X

TIME SERIES REGRESSIONS ON $\tilde{R}_{it} = b_{i0} + b_{i1}\tilde{UI}_t + b_{i2}\widetilde{URF}_t + b_{i3}\widetilde{UDRP}_t + \tilde{\varepsilon}_{it}$

JANUARY 1981 - NOVEMBER 1985 [t-STATISTICS IN BRACKETS]
(P-VALUES IN PARENTHESES)

Portfolio (Monthly Return)[a]	Intercept	$\tilde{UI}$	$\widetilde{URF}$	$\widetilde{UDRP}$	R^2	DW
HiCp, ShTm, Inv.[b]	1.30 [7.27] (.0001)	-.88 [-1.15] (.25)	1.33 [.48] (.63)	16.97 [3.48] (.0003)	.2542	1.910
HiCp, ShTm, Spe.	1.37 [7.40] (.0001)	-.86 [-1.09] (.27)	4.84 [1.69] (.09)	20.02 [4.37] (.0001)	.3169	1.899
LwCp, ShTm, Inv.	1.25 [8.13] (.0001)	-1.02 [-1.55] (.12)	3.67 [1.54] (.13)	16.55 [4.35] (.0001)	.3273	1.787
LwCp, ShTm, Spe.	1.37 [7.44] (.0001)	-1.19 [-1.52] (.13)	1.94 [.68] (.49)	13.75 [3.03] (.003)	.2054	2.020
HiCp, MdTm, Inc.	1.56 [6.75] (.0001)	-.74 [-.75] (.45)	5.75 [1.61] (.11)	25.94 [4.55] (.0002)	.3172	1.377
HiCp, MdTm, Spe.	1.58 [5.28] (.0001)	.08 [.06] (.95)	5.88 [1.26] (.21)	30.04 [4.05] (.0002)	.2484	1.955

TABLE X (CONTINUED)

Portfolio (Monthly Return)	Intercept	$\widetilde{UI}$	$\widetilde{URF}$	$\widetilde{UDRP}$	R^2	DW
LwCp, MdTm, Inv.	1.53 [5.38] (.0001)	-.75 [-.62] (.53)	7.52 [1.71] (.09)	24.54 [3.49] (.0009)	.2299	1.647
LwCp, MdTm, Spe.	1.84 [6.73] (.0001)	-2.22 [-1.89] (.06)	4.87 [1.15] (.25)	19.52 [2.88] (.005)	.2212	1.821
HiCp, LgTm, Inv.	1.49 [5.44] (.0001)	-.10 [-.08] (.93)	7.54 [1.78] (.08)	26.97 [3.98] (.0002)	.2595	1.429
HiCp, LgTm, Spe.	1.60 [4.22] (.0001)	-1.10 [-.68] (.50)	8.06 [1.37] (.17)	28.69 [3.09] (.003)	.1866	2.194
LwCp, LgTm, Inv.	1.48 [4.32] (.0001)	-.06 [-.04] (.96)	5.45 [1.03] (.30)	30.29 [3.97] (.0007)	.2043	1.694
LwCp, LgTm, Spe.	2.41 [3.45] (.001)	.11 [.04] (.97)	9.34 [.86] (.39)	7.12 [.41] (.68)	.0159	1.831

[a] N = 59.

[b] Refer to Table I for the interpretation of abbreviations.

D. Analysis of Results

Both parts of this research unequivocally indicated that default risk is the most important component of corporate bond risk. This finding is encouraging given that previous studies (Percival, 1974; Reilly and Joehnk, 1976; Weinstein, 1981) found that the CAPM's beta cannot capture bond's default risk. However, the findings also consistently revealed that both the interest rate risk and inflation risk have no significant impact on returns of corporate bond portfolios. What are some possible explanations for these somewhat counterintuitive results?

1. The interest rate risk can be immunized by matching the investment horizon with the bond's duration. As a result, such risk may not be compensated.

2. While bond rating agencies such as Moody's and Standard & Poor's periodically publish bond ratings information, they do not provide service as to bonds' interest-rate sensitivities. That is, for a particular bond, the interest rate risk is not as obvious as the default risk to an investor.

3. For the period covered in this study, January 1981 through December 1985, inflation is not a serious problem. Thus, inflation may not be a main source of corporate bond risk.

4. Possibly, the findings are not correct because of methodological or statistical errors.

ENDNOTES

[15]The scree plot is a curve in which the factors' numbers are plotted against the corresponding eigenvalues. The curve will have a decreasing negative slope (the difference in eigenvalues between successive factors will decrease) until the random error factors--or trivial factors--are reached. Then the curve will level off and the incremental difference between successive factors will be about the same. It is called the scree plot, since the random error factors in a plot like that of Figure 1 resemble scree--the debris that has fallen or been eroded off a mountain and that lies at its base.

[16]The degrees of freedom for Barlett's Chi-square test is: $df = \frac{1}{2}[(m-k)^2 - m - k]$, where m is the number of portfolios and k is a prespecified number of factors.

[17]A bond with a longer maturity can have a shorter duration than another bond with shorter maturity but longer duration since duration is calculated from three inputs (i.e., coupon rate, yield to maturity, and term to maturity).

CHAPTER VI

SUMMARY AND CONCLUSIONS

A. Summary of the Study

1. Purpose of the Study

Uncertainty about corporate bond returns is usually attributed to three factors: (1) inflation risk, (2) interest rate risk, and (3) default risk. Inflation can erode the ability of bonds, which are denominated in dollars, to buy real physical goods. Interest rate risk arises from the price fluctuation in a bond caused by simultaneous changes in the level of interest rates. Default risk is the risk of defaulting on either the payment of interest or principal. Risk-averse investors would require risk premiums commensurate with these risks.

Empirical studies which applied the CAPM to corporate bond data indicated that the CAPM does not perform well in explaining relevant risk for corporate bonds. For example, bond beta was found to be incapable of capturing the default risk of corporate bonds (Percival, 1974; Reilly and Joehnk, 1976; Weinstein, 1981).

The APT is a relatively new theoretical model that suggests how to price marketable assets. It was derived under fewer and less restrictive assumptions than the CAPM and admits more than just one return generating factor. Since the APT has been in existence for a relatively short time, it has not been previously tested with corporate bond data.

Most of the initial APT empirical studies have employed factor analysis first to endogenously extract the common risk factors and then to test the implications of the APT. An alternative approach in testing the APT is first to exogenously hypothesize the macroeconomic factors that may affect asset prices and then to verify or reject the hypothesized economic variables using the regression analysis. Either approach has its drawbacks. For example, the application of factor analysis has shortcomings such as the number of factors problem, the nonuniqueness of factor loadings problem, and the identification of common factors problem. These problems are far from resolved and therefore make the test of the APT and the application of the theory to portfolio management more difficult.

The regression approach of testing the APT also has weaknesses. For instance, the selection of the macroeconomic factors is somewhat ad hoc and therefore not theoretically sound. Furthermore, the measurement of the selected risk factors (i.e., the independent variables) is a problem far from settled.

Based on the above reasons, this research intends to achieve two purposes:

1. To investigate corporate bond risk by applying the APT to corporate bonds, thereby providing evidence that the three commonly perceived sources of corporate bond risk are the main factors affecting corporate bond returns. This research is needed since the CAPM is not a robust model of the risk inherent in corporate bonds. In addition, previous tests of the APT did not include corporate bonds.

2. To provide an alternative way of testing the APT which minimizes the drawbacks and combines the strengths of both the factor analysis and the regression analysis approaches.

2. Statement of Issues

The intuitive appeal of applying the APT to corporate bonds is that the APT allows more than just one factor in the return generating process. However, the APT does not prespecify the underlying risk factors. The presence of a set of unnamed factors in the APT is not better than the existence of an unobservable market portfolio in the CAPM. Several issues need to be investigated before the APT can be used in investment and portfolio management. Because of the inadequacy of literature, the following issues were addressed in this research:

1. The identification (or interpretation) of the common factors which were extracted from factor analysis;

2. The measurement of the unanticipated changes in risk factors which were used in the regression analysis;

3. The unique measurement of factor sensitivities which may be used in portfolio management; and

4. The appropriateness of the APT for corporate bonds.

3. Data and Methodology

Monthly corporate bond data were collected from Moody's Bond Record covering a five-year period, January 1981 through December 1985. Values of the coupon rate, maturity date, month-end price, and ratings on about 400 corporate bond issues which met the selection criteria were collected as of the end of each month. Monthly holding period returns were calculated and used in the analysis.

Factor analysis was used in the first part of this study to extract common factors affecting corporate bond returns. An approach which constructs corporate bond portfolios according to bonds' characteristics was proposed to facilitate the interpretation (or identification) of the economic meanings of the extracted common factors. The implications of the APT were also tested. In brief, the tests of the APT through factor analysis proceeded in the following steps:

1. Twelve corporate bond portfolios were formed on the basis of bond characteristics;

2. The variance-covariance matrix was computed from the time series of portfolio returns;

3. A principal factor analysis was performed on the variance-covariance matrix and the factor loadings matrix was estimated;

4. The estimated factor loadings from the previous step were used to explain the cross-sectional variation of portfolio returns; and

5. Estimates from the cross-sectional regression (i.e., Step 4) were used to calculate the Chi-square statistic for testing the joint significance of risk premiums.

The nonuniqueness of the estimated factor loadings makes the tests of the APT imprecise and the application of the APT to portfolio management difficult. Furthermore, the interpretation of common factors through visual inspection of the rotated factor loadings is somewhat subjective. To verify the significance of the risk factors identified in the first part of this study, and to obtain the unique measures of factor sensitivities, the following risk-return relationship was hypothesized and tested by using regression analysis:

Return = b_0 + b_1 (unanticipated inflation risk) + b_2 (unanticipated interest rate risk) + b_3 (unanticipated default risk) + random error.

The measures of unanticipated changes in inflation, interest rates, and default risk premiums were discussed and derived.

4. Main Results

The findings from factor analysis include the following:

1. The first three common factors explain 84.19 percent of the total variability in bond portfolio returns;

2. The first common factor is the dominant factor and is identified as a default risk factor;

3. The second common factor is related to bonds' coupon rates;

4. The third common factor is related to bonds' term to maturity; and

5. The evidence does not provide substantial support for the three-factor-model APT.

The findings from the regression analysis include the following:

1. The intercept terms significantly reflect the expected returns of the corporate bond portfolios;

2. The regression coefficients of unanticipated inflation are highly insignificant although the negative sign is consistent with the findings in Jaffe and Mandelker (1979);

3. The regression coefficients of unanticipated changes in interest rates are insignificant at the 5 percent level although the positive signs are consistent with expectation; and

4. Unanticipated changes in default risk have a strong positive relationship with returns on corporate bond portfolios. This is consistent with the result of factor analysis which showed that the default risk is a dominant factor.

Both parts of this study unequivocally indicated that default risk is the most important component of corporate bond risk. This finding is encouraging given that previous studies (Percival, 1974; Reilly and Joehnk, 1976; Weinstein, 1981) found that the CAPM's beta cannot capture bond's default risk. However, the findings also consistently revealed that both the interest rate risk and inflation risk have no significant impact on returns of corporate bond portfolios. The following four reasons are some possible explanations for these somewhat counter-intuitive results:

1. Interest rate risk can be immunized by matching the investment horizon with the bond's duration. As a result, such risk may not be compensated.

2. While bond rating agencies such as Moody's and Standard & Poor's periodically publish bond ratings information, they do not provide information as to bonds' interest rate sensitivities. That is, for a particular bond, the interest rate risk is not as obvious as the default risk to an investor.

3. For the period covered in this study, January 1981 through December 1985, inflation is not a serious problem. Thus, inflation may not be a main source of corporate bond risk.

4. Possibly, the findings are not correct because of methodological or statistical errors.

5. Limitations of the Research

As any other empirical study, this research itself is subject to potential limitations:

1. The data of this study were hand-collected from Moody's Bond Record because there is no machine-readable, standardized data on corporate bonds available for use. It is possible that different empirical findings may be obtained from other sources of data such as Standard & Poor's Bond Guide. Thus, the construction of a standardized data file for corporate bond prices would provide the greatest benefits for further study in this area.

2. Because unanticipated changes in the hypothesized risk factors are not directly observable, proxies for these variables were used in this study. Better proxies for these variables may improve the ability of researchers to identify the risk factors determining corporate bond returns.

3. Factor analysis is concerned only with factoring the estimated variance-covariance matrix of portfolio returns, it cannot pick up the presence of systematic coskewness in returns.

4. This study has assumed that the factor structure was constant over the five-year period of investigation. This is certainly a rough approximation. It is possible that a factor structure extracted from estimates based on this period would be so unstable that it would have little to do with bond returns.

6. Contribution to Literature

The significance of this study comes from the empirical procedure itself, its results, and its implications. Specifically, the contribution to literature is suggested to be as follows:

1. It provides an approach which constructs bond portfolios according to bonds' risk characteristics so that the extracted common factors might be identified through the inspection of the rotated factor loadings;

2. It derived measures of unanticipated changes in interest rates and default risk premiums based on the Unbiased Expectation Theory of the term structure of interest rates;

3. It provides evidence that the bond default risk is an important factor in determining corporate bond returns (this finding is significant because previous studies documented that the CAPM's beta cannot capture the default risk of corporate bonds); and

4. It provides a possible way of putting the APT into practical use. That is, the empirical procedure of this study has implications for strategic portfolio planning.

B. Directions for Future Research

1. Further Research I: Other Sources of Risk

One advantage of the portfolio approach in testing the APT through factor analysis is that portfolios can be constructed according to the purpose of the research. One purpose of this research is to provide evidence which may support that the commonly perceived sources of corporate bond risk (i.e., inflation risk, interest rate risk, default risk) are the main factors affecting corporate bond returns. Therefore, this study constructed corporate bond portfolios according to bonds' risk characteristics which are related to the three types of risk. Of course, if a hypothesized source of risk has no pervasive impact on corporate bond returns, it will be diversified away in portfolios and factor analysis cannot extract a common factor related to that source of risk.

However, there are other sources of risk that may be important in determining corporate bond returns. For example, corporate bonds are roughly classified into three categories: industrial bonds, utility bonds, and transportation bonds; thus, there might be an "industry factor" affecting bond returns. Other bond features such as callability and convertibility are possible sources of corporate bond risk. Therefore, constructing corporate bond portfolios according to these possible sources of risk to investigate their significance in determining corporate bond returns is a subject for further research.

2. Further Research II: Strategic Portfolio Management

The empirical procedures in this study has implications for strategic portfolio management. Specifically, the proposed procedure of applying the APT to the management of corporate bond portfolios is as follows:

1. Construct bond portfolios according to the hypothesized sources of corporate bond risk;

2. Factor-analyze the returns of corporate bond portfolios to extract the major common factors determining corporate bond returns;

3. Identify the common risk factors through the interpretation of the estimated factor loadings;

4. Measure the unanticipated changes in the identified risk factors for the time period being investigated;

5. Use regression analysis to obtain the unique measure of factor sensitivities for individual bonds;

6. Use the estimated factor sensitivities from Step 5 to construct bond portfolios which have the desired factor sensitivities for strategic portfolio management (for example, a portfolio with low or zero sensitivity to inflation risk might be hedged against unanticipated inflation risk); and

7. Evaluate and revise portfolios periodically.

The performance of this proposed approach might be investigated through the use of a "goodness-of-fit" method. That is, performance is measured by the technique's ability to forecast. Specifically, corporate bond portfolios are constructed using the proposed approach, based on the analysis of bonds' monthly returns over a five-year period beginning in January 1981. Then, when a forecast is made (e.g., in January 1986), the first month (January 1981) is dropped from the series and another (January 1986) is added to revise the portfolios and to get a forecast for the next month (February 1986). The procedure is repeated until a series of forecasts are obtained.

Two statistics can be used to measure the "goodness-of-fit." One is the correlation coefficient between forecasted and actual rates of return within the sample period. A high correlation coefficient represents a good performance. The other is the cumulative errors of forecasts. Of course, a low value of cumulative errors represents a good performance.

3. Further Research III: Alternative Measures of Unanticipated Changes in Variables

In the second part of this research, three types of unanticipated changes in the hypothesized risk factors were used in testing the hypothesized risk-return relationship of corporate bonds. Better measures for these unanticipated risk may improve the empirical results. The development of better measures and the test of the "rationality" of the proposed measures are an area for further research.

The concept of rational expectations is useful in developing the "unanticipated changes" of macroeconomic variables. Once a rational forecast was made, the forecast error represents the unanticipated change. A rational forecast is based on the efficient use of the available, relevant information. That is, there will be no systematic error.

There are three properties that can be used in testing the rationality of a forecast model:

1. Unbiasedness, i.e., the expectation should be an unbiased predictor of the variable;

2. Efficiency, i.e., the expectation should use information about the past history of the variable in the same way that the variable actually evolves through time; and

3. Forecast error unpredictability, i.e., the forecast error (the difference between the expectation and the actual realization of the variable) should be uncorrelated with any information available at the time the forecast is made.

4. Others

Other directions for future research include the following:

1. The empirical results may change if the period under investigation is different. For example, if the investigation covers a period when inflation was high or interest rates were volatile, then significant effects of the two types of risk might be obtained.

2. As pointed out in Levhari and Levy (1977), the investment horizon is important in estimating the beta of a security. Whether the investment horizon is important in estimating the factor sensitivities of a bond portfolio is a topic which needs to be investigated. However, there is good reason to question the investment horizon problem since interest rate risk can be immunized by matching the duration with the investment horizon. Thus, it is possible to get different results if the holding period returns were calculated from different time intervals such as a quarter, six months, and a year. The problem is, the longer the time interval, the fewer the observations. The construction of a machine-readable, standardized data file for corporate bond prices would provide the greatest benefits for further study in this area.

C. Conclusions

The APT is a new theoretical model that suggests how to price marketable assets. It requires fewer underlying assumptions and admits more variables into the analysis than the CAPM. Since the APT has been in existence for a relatively short time, it has not been previously tested with corporate bond data. Most of the initial APT empirical studies employed factor analysis to endogenously extract the common risk factors. An alternative to factor analysis, in testing the APT, is first to develop risk factors that may affect asset prices from exogenous economic theory and then to verify or reject the hypothesized economic variables using regression analysis. Both factor analysis and regression analysis were employed in this study.

While previous studies (Percival, 1974; Reilly and Joehnk, 1976; Weinstein, 1981) documented that the CAPM's beta cannot capture the default risk of corporate bonds, this study provided evidence that default risk is an important factor in determining corporate bond returns. It also indicated that inflation risk and interest rate risk have no significant impact on the monthly holding period returns of corporate bonds. The findings have implications for strategic portfolio management. Portfolio managers could construct a portfolio which has a desired degree of sensitivity to a certain type of risk. For example, a portfolio with low or zero sensitivity to inflation risk might be hedged against unexpected inflation risk.

The multi-factor model of the APT offers a promising line of research for better understanding corporate bond risk and its linkage with macroeconomic variables. Further endeavors in this area are needed. The availability of standardized data on corporate bond prices would provide the greatest benefit for further study in this area. Furthermore, because unanticipated changes in the hypothesized risk factors are not directly observable, better proxies for these variables would improve the ability of researchers to identify the underlying relationships determining corporate bond returns.

REFERENCES

Alexander, Gordon J. "Applying the Market Model to Long-Term Corporate Bond." Journal of Financial and Quantitative Analysis, 15 (December 1980), 1063-1080.

Broske, Mary S. "The Measurement of Bond Default Risk." Research in Finance 5 (1985a), 107-143.

__________. "A Market-Based Technique for Measuring Default Risk." University of Notre Dame, Center for Research in Business, Research Paper Series 84-21, June 1985b.

Burmeister, Edwin and Kent D. Wall. "The Arbitrage Pricing Theory and Macroeconomic Factor Measures." The Financial Review, 21 (February 1986), 1-20.

Burmeister, Edwin, Kent D. Wall, and James D. Hamilton. "Estimation of Unobserved Expected Monthly Inflation Using Kalman Filtering." Journal of Business and Economic Statistics, 4 (April 1986), 147-160.

Chang, Eric C. and Wilbur G. Lewellen. "An Arbitrage Pricing Approach to Evaluating Mutual Fund Performance." Journal of Financial Research, 8 (Spring 1985), 15-30.

Chen, Nai-Fu. "Some Empirical Tests of the Theory of Arbitrage Pricing." Journal of Finance, 38 (December 1983), 1393-1414.

Cho, D. Chinhyung. "On Testing the Arbitrage Pricing Theory: Inter-Battery Factor Analysis," Journal of Finance, 39 (December 1984), 1485-1502.

Dhrymes, Phoebus J., Irwin Friend, and N. Bulent Gultekin. "A Critical Reexamination of the Empirical Evidence on the Arbitrage Pricing Theory." Journal of Finance, 39 (June 1984), 323-346.

Dhrymes, Phoebus J., Irwin Friend, N. Bulent Gultekin, and Mustafa N. Gultekin. "An Empirical Examination of the Implications of Arbitrage Pricing Theory." Journal of Banking and Finance, 9 (March 1985a), 73-99.

__________. "New Tests of the APT and Their Implications." Journal of Finance, 40 (July 1985b), 659-674.

Duvall, Richard M. and John M. Chenney. "Bond Beta and Default Risk." Journal of Financial Research, 7 (Fall 1984), 243-254.

Dybvig, Philip H. and Stephen A. Ross. "Yes, the APT is Testable." Journal of Finance, 40 (September 1985), 1173-1188.

Fama, Eugene F. "Short-Term Interest Rates as Predictors of Inflation." American Economic Review, 65 (June 1975), 269-282.

Fisher, Lawrence. "Determinants of Risk Premiums on Corporate Bonds." Journal of Political Economy, 67 (June 1959), 217-237.

Fogler, E. Russell. "Common Sense on CAPM, APT, and Correlated Residuals." Journal of Portfolio Management, 8 (Summer 1982), 1073-1103.

Friend, I., R. Westerfield, and M. Granito. "New Evidence on the Capital Asset Pricing Model." Journal of Finance, 33 (June 1978), 903-920.

Gultekin, N. Bulent and Richard J. Rogalski. "Government Bond Returns, Measurement of Interest Rate Risk, and the Arbitrage Pricing Theory." Journal of Finance 40 (March 1985), 43-61.

Hopewell, Michael H. and George G. Kaufman. "Bond Price Volatility and Term to Maturity: A Generalized Respectification." American Economic Review, 63 (September 1973), 749-753.

Jaffe, Jaffrey F. and Gershon Mandelker. "Inflation and the Holding Period Returns on Bonds." Journal of Financial and Quantitative Analysis, 14 (December 1979), 959-979.

Johnson, Richard A. and Dean W. Wichern. Applied Multivariate Statistical Analysis. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1982.

King, Benjamin F. "Market and Industry Factors in Stock Pricing Behavior." Journal of Business, 39 (January 1966), 139-190.

Kraus, Alan. "New Tests of the APT and Their Implications: Discussion." Journal of Finance, 40 (July 1985), 674-675.

Kraus, Alan and Robert H. Litzenberger. "Skewness Preference and the Valuation of Risk Assets." Journal of Finance, 31 (September 1976), 1085-1100.

Lehmann, Bruce N. and David M. Modest. "The Empirical Foundations of the Arbitrage Pricing Theory I: The Empirical Tests." Working Paper No. 1725, National Bureau of Economic Research, Inc.

Levhari, David and Haim Levi. "The Capital Asset Pricing Model and the Investment Horizon." Review of Economics and Statistics, 59 (February 1977), 92-104.

Livingston, Miles. "Industry Movements of Common Stocks." Journal of Finance, 32 (June 1977), 861-874.

McEnnally, Richard and Calvin Boardman. "Aspects of Corporate Bond Portfolio Diversification." Journal of Financial Research, 2 (Spring 1979), 27-36.

Merton, Robert C. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." Journal of Finance, 29 (June 1974), 449-470.

Pari, Robert A. and Son-Nan Chen. "An Empirical Test of the Arbitrage Pricing Theory." Journal of Financial Research, 7 (Summer 1984), 121-130.

Percival, John. "Corporate Bonds in a Market Model Context." Journal of Business Research, 2 (October 1974), 461-468.

Pfleiderer, Paul. "A Short Note on the Similarities and the Differences Between the Capital Asset Pricing Model and the Arbitrage Pricing Theory." Graduate School of Business Working Paper, Stanford University, 1983.

Reilly, Frank K. and Michael D. Joehnk. "The Association Between Market Determined Risk Measures for Bonds and Bond Ratings." Journal of Finance, 31 (December 1976), 1387-1403.

Reinganum, Marc R. "The Arbitrage Pricing Theory: Some Empirical Results." Journal of Finance, 36 (May 1981), 313-321.

Roll, Richard. "A Critique of the Asset Pricing Theory's Tests." Journal of Financial Economics, 4 (March 1977), 129-176.

Roll, Richard and Stephen A. Ross. "An Empirical Investigation of the Arbitrage Pricing Theory." Journal of Finance, 35 (December 1980), 1073-1103.

__________. "A Critical Reexamination of the Empirical Evidence on the Arbitrage Pricing Theory: A Reply." Journal of Finance, 39 (June 1984a), 347-350.

__________. "The Arbitrage Pricing Theory Approach to Strategic Portfolio Planning." Financial Analyst Journal, (May-June 1984b), 14-26.

Ross, Stephen A. "The Arbitrage Theory of Capital Asset Pricing." Journal of Economic Theory, 13 (December 1976), 341-360.

Shanken, Jay. "The Arbitrage Pricing Theory: Is It Testable?" Journal of Finance, 37 (December 1982), 1129-1140.

Sheffrin, Steven M. Rational Expectations. Cambridge, NY: Cambridge University Press, 1983.

Silvers, J. B. "An Alternative to the Yield Spread as a Measure of Risk." Journal of Finance, 28 (September 1973), 933-955.

Trzcinka, Charles. "On the Number of Factors in the Arbitrage Pricing Model." Journal of Finance, 41 (June 1986), 347-368.

Van Horne, James. "Interest-Rate Risk and the Term Structure of Interest Rates." Journal of Political Economy, 73 (August 1965), 344-351.

Weinstein, Mark I. "The Systematic Risk of Corporate Bonds." Journal of Financial and Quantitative Analysis, 16 (September 1981), 257-278.

__________. "Bond Systematic Risk and the Option Pricing Model." Journal of Finance, 38 (December 1983), 1415-1429.

Yawitz, Jess B. and William J. Marshall. "Risk and Return in the Government Bond Market." Journal of Portfolio Management, 3 (Summer 1977), 48-52.

APPENDIXES

APPENDIX A

TESTS OF THE APT

The notations used in the following expressions are defined as follows.

$$\tilde{R}_t = \begin{bmatrix} \tilde{R}_{1t} \\ \tilde{R}_{2t} \\ \cdot \\ \cdot \\ \cdot \\ \tilde{R}_{mt} \end{bmatrix}_{mx1}$$

, is a column vector of observed returns, m is the number of bond portfolios;

$$E_t = \begin{bmatrix} E_{1t} \\ E_{2t} \\ \cdot \\ \cdot \\ \cdot \\ E_{mt} \end{bmatrix}_{mx1}$$

, is a column vector of expected returns;

$$B = \begin{bmatrix} b_{11}, & b_{12} & \cdots & b_{1k} \\ b_{21}, & b_{22} & \cdots & b_{2k} \\ \cdot & \cdot & & \\ \cdot & \cdot & & \\ \cdot & \cdot & & \\ b_{m1}, & b_{m2} & \cdots & b_{mk} \end{bmatrix}_{mxk}$$

, is a factor loadings matrix, k is the number of common factors;

$\hat{B}$ is the estimate of B;

$$B^* = \begin{bmatrix} 1 & b_{11} & b_{12} & \cdots & b_{1k} \\ 1 & b_{21} & b_{22} & \cdots & b_{2k} \\ \cdot & \cdot & \cdot & & \\ \cdot & \cdot & \cdot & & \\ \cdot & \cdot & \cdot & & \\ 1 & b_{m1} & b_{m2} & \cdots & b_{mk} \end{bmatrix}_{mxk\ (k+1)}$$

;

$\hat{B}^*$ is the estimate of B^*;

$$\tilde{F}_t = \begin{bmatrix} \tilde{F}_{1t} \\ \tilde{F}_{2t} \\ \cdot \\ \cdot \\ \cdot \\ \tilde{F}_{kt} \end{bmatrix}_{k\times1}$$, is a column vector of unobserved common factors;

$$\tilde{\varepsilon}_t = \begin{bmatrix} \tilde{\varepsilon}_{1t} \\ \tilde{\varepsilon}_{2t} \\ \cdot \\ \cdot \\ \cdot \\ \tilde{\varepsilon}_{mt} \end{bmatrix}_{m\times1}$$, is a column vector of independently identicially distributed (i.i.d.) residuals;

Exp is the expectation operator;

Var represents variance;

Cov represents covariance;

I represents identity matrix;

$$D = \begin{bmatrix} Var(\tilde{\varepsilon}_{1t}) & 0 & \cdots & 0 \\ 0 & Var(\tilde{\varepsilon}_{2t}) & \cdots & 0 \\ \vdots & \vdots & & \\ 0 & 0 & \cdots & Var(\tilde{\varepsilon}_{mt}) \end{bmatrix}_{m\times m}$$, is a diagonal matrix;

$\hat{D}$ is the estimate of D;

$$V = \begin{bmatrix} Var(\tilde{\varepsilon}_{1t}) & Cov(\tilde{\varepsilon}_{1t}, \tilde{\varepsilon}_{2t}) & \cdots & Cov(\tilde{\varepsilon}_{1t}, \tilde{\varepsilon}_{mt}) \\ Cov(\tilde{\varepsilon}_{2t}, \tilde{\varepsilon}_{1t}) & Var(\tilde{\varepsilon}_{2t}) & \cdots & \\ \vdots & \vdots & & \\ Cov(\tilde{\varepsilon}_{mt}, \tilde{\varepsilon}_{1t}) & Cov(\tilde{\varepsilon}_{mt}, \tilde{\varepsilon}_{2t}) & \cdots & Var(\tilde{\varepsilon}_{mt}) \end{bmatrix}_{m\times m}$$,

is the variance-covariance matrix of m observed returns;

$\hat{V}$ is the estimate of V;

$$\lambda_t = \begin{bmatrix} \lambda_{1t} \\ \lambda_{2t} \\ \cdot \\ \cdot \\ \cdot \\ \lambda_{kt} \end{bmatrix}_{k\times 1}$$, is a column vector of risk premiums;

$\hat{\lambda}_t$ is the estimate of λ_t;

$$\lambda_t^* = \begin{bmatrix} \lambda_{0t} \\ \lambda_{1t} \\ \lambda_{2t} \\ \cdot \\ \cdot \\ \cdot \\ \lambda_{kt} \end{bmatrix}_{(k+1)\times 1}$$, is a column vector of risk-free return and risk premiums;

$\hat{\lambda}_t^*$ is the estimate of λ_t^*; and

T is the number of time periods.

According to the APT, the return-generating model in each time period t is:

$$\tilde{R}_t = E_t + B\tilde{F}_t + \tilde{\varepsilon}_t, \text{ and} \tag{A.1}$$

$$\begin{cases} \text{Exp}(\tilde{F}_t) = 0, \ \text{Exp}(\tilde{F}_t\tilde{F}_t') = I, \\ \text{Exp}(\tilde{\varepsilon}_t) = 0, \ \text{Var}(\tilde{\varepsilon}_t) = D, \\ \text{Exp}(\tilde{\varepsilon}_t\tilde{F}_t') = 0. \end{cases} \tag{A.2}$$

$$
\begin{aligned}
V &= Var(\tilde{R}_t) \\
&= Exp(\tilde{R}_t - E_t)(\tilde{R}_t - E_t)' \\
&= Exp[(B\tilde{F}_t + \tilde{\varepsilon}_t)(\tilde{F}_t'B' + \varepsilon_t')] \\
&= Exp[B\tilde{F}_t\tilde{F}_t'B' + B\tilde{F}_t\tilde{\varepsilon}_t' + \tilde{\varepsilon}_t\tilde{F}_t'B' + \tilde{\varepsilon}_t\tilde{\varepsilon}_t'] \\
&= BIB' + 0 + 0 + D \\
&= BB' + D
\end{aligned}
\tag{A.3}
$$

If T is large enough, V can be estimated without sampling error. $\hat{V}$ is then factor-analyzed, and $\hat{B}$ and $\hat{D}$ are obtained. That is, from the factor analysis,

$$\hat{V} = \hat{B}\hat{B}' + \hat{D}. \tag{A.4}$$

Equation (3.11), in matrix notation, is:

$$\tilde{R}_t = B^*\lambda_t^* + \tilde{\varepsilon}_t \tag{A.5}$$

The Generalized Least Squares (GLS) estimate of λ_t^* is

$$\hat{\lambda}_t^* = (\hat{B}^{*\prime}\ \hat{V}^{-1}\ \hat{B}^*)^{-1}\ \hat{B}^{*\prime}\ \hat{V}^{-1}\ \tilde{R}_t,\ t = 1, 2, \ldots, T. \tag{A.6}$$

and $\sqrt{T}(\hat{\lambda}_t^* - \lambda_t^*)$ is a normal distribution with mean equals zero, and variance equals $(B^{*\prime}\ V^{-1}\ B^*)^{-1}$. Thus, the intercept term can be tested by the following t-statistics:

$$t_{\alpha, df} = \frac{\hat{\lambda}_{0t} - \lambda_{0t}}{\sqrt{Var(\hat{\lambda}_{0t})}}, \text{ where } df = T - (k + 1).$$

A test statistic for the joint significance of the risk premiums hypothesis is:

$$T\ \bar{\lambda}'\ \Phi^{-1}\ \bar{\lambda} \sim \chi_k^2,$$

where k is the degrees of freedom (which is also the number or common factors), $\bar{\lambda} = (1/T) \sum_{t=1}^{T} \hat{\lambda}_t$, and $\Phi = (1/T) \sum_{t=1}^{T} (\hat{\lambda}_t - \bar{\lambda})(\hat{\lambda}_t - \bar{\lambda})'$.

APPENDIX B

THE ESTIMATION OF FACTOR LOADINGS

Let V be an mxm square matrix and I be the mxm identity matrix. The scalars α_1, α_2, ..., α_m satisfying the polynomial equation $|V - \alpha I| = 0$ are called the eigenvalues of matrix V.

If e_{mx1} is a nonzero vector such that $Ve = \alpha e$, then e_{mx1} is said to be an eigenvector of the matrix V associated with eigenvalue α.

To factor-analyze matrix V is to decompose matrix V into two components,

$$V = BB' + D \tag{B.1}$$

where B is an mxk matrix called factor loadings matrix, k is the number of common factors and $k \leq m$,

D is an mxm diagonal matrix consisting of specific variance.

The estimation of B through the principal factor analysis is as follows.

Let α_1, α_2, ..., α_k be the first k eigenvalues of matrix V, and $\alpha_1 \geq \alpha_2 \geq \ldots \geq \alpha_k$; and e_1, e_2, ..., e_k be the first k eigenvectors of matrix V associated with eigenvalues α_1, α_2, ..., α_k respectively; then

$$B_{mxk} = \left[\sqrt{\alpha}_1 e_{1,mx1} \;\vdots\; \sqrt{\alpha}_2 e_{2,mx1} \;\vdots\; \ldots \;\vdots\; \sqrt{\alpha}_k e_{k,mx1} \right] \tag{B.2}$$

$\sqrt{\alpha}_1 e_{1,mx1}$ is the factor loadings for the first common factor,

$\sqrt{\alpha}_2 e_{2,mx1}$ is the factor loadings for the second common factor, and

$\sqrt{\alpha}_k e_{k,mx1}$ is the factor loadings for the k^{th} common factor.

The orthogonal transformation of the factor loadings is as follows. If B is the mxk matrix of estimated factor loadings then

$$B^t = BT \tag{B.3}$$

is an mxk matrix of "rotated" factor loadings; where T is a kxk orthogonal transformation matrix and $TT' = T'T = I$.

VITA

Chihuang Herman Lin

Candidate for the Degree of

Doctor of Philosophy

Thesis: CORPORATE BOND RISK AND THE ARBITRAGE PRICING THEORY: AN EMPIRICAL STUDY

Major Field: Business Administration

Biographical:

Personal Data: Born in Pingdong, Taiwan, Republic of China, June 19, 1954, the son of Chin and Chen-Yuh Lin. Married to Sujan Emma Yang on August 16, 1984.

Education: Graduated from Kaohsiung High School, Kaohsiung, Taiwan, Republic of China, in June 1972; received Bachelor of Science in Agriculture degree in Agricultural Economics from National Taiwan University, Taipei, Taiwan, Republic of China, in June 1976; received Master of Science degree in Accounting from Oklahoma State University, Stillwater, Oklahoma, in December 1982; completed requirements for Doctor of Philosophy degree at Oklahoma State University in December 1987.

Professional Experience: Researcher, Department of Economic Research, The Land Bank of Taiwan, Taipei, Taiwan, Republic of China, 1978-1980; Graduate Assistant, Department of Finance, Oklahoma State University, 1983-1987.

Professional Organization: Financial Management Association.