VARIABLE RISK AND THE TERM STRUCTURE

by

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DEDICATION

This work can only be dedicated to my family and especially to my parents. Without their support and encouragement, the following pages could not have been written. I hope that they will accept this dissertation as a small indication of the tremendous respect and love I have for them.

P. J. A.

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The intellectual guidance and friendship of for the past two years has been a major part of my graduate education. He encouraged me to always accept nothing less than my best while helping to improve my abilities.

and made me think about what I was doing in my dissertation, and its present form owes much to their efforts.

typed many drafts and, more importantly, suffered the drafts and me with quiet patience and acceptance. turned a jumbled mass into a work of art in the final typing.

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INTRODUCTION

The subject of decision making under conditions of risk has been researched by many economists. The works of Kenneth Arrow, Eugene Fama, Edmund Phelps, Agnar Sandmo, James Tobin and others have examined the effect of risk on the decision-making process of individuals.[1] Specifically, their analyses have been on a theoretical level, and their efforts have analyzed consumption and investment decisions under conditions of risk. The comparative static analysis of risk and, more importantly, the changing perception of risk, has led to certain conclusions about the allocation of wealth among alternative assets based on the assumption of risk aversion. However, there have been few attempts to empirically test these conclusions in a manner which is consistent with the theoretical analysis.

If individuals do perceive a change in risk, and if they act upon these changed perceptions, then it would seem

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[1]Kenneth Arrow, Essays on the Theory of Risk Bearing (American Elsevier, 1970); Eugene Fama, "Multiperiod Consumption and Investment Decisions," American Economic Review 60 (March 1970): 163-74; Agnar Sandmo, "Capital Risk, Conumption and Portfolio Choice," Econometrica 37 (October 1969): 586-99; Edmund Phelps, "The Accumulation of Risky Capital: A Sequential Utility Analysis," Econometrica 30 (October 1962): 729-43; and James Tobin, "Liquidity Preference as Behavior Towards Risk," Review of Economic Studies 25 (February 1958): 65-86.

plausible to include some measure of risk as a variable in an empirical investigation. Briefly, this is the variable risk hypothesis which was first proposed by Vittorio Bonomo in an application to aggregate consumption.[2] There, risk entered the model as the confidence placed in expectations and the effect of changes in risk on the average propensity to consume was estimated.

The purpose of this dissertation is to place the variable risk hypothesis in perspective with the risk literature and to extend the scope of the variable risk hypothesis to another application--specifically, the term structure of interest rates.

We will suggest a reasonable measure of risk and then empirically test to determine (1) whether this measure is appropriate, and (2) whether risk can explain the movement of economic variables over time. In addition to testing the variable risk hypothesis on its own merits, we will use the variable risk hypothesis to test various hypotheses based on the prevailing theories about the term structure. If the variable risk hypothesis is a valid one, it should not be dependent upon the particular measure used in any one application. This is not to say that all measures would serve equally well. There should be some justification for

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[2] Vittorio Bonomo, "Variable Risk and Aggregate Consumption Behavior" VPI&SU, October 1975 (mimeographed).

a particular measure based on acceptable theory. If risk is a significant explanatory variable, then it could be argued that previous work has been extended and, to the extent that the risk variable is correlated with included variables, has been susceptible to biased estimates of coefficients.

Plan of the Dissertation

Chapter I will summarize the different analyses of the effect of risk by Arrow and Tobin. The purpose is to show that the effect of risk has been theoretically researched and to introduce the concept of a moving information set as a means of arriving at a measure of perceived risk. An illustrative example incorporating risk as a variable into a model, based on Tobin's analysis, will be given to show that this concept can be easily introduced into current models.

Chapter II contains the results from an exploratory first test of the variable risk hypothesis in an application to the term structure of interest rates. The empirical research done by Meiselman will be summarized first. Then the criticism offered by Kessel will be reviewed as the argument is developed that the exclusion of variable risk by both authors could lead to a different conclusion about the merits of the expectations, liquidity premium, and term premium theories about term structure. The conclusions reached will depend on the performance of variable risk in explaining the difference between the actual and forward rates.

Chapter III extends the analyses of Chapter II to include corporate bonds of a longer maturity and shows that the measure of variable risk performs better as the term to maturity increases.

Chapter IV continues the approach of using the variable risk hypothesis within the context of the prevailing term structure theories by testing the segmented markets hypothesis. If this theory is correct, there should be separate and distinct markets for bonds of different maturities with no crossover of effects from other markets. Specifically, I test for the effects of risk on one maturity in the market for a bond of a different maturity.

Chapter V takes the opposite approach to that of Chapters II and III, and it attempts to provide further confirmation or refutation of the results of those chapters. We specify a naive model which is in direct opposition to the more sophisticated approach presented earlier. The test is then to see which approach performs better.

Chapter VI presents some final comments and suggestions for further applications.

CHAPTER I

THEORETICAL ANALYSIS OF RISK AND THE VARIABLE RISK HYPOTHESIS

In this chapter, we present the analyses of Arrow and Tobin on the effect of changes in perceived risk.[1] The purpose is to establish a theoretical background for the variable risk hypothesis derived from utility maximizing postulates. Arrow's analysis is a refinement of Tobin's, but the two works agree substantially on the effect of a change in perceived risk. We are specifically interested in the effect of changes in perceived risk, and for that purpose we will concentrate on summarizing the analyses of the change in risk and the necessary assumptions in their models which lead to their conclusions. We do not intend to add to the body of theoretical analysis of risk. Arrow's work is summarized because it is a further refinement of Tobin's, and we include Tobin's because the measure of risk used in this dissertation follows from his measure. Previous works testing the variable risk hypothesis will then be summarized, and the moving information set will be introduced. Finally, a model based on Tobin's analysis of liquidity

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[1]See, Arrow, Risk Bearing, and Tobin, "Liquidity Preference."

preference will be given to demonstrate that the variable risk hypothesis can be easily included in current models.

The Contribution of Arrow

Arrow has analyzed the effect of risk when an individual is faced with the decision of dividing his wealth between two different assets.[2] The first is money, which is a riskless asset that does not have a positive yield, and the second is a risky asset whose yield is a random variable. The individual must choose what proportion of his initial wealth to hold in each asset. He is postulated to maximize an expected utility function of the form:

$$\max E[U(Y)] \tag{1.1}$$

where

$E[U(Y)]$ is the expected utility of wealth.

Arrow takes exception to Tobin's formulation, a quadratic utility function, and he argues that the utility function must be monotonically increasing as well as bounded and strictly convex. In this manner, the individual is faced with the familiar constrained maximization problem.

Risk is introduced into the utility function by means of the risky asset. First, income is defined as

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[2] Arrow, Risk Bearing, ch. 3.

$$Y = a(1 + R) + (A - a) , \tag{1.2}$$

where

A = initial wealth,

a = amount invested in the risky asset, and

R = rate of return on the risky asset, a random variable.

Simplifying the equation (1.2) yields

$$Y = A + aR . \tag{1.3}$$

Substituting into equation (1.1) yields the individual's expected utility function which is to be maximized:[3]

$$E[U(Y)] = E[U(A + aR)] . \tag{1.4}$$

Arrow then analyzes the effect of risk by changing the distribution of R, the random yield variable. A shift of the distribution of R to the right or left is written as:

$$R(h) = R + h , \tag{1.5}$$

where

h = a shift parameter.

Similarly, the distribution can be arbitrarily expanded or contracted by the shift parameter and is written as:[4]

$$R(h) = R^* + (1 + h)(R - R^*) , \tag{1.6}$$

where

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[3] Ibid., pp. 98-99. [4] Ibid., p. 104.

R^* is an arbitrary center.

Arrow used equation (1.6) as his measure of the spread or dispersion of the distribution instead of the standard deviation. The deviation between the actual rate of return and the center, $(R - R^*)$, is arbitrarily increased or decreased by increasing or decreasing the value of the shift parameter, h. The deviations from the mean are usually squared and summed for the calculation of the standard deviation. Arrow then states: "A multiplicative shift about a non-negative center diminishes the demand for risky assets in even greater proportion than the shift itself."[5] This statement implies that the demand for risky assets is elastic with respect to risk. If a demand curve for risky assets is being estimated, then the coefficient on risk should be greater than one. The purpose of this study, however, is to test the variable risk hypothesis.

Later, Arrow states:

> A particular application is that in which $R^* = E(R)$. In that case, the shift preserves the mean but increases the spread about it. It may therefore be regarded as a pure increase in uncertainty . . . a pure uncertainty increasing spread decreases the demand for risky assets in even greater proportion.[6]

Tobin's Risk and Liquidity Preferences

Tobin's approach to the analysis of risk is similar to that of Arrow's in that the individual is assumed to

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[5]Ibid., p. 106. [6]Ibid.

have an initial investment balance which is to be held in either cash or consols.[7] Negative amounts are excluded by assumption, so the individual is not permitted to sell short or borrow. The return to the portfolio is:

$$R = A_2(r + g) \ , \tag{1.7}$$

where

R = return to the portfolio,

A_2 = proportion of initial amount held in consols,

r = rate on consols per year, and

g = expected capital gain or loss.

Since the expected capital gain or loss is a random variable with an expected value of zero, the expected return is:

$$E(R) = \mu_R = A_2 r \ . \tag{1.8}$$

Tobin then introduces risk as follows: "The risk attached to a portfolio is to be measured by the standard deviation of R, σ_R,"[8] which is

$$\sigma_R = A_2 \sigma_g \ . \tag{1.9}$$

Combining (1.8) and (1.9) yields the risk-return relationship:

$$\mu_R = \frac{r}{\sigma_g} \sigma_R \ . \tag{1.10}$$

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[7] Tobin, "Liquidity Preference." [8] Ibid., p. 72.

Tobin then analyzes diagrammatically the risk-return trade-off with respect to indifference curves and an opportunity locus.[9] For our purposes, it will not be necessary to repeat this analysis. However, the following statement indicates that Tobin did analyze the effects of changing risk and the role of information in the perception of risk.

> Investor's estimates, σ_g, of the risk of holding monetary assets other than cash, "consols" are subjective. But they are undoubtedly affected by market experience, and they are also subject to influence by measures of monetary and fiscal policy. By actions and words, the central bank can influence investors' estimates of the variability of interest rates; its influence on these estimates of risk may be as important in accomplishing or preventing changes in the rate as open market opeations and other direct interventions in the market. Tax rates, and differences in tax treatment of capital gains, losses and interest earnings, affect in calculable ways the investor's risks and expected returns. For these reasons, it is worthwhile to examine the effects of a change in an investor's estimate of risk on his allocation between cash and consols.[10]

Tobin concludes that as the investor's estimate of risk decreases, the amount held in consols increases.[11] Hence, Tobin recognizes the importance of experience and information in changing the perception of risk.

The works of Arrow and Tobin suggest that changing perceptions of risk are important to the individual. A next step would be to test whether the theoretical analysis of

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[9] Ibid., fig. 3, p. 73. [10] Ibid., p. 80.

[11] Ibid.

the changing perception of risk is valid, but the empirical testing must be done in a manner consistent with the theoretical approach.

The Variable Risk Hypothesis

The variable risk hypothesis can be stated quite simply. If individuals perceive risk, and this risk is taken into account in their decision-making process, then some measure of the changing perceptions of risk would appropriately be included in a complete model of risky decision making. As stated above, the variable risk hypothesis is a link between theory and empirical testing. As such, it should be compatible with different approaches or models of risky decision making, if it is to be of any use. Below, we show how variable risk can be incorporated in a model for empirical testing based on Tobin's analysis; but this is only one example of variable risk. The applications in later chapters show the merit of this concept.

Previous empirical studies which did not include a measure of the risk variable may have been subject to bias in their estimated coefficients. In other words, inclusion of risk as a variable corrects an omitted variables problem. As Johnston states:

> the estimated regression coefficients will be biased estimates of the true coefficients, the extent of the biases depending on the correlations between the

included and the excluded variables and the coefficients of the excluded variables.[12]

There have been two previous tests of the variable risk hypothesis. First tested by Bonomo,[13] it was applied to aggregate consumption behavior, although the thrust was slightly different from that in this dissertation. In Bonomo's framework, risk is conceived as an indicator of the confidence placed in expectations of future income and how that degree of confidence affects consumption. As Keynes has stated:

> The state of long-term expectation, upon which our decisions are based, does not solely depend, therefore, on the most probable forecast we can make. It also depends on the confidence with which we make this forecast--on how highly we rate the likelihood of our best forecast turning out quite wrong.[14]

As his measure of the degrees of expectational risk increased, Bonomo found that the average propensity to consume decreased.

Scott Jones introduces risk as a time-series variable in foreign exchange markets.[15] His approach followed Bonomo's in that the confidence placed in expectations of the future value of an exchange rate was emphasized. His

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[12] J. Johnston, Econometric Methods (McGraw-Hill, 1972), p. 169.

[13] Bonomo, "Variable Risk."

[14] John M. Keynes, The General Theory of Employment, Interest and Money (Harcourt, Brace and World, 1936), p. 148.

[15] Scott Jones, "A Variable Risk Hypothesis in a Forward Exchange Market" (Ph.D. dissertation, Virginia Polytechnic Institute and State University, 1976).

results showed that as confidence in expectations decreased, the forward exchange rates (price of a foreign currency in terms of speculative currency) increased. The application to term structure in Chapter II will examine the effect of variable risk on U.S. corporate bonds, which is similar to Jones's study, in that both are finance-oriented tests.

The importance of information and a set of information which is changing over time are key underlying concepts of the variable risk hypothesis and will be discussed in the next section as an introduction to the measure of risk which is proposed in that section.

The Moving Information Set

The passage from Tobin emphasized the importance of information in the perception of risk. If we consider the use of time-series data, two questions arise concerning how much and which information is used: How much of the past is relevant and how are the various information bits to be weighted? In this section, we examine the way in which information is used in the evaluation of risk.

Tobin's use of the standard deviation to measure risk is reasonable at first glance, but on what information is it calculated? Tobin seems to imply that all past information is to be used. If the individual enters the market at time t, he uses all past information up to that point to form his estimate of risk. Then, after period t + 1, he adds the new information acquired during that time, reevaluates risk, and does the same after period t + 2, t + 3, and so on. There may be some problems with this concpetion if a smaller set of information is actually used in the calculation of risk.

First, information from the distant past may no longer be relevant. Structural changes in a market brought on by new technology or new institutions could make such information irrelevant.

Second, if information is costly, the efficient markets hypothesis implies that this period's interest rate contains all the necessary information to forecast next period's interest rate. While this may be true for the mean or first moment of the distribution of next period's interest rates, we are interested in the second moment as an estimate of risk. For this, more than one observation is needed to obtain an estimate of the variance or standard deviation.

The second point raises some questions concerning the consistency of this approach with the efficient market hypothesis. In Fama's survey article,[16] he defines three information subsets. The weak form consists of the set of historical prices, the semi-strong form consists of information publicly available, and the strong form consists

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[16]Eugene Fama, "Efficient Capital Markets: A Review of Theory and Empirical Work," Journal of Finance 25 (May 1970): 383-417.

of individuals or groups who have monopolistic access to information.[17] The approach of this diddsertation falls into the weak form subset in that we will use historical data on corporate bonds.

Fama then proceeds to discuss equilibrium security prices in terms of Sharpe's two-parameter world. Briefly, Sharpe postulated a utility function of the form:[18]

$$U = f(E_R, \sigma_R) \quad , \tag{1.11}$$

where

E_R = expected rate of return, and

σ_R = standard deviation of expected rate of return.

This formulation is similar to Tobin's, and Arrow's work proceeds from these two works.

Speaking about the various expected returns theories of security pricing, Fama states, "such theories would posit that conditional on some relevant information set, the equilibrium expected return on a security is a function of its 'risk'."[19] The remainder of the article is a survey of tests using one of the three forms of information. There is no further mention of risk. The work of Bonomo and Jones

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[17] Ibid., p. 383.

[18] William F. Sharpe, "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," Journal of Finance 19 (September 1964): 428.

[19] Fama, "Efficient Capital Markets," p. 384.

would seem to fit in this framework as an extension of the expected returns theories.

This dissertation would also seem to fit in this framework as an extension of the expected returns theories. Referring to equation (1.11), the efficient markets literature has concentrated on E_R, while this dissertation concentrates on developing and testing a measure of σ_R. We are also specifying the weak information subset as the relevant one for investors' perception of risk.

This suggests that a <u>moving information set</u> is appropriate for the evaluation of risk by individuals. That is, the set of information used by the individual is hypothesized to be continually changing as new information is added and old information is discarded. Exactly how much of the past is considered relevant cannot be determined a priori. However, it is possible to test various information sets to determine what is the appropriate length of time considered by the individual.

A moving information set is compatible with current theories of expectations formation. If the information set contains just one variable, say interest rates, then it would be similar in approach to the adaptive expectations theory or a simple autoregressive scheme. Another approach to expectations formation is the rational expectations approach. The individual is hypothesized to consider more than just past interest rates as he attempts to identify the underlying forces affecting interest rates. In this case, the moving information set would consist of more than one variable. Measures of monetary and fiscal policy and the inflation rate or, more specifically, the variability of these forces would be included in the information set on which the individual bases his estimate of risk.

Measuring Variable Risk

We now seek a measure of variable risk which is consistent with the moving information set. This could be done by using a moving standard deviation through time. In this way, as new information becomes available, it is added to the set, while outdated information is dropped from the set. The weighting scheme is simply that current information, or the recent past, is more useful than old information or the distant past.

Using the raw standard deviation could lead to problems of scale. Frederick Mills says:

> Because the standard deviation of horse weights is greater than the standard deviation of dog weights, it does not follow that the degree of variability is greater in the former case. A measure of absolute variation is significant only in relation to the average from which the deviations are measured.[20]

For this reason, the measure of risk that will be used in this dissertation will be the moving standard deviation

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[20] Frederick Mills, Statistical Methods (Henry Holt and Co., 1924), p. 129.

divided by the moving average which might be called the moving coefficient of variation. Various information sets can be tested by simply changing the period over which the mean and standard deviation are measured.

Applying Variable Risk

Incorporating variable risk into existing models can be accomplished in a straightforward manner. For example, Tobin's analysis implies an inverse relationship between the interest rate and the proportion of income held as cash, or

$$\frac{M}{Y} = f(R) \qquad f' < 0 \tag{1.12}$$

where

M = nominal cash holdings,

Y = nominal income, and

R = interest rate (assuming only one other asset as Tobin does).

If equation (1.12) were to be estimated as a linear relationship, the equation would be:

$$\frac{M(t)}{Y(t)} = a - bR(t)\ . \tag{1.13}$$

Note that as R increases, the proportion of income held as cash decreases due to the opportunity cost of holding the zero yield asset, money. Risk could then be included as an explanatory variable and the theoretical equation (1.12) rewritten as:

$$\frac{M}{Y} = f(R,\sigma^*) \qquad f'(R) < 0 \qquad f'(\sigma^*) > 0 \tag{1.14}$$

where

σ^* is the measure of risk.

As risk, σ^*, increases, cash holding increases according to the previous analyses of Tobin and Arrow. Estimating the theoretical equation (1.13) would require the respecification of equation (1.12) to include a measure of risk as an explanatory variable. One form might be

$$\frac{M(t)}{Y(t)} = a - bR(t) + c\left[\frac{\sigma^*(t)}{\overline{R}(t)}\right] , \tag{1.15}$$

where

$\frac{\sigma^*(t)}{\overline{R}(t)}$ is the measure of risk discussed previously.

Including a measure or risk would be consistent with the theoretical analysis of Tobin, while solving a possible omitted variables problem and removing the resulting bias in the coefficients.

Conclusion

The emphasis on variability in this dissertation is also reflected in the economics profession. In his Nobel lecture, Milton Friedman stressed the importance of the increased variability of the inflation rate.[21] While the object of the analysis is unemployment, the effects of

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[21] Milton Friedman, "Nobel Lecture: Inflation and Unemployment," Journal of Political Economy 85 (June 1977): 451-72.

increased variability on employment can be generalized to cover other subjects. Friedman concludes that: "Higher average inventories of all kinds are one way to meet increased rigidity and uncertainty."[22] Friedman also states that "The more volatile the rate of general inflation, the harder it becomes to extract the signal about relative prices from the absolute prices."[23]

In the first statement, higher inventories could be read as higher cash balances needed to conduct transactions, and the analysis could have come from Arrow or Tobin. In the second statement, higher volatility (or higher risk) requires more information to evaluate the effects of the increased volatility (or risk). This is the analysis that was presented when the moving information set was discussed: The current interest rate may contain all the necessary information to estimate next period's interest rate, but more information is needed to evaluate the risk.

Friedman's remarks appeared in the Journal of Political Economy. There is also evidence that volatility or variability is receiving attention in journals not specifically concerned with the higher realms of economic theory. For example, in Business Economics, the following comment appeared: "One way or the other, yields on

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[22]Ibid., p. 466. [23]Ibid., p. 467.

existing portfolios must and will be better attuned to volatile open market rates."[24] Since this journal is concerned with research that has more practical applications, such a quote shows that concern over variability is not confined to the academic researcher.

In the next four chapters, we present an analysis of risk as applied to the term structure of interest rates. The thrust of the analysis is empirical and we hope to draw some conclusions concerning macro and monetary policy.

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[24] George Hanc and Saul B. Klaman, "Innovation and Evolution in the Thrift Industry," Business Economics 12 (January 1977): 43-47.

CHAPTER II

TERM STRUCTURE THEORIES

The first test of the variable risk hypothesis in this dissertation will focus on a test of the effect of risk on the term structure of interest rates. Term structure is the study of the relationships of the levels of yields to maturity and the time to maturity of default-free financial assets. In testing the variable risk hypothesis, we will also provide further evidence in the continuing debate among the four theories which attempt to explain the term structure. The two empirical works which started the debate, by David Meiselman and Reuben Kessel, will be summarized after the four theories have been capsuled.

Prevailing Term Structure Theories

In order to understand the works of Meiselman and Kessel, and the test to be presented in the following chapters, it would be helpful to briefly summarize the four theories concerning the term structure.[2]

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[1]David Meiselman, The Term Structure of Interest Rates (Prentice-Hall, 1962); and, Reuben Kessel, The Cyclical Behavior of the Term Structure of Interest Rates (NBER Occasional Paper, no. 91, 1965).

[2]For further references, see, Jacob Michaelsen, The Term Structure of Interest Rates (Intext Educational Publishers, 1973).

Segmented Markets Hypothesis. As the title of this hypothesis suggests, bonds of different maturities are treated as belonging to separate and distinct markets. Individuals in the market are assumed to have preferences concerning the length of time to maturity. They buy assets such that assets provide sufficient cash when they mature to meet expenditures as they occur.

These individuals are called hedgers as opposed to speculators who do seek capital gains. Hedgers are also characterized by the term "widows and orphans" who are interested in meeting their expenses and do not forecast interest rates, since they do not have a speculative motive.

The main criticism levied against this view is that information on alternative assets is not incorporated in bond prices. If there are speculative gains to be made by forecasting interest rates, why does one not do so? It would seem that each individual and market operates in a vacuum unaffected by any outside forces in the real world.

The segmented markets hypothesis was first proposed by J. M. Culbertson.[3] A more modern version of this hypothesis was advanced by Franco Modigliani and Richard Sutch and given the title of the preferred habitat theory.[4]

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[3]J. M. Culbertson, "The Term Structure of Interest Rates," Quarterly Journal of Economics 71 (November 1957): 485-517.

[4]Franco Modigliani and Richard Sutch, "Innovations in Interest Rate Policy," American Economic Review 56 (May 1966): 178-97.

> Following their argument, market participants have preferred maturity habitats which reflect the desire, and serve to eliminate interest rate risk by insuring that maturing assets provide sufficient cash to meet liabilities as they fall due.[5]

The preferred habitat theory places emphasis on the investors, while the segmented markets hypothesis treats each market as a separate institution. The preferred habitat theory is more flexible in that it is compatible with other approaches such as the liquidity premium theory to be summarized next.

The Expectations Hypothesis. The expectations hypothesis states that a long-term interest rate is an average of expected future short-term rates, and that forward rates are unbiased estimates of expected future rates of the same maturity. In this view, bonds are identical except for differing maturity.

This theory represents an improvement over the segmented markets theory in that it allows both information and expectations to be incorporated in the term structure. As new information is obtained and expectations of future rates are revised, the changes are reflected in the current term structure.

There are two criticisms here. First, how is information processed by the market? Do all individuals have the

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[5] Michaelsen, Term Structure, p. 81.

same information and forecasts? It would seem from the description given above that expectations are homogeneous. However, Michaelsen cites evidence that this is not true.[6] Second, the possibility that these homogeneous expectations could be incorrect is ignored because of the assumed indifference to risk.

Liquidity Preference Hypothesis. The liquidity preference hypothesis combines and builds upon the two previous theories. As above, there are assumed to be two types of individuals: hedgers, who wish to stay in their preferred habitat, and speculators, who will depart from their preferred habitat, the preferred habitat being a particular length of time to maturity which is more desirable than any other maturity. These speculators will only leave their preferred habitat if compensated by a liquidity premium for the risk they incur.

Theoretically, a speculator could buy either shorter or longer maturing assets. However, relying heavily on the risk aversion assumption and the uncertainty of the future in general, it is reasonable to say that liquidity premiums rise as the term to maturity increases. Borrowers wish to borrow long, while lenders have a shorter preferred habitat. Therefore, lenders must be increasingly compensated in order to buy longer maturities.

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[6] Ibid., p. 84.

Term Premium Hypothesis. The term premium hypothesis is proposed by Michaelsen in his book.[7] A term premium exists because of the existence of risk as Michaelsen states:

> Interest rate risk, then, arises because of the necessity of making commitments which may turn out to be inappropriate not because of changes in circumstances internal to the enterprise but because of such changes elsewhere.[8]

Notice that Michaelsen follows the line of reasoning used by Arrow and, especially, Tobin. Disturbances external to the enterprise are the cause of risk. In other words, the information set is changing over time which, in turn, leads to changes in risk. Term premiums may be considered to be an application of the more genreal analyses of Arrow and Tobin to term structure. This is easily seen in the definition of a term premium.

> Because interest rate risk is undesirable, the prices of dated securities are lower than they would otherwise be in proportion to the amount of time they span, given the levels of successive short-period rates. The price of perpetuities are similarly affected. Yields to maturity are consequently higher by an amount which we designate a term premium, term premiums being an increasing function of term to maturity. The magnitude and rate of increase in term premiums depends on, among other things, the amount of interest rate risk to be borne. Alterations of the maturity composition changes the amount of interest rate risk in the system, increases in average maturity increasing the magnitude of term premiums, and decreases in average maturity decreasing them.[9]

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[7]Ibid., ch. 3. [8]Ibid., p. 71. [9]Ibid., p. 72.

The passage quoted above does not explicitly state the behavioral assumptions underlying term premiums. It is obviously risk aversion on the part of investors who have a shorter preferred habitat facing borrowers who wish to borrow long which leads to the existence of term premiums. Also, term premiums would seem to be indistinguishable from liquidity premiums. On this, Michaelsen states that at a given point in time, two premiums are formally equivalent. However, liquidity premiums could be negative if borrowers had shorter habitats and lenders had longer habitats. Term premiums must be positive, he claims, because of the empirical circumstance that disequilibrating disturbances tend to produce positively correlated movement in one-period rates.[10] We will have more to say on this point in the following sections.

Meiselman's Investigation

Before describing Meiselman's study of the term structure, it would be helpful to define a forward rate as

$$F_i(t,t+n) = \frac{(1+R_{t+n}(t))^{t+n}}{(1+R_{t+n-i})^{t+n-i}} - 1 \quad \text{for } i=1,\ldots,n \qquad (2.1)$$

where

$F_i(t,t+n)$ = the forward rate for a bond of i years maturity at time t for period t+n, and

$R_{t+n}(t)$ = the actual rate on a bond of t+n years maturity at time t.

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[10] Ibid., p. 90.

The forward rate can be defined as "the rate at which the capital sum invested in a simple claim grows when invested for one more period."[11] More properly, $F_i(t,t+n)$ is the implicit forward rate, since it must be calculated using the returns on bonds of different maturities and should not be confused with forward contracts or futures trading.

If we consider one- and two-year bonds, the forward rate, or marginal rate as it is sometimes called, is simply the rate of return earned in the second year of the two-year bond discounted to the present using the one-year rate. Likewise, there is a one-year forward rate two periods ahead, three periods ahead, and so on. There is also a two-year forward rate one period ahead, a three-year forward rate one period ahead, and so on.[12]

The expectations hypothesis implies that forward rates are unbiased estimates of the expected future rates or

$$F_i(t,t+n) = R_i^*(t,t+n) \ , \tag{2.2}$$

where

$R_i^*(t,t+n)$ = the rate expected at period t to prevail in period t+n.

The liquidity premium hypothesis adds the liquidity premium to equation (2.2),

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[11]Eugene Fama and Merton Miller, The Theory of Finance (Dryden Press, 1972), p. 35.

[12]Michaelsen, Term Structure, p. 83.

$$F_i(t,t+n) = R_i^*(t,t+n) + L_i(t,t+n) \ , \qquad (2.3)$$

where

$L_i(t,t+n)$ = the liquidity premium at time t for period t+n.

The term premium hypothesis substitutes a term premium for the liquidity premium in equation (2.3),

$$F_i(t,t+n) = R_i^*(t,t+n) + T_i(t,t+n) \ , \qquad (2.4)$$

where

$T_i(t,t+n)$ = the term premium at time t for period t+n.

Meiselman applied the adaptive expectations or error learning approach to the term structure by saying that forecasts of interest rates are revised based on previous forecasting errors.[13] In other words, individuals learn from past mistakes. Define the error in forecasting as

$$E_i(t) = R_i(t) - F_i(t-1,t) \ , \qquad (2.5)$$

and define the revision in expectations as

$$\Delta R_i^*(t,t+n) = R_i^*(t,t+n) - R_i^*(t-1,t+n) \ . \qquad (2.6)$$

Meiselman then assumed a linear relationship between the changes in expectations and the error in forecasting, and he estimated the following equation:

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[13]Meiselman, Interest Rates.

$$\Delta R_i^*(t,t+n) = \alpha + \beta\, \varepsilon_i(t) + \varepsilon(t) \quad , \tag{2.7}$$

where

$\varepsilon(t)$ is the disturbance term.

Meiselman's results for the one-period rate seem to support his error-learning postulate.[14] The βs are all significant and positive, while the αs are zero, or close to zero, and not significant. These results were interpreted by Meiselman as support for his view and the expectations hypothesis. Especially important was the lack of significance of the constant term. If it were statistically significant, it would imply that expectations were revised even if no error occurred.

The most important analysis criticizing Meiselman for our purposes is that by Kessel, and it will be summarized next.[15] Other criticisms of Meiselman's work have been given, but they are not relevant for the argument being developed here.[16]

Kessel's Criticism

Kessel followed Meiselman's approach in that he accepted forward rates as representing expected rates. He proposed to test the expectations hypothesis by examining the errors or differences between the forward rate and the

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[14] Ibid., p. 22. [15] Kessel, Cyclical Behavior.

[16] See, Michaelsen, Term Structure, pp. 86-88.

actual rate. If the expectations theory is correct, the errors should have a mean of zero and the forward rate would be an unbiased estimate of the actual rate. Kessel did not use the Durand data, but calculated forward rates using Treasury Bill data on 14 to 91 day rates. Kessel found the following mean errors:[17]

Length of Maturity	Mean Error (%)	Average Actual Rate (%)
14 days	0.199	2.34
28 days	0.567	2.39
42 days	0.599	2.54
56 days	0.444	2.67
63 days	0.455	2.79
91 days	0.669	2.91

As Kessel noted, these results show the forward rate to be a biased and high estimator of the actual rate, although the statistical significance, if any, is not reported. The mean difference was attributed to the existence of a liquidity premium. The errors increase from the 14 to the 42 day rate, then they decline and begin to rise again from the 56 to 91 day rate. Notice, also, that the average actual rate increases monotonically as maturity increases, which is consistent with the liequidity premium hypothesis, although the mean differences do not consistently support this hypothesis.

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[17]Kessel, Cyclical Behavior, p. 24.

Kessel then hypothesized that the liquidity premium would rise as the level of interest rates increased. He tested this by regressing the difference between the forward and actual rates in t on the level of rates in t-1. He found a positive relationship. These results were for the short-term Treasury Bill data only. As the maturity increased to one and two years, the results were not significant.[18]

Since the publication of these two works, the debate over which theory is correct has been continued by different authors with many empirical studies. We will now introduce the variable risk hypothesis into the debate.

How Variable Risk Fits In

In Chapter I, it was argued that the exclusion of risk as a variable from empirical studies is not consistent with the theoretical analyses of risk by Arrow and Tobin. And, Kessel showed the mean difference between forward and actual rates to be positive.

Our hypothesis can be stated just as simply: it is postulated that the difference between the forward and actual rates depends on risk. Furthermore, as risk increases, it is postulated that the difference between the rates would increase. This is similar to Michaelsen's term premium hypothesis. As risk increases, and therefore

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[18] Ibid., pp. 32-33.

the chance of a loss increases (with the corresponding loss of utility), investors will require a larger and larger premium in order to hold assets of a longer maturity. The term premium can be thought of as the price of insurance against possible losses due to an undertain future. Michaelsen also stated that term premiums can vary over time due to the changing perception of risk. But Michaelsen does not test his theory empirically. We propose to do so as our test of the variable risk hypothesis. In this application, testing the variable risk hypothesis will also test the term premium hypothesis.

In order to avoid the problems of scale discussed in Chapter I, we do not propose to test the absolute difference between the forward and actual rates. Instead, we propose to use the relative difference or error between the two rates which is defined as

$$\text{Relative Error} = \frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} \qquad (2.8)$$

where

the variables are those as defined in equation (2.1).

Using the relative error rather than the absolute error will avoid any problems which could arise when the absolute error is large because interest rates are high. Indeed, this is what Kessel found in this regression analysis and was criticized for it by Michaelsen.[19]

[19] Michaelsen, Term Structure, p. 94.

The equation we will estimate is

$$\frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} = \Theta + \lambda \frac{\sigma_i^*(t)}{\overline{R}_i(t)} \qquad (2.9)$$

where

$\frac{\sigma_i^*(t)}{\overline{R}_i(t)}$ is our measure of risk.

It should not be expected that movements in risk explain all of the movement in the relative error. Certainly there are other factors affecting the relative error and many of these would not be amenable to quanitification and empirical testing. However, we do propose to test whether the variable risk hypothesis has any explanatory power.

Previous Research: Economic Literature

There have been two empirical studies on risk and term structure, and of particular interest are the measures of risk used in the empirical testing. James Van Horne uses monthly Treasury yield-curve data to group the observations into two clusters representing changes in the accustomed level of interest rates.[20] The accustomed level is the average level of interest rates in each cluster. Risk is then "the difference of the actual forward-rate level from

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[20] James Van Horne, "Interest Rate Risk and the Term Structure of Interest Rates," Journal of Political Economy 73 (August 1965): 344-51.

the accustomed level."[21] Van Horne analyzes only the one month forward rate which is calculated up to twelve months in the future, and his dependent variable is the change in forward rates such as Meiselman used.

Van Horne's study is an attempt to add a measure of risk to Meiselman's study. While the statistical results showed that interest-rate risk varied inversely with the level of interest rates, the measure of risk is open to some criticism.

Taking the deviation from an average is an interesting approach to obtaining a measure of risk; however, care must be taken in selecting the approrpiate time series over which to average. The deviation of the first observation from the average is based on information not known at the beginning of the series. The average can only be calculated once the entire cluster is known, and a deviation from the average is therefore not a good measure of risk.

The second study of risk is by Robert Olsen who also used Treasury Bill data.[22] The dependent variable is the difference between the 3 month forward rate 3 months ahead and the actual rate to prevail at that time. This is the unadjusted liquidity premium and is subject to the same

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[21] Ibid., p. 349.

[22] Robert A. Olsen, "The Effect of Interest-Rate Risk on Liquidity Premiums: An Empirical Investigation," Journal of Financial and Quantitative Analysis 9 (November 1974): 901-10.

criticism about levels of interest rates which led to the use of the relative error in this dissertation. Olsen's measure of risk is the variance of the expected rate of inflation. The expected rate of inflation is calculated from a survey, compiled by Joseph Livingston, of business economists and finance officers on their expectations of the Consumer Price Index six months ahead. The results showed that as the variance in the expected inflation rate increased, the liquidity premium increased. Again, there are some problems in this study.

In his comment, Burton Zwick points out that there is a lag between the formation of inflationary expectations and their inclusion in nominal interest rates, and perhaps Olsen's measure of risk does not account for this.[23] But there is a more serious defect in that changes in the real rate of interest are not taken into account. This will be discussed later as a further development of this dissertation.

Previous Research: Stock Market Literature

The empirical research on risk and return in the stock market contains many different measures of risk. In general, the emphasis of this research has been on developing measures of risk and return to identify superior portfolios

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[23] Burton Zwick, "Comment: The Effect of Interest-Rate Risk on Liquidity Premiums: An Empirical Investigation," Journal of Financial and Quantitative Analysis 9 (November 1974): 911-13.

or individual stocks. We will give a brief survey of these measures in this section.

The first common measure is called the "reward-to-risk" ratio or "return-to-risk" ratio. Quite simply, it is the inverse of the coefficient of variation and relates the average yield of the stock or portfolio over time to its standard deviation. This measure is used by Robert Soldofsky and Roger Biderman to evaluate the relative performance of high and low grade stocks.[24] They conclude that low grade stocks have had a better performance than high grade stocks using this criterion. James Gentry and John Pike use the same measure to evaluate the yield of common stock portfolios of life insurance companies.[25] There is no attempt to separate rate of return risk and default risk in these works, and, for their purposes, it is not necessary. The aim is to provide a measure of performance to be used by portfolio managers in selecting stocks for investment.

The second common measure is called "beta" and is derived from the following equation.

$$R_i = \alpha + \beta R_m \,, \tag{2.10}$$

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[24] Robert M. Soldofsky and Roger Biderman, "Yield-Risk Measurements of the Performance of Common Stocks," Journal of Financial and Quantitative Analysis 3 (March 1968): 59-74.

[25] James Gentry and John Pike, "An Empirical Study of the Risk-Return Hypothesis Using Common Stock Portfolios of Life Insurance Companies," Journal of Financial and Quantitative Analysis 15 (June 1970): 179-85.

where

R_i = rate of return of a particular stock or mutual fund, and

R_m = some measure of the market rate of return such as the Standard and Poor's Index or the return on government securities such as Treasury Bills.

Equation (2.10) is called the "characteristic line," and β measures the sensitivity of the particular stock to fluctuations in the overall stock market. There has also been much controversy over this measure, and Allen Silver has done an excellent review of the arguments for and against its use.[26] The controversy is centered around using the past as an indicator of the future and separating the market into "up" and "down" periods for a more sophisticated measure.

William Sharpe has published two articles of interest. The first deals with the yield of 34 mutual funds over the period 1954 to 1963.[27] Sharpe estimates the following equation

$$ARR = \alpha + \gamma \sigma \qquad (2.11)$$

where

ARR = average rate of return for each mutual fund, and

σ = standard deviation of the returns for each fund.

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[26] Allen Silver, "Beta: Up, Down and Sideways," Journal of Portfolio Management 1 (Summer 1975): 54-60.

[27] William F. Sharpe, "Risk-Aversion in the Stock Market: Some Empirical Evidence," Journal of Finance 20 (September 1965): 416-22.

γ was found to be positive, and Sharpe concludes that the mutual funds with higher standard deviations (risk) pay a higher rate of return.

In the second article,[28] Sharpe advocates the use of a reward to variability ratio of the form

$$\text{Performance Ratio} = \frac{\text{Avg. Quarterly Excess Return}}{\text{Standard Deviation}} \tag{2.12}$$

Excess return is defined as the difference between the return of a stock and the return on a riskless asset such as the 90-day Treasury Bill. This measure is a more sophisticated version of the ratios surveyed above.

Lastly, A. James Heins and Stephan L. Allison make use of a different measure of stock price variability.[29] Their measure is

$$\text{Price Variability} = \frac{\text{High Price - Low Price}}{\text{Average Price}} \tag{2.13}$$

This measure captures the total spread of the stock price and relates it to the mean. However, the standard deviation would seem to be a better measure of the dispersion of the distribution of a stock price, since Heins's and Allison's

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[28] William F. Sharpe, "Adjusting for Risk in Portfolio Performance Measurement," Journal of Portfolio Management 1 (Winter 1975): 29-34.

[29] A. James Heins and Stephan L. Allison, "Some Factors Affecting Stock Price Variability," Journal of Business 39 (January 1966): 19-23.

measure excludes the distribution of stock prices between the two extreme values.

All of these measures attempt to capture the risk-return trade-off for stocks and mutual funds. It is gratifying to note that the measure of risk proposed in this dissertation has some basis in published research.

Measuring Risk

The measure of risk is that proposed in Chapter I--the standard deviation divided by the average level of interest rates. This measure adjusts for a high level of interest rates, and it does not appear to be susceptible to problems of scale.

Note that if the standard deviation increases or decreases with no change in the average, then there is a pure change in risk which both Arrow and Tobin analyzed in some detail. If the standard deviation remains constant, and the average increases, it is hypothesized that perceived risk decreases. This is Arrow's additive shift, and our model predicts that the relative error should decrease. This could be justified by postulating that the effect of an increased return due to previous higher interest rates, with no increase in perceived risk, would be of sufficient magnitude to offset any desire for a term premium. If both numerator and denominator are changing at the same time, it is possible that an increase in the standard deviation will be offset by a corresponding increase in the mean, and there may not be a change in perceived risk. If this is not the case, we must allow the data to determine whether or not risk is a statistically significant factor.

The Data and Methodology

Equation (2.9) was estimated using ordinary least-squares regression analysis. The data used were Durand's annual observations of annual yields on U.S. corporate bonds of 1 to 10 years maturity. The data cover the period from 1900 to 1954.

The approach was to calculate the forward rate as far in the future as the data would allow. In this chapter, the one-year forward rate is calculated nine years in the future with the Durand data. The 55 observations of the original data were reduced to 51, due to the calculation of risk using a 5-year moving average and standard deviation. The 5-year period was arbitrarily chosen because up to 9 observations are lost calculating the relative error, and, together with the 4 observations lost in calculating risk, it adds up to 13 observations lost in a sample of 55. If a 10-year moving average and standard deviation were to be used, 18 observations would be lost. Also, it was felt that 5 years is sufficiently long for information to be obtained, evaluated, and to arrive at an assessment of risk.

The Statistical Results

Table 2.1 presents the results of estimating equation (2.9) for the one-year forward rate from one to nine years ahead.[30] At first glance, the results appear to support the variable risk hypothesis until the Durbin-Watson statistics are examined. They decline steadily from 1.14 to 0.28. These statistics indicate the presence of serial correlation which would result in standard errors which are biased downward and t-statistics which are biased upward. To correct for this problem, the Cochrane-Orcutt procedure was used.

Table 2.2 presents the results of estimating equation (2.9) using the Cochrane-Orcutt procedure. The Durbin-Watson statistics are considerably improved ranging from 1.90 to 1.28. However, the other results do not appear encouraging. The coefficient on risk, λ, is significant in only one case--the three-period ahead equation. The R^2 on Cochrane-Orcutt differences, R^2(c-o), reaches a maximum at 0.3098 for the three-period equation and then declines steadily. All told, the results are disappointing.

Conclusion

The statistical results do not support the variable risk hypothesis. Because these results are for the one-year

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[30] The author apologizes for the lengthy tables, but it was felt that summary tables could be interpreted as an attempt to mislead the reader regarding unsuccessful results.

TABLE 2.1

REGRESSION RESULTS, R_1 - OLS

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W
1	-0.192 (1.47)	2.267* (4.15)	0.2636	17.18**	1.14
2	-0.473 (1.96)	4.973* (4.94)	0.3417	24.40**	0.87
3	-0.725* (2.43)	7.392* (5.94)	0.4339	35.25**	0.50
4	-0.585 (1.50)	7.634* (4.71)	0.3300	22.17**	0.45
5	-0.187 (0.39)	6.593* (3.26)	0.1947	10.64**	0.39
6	0.334 (0.59)	4.685 (1.99)	0.0840	3.94	0.32
7	0.742 (1.17)	3.211 (1.22)	0.0343	1.49	0.30
8	0.869 (1.44)	2.549 (0.92)	0.0202	0.84	0.28
9	1.299 (1.87)	1.248 (0.44)	0.0048	0.19	0.29

*t statistics (shown in parentheses) are significant at 5 percent level or better.

**F statistic significant at 1 percent level or better.

NOTE: The notation above will remain the same for all other tables in the text.

TABLE 2.2

REGRESSION RESULTS, R_1 - CORC

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W	R^2(c-o)
1	0.233 (0.94)	0.165 (0.21)	0.4471	38.00**	1.90	0.1668
2	0.169 (0.37)	1.798 (1.35)	0.5876	65.54**	1.51	0.1498
3	-0.324 (0.55)	5.207* (3.79)	0.7602	142.64**	1.42	0.3038
4	0.295 (0.33)	3.135 (1.93)	0.7654	143.55**	1.59	0.1404
5	1.123 (0.87)	0.111 (0.06)	0.7751	148.20**	1.44	0.0605
6	1.853 (1.15)	-2.248 (1.20)	0.7947	162.60**	1.36	0.0888
7	1.920 (1.17)	-2.453 (1.10)	0.7634	132.30**	1.39	0.0923
8	1.236 (0.79)	1.449 (0.60)	0.7457	117.32**	1.28	0.0781
9	1.745 (1.09)	-0.353 (0.14)	0.7361	108.79**	1.54	0.0742

NOTE: R^2(c-o) is the R^2 on Cochrane-Orcutt differences.

*t statistics significant at the 5 percent level or better.

**F statistic significant at 1 percent level or better.

rate, we should not be too hasty in abandoning the validity of the variable risk hypothesis. We will postpone any further analysis of these results until the regression results for bonds of longer maturity are reported in Chapter III. At that point, it will be possible to analyze all the results at one time and arrive at some meaningful conclusions.

CHAPTER III

EMPIRICAL TEST OF THE VARIABLE RISK HYPOTHESIS

In this chapter, variable risk is tested using bonds of a longer maturity. In the process of testing the variable risk hypothesis, the liquidity premium and term premium theories will also be tested.

Preliminary Expectations

The equation to be estimated is the same as that proposed in Chapter II.

$$\frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} = \theta + \lambda \frac{\sigma_i^*(t)}{\overline{R}_i(t)} \tag{3.1}$$

where

the variables are the same as those defined in equations (2.1) and (2.9), and $i = 2,\ldots,9$ years maturity.

Since the term to maturity is longer, we expect the coefficient on risk, λ, the be greater than those for the one year rate. The t statistics and R^2 should also be larger, and the explanatory power of the measure of risk should increase as the term to maturity increases from 2 to 9 years. The reasons are the following.

Quite simply, we are following the line of reasoning used by Michaelsen for the existence of term premiums and detailed in the cited passages in Chapter II. Increasing maturity leads to increasing interest-rate risk, since the future course of interest rates is unknown. In addition, the liquidity premium hypothesis is consistent with the term premium hypothesis in predicting that risk is more important as maturity increases. An investor can be induced out of his preferred habitat by the addition of a liquidity premium on an asset of a different maturity. It makes no difference whether the preferred maturity is short or long; the investor is satisfied in that maturity and must be compensated to invest in an asset of a different maturity.

If the "constitutional weakness" of the market for debt is considered, a more precise prediction using the liquidity preference theory can be obtained. The weakness is that borrowers wish to borrow long and lenders prefer to lend for a shorter period. This suggests that the borrowers must offer higher liquidity premiums as the term to maturity increases. The larger premium should also result in a larger relative error as maturity increases. Assuming investors are risk averse, the measure of risk should perform better as maturity increases. Therefore, the term and liquidity premium theories are consistent with each other in predicting a more important role for risk as maturity increases.

Implicitly assumed in these theories is that investors buy the assets and then keep them until they mature. But what of the speculator who buys an asset in the hope of a decrease in interest rates? He has no preferred habitat and, since bonds are traded daily, has the chance to earn a capital gain. The relative mix of hedgers and speculators in the market could affect the results predicted above if there were a sufficiently large number of speculators. Again, relying on the assumption of risk aversion, there is a possible solution. Taking a strong view of risk aversion, the speculator cannot be certain that he would be able to sell the asset at a profit at some future date. At worst, he could be forced to hold the asset until maturity if an opportunity does not present itself to sell at a profit, and he joins the rest of the market as analyzed above. The longer is the maturity, the greater the chance of a capital gain or loss. The speculator is looking for a gain, but he must insure himself against a loss. This suggests that the speculator will also demand a term premium. This premium may not be as large in magnitude as that required by a hedger because the speculator is hoping for a capital gain and does not see himself as holding the asset to maturity. Also, it is in his interest to behave as a hedger to obtain the lowest price possible and afford himself of the opportunity for a larger capital gain.

The variable risk hypothesis is closely tied with both the term and liquidity premium theories. The test of the variable risk hypothesis in this chapter is also a test of these two theories. However, if the measure of risk does not perform well, it should not be taken as proof that the term and liquidity premium theories are incorrect. Rather, the interpretation should be that the measure of risk is incorrect.

The Statistical Results

Table 3.1 presents the results of estimating equation (3.1) for bonds of 2 to 9 years maturity using ordinary least-squares. It would be tedious to discuss individual coefficients and t-statistics, since there are a total of 36 regressions in this table. It would be more useful to identify patterns in the coefficients in order to draw some conclusions about the variable risk hypothesis and perhaps the conduct of macro and monetary policy.

Again, as was pointed out in the previous chapter, the Durbin-Watson statistics are the key to the OLS results. These statistics range from 0.24 to 1.21 for the two-year rate, R_2, and strongly indicate the presence of serial correlation. Taken as a group, the D-Ws improve as the term to maturity increases. For R_8, the D-W is 1.62 and for R_9

TABLE 3.1

REGRESSION RESULTS

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W
		R_2 - OLS			
1	0.759* (4.47)	3.818* (4.29)	0.2776	18.45**	1.21
2	0.419 (1.40)	8.032* (5.10)	0.3566	26.05**	0.84
3	0.123 (0.33)	11.808* (5.95)	0.4347	35.37**	0.52
4	0.230 (0.48)	12.893* (5.13)	0.3694	26.36**	0.42
5	0.656 (1.11)	11.807* (3.80)	0.2468	14.42**	0.37
6	1.243 (1.80)	9.346* (2.56)	0.1325	6.57	0.29
7	1.756* (2.27)	7.175 (1.75)	0.0678	3.06	0.29
8	1.997* (2.41)	6.537 (1.50)	0.0521	2.25	0.24
		R_3 - OLS			
1	1.791* (9.33)	5.081* (4.25)	0.2732	18.04**	1.27
2	1.423* (4.31)	10.547* (5.09)	0.3556	25.93**	0.82
3	1.104* (2.64)	15.641* (5.93)	0.4332	35.16**	0.54
4	1.161* (2.23)	17.590* (5.38)	0.3918	28.99**	0.39

TABLE 3.1--Continued

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W
5	1.563* (2.45)	16.767* (4.17)	0.2830	17.37**	0.35
6	2.148* (2.88)	14.221* (3.01)	0.1737	9.04**	0.29
7	2.674* (3.15)	11.784* (2.19)	0.1021	4.79	0.29
		R_4 - OLS			
1	2.889* (13.57)	6.092* (4.00)	0.2496	15.96**	1.32
2	2.490* (7.00)	12.926* (5.04)	0.3506	25.37**	0.81
3	2.154* (4.76)	19.090* (5.82)	0.4242	33.89**	0.56
4	2.156* (3.90)	21.978* (5.50)	0.4018	30.23**	0.37
5	2.525* (3.74)	21.670* (4.43)	0.3085	19.63**	0.35
6	3.104* (3.92)	19.048* (3.30)	0.2018	10.87**	0.29
		R_5 - OLS			
1	4.022* (17.55)	7.276* (3.94)	0.2441	15.50**	1.39
2	3.605* (9.50)	15.257* (4.95)	0.3423	24.46**	0.81
3	3.245* (6.70)	22.504* (5.70)	0.4139	32.49**	0.58

TABLE 3.1--Continued

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W
4	3.156* (5.44)	26.866* (5.70)	0.4192	32.48**	0.36
5	3.487* (4.94)	27.117* (4.72)	0.3358	22.25**	0.34
		R_6 - OLS			
1	5.206* (20.67)	8.229* (3.66)	0.2187	13.44**	1.49
2	4.754* (11.76)	17.398* (4.80)	0.3287	23.01**	0.84
3	4.369* (8.54)	25.718* (5.59)	0.4048	31.29**	0.59
4	4.264* (6.95)	30.734* (5.60)	0.4107	31.36**	0.37
		R_7 - OLS			
1	6.440* (23.77)	9.092* (3.43)	0.1973	11.80**	1.56
2	5.974* (13.98)	19.407* (4.62)	0.3124	21.35**	0.86
3	5.566* (10.31)	28.765* (5.42)	0.3899	29.39**	0.60
		R_8 - OLS			
1	7.732* (26.18)	9.935* (3.19)	0.1752	10.19**	1.62
2	7.246* (15.91)	21.300* (4.41)	0.2932	19.50**	0.88

TABLE 3.1--Continued

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W
		R_9 - OLS			
1	9.059* (28.27)	10.792* (2.98)	0.1566	8.91**	1.65

it is 1.65. These measures are barely acceptable, and it was decided to use the Cochrane-Orcutt procedure to correct for the serial correlation.

Table 3.2 presents the results of reestimating equation (3.1) using the Cochrane-Orcutt procedure. The D-W statistics are higher as a group than those reported in Table 3.1. Again, there is an increase in the D-Ws as maturity increases and they do not indicate serial correlation for most of the relative errors up to 4 or 5 periods ahead. The low Durbin-Watson's at this point are attributed to the effect of other variables influencing the relative error which were discussed earlier as not being quantifiable. As Van Horne noted, "expectations beyond the immediate future are likely to be cloudier than near-term expectations."[1]

The regression coefficients exhibit two patterns. Within each interest rate group, R_2, R_3, R_4, ..., the coefficients increase, reach a maximum, and then decrease depending on how far in the future it is possible to calculate the relative error. The highest coefficient occurs about three or four periods ahead, and the t-statistics correspond to this pattern. The R^2(c-o)s correspond to the pattern of the coefficients for R_2 and R_3, but for R_4 through R_9 they reach a maximum in the one-period equation.

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[1]Van Horne, "Interest Rate Risk," p. 345.

TABLE 3.2

REGRESSION RESULTS

Periods Ahead	$\hat{\Theta}$	$\hat{\lambda}$	R^2	F	D-W	R^2(c-o)
			R_2 - CORC			
1	1.086* (3.93)	1.751 (1.37)	0.4102	32.68**	1.90	0.1978
2	1.338* (2.22)	2.363 (1.09)	0.6097	71.87**	1.49	0.1321
3	0.708 (0.93)	7.823* (3.32)	0.7565	139.79**	1.51	0.2571
4	1.348 (1.17)	5.658* (2.17)	0.7924	167.96**	1.60	0.1523
5	2.325 (1.39)	1.271 (0.44)	0.8023	174.47**	1.57	0.0577
6	3.387 (1.58)	-2.632 (0.91)	0.8295	204.31**	1.40	0.0669
7	3.851 (1.64)	-5.328 (1.56)	0.8076	172.11**	1.45	0.1073
8	2.597 (1.25)	3.271 (0.87)	0.7914	151.72**	1.28	0.0759
			R_3 - CORC			
1	2.009* (7.00)	3.412* (2.06)	0.3806	28.88**	1.90	0.2363
2	2.437* (3.59)	3.081 (1.04)	0.6170	74.11**	1.46	0.1279
3	1.864* (2.18)	9.556* (2.88)	0.7485	133.93**	1.58	0.2143
4	2.325 (1.81)	8.525* (2.44)	0.8088	186.17**	1.62	0.1712

TABLE 3.2--Continued

Periods Ahead	$\hat{\Theta}$	$\hat{\lambda}$	R^2	F	D-W	R^2(c-o)
5	3.354 (1.82)	3.153 (0.81)	0.8153	189.87**	1.69	0.0651
6	4.774 (1.96)	-2.773 (0.72)	0.8468	232.11**	1.43	0.0566
7	5.459 (1.96)	-7.699 (1.69)	0.8268	195.71**	1.52	0.1112
			R_4 - CORC			
1	3.046* (10.04)	4.692* (2.29)	0.3405	3.61	1.91	0.2746
2	3.503* (4.89)	4.283 (1.15)	0.6098	71.89**	1.49	0.1328
3	3.102* (3.25)	10.501* (2.47)	0.7415	129.08**	1.65	0.1816
4	3.312* (2.42)	11.564* (2.66)	0.8156	194.58**	1.65	0.1896
5	4.317* (2.28)	5.886 (1.20)	0.8181	193.35**	1.79	0.0822
6	6.164* (2.37)	-3.030 (0.64)	0.8543	246.23**	1.45	0.0531
			R_5 - CORC			
1	4.125* (13.28)	6.219* (2.60)	0.3158	21.69**	1.95	0.3139
2	4.655* (6.18)	5.142 (1.15)	0.6044	70.28**	1.53	0.1337
3	4.470* (4.27)	10.300* (2.01)	0.7366	125.82**	1.68	0.1462
4	4.231* (3.00)	15.794* (3.09)	0.8240	206.06**	1.68	0.2276

TABLE 3.2--*Continued*

Periods Ahead	$\hat{\theta}$	$\hat{\lambda}$	R^2	F	D-W	R^2(c-o)
5	5.335* (2.73)	8.949 (1.55)	0.8264	204.69**	1.87	0.1010
			R_6 - CORC			
1	5.269* (16.22)	7.488* (2.67)	0.2709	17.46**	1.96	0.3540
2	5.698* (7.57)	7.305 (1.39)	0.5783	63.08**	1.56	0.1503
3	5.613* (5.28)	12.207* (2.04)	0.7263	119.42**	1.75	0.1504
4	5.433* (3.73)	17.748* (2.95)	0.8176	197.29**	1.74	0.2156
			R_7 - CORC			
1	6.473* (19.26)	8.643* (2.70)	0.2368	14.58**	1.97	0.3863
2	6.823* (9.05)	9.442 (1.57)	0.5554	57.47**	1.59	0.1647
3	6.908* (6.27)	12.991 (1.90)	0.7153	113.04**	1.78	0.1433
			R_8 - CORC			
1	7.743* (21.68)	9.722* (2.64)	0.2056	12.16**	1.98	0.4119
2	8.040* (10.37)	11.300 (1.64)	0.5292	51.71**	1.60	0.1776
			R_9 - CORC			
1	9.055* (23.73)	10.769* (2.55)	0.1824	10.49**	1.98	0.4280

The second pattern worth noting is that the regression coefficients increase across maturities holding the period ahead constant. For example, from R_2 to R_9 in the one-period ahead equation, the coefficient increases monotonically from 1.751 to 10.769.

There is also one pattern as yet unexplainable. Notice that the explanatory power decreases in the two-period ahead equation and then begins to increase for all maturities up to R_6. It is not possible to calculate the relative error far enough ahead for R_7 to R_9 for a pattern to emerge. This "dip" in the R^2(c-o) at that point has not occurred due to computational error, and the author has no reasonable explanation for this pattern.

Interpretation of the Statistical Results

It is now possible to combine the results for the one-year relative error from Chapter II with those of Chapter III. Referring back to Kessel's study,[2] the average relative error one period ahead for the different maturities is:

R_1	0.26	R_4	3.60	R_7	7.23
R_2	1.36	R_5	4.78	R_8	8.54
R_3	2.47	R_6	5.99	R_9	9.88

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[2]Kessel, *Cyclical Behavior*.

Note that the average relative error increases monotonically as maturity increases, while Kessel's mean difference did not. To take account of scale differences, the relative error, not the mean difference, should be used. This table provides partial support for the term and liquidity premium theories.

Additional support for these approaches to term structure is provided by the statistical results of Chapters II and III. An explanation of the relatively poor results for the one-year relative error is that perhaps the expectations hypothesis holds for the one-year rate. The one-period forward rate has been relatively close to the actual rate as shown in the table above. Beyond one year, a premium is necessary to insure against a capital loss which explains the better results for the longer maturities.

More importantly, the statistical results support the validity of the variable risk hypothesis. Theory suggests that as maturity increases, risk increases and the coefficient of the measure of risk does just this. There is also a slight increase in the t-statistics across all maturities using the one-period ahead results. The results also support Friedman's statements on variability. As variability increases, a larger term premium is needed to make longer term bonds competitive with short-term bonds. Therefore, as variability increases across all interest rates, long-term bonds will sell at a lower price due to higher term premiums. This could affect long-term investment plans of corporations who might be forced to seek other means of financing their investment plans or put them off to a later date or abandon them entirely.

Conclusion

Another interesting point about these results comes from a similar study by the author completed some time ago. The approach in this study was the same, but the measure of risk was different. The measure was based upon the method used by Bonomo in the first test of the variable risk hypothesis, and the interested reader is referred to his paper for a detailed explanation of the method. The point is that the general pattern of coefficients, t-statistics and R^2s was virtually the same in both studies. This lends further support to the variable risk hypothesis, because in the same application using two different measures of risk, the results were quite similar. This demonstrates that indeed the variable risk hypothesis is not dependent on the particular measure of risk used in the application.

The next chapter presents a different application following the approach of using the variable risk hypothesis to test term structure theories.

CHAPTER IV

TEST OF THE SEGMENTED MARKETS HYPOTHESIS

The results of the previous tests of the variable risk hypothesis have been in conjunction with the liquidity and term premium hypotheses. In this chapter, we propose to use the variable risk hypothesis in a test of the segmented markets hypothesis.

The Previous Applications

The introduction of risk in the previous two chapters has been of the form

$$\frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} = \Theta + \lambda \frac{\sigma_i^*(t)}{\overline{R}_i(t)} , \qquad (4.1)$$

where

$i = 1, \ldots, 9$,

which is equation (2.9) repeated for convenience.

It was concluded that the statistical results supported the liquidity and term premium hypotheses, while little has been said about the segmented markets hypothesis. Implicitly, we have been testing this theory by regressing the one-year relative error on the one year measure of risk, the two-year relative error on the two year measure of risk, and so on.

If the results had not been acceptable, indirectly the segmented markets hypothesis would not have been supported because one year risk did not affect the one-year relative error. In this chapter, another test of the segmented markets hypothesis will be proposed which should give more definite proof.

The Segmented Markets Hypothesis

The segmented markets hypothesis was discussed in Chapter II, and we briefly repeat its essence here. Bonds of different maturities are treated as if each is sold in a separate and distinct market. Therefore, as Michaelsen states: "The segmented markets hypothesis suggests, if anything, that the relationship between price movement on securities with different maturities should be unrelated."[1] This means that prices of bonds are determined by forces peculiar to each market, and there is no crossover of effects from the markets of bonds of different maturities. The results of estimating equation (4.1) have suggested that risk within the market is important. It remains to be seen whether risk outside the market for a bond of specific maturity can also affect the relative error.

Specifically, we intend to use the variable risk hypothesis to test the sensitivity of the relative error of one maturity to interest rate risk of a different maturity. We propose to test the segmented markets hypothesis with

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[1] Michaelsen, Term Structure, p. 105.

the following equation:

$$\frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} = \Theta + \sum_{j=1}^{10} \lambda_j \frac{\sigma_j^*(t)}{\overline{R}_j(t)} , \qquad (4.2)$$

where

$i = 1, . . ., 9,$

$j = 1, . . ., 10,$ and

$i \neq j$.

Equation (4.2) postulates that the relative error in the one year rate will be regressed on the measure of risk for 2, 3, ..., 10 year rates, the 2-year relative error on risk for the 1, 3, ..., 10 year rates, and so on.

Notice that the measure of risk for the one year rate is <u>not</u> included in the test of the one-year relative error. As was discussed in Chapter I, the exclusion of an explanatory variable could lead to bias in the estimated coefficients, the extent of bias depending on the correlation of the excluded variable with the included variables. The test proposed in this chapter is subject to such bias, especially since the measures of risk for the different maturities will probably be highly correlated with each other.

The only justification for ignoring such bias is that the segmented markets hypothesis cannot be tested in a consistent manner if risk for that maturity is included. The statistical results in Chapters II and III show that risk does affect the relative error when both are measured for the same maturity. But the segmented markets hypothesis implies that forces outside the market for a bond of specific maturity have no effect in that market. Therefore, a test of this hypothesis would exclude internal forces and include external forces. Equation (4.2) attempts to capture this notion by including the measures of risk for other maturities and excluding the measure of risk for the specific maturity of the dependent variable.

Preliminary Expectations

If the segmented markets hypothesis is valid, we would expect generally poor results with non-significant t-statistics; low R^2s and low F-statistics, thus, would indicate that risk from other bonds has no explanatory power in the movement of the relative error of a specific bond and that the market for each bond is a self-contained unit excluding forces from the markets of other bonds of different maturities.

If the segmented markets hypothesis is to be disproved, we would expect good results in terms of the summary statistics mentioned above. The measures of risk of the different maturities should perform well when tested on the relative error of other maturities. This is not to say that the coefficients for all measures of risk should be significant in every equation. It would be interesting to see a pattern emerge in the estimated coefficients, but that will be pointed out when the results are discussed.

Theoretically, if a general equilibrium approach is taken, it is easy to see why the effects of risk in one maturity could affect the relative error of other maturities. Investors are confronted with an array of assets each of which has risk and return characteristics. If one maturity has a comparative advantage in either return or risk, investors should attempt to acquire this asset and, in so doing, bid up the price until the asset is just competitive with other assets instead of being superior. It makes no difference whether the comparative advantage is in return or risk. If the return is high relative to the risk, the bidding up of the price will bring the asset in line with other assets. If the risk is low relative to the return, the situation is the same. The investor cannot affect the risk immediately, but the price of the bond is directly affected by the investors. This suggests that a daily study of the bond market would be interesting if sufficient data were available. This argument supports the proposition that the segmented markets hypothesis will be disproved, but we will have to examine the statistical results for clarification.

In addition, the signs of the coefficients cannot be specified beforehand. It is possible that changes in risk could increase the relative error as a "shock" makes its way through the economy, resulting in positive coefficients for the measure of risk in different maturities. It is also possible that an increase in risk in a bond of one maturity could increase the demand for a bond of a different maturity and thus decrease the relative error resulting in a negative coefficient. This is the argument made in the preceding paragraph.

Concerning patterns in the coefficients, it is possible that risk in short-term bonds affects the long-term relative error more than vice versa. The rationale is the following.

If we accept the proposition that the economic system tends toward equilibrium, then short-term rates reflect the immediate impact of a shock to the system, while the long-term rates reflect both the diffusion of the shock as it is absorbed by the economy and counter-measures by fiscal and monetary authorities to return the economy to a stable state. Therefore, what happens to short-term rates is partially reflected in long-term rates plus the expectation of corrective measures by economic policy makers. The flow of causality is from the short term to the long term. While this is an interesting theory, it remains for the data to support or reject it.

The Statistical Results: Correlation Coefficients

Before discussing the regression results, some analysis of Table 4.1, which shows the correlation coefficients of the measure of risk for the different maturities, would be

TABLE 4.1

CORRELATION COEFFICIENTS

	σ_1^*	σ_2^*	σ_3^*	σ_4^*	σ_5^*	σ_6^*	σ_7^*	σ_8^*	σ_9^*	σ_{10}^*
σ_1^*	1.00	0.988	0.964	0.937	0.910	0.886	0.861	0.840	0.822	0.808
σ_2^*		1.00	0.993	0.977	0.958	0.939	0.918	0.900	0.883	0.871
σ_3^*			1.00	0.995	0.984	0.971	0.954	0.939	0.925	0.914
σ_4^*				1.00	0.997	0.989	0.977	0.965	0.953	0.943
σ_5^*					1.00	0.998	0.991	0.982	0.972	0.964
σ_6^*						1.00	0.998	0.992	0.985	0.978
σ_7^*							1.00	0.998	0.994	0.989
σ_8^*								1.00	0.999	0.996
σ_9^*									1.00	0.999
σ_{10}^*										1.00

helpful. Table 4.1 presents the correlation coefficients between the measure of risk for the one-year rate, σ_1^*, the measure of risk for the two-year rate, σ_2^*, and so on. The lowest coefficient is 0.808, which is the correlation between σ_1^* and σ_{10}^*. The highest coefficient is 0.999 between σ_8^* and σ_9^* and between σ_9^* and σ_{10}^*. Also of interest is the diagonal adjacent to the row of 1.00s indicating the correlation of σ_1^* and σ_2^*, σ_2^* and σ_3^*, and so on. The coefficient increases as maturity increases from 0.988 to 0.999. The same is true for all of these diagonals. By itself, this table could be offered as evidence against the segmented markets hypothesis, since the cross-correlations should be low according to this theory.

Another point to be considered is the severe multicollinearity indicated by table 4.1 Since these correlation coefficients are high, it will be difficult to distinguish between the effect of the individual σ^*s in the regression equation. Standard errors will be biased upward and, therefore, the t-statistics will be biased downward, leading one to suspect that the variable has no explanatory power. The coefficients themselves will not be biased, so we must rely on summary statistics, such as the R^2 and F statistics, to indicate overall goodness of fit, while not being able to identify significant variables by t-statistics.

The usual approach to correct for multicollinearity is to take first differences or deviations from the mean.

However, the Cochrane-Orcutt procedure uses differences, and the t-statistics are not improved as a result of correcting for serial correlation, as will be seen. The second method is to use deviations from the mean instead of the levels of the variable. The use of deviations from the mean is questionable here, since the original data are standard deviations and means and leave the analysis open to the criticism of manufacturing the results. For this reason, there was no attempt to generate unbiased t-statistics.

The Regression Results

Table 4.2 presents the results of estimating equation (4.2) using ordinary least-squares and the Cochrane-Orcutt procedure. The OLS results are on the left side, including the summary statistics, and the Cochrane-Orcutt results are on the right side. The simple correlation coefficient between the dependent variable and each of the independent variables, ρ, is shown in the column in the middle of the table.

Once again, the low Durbin-Watson statistics make the OLS results unreliable, so the Cochrane-Orcutt results are to be analyzed. In general, the results improve as term to maturity increases. Using the R^2 on Cochrane-Orcutt differences, R^2(c-o), as the criterion, the explanatory power of the model increases going from R_2 to R_9. There

TABLE 4.2

REGRESSION RESULTS

Coefficient	OLS	ρ	CORC
	R_1 - 1 period ahead		
Θ	-0.455* (2.51)		-0.072 (0.23)
λ_2	-4.61 (0.15)	0.512	-8.24 (0.30)
λ_3	49.82 (0.43)	0.509	102.91 (0.93)
λ_4	-49.11 (0.30)	0.504	-233.26 (1.33)
λ_5	-87.25 (0.51)	0.502	88.83 (0.63)
λ_6	115.63 (0.81)	0.504	203.76 (1.09)
λ_7	175.47 (0.78)	0.507	-192.92 (0.69)
λ_8	-497.41 (1.59)	0.508	3.68 (0.01)
λ_9	382.18 (1.28)	0.511	5.73 (0.02)
λ_{10}	-74.64 (0.61)	0.511	34.45 (0.31)
R^2	0.3819		0.4908
D-W	1.36		1.84
F	2.75		4.18**
R^2(c-o)			0.2327

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 2 periods ahead		
Θ	-0.767* (2.25)		0.512 (0.79)
λ_2	0.637 (0.01)	0.573	7.14 (0.16)
λ_3	24.08 (0.11)	0.558	-25.35 (0.14)
λ_4	84.48 (0.27)	0.541	91.53 (0.31)
λ_5	-238.87 (0.76)	0.528	-54.20 (0.24)
λ_6	-44.49 (0.17)	0.518	-270.78 (0.82)
λ_7	734.12 (1.72)	0.513	564.65 (1.12)
λ_8	-1,111.34 (1.82)	0.508	409.18 (0.77)
λ_9	670.29 (1.16)	0.506	54.64 (0.11)
λ_{10}	-105.06 (0.45)	0.505	38.61 (0.19)
R^2	0.4465		0.6177
D-W	1.05		1.53
F	3.50**		6.82**
R^2(c-o)			0.2118

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 3 periods ahead		
Θ	-1.015* (2.21)		0.173 (0.21)
λ_2	20.15 (0.26)	0.644	19.53 (0.39)
λ_3	-17.15 (0.06)	0.623	-48.97 (0.25)
λ_4	163.91 (0.43)	0.601	106.48 (0.36)
λ_5	-266.81 (0.70)	0.583	-69.25 (0.31)
λ_6	-362.67 (1.09)	0.569	-262.02 (0.75)
λ_7	1,140.06* (2.09)	0.561	519.62 (0.97)
λ_8	-905.70 (1.22)	0.552	-102.75 (0.19)
λ_9	164.94 (0.23)	0.548	-295.20 (0.58)
λ_{10}	77.00 (0.27)	0.546	127.14 (0.63)
R^2	0.5461		0.7772
D-W	0.71		1.48
F	5.08**		14.34**
R^2(c-0)			0.3532

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 4 periods ahead		
Θ	-1.398* (2.42)		-0.442 (0.44)
λ_2	86.11 (0.86)	0.570	-21.81 (0.37)
λ_3	-212.66 (0.60)	0.559	136.83 (0.61)
λ_4	312.84 (0.65)	0.547	-149.26 (0.43)
λ_5	-224.21 (0.46)	0.539	-108.98 (0.40)
λ_6	-332.59 (0.80)	0.533	104.42 (0.25)
λ_7	1,046.09 (1.53)	0.534	115.07 (0.18)
λ_8	-1,250.14 (1.28)	0.534	56.59 (0.09)
λ_9	504.82 (0.52)	0.537	-240.86 (0.40)
λ_{10}	101.74 (0.28)	0.541	126.13 (0.52)
R^2	0.5039		0.7899
D-W	0.70		1.52
F	4.18**		15.04**
R^2(c-o)			0.2301

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 5 periods ahead		
Θ	-1.460* (2.05)		-0.335 (0.25)
λ_2	193.62 (1.53)	0.440	3.77 (0.06)
λ_3	-598.64 (1.29)	0.436	49.04 (0.20)
λ_4	739.24 (1.13)	0.432	-140.30 (0.37)
λ_5	-305.78 (0.49)	0.431	83.76 (0.27)
λ_6	-214.96 (0.42)	0.432	27.65 (0.06)
λ_7	804.69 (0.96)	0.440	36.32 (0.05)
λ_8	-1,943.00 (1.61)	0.446	-224.41 (0.28)
λ_9	1,619.24 (1.34)	0.453	67.61 (0.10)
λ_{10}	-248.63 (0.55)	0.460	119.53 (0.42)
R^2	0.4241		0.8041
D-W	0.64		1.40
F	2.95**		15.97**
R^2(c-o)			0.1818

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 6 periods ahead		
Θ	-1.064 (1.30)		2.27 (1.21)
λ_2	306.85* (2.09)	0.278	85.43 (1.26)
λ_3	-1,017.00 (1.87)	0.268	-212.81 (0.82)
λ_4	1,241.37 (1.61)	0.261	39.00 (0.10)
λ_5	-418.07 (0.58)	0.258	217.96 (0.67)
λ_6	-216.71 (0.37)	0.259	-3.56 (0.01)
λ_7	873.47 (0.86)	0.267	-134.70 (0.17)
λ_8	-3,009.19* (2.03)	0.274	-319.40 (0.37)
λ_9	2,947.88* (2.08)	0.283	327.97 (0.43)
λ_{10}	-660.51 (1.26)	0.291	-0.658 (0.00)
R^2	0.3707		0.8146
D-W	0.70		1.42
F	2.29		16.60**
R^2(c-o)			0.1771

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 7 periods ahead		
Θ	-0.598 (0.66)		2.80 (1.44)
λ_2	335.91* (2.01)	0.163	113.16 (1.37)
λ_3	-1,173.14 (1.81)	0.149	-373.43 (1.11)
λ_4	1,565.47 (1.65)	0.139	463.05 (0.88)
λ_5	-616.67 (0.75)	0.133	-18.61 (0.05)
λ_6	-396.73 (0.60)	0.133	-739.29 (1.31)
λ_7	1,190.31 (1.02)	0.142	1,156.63 (1.36)
λ_8	3,284.06 (1.95)	0.149	-1,123.29 (1.20)
λ_9	3,134.79 (1.99)	0.158	395.18 (0.48)
λ_{10}	-711.60 (1.22)	0.168	130.76 (0.40)
R^2	0.3501		0.8188
D-W	0.54		1.57
F	2.04		16.57**
R^2(c-o)			0.3049

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_1 - 8 periods ahead		
Θ	-0.208 (0.22)		1.40 (0.83)
λ_2	503.40* (2.46)	0.122	80.11 (0.64)
λ_3	-1,680.80* (2.25)	0.109	-259.58 (0.54)
λ_4	1,830.03 (1.81)	0.099	320.09 (0.48)
λ_5	459.82 (0.48)	0.093	102.79 (0.21)
λ_6	-1,913.92* (2.20)	0.091	-722.27 (1.03)
λ_7	774.88 (0.62)	0.098	772.65 (0.73)
λ_8	-2,128.05 (1.21)	0.103	-578.61 (0.51)
λ_9	3,512.78 (1.97)	0.111	294.87 (0.26)
λ_{10}	1,330.40 (1.82)	0.119	-2.10 (0.00)
R^2	0.3487		0.7634
D-W	0.65		1.42
F	1.96		11.47**
R^2 (c-o)			0.1421

TABLE 4.2--*Continued*

Coefficient	OLS	ρ	CORC
	R_1 - 9 periods ahead		
Θ	0.416 (0.39)		2.46 (1.20)
λ_2	352.68 (1.55)	0.057	-94.77 (0.74)
λ_3	-1,255.19 (1.52)	0.051	359.38 (0.73)
λ_4	1,589.59 (1.43)	0.047	-376.30 (0.54)
λ_5	232.83 (0.22)	0.045	-41.38 (0.08)
λ_6	-2,129.08* (2.14)	0.045	-94.12 (0.13)
λ_7	1,203.67 (0.78)	0.052	99.98 (0.09)
λ_8	-937.88 (0.48)	0.058	1,418.46 (1.21)
λ_9	1,799.45 (0.92)	0.065	-1,960.84 (1.71)
λ_{10}	-843.81 (1.05)	0.072	679.21 (1.37)
R^2	0.2382		0.7621
D-W	0.62		1.66
F	1.11		11.03**
R^2(c-o)			0.1652

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 1 period ahead		
Θ	0.432 (1.83)		0.756* (2.28)
λ_1	2.03 (0.22)	0.532	-0.120 (0.01)
λ_3	34.98 (0.38)	0.520	100.07 (0.95)
λ_4	-45.43 (0.23)	0.513	-251.84 (1.15)
λ_5	-92.14 (0.42)	0.511	89.41 (0.45)
λ_6	148.13 (0.83)	0.511	216.87 (0.97)
λ_7	181.27 (0.63)	0.512	-119.81 (0.35)
λ_8	-594.61 (1.46)	0.512	-161.80 (0.41)
λ_9	471.77 (1.26)	0.513	122.99 (0.34)
λ_{10}	-93.29 (0.63)	0.512	13.54 (0.09)
R^2	0.3835		0.4609
D-W	1.43		1.85
F	2.77		3.70**
R^2(c-o)			0.2667

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 2 periods ahead		
Θ	0.002 (0.00)		1.71* (2.02)
λ_1	8.80 (0.55)	0.611	6.59 (0.50)
λ_3	-32.36 (0.20)	0.582	-68.67 (0.46)
λ_4	183.41 (0.53)	0.564	196.51 (0.61)
λ_5	-313.58 (0.82)	0.550	-119.18 (0.44)
λ_6	-25.87 (0.08)	0.541	-359.92 (0.91)
λ_7	844.12 (1.63)	0.535	770.23 (1.26)
λ_8	-1,365.07 (1.82)	0.528	-491.23 (0.78)
λ_9	858.89 (1.24)	0.525	51.06 (0.09)
λ_{10}	-140.90 (0.52)	0.523	112.83 (0.48)
R^2	0.4665		0.6479
D-W	1.03		1.50
F	3.79		7.77**
R^2 (c-o)			0.2169

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 3 periods ahead		
Θ	-0.40 (0.71)		1.13 (1.08)
λ_1	14.59 (0.71)	0.677	11.10 (0.75)
λ_3	-49.20 (0.24)	0.639	64.22 (0.41)
λ_4	281.28 (0.67)	0.616	182.03 (0.55)
λ_5	-414.50 (0.88)	0.598	-200.80 (0.73)
λ_6	-303.20 (0.74)	0.584	-118.63 (0.28)
λ_7	1,299.18 (1.97)	0.575	516.14 (0.78)
λ_8	-1,277.72 (1.39)	0.567	-246.85 (0.37)
λ_9	445.47 (0.51)	0.561	-253.80 (0.40)
λ_{10}	24.38 (0.07)	0.558	171.32 (0.70)
R^2	0.5577		0.7870
D-W	0.70		1.57
F	5.32**		15.19**
R^2 (c-o)			0.3502

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 4 periods ahead		
Θ	-0.692 (0.97)		0.858 (0.67)
λ_1	22.96 (0.87)	0.613	-5.84 (0.34)
λ_3	-68.56 (0.26)	0.598	130.59 (0.74)
λ_4	191.61 (0.36)	0.586	-212.60 (0.57)
λ_5	-176.08 (0.30)	0.578	44.92 (0.14)
λ_6	-399.61 (0.78)	0.572	-154.99 (0.32)
λ_7	1,205.61 (1.46)	0.573	319.93 (0.43)
λ_8	-1,422.68 (1.17)	0.572	111.03 (0.14)
λ_9	633.70 (0.56)	0.572	-322.64 (0.46)
λ_{10}	49.87 (0.12)	0.574	106.13 (0.37)
R^2	0.5162		0.8115
D-W	0.65		1.52
F	4.39**		17.22**
R^2 (c-o)			0.2301

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 5 periods ahead		
Θ	-0.830 (0.95)		1.56 (0.90)
λ_1	37.42 (1.17)	0.497	-2.99 (0.17)
λ_3	-211.53 (0.65)	0.493	103.46 (0.56)
λ_4	443.42 (0.65)	0.488	-231.81 (0.59)
λ_5	-352.22 (0.46)	0.487	136.58 (0.39)
λ_6	-149.47 (0.24)	0.487	-2.64 (0.05)
λ_7	1,124.95 (1.12)	0.495	94.48 (0.11)
λ_8	-2,362.15 (1.60)	0.499	-285.07 (0.32)
λ_9	1,727.96 (1.25)	0.505	33.97 (0.04)
λ_{10}	-203.00 (0.40)	0.511	183.63 (0.57)
R^2	0.4473		0.8348
D-W	0.54		1.46
F	3.24**		19.65**
R^2(c-o)			0.2126

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 6 periods ahead		
Θ	-0.496 (0.50)		3.57 (1.52)
λ_1	66.49 (1.77)	0.374	14.78 (0.79)
λ_3	-473.93 (1.27)	0.355	-15.92 (0.08)
λ_4	915.88 (1.16)	0.347	-128.79 (0.31)
λ_5	-590.93 (0.67)	0.344	192.50 (0.51)
λ_6	-124.57 (0.17)	0.344	32.64 (0.06)
λ_7	1,525.21 (1.28)	0.351	1.04 (0.00)
λ_8	-3,877.67* (2.14)	0.356	-423.79 (0.43)
λ_9	3,202.47 (1.94)	0.364	300.42 (0.34)
λ_{10}	-581.40 (0.98)	0.370	29.34 (0.09)
R^2	0.3963		0.8404
D-W	0.58		1.45
F	2.55		19.89**
R^2(c-o)			0.1266

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 7 periods ahead		
Θ	-0.049 (0.04)		4.42 (1.71)
λ_1	84.43* (2.10)	0.277	27.42 (1.29)
λ_3	-682.20 (1.57)	0.249	-191.56 (0.80)
λ_4	1,303.70 (1.39)	0.240	333.28 (0.65)
λ_5	-697.76 (0.69)	0.235	-22.06 (0.06)
λ_6	-411.49 (0.51)	0.234	-741.21 (1.18)
λ_7	1,967.29 (1.46)	0.242	1,347.97 (1.40)
λ_8	-4,536.24* (2.22)	0.248	-1,318.99 (1.25)
λ_9	3,716.69* (2.01)	0.257	324.66 (0.35)
λ_{10}	-686.43 (1.04)	0.265	249.41 (0.69)
R^2	0.3875		0.8505
D-W	0.50		1.65
F	2.39		20.86**
R^2 (c-o)			0.3064

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_2 - 8 periods ahead		
Θ	0.407 (0.36)		2.62 (0.19)
λ_1	128.04* (2.77)	0.244	33.64 (1.08)
λ_3	-927.55* (2.02)	0.218	-237.39 (0.77)
λ_4	1,276.70 (1.31)	0.209	333.37 (0.54)
λ_5	729.88 (0.63)	0.203	276.25 (0.51)
λ_6	-2,252.18* (2.22)	0.201	-972.50 (1.30)
λ_7	1,700.09 (1.21)	0.207	909.46 (0.76)
λ_8	-3,353.95 (1.58)	0.211	-819.45 (0.65)
λ_9	4,002.01 (2.00)	0.218	556.56 (0.46)
λ_{10}	-1,264.43 (1.63)	0.225	67.99 (0.13)
R^2	0.4042		0.8145
D-W	0.55		1.40
F	2.49		15.61**
R^2(c-o)			0.1782

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 1 period ahead		
Θ	1.43* (5.43)		1.62* (4.88)
λ_1	7.05 (0.37)	0.538	2.83 (0.12)
λ_2	-2.77 (0.05)	0.531	15.05 (0.23)
λ_4	18.80 (0.12)	0.515	-79.71 (0.47)
λ_5	-125.28 (0.50)	0.512	13.53 (0.06)
λ_6	154.71 (0.81)	0.512	150.08 (0.67)
λ_7	192.82 (0.59)	0.512	-1.11 (0.00)
λ_8	-666.76 (1.46)	0.511	-343.70 (0.76)
λ_9	549.30 (1.37)	0.511	300.62 (0.75)
λ_{10}	-114.55 (0.74)	0.509	-46.53 (0.28)
R^2	0.3809		0.4291
D-W	1.52		1.87
F	2.73		3.26**
R^2(c-o)			0.2961

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 2 periods ahead		
θ	0.915* (2.05)		2.62* (2.94)
λ_1	32.91 (1.03)	0.628	35.82 (1.11)
λ_2	-75.72 (0.84)	0.613	-100.90 (1.12)
λ_4	307.39 (1.17)	0.578	298.01 (1.31)
λ_5	-495.20 (1.19)	0.564	-281.69 (1.01)
λ_6	34.89 (0.11)	0.554	-327.82 (0.82)
λ_7	990.35 (1.76)	0.547	918.50 (1.43)
λ_8	-1,582.51 (1.97)	0.540	-620.44 (0.92)
λ_9	927.00 (1.31)	0.536	-106.02 (0.17)
λ_{10}	-116.34 (0.43)	0.533	182.24 (0.74)
R^2	0.4891		0.6722
D-W	1.00		1.47
F	4.15**		8.66**
R^2 (c-o)			0.2537

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 3 periods ahead		
Θ	0.473 (0.77)		2.04 (1.85)
λ_1	39.89 (1.00)	0.695	38.68 (1.10)
λ_2	-78.13 (0.70)	0.678	-88.70 (0.91)
λ_4	343.36 (1.06)	0.637	226.75 (0.92)
λ_5	-507.74 (0.98)	0.620	-256.72 (0.86)
λ_6	-261.32 (0.60)	0.607	-136.05 (0.29)
λ_7	1,357.04 (1.87)	0.598	619.53 (0.86)
λ_8	1,449.70 (1.43)	0.589	-398.48 (0.54)
λ_9	600.41 (0.67)	0.583	-170.18 (0.25)
λ_{10}	-21.07 (0.06)	0.578	165.46 (0.63)
R_2	0.5720		0.7895
D-W	0.70		1.65
F	5.64**		15.42**
R^2(c-o)			0.3425

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 4 periods ahead		
Θ	0.186 (0.24)		2.17 (1.48)
λ_1	29.13 (0.58)	0.639	-17.38 (0.45)
λ_2	-26.23 (0.19)	0.635	60.53 (0.58)
λ_4	84.03 (0.21)	0.615	-99.54 (0.37)
λ_5	-100.06 (0.15)	0.608	108.70 (0.32)
λ_6	-386.72 (0.71)	0.602	-363.89 (0.71)
λ_7	1,176.89 (1.29)	0.602	461.22 (0.58)
λ_8	-1,505.44 (1.15)	0.600	81.07 (0.10)
λ_9	804.69 (0.70)	0.600	-284.53 (0.38)
λ_{10}	-36.88 (0.09)	0.600	68.26 (0.23)
R^2	0.5318		0.8235
D-W	0.62		1.55
F	4.67**		18.66**
R^2(c-o)			0.2348

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 5 periods ahead		
Θ	-0.068 (0.07)		2.83 (1.44)
λ_1	36.26 (0.59)	0.535	-26.81 (0.68)
λ_2	-38.74 (0.23)	0.535	93.39 (0.87)
λ_4	122.60 (0.24)	0.527	-220.77 (0.79)
λ_5	-259.29 (0.32)	0.526	185.88 (0.52)
λ_6	-41.59 (0.06)	0.526	-48.92 (0.09)
λ_7	1,105.41 (1.01)	0.533	117.44 (0.13)
λ_8	-2,401.10 (1.52)	0.536	-315.68 (0.34)
λ_9	1,749.53 (1.27)	0.542	35.19 (0.04)
λ_{10}	-212.15 (0.42)	0.546	213.80 (0.65)
R^2	0.4722		0.8513
D-W	0.50		1.56
F	3.58**		22.25**
R^2(c-o)			0.2469

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 6 periods ahead		
Θ	0.183 (0.17)		4.94 (1.96)
λ_1	84.34 (1.20)	0.434	-17.19 (0.42)
λ_2	-159.64 (0.82)	0.426	97.89 (0.87)
λ_4	368.45 (0.64)	0.409	-350.87 (1.21)
λ_5	-524.48 (0.56)	0.405	300.63 (0.80)
λ_6	46.13 (0.06)	0.404	81.22 (0.14)
λ_7	1,746.55 (1.34)	0.410	26.99 (0.03)
λ_8	-4,142.77* (2.10)	0.414	-470.67 (0.46)
λ_9	3,129.67 (1.83)	0.421	281.20 (0.32)
λ_{10}	-481.82 (0.79)	0.426	57.19 (0.17)
R^2	0.4196		0.8621
D-W	0.52		1.44
F	2.81		23.62**
R^2(c-o)			0.1511

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_3 - 7 periods ahead		
Θ	0.613 (0.52)		5.67 (1.93)
λ_1	148.99 (1.92)	0.343	44.21 (0.94)
λ_2	-336.08 (1.55)	0.329	-91.17 (0.70)
λ_4	720.44 (1.10)	0.312	165.96 (0.50)
λ_5	-695.64 (0.65)	0.306	-42.24 (0.10)
λ_6	-321.99 (0.37)	0.305	-662.28 (1.05)
λ_7	2,569.43 (1.75)	0.312	1,427.22 (1.40)
λ_8	-5,217.89* (2.33)	0.318	-1,354.09 (1.21)
λ_9	3,725.97 (1.91)	0.325	158.61 (0.17)
λ_{10}	-527.70 (0.76)	0.333	365.98 (0.97)
R^2	0.4125		0.8627
D-W	0.48		1.73
F	2.65		23.04**
R^2(c-o)			0.2955

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 1 period ahead		
Θ	2.47* (8.55)		2.59* (7.54)
λ_1	18.57 (0.71)	0.524	18.18 (0.60)
λ_2	-59.21 (0.55)	0.516	-49.71 (0.42)
λ_3	89.31 (0.60)	0.507	62.38 (0.41)
λ_5	-222.77 (0.94)	0.496	-159.11 (0.70)
λ_6	224.41 (1.02)	0.496	180.02 (0.75)
λ_7	282.48 (0.81)	0.495	179.64 (0.47)
λ_8	-771.36 (1.59)	0.494	-543.66 (1.09)
λ_9	517.23 (1.15)	0.494	356.81 (0.78)
λ_{10}	-63.64 (0.34)	0.493	-31.38 (0.16)
R^2	0.3703		0.4003
D-W	1.59		1.91
F	2.61		2.89**
R^2(c-o)			0.3403

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 2 periods ahead		
Θ	1.86* (4.01)		3.16* (3.90)
λ_1	69.58 (1.68)	0.641	78.02 (1.68)
λ_2	-281.33 (1.66)	0.626	-301.56 (1.75)
λ_3	415.42 (1.76)	0.609	374.59 (1.84)
λ_5	-621.92 (1.66)	0.578	-321.40 (1.29)
λ_6	-241.53 (0.70)	0.569	-163.52 (0.42)
λ_7	1,146.51* (2.02)	0.561	1,044.63 (1.68)
λ_8	-1,611.84 (1.99)	0.554	821.39 (1.17)
λ_9	565.51 (0.77)	0.549	165.15 (0.26)
λ_{10}	99.24 (0.33)	0.544	281.51 (1.08)
R^2	0.5185		0.6823
D-W	0.98		1.52
F	4.67**		9.07**
R^2 (c-o)			0.2939

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 3 periods ahead		
Θ	1.43* (2.22)		2.82* (2.62)
λ_1	74.76 (1.44)	0.707	84.36 (1.69)
λ_2	-279.12 (1.29)	0.690	-291.59 (1.54)
λ_3	420.28 (1.39)	0.671	340.28 (1.48)
λ_5	-577.51 (1.23)	0.635	-316.95 (1.21)
λ_6	-69.61 (0.15)	0.623	-4.90 (0.01)
λ_7	1,473.45 (1.92)	0.614	686.04 (0.96)
λ_8	-1,464.65 (1.44)	0.604	-489.94 (0.65)
λ_9	285.77 (0.30)	0.598	-225.56 (0.32)
λ_{10}	162.07 (0.42)	0.592	224.13 (0.81)
R^2	0.5892		0.7983
D-W	0.67		1.71
F	6.05**		16.27**
R^2(c-o)			0.3613

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 4 periods ahead		
Θ	1.17 (1.43)		3.37* (2.14)
λ_1	33.33 (0.51)	0.655	-12.13 (0.22)
λ_2	-41.99 (0.15)	0.652	32.36 (0.16)
λ_3	41.66 (0.11)	0.644	6.82 (0.03)
λ_5	-15.23 (0.02)	0.627	60.22 (0.20)
λ_6	-374.46 (0.64)	0.622	-592.83 (1.18)
λ_7	1,086.14 (1.12)	0.621	759.65 (0.95)
λ_8	-1,506.16 (1.13)	0.619	9.95 (0.01)
λ_9	928.65 (0.74)	0.618	-291.77 (0.37)
λ_{10}	-110.87 (0.23)	0.617	40.69 (0.13)
R^2	0.5424		0.8283
D-W	0.61		1.59
F	4.87**		19.29**
R^2 (c-o)			0.2453

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 5 periods ahead		
Θ	0.848 (0.87)		4.19 (1.92)
λ_1	12.68 (0.16)	0.561	-64.86 (1.14)
λ_2	100.72 (0.30)	0.563	273.72 (1.28)
λ_3	-187.08 (0.40)	0.560	-311.64 (1.20)
λ_5	142.77 (0.19)	0.554	226.45 (0.74)
λ_6	-42.18 (0.06)	0.554	-194.70 (0.37)
λ_7	622.35 (0.53)	0.559	164.55 (0.19)
λ_8	-2,335.05 (1.47)	0.562	-407.56 (0.43)
λ_9	2,159.62 (1.45)	0.567	153.20 (0.18)
λ_{10}	-408.10 (0.70)	0.570	196.29 (0.58)
R^2	0.4943		0.8571
D-W	0.51		1.68
F	3.91**		23.33**
R^2(c-o)			0.2793

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_4 - 6 periods ahead		
Θ	0.982 (0.87)		6.75* (2.38)
λ_1	68.99 (0.73)	0.474	-89.25 (1.61)
λ_2	-69.56 (0.18)	0.465	457.86* (2.20)
λ_3	-29.87 (0.05)	0.457	-604.56* (2.40)
λ_5	-3.11 (0.00)	0.445	405.08 (1.35)
λ_6	107.21 (0.13)	0.443	-6.05 (0.01)
λ_7	1,224.88 (0.86)	0.449	-152.20 (0.18)
λ_8	-4,038.26 (1.98)	0.453	-530.08 (0.55)
λ_9	3,404.63 (1.87)	0.458	542.53 (0.64)
λ_{10}	-591.16 (0.87)	0.462	-14.71 (0.04)
R^2	0.4433		0.8861
D-W	0.47		1.40
F	3.10**		29.39**
R^2(c-o)			0.2599

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_5 - 1 period ahead		
Θ	3.64* (12.34)		3.69* (10.49)
λ_1	23.65 (0.82)	0.516	26.69 (0.82)
λ_2	-83.92 (0.65)	0.508	-106.77 (0.77)
λ_3	175.25 (0.69)	0.501	238.84 (0.90)
λ_4	-202.14 (0.80)	0.496	-277.53 (1.01)
λ_6	197.82 (0.89)	0.495	246.99 (0.93)
λ_7	108.67 (0.37)	0.496	75.74 (0.22)
λ_8	-604.27 (1.26)	0.496	-479.11 (0.97)
λ_9	460.77 (0.89)	0.497	273.87 (0.54)
λ_{10}	-60.42 (0.28)	0.495	16.64 (0.08)
R^2	0.3628		0.3911
D-W	1.60		1.94
F	2.53		2.78
R^2 (c-o)			0.3894

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_5 - 2 periods ahead		
Θ	3.07* (6.46)		4.12* (5.09)
λ_1	70.87 (1.56)	0.644	82.79 (1.59)
λ_2	-283.14 (1.40)	0.629	-334.32 (1.59)
λ_3	530.39 (1.33)	0.614	562.74 (1.54)
λ_4	-467.21 (1.17)	0.598	-434.66 (1.20)
λ_6	141.53 (0.40)	0.577	-24.28 (0.05)
λ_7	614.40 (1.26)	0.569	729.03 (1.18)
λ_8	-1,079.40 (1.34)	0.562	-619.83 (0.86)
λ_9	386.63 (0.46)	0.557	-295.15 (0.42)
λ_{10}	108.37 (0.31)	0.552	342.93 (1.19)
R^2	0.5007		0.6730
D-W	0.92		1.56
F	4.35**		8.69**
R^2 (c-o)			0.2838

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_5 - 3 periods ahead		
Θ	2.65* (4.03)		3.81* (3.46)
λ_1	80.32 (1.42)	0.710	114.80* (2.00)
λ_2	-295.07 (1.13)	0.694	-430.95 (1.81)
λ_3	523.64 (1.00)	0.677	667.66 (1.60)
λ_4	-396.57 (0.78)	0.659	-490.38 (1.24)
λ_6	-189.78 (0.42)	0.632	182.72 (0.35)
λ_7	960.14 (1.42)	0.623	262.71 (0.37)
λ_8	-994.60 (1.00)	0.614	-284.64 (0.37)
λ_9	217.42 (0.20)	0.608	-255.59 (0.33)
λ_{10}	119.53 (0.26)	0.602	244.91 (0.82)
R^2	0.5809		0.7965
D-W	0.66		1.74
F	5.85**		16.09**
R^2(c-o)			0.3405

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_5 - 4 periods ahead		
Θ	2.23* (2.75)		4.34* (2.81)
λ_1	37.87 (0.54)	0.675	-2.20 (0.04)
λ_2	-58.37 (0.18)	0.672	-44.68 (0.17)
λ_3	62.29 (0.09)	0.665	211.86 (0.46)
λ_4	-13.89 (0.02)	0.655	-181.95 (0.42)
λ_6	-370.31 (0.66)	0.641	-524.48 (0.91)
λ_7	1,088.05 (1.30)	0.640	949.09 (1.20)
λ_8	-1,583.93 (1.19)	0.636	-71.95 (0.08)
λ_9	1,034.65 (0.72)	0.634	-437.29 (0.54)
λ_{10}	-154.58 (0.27)	0.632	115.78 (0.35)
R^2	0.5596		0.8353
D-W	0.60		1.67
F	5.22**		20.28**
R^2(c-o)			0.2768

TABLE 4.2--*Continued*

Coefficient	OLS	ρ	CORC
	R_5 - 5 periods ahead		
Θ	1.83 (1.91)		5.30* (2.33)
λ_1	-23.13 (0.25)	0.587	-83.63 (1.24)
λ_2	377.37 (0.83)	0.588	349.09 (1.24)
λ_3	-918.60 (0.99)	0.586	-461.34 (0.94)
λ_4	805.04 (0.92)	0.581	242.99 (0.54)
λ_6	-185.96 (0.28)	0.579	-227.58 (0.37)
λ_7	411.08 (0.40)	0.584	370.87 (0.43)
λ_8	-2,697.69 (1.71)	0.586	-515.69 (0.53)
λ_9	3,161.97 (1.78)	0.590	167.59 (0.19)
λ_{10}	860.54 (1.19)	0.592	196.11 (0.54)
R^2	0.5258		0.8639
D-W	0.64		1.74
F	4.44**		24.68**
R^2(c-o)			0.2952

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_6 - 1 period ahead		
Θ	4.89* (15.57)		4.93* (13.63)
λ_1	22.80 (0.73)	0.486	25.44 (0.73)
λ_2	-60.78 (0.45)	0.478	-77.55 (0.53)
λ_3	78.85 (0.31)	0.472	125.32 (0.48)
λ_4	-49.37 (0.16)	0.467	-123.89 (0.39)
λ_5	-21.89 (0.08)	0.466	31.83 (0.11)
λ_7	268.46 (0.65)	0.469	220.84 (0.51)
λ_8	-581.65 (1.07)	0.470	-464.84 (0.82)
λ_9	438.88 (0.78)	0.472	312.28 (0.55)
λ_{10}	-81.48 (0.34)	0.471	-36.31 (0.15)
R^2	0.3242		0.3408
D-W	1.70		1.95
F	2.13		2.24
R^2(c-o)			0.4159

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_6 - 2 periods ahead		
Θ	4.19* (8.88)		4.97* (6.49)
λ_1	73.01 (1.58)	0.641	81.04 (1.52)
λ_2	-286.09 (1.42)	0.625	-340.41 (1.60)
λ_3	432.06 (1.16)	0.610	543.27 (1.52)
λ_4	-70.73 (0.16)	0.594	-236.04 (0.57)
λ_5	-455.63 (1.06)	0.581	-326.04 (0.92)
λ_7	1,186.92 (1.86)	0.566	1,093.19 (1.92)
λ_8	-1,256.25 (1.44)	0.559	-863.16 (1.07)
λ_9	231.57 (0.27)	0.554	-354.42 (0.48)
λ_{10}	166.22 (0.46)	0.550	415.88 (1.36)
R^2	0.5056		0.6604
D-W	0.96		1.62
F	4.43*		8.21**
R^2 (c-o)			0.3158

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_6 - 3 periods ahead		
Θ	3.57* (5.75)		4.80* (4.53)
λ_1	86.37 (1.51)	0.713	108.38 (1.86)
λ_2	-321.46 (1.22)	0.697	-384.22 (1.60)
λ_3	498.06 (0.98)	0.680	511.93 (1.23)
λ_4	-91.69 (0.16)	0.662	-184.11 (0.41)
λ_5	-542.30 (1.02)	0.647	-228.62 (0.65)
λ_7	1,312.43 (1.60)	0.628	608.17 (1.04)
λ_8	-1,285.71 (1.20)	0.619	363.30 (0.44)
λ_9	189.21 (0.17)	0.612	324.37 (0.41)
λ_{10}	184.09 (0.40)	0.607	269.90 (0.87)
R^2	0.5907		0.7955
D-W	0.66		1.80
F	6.09**		15.99**
R^2(c-o)			0.3653

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_6 - 4 periods ahead		
Θ	3.17* (4.02)		5.48* (3.60)
λ_1	46.89 (0.65)	0.670	12.58 (0.20)
λ_2	-106.86 (0.32)	0.668	-112.89 (0.43)
λ_3	195.21 (0.30)	0.662	452.84 (0.98)
λ_4	-196.84 (0.27)	0.653	-740.83 (1.52)
λ_5	-23.69 (0.03)	0.646	410.93 (1.06)
λ_7	773.81 (0.75)	0.640	9.97 (0.02)
λ_8	-1,675.97 (1.17)	0.637	207.19 (0.22)
λ_9	1,183.90 (0.80)	0.635	-366.48 (0.44)
λ_{10}	-146.79 (0.25)	0.633	147.48 (0.43)
R^2	0.5471		0.8305
D-W	0.61		1.70
F	4.97**		19.59**
R^2(c-o)			0.2708

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_7 - 1 period ahead		
Θ	6.07* (17.38)		6.09* (15.64)
λ_1	24.79 (0.75)	0.450	25.77 (0.71)
λ_2	-78.51 (0.53)	0.443	-87.86 (0.56)
λ_3	142.29 (0.49)	0.439	177.76 (0.58)
λ_4	-159.11 (0.48)	0.435	-220.29 (0.62)
λ_5	3.31 (0.01)	0.436	37.47 (0.14)
λ_6	200.65 (0.71)	0.440	198.53 (0.64)
λ_8	-519.64 (1.05)	0.447	-449.32 (0.89)
λ_9	481.70 (0.81)	0.450	367.55 (0.61)
λ_{10}	-78.12 (0.32)	0.451	32.45 (0.13)
R^2	0.3019		0.3128
D-W	1.76		1.97
F	1.92		1.97
R^2 (c-o)			0.4474

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_7 - 2 periods ahead		
Θ	5.35* (9.96)		6.12* (7.47)
λ_1	69.52 (1.40)	0.630	78.87 (1.36)
λ_2	-275.02 (1.24)	0.615	-333.75 (1.42)
λ_3	515.34 (1.18)	0.600	619.20 (1.48)
λ_4	-431.82 (0.88)	0.584	-557.63 (1.17)
λ_5	-106.54 (0.27)	0.573	-46.84 (0.14)
λ_6	431.89 (1.02)	0.565	461.11 (1.13)
λ_8	-418.90 (0.55)	0.552	60.99 (0.09)
λ_9	74.06 (0.08)	0.548	-600.92 (0.75)
λ_{10}	167.80 (0.43)	0.544	456.53 (1.35)
R^2	0.4637		0.6213
D-W	1.01		1.73
F	3.75**		6.93**
R^2 (c-o)			0.2885

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
R_7 - 3 periods ahead			
Θ	4.66* (6.34)		5.79* (5.01)
λ_1	79.16 (1.30)	0.707	115.55 (1.89)
λ_2	-235.26 (0.85)	0.691	-338.39 (1.53)
λ_3	348.99 (0.63)	0.674	501.58 (1.11)
λ_4	-217.02 (0.35)	0.657	-236.46 (0.48)
λ_5	-120.98 (0.24)	0.643	-211.28 (0.65)
λ_6	225.82 (0.43)	0.632	369.74 (0.92)
λ_8	-317.51 (0.32)	0.616	-94.84 (0.13)
λ_9	229.51 (0.19)	0.610	-356.00 (0.44)
λ_{10}	42.79 (0.09)	0.605	320.65 (1.00)
R^2	0.5595		0.7915
D-W	0.63		1.79
F	5.36**		15.61**
R^2(c-o)			0.3727

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_8 - 1 period ahead		
Θ	7.44* (19.70)		7.46* (17.71)
λ_1	24.33 (0.66)	0.414	24.42 (0.61)
λ_2	-75.93 (0.46)	0.408	-77.12 (0.44)
λ_3	149.70 (0.46)	0.404	161.40 (0.48)
λ_4	-204.92 (0.57)	0.402	-244.46 (0.62)
λ_5	121.94 (0.37)	0.404	161.53 (0.48)
λ_6	37.13 (0.13)	0.408	45.40 (0.14)
λ_7	100.73 (0.26)	0.414	-123.80 (0.30)
λ_9	43.37 (0.09)	0.422	41.64 (0.09)
λ_{10}	20.40 (0.08)	0.424	26.54 (0.10)
R^2	0.2572		0.2697
D-W	1.73		1.96
F	1.54		1.60
R^2 (c-o)			0.4594

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_8 - 2 periods ahead		
Θ	6.58* (11.78)		7.39* (8.94)
λ_1	78.30 (1.50)	0.616	70.75 (1.17)
λ_2	-337.92 (1.43)	0.600	-313.15 (1.27)
λ_3	641.78 (1.40)	0.586	583.36 (1.33)
λ_4	-406.01 (0.79)	0.571	-394.89 (0.75)
λ_5	-334.83 (0.70)	0.560	-213.62 (0.55)
λ_6	232.11 (0.55)	0.553	63.60 (0.12)
λ_7	494.78 (0.89)	0.547	674.52 (1.07)
λ_9	-859.09 (1.29)	0.537	-1,103.02 (1.97)
λ_{10}	515.43 (1.33)	0.534	647.45 (1.99)
R^2	0.4576		0.6131
D-W	1.00		1.71
F	3.66**		6.69**
R^2 (c-o)			0.3240

TABLE 4.2--Continued

Coefficient	OLS	ρ	CORC
	R_9 - 1 period ahead		
Θ	8.70* (20.77)		8.73* (19.01)
λ_1	31.66 (0.82)	0.370	29.23 (0.70)
λ_2	-106.63 (0.64)	0.365	-93.44 (0.53)
λ_3	192.98 (0.62)	0.363	178.22 (0.54)
λ_4	-203.60 (0.55)	0.363	-232.93 (0.58)
λ_5	43.61 (0.11)	0.367	115.55 (0.29)
λ_6	40.20 (0.12)	0.373	20.04 (0.05)
λ_7	125.26 (0.24)	0.382	54.01 (0.10)
λ_8	-211.86 (0.41)	0.389	-145.56 (0.27)
λ_{10}	106.70 (0.69)	0.399	92.98 (0.57)
R^2	0.2406		0.2496
D-W	1.78		1.96
F	1.41		1.44
R^2 (c-o)			0.4749

appears to be a definite pattern in the R^2(c-o) across all maturities. For the one-, two-, and three-year rates, the R^2(c-o) reach a maximum in the 3 period ahead equation, decline, and then increase 8 or 9 periods ahead. The results for R_4 exhibit a similar pattern, although the relative error can only be calculated for six periods ahead. A similar trend is exhibited in the results for R_5 through R_9, but the relative error cannot be calculated far enough in the future to determine whether the pattern would be the same as that in the short-term rates.

In general, the coefficients are much larger than those reported in Chapters II and III. The largest coefficient in the earlier results occurred in the 4 period ahead equation for R_6, but this was an OLS result. In table 4.2, the 3 and 4 digit coefficients are common and, while the results are not directly comparable, they indicate that crossover effects from risk in other maturities seem to affect the relative error of a different maturity.

There is one pattern that corresponds exactly to the results of the previous chapters. The explanatory power decreases in the 2 period ahead equation and then increases. As before, there does not seem to be a computational error to account for this. A possible explanation might be that while the next year is important (which accounts for the results of the one-period ahead equations), the near future is not as important as the more distant future. In other words, there is a gap in investors' considerations from the short-term to the long-term future. The "middle" future is not that important.

Conclusion

These results do not lend support to the segmented markets hypothesis. The low t-statistics can be attributed to the presence of multicollinearity and the table of correlation coefficients seems to confirm this explanation. Despite the low t-statistics, the R^2(c-o) and the F statistics indicate that risk in the j^{th} maturity affects the relative error of the i^{th} maturity. The signs on the estimated coefficients vary from positive to negative, and they do not seem to exhibit a pattern either within one maturity or across all maturities. Therefore, little can be said about the relative importance of long- or short-term risk. The hypothesis stated earlier concerning the flow of causality from short-term to long-term risk has been neither substantiated nor disproved. It is doubtful whether the multicollinearlity and omitted variables problems can be solved jointly, so that unbiased coefficients with valid t-statistics can be estimated.

CHAPTER V

NAIVE VERSUS SOPHISTICATED MODEL

In this chapter, we intend to test a model which might be labeled "naive" against the model presented in Chapters II and III, which we label "sophisticated." This might also be considered a test of the ability of the market to distinguish between simple and more elaborate measures of risk.

The Sophisticated Model

In Chapter I, the argument was made that the standard deviation was a good start as a measure of risk, but that a high standard deviation did not necessarily mean a high degree of variability due to considerations of scale. If interest rates are high, the standard deviation would tend to be high, but it does not imply that risk is greater than when interest rates are low. For this reason, it was proposed that the standard deviation be divided by the mean to obtain a more accurate measure of the degree of variability. This measure is the coefficient of variation and was calculated using a moving average and standard deviation.

In Chapter II we proposed to test the variable risk hypothesis in an application to the term structure of interest rates. Specifically, we proposed to test the explanatory power of risk on the error between the forward rate at time t for period t+n and the actual rate to prevail at period t+n. Following the same reasoning used in deriving the measure of risk, the absolute difference between the two rates was changed to the relative error by dividing the absolute error by the actual interest rate at t+n. This resulted in the following equation being estimated:

$$\frac{F_i(t,t+n) - R_i(t+n)}{R_i(t+n)} = \Theta + \lambda \frac{\sigma_i^*(t)}{\bar{R}_i(t)} \quad . \tag{5.1}$$

The results of estimating equation (5.1) were presented in Chapters II and III. Risk was seen to have some explanatory power with the R^2(c-o) and F statistics being significantly different from zero.

The Naive Model

The objection that could be raised about the statistical results and equation (5.1) is that the data were artificially generated, and therefore the results were preordained to be acceptable. Instead of the forward rate, the difference between the forward rate and the actual rate was used, and even the absolute difference was changed to a relative error. Instead of the standard deviation, the coefficient of variation was used. Despite theoretical justification for estimating equation (5.1), it must be admitted that the objection could be true, and the only way to answer such objections is to follow a simpler method of approach and compare statistical results to see whether the charge of "cooking" the data is valid.

To put it in a different perspective, does equation (5.1) truly reflect the behavior of investors, or would a less sophisticated approach do as well? Would the statistical results be as good as those previously reported if the raw data were used instead of "adjusting" for scale problems and degree of variability? This is what we intend to examine in this chapter.

A naive approach to the effect of risk on the term structure would still use the concept of a moving standard deviation to be consistent with a moving information set; but there would be no adjustment for differences in scale, so the independent variable would be the simple moving standard deviation.

Simplifying the dependent variable would mean doing away with the relative error by not dividing by the actual rate and eliminating the absolute difference by not subtracting the actual rate to obtain the term premium. The hypothesis could then be stated as

$$F_i(t,t+n) = f(\sigma_i) \quad \text{and} \quad f' > 0 \, . \qquad (5.2)$$

The equation to be estimated would be of the form

$$F_i(t,t+n) = \Theta + \lambda\ \sigma_i(t)\ , \qquad (5.3)$$

where

$\sigma_i(t)$ is again the 5-year moving standard deviation.

The results of estimating equation (5.3) will show whether or not investors take into account such abstract ideas as scale problems and degree of variability.

The Statistical Results

Table 5.1 presents the results of estimating equation (5.3) using ordinary least-squares. And, again, the Durbin-Watson statistics are the key. The D-Ws reach a maximum of 0.33 for R_1 nine periods ahead and steadily decline to 0.09 for R_5 through R_9. Since the ideal D-W is 2.00, the presence of serial correlation is strongly indicated, and the standard errors will be biased downward.

To correct for the problem of serial correlation, the Cochrane-Orcutt procedure was used, and the results are reported in table 5.2. The D-Ws are now in the acceptable range, and the R^2s appear to be higher than those in table 3.1, while the F statistics are all highly significant. Looking at the results for R_1 one period ahead, one must question an R^2 on levels of 0.9020 when the t-statistic for the constant term is 2.06 and the t-statistic for risk is 0.71. The answer is in the R^2 on Cochrane-Orcutt differences,

TABLE 5.1

REGRESSION RESULTS

Periods Ahead	Θ	λ	R^2	F	D-W
		R_1 - OLS			
1	0.022 (5.14)	2.23* (3.01)	0.1585	9.04**	0.19
2	0.023* (6.27)	2.25* (3.55)	0.2110	12.57**	0.20
3	0.024* (7.59)	2.18* (3.95)	0.2530	15.58**	0.24
4	0.026* (9.04)	2.07* (4.26)	0.2875	18.16**	0.25
5	0.028* (11.16)	1.84* (4.36)	0.3018	19.02**	0.30
6	0.029* (13.21)	1.69* (4.53)	0.3229	20.51**	0.31
7	0.030* (14.76)	1.55* (4.53)	0.3278	20.48**	0.30
8	0.032* (16.79)	1.29* (4.09)	0.2899	16.74**	0.29
9	0.033* (17.84)	1.11* (3.64)	0.2489	13.25**	0.33
		R_2 - OLS			
1	0.055* (6.57)	3.34 (1.99)	0.0759	3.94	0.12
2	0.055* (7.64)	3.61* (2.46)	0.1137	6.03	0.13
3	0.057* (8.87)	3.68* (2.84)	0.1495	8.08**	0.15

TABLE 5.1--Continued

Periods Ahead	Θ	λ	R^2	F	D-W
4	0.060* (10.53)	3.49* (3.08)	0.1738	9.46**	0.16
5	0.062* (12.44)	3.23* (3.24)	0.1923	10.47**	0.19
6	0.065* (14.35)	2.97* (3.34)	0.2058	11.14**	0.19
7	0.067* (16.09)	2.66* (3.26)	0.2020	10.63**	0.19
8	0.070* (17.98)	2.19* (2.90)	0.1698	8.39**	0.21
		R_3 - OLS			
1	0.091* (7.71)	4.08 (1.52)	0.0462	2.32	0.11
2	0.092* (8.78)	4.66 (1.97)	0.0763	3.88	0.11
3	0.094* (10.17)	4.84* (2.32)	0.1048	5.39	0.12
4	0.097* (11.83)	4.65* (2.52)	0.1239	6.37	0.13
5	0.101* (13.68)	4.35* (2.66)	0.1382	7.05	0.15
6	0.104* (15.73)	3.95* (2.70)	0.1448	7.28	0.16
7	0.107* (17.34)	3.54* (2.61)	0.1398	6.82	0.16
		R_4 - OLS			
1	0.129* (8.52)	5.00 (1.34)	0.0360	1.79	0.10

TABLE 5.1--Continued

Periods Ahead	Θ	λ	R^2	F	D-W
2	0.130* (9.70)	5.80 (1.75)	0.0614	3.07	0.10
3	0.133* (11.10)	6.09* (2.07)	0.0855	4.30	0.11
4	0.137* (12.75)	5.82* (2.22)	0.0986	4.92	0.12
5	0.142* (14.70)	5.40* (2.31)	0.1083	5.35	0.14
6	0.146* (16.67)	4.90 (2.33)	0.1120	5.43	0.15
		R_5 - OLS			
1	0.169* (9.16)	6.36 (1.31)	0.0343	1.70	0.09
2	0.170* (10.37)	7.33 (1.69)	0.0572	2.85	0.10
3	0.173* (11.77)	7.61 (1.96)	0.0772	3.85	0.11
4	0.179* (13.47)	7.11* (2.05)	0.0851	4.18	0.12
5	0.184* (15.39)	6.59* (2.12)	0.0924	4.48	0.14
		R_6 - OLS			
1	0.209* (9.58)	8.11 (1.32)	0.0350	1.74	0.09
2	0.211* (10.78)	9.16 (1.66)	0.0556	2.76	0.10
3	0.216* (12.21)	9.30 (1.88)	0.0714	3.54	0.10

TABLE 5.1--Continued

Periods Ahead	Θ	λ	R^2	F	D-W
4	0.222* (13.85)	8.56 (1.92)	0.0757	3.69	0.12
		R_7 - OLS			
1	0.250* (9.92)	10.65 (1.42)	0.0403	2.02	0.09
2	0.253* (11.16)	11.61 (1.72)	0.0594	2.97	0.10
3	0.258* (12.57)	11.56 (1.90)	0.0728	3.61	0.11
		R_8 - OLS			
1	0.293* (10.26)	13.20 (1.48)	0.0434	2.18	0.09
2	0.297* (11.48)	14.13 (1.75)	0.0611	3.06	0.10
		R_9 - OLS			
1	0.338* (10.53)	16.11 (1.53)	0.0465	2.34	0.09

TABLE 5.2

REGRESSION RESULTS

Periods Ahead	Θ	λ	R^2	F	D-W	R^2(c-o)
			R_1 - CORC			
1	0.028* (2.06)	0.275 (0.71)	0.9020	432.79**	2.06	0.0340
2	0.029* (2.23)	0.315 (0.97)	0.9126	480.48**	1.88	0.0397
3	0.027* (2.14)	0.293 (1.00)	0.9113	462.36**	1.94	0.0344
4	0.028* (2.39)	0.359 (1.36)	0.9107	448.94**	2.01	0.0509
5	0.030* (3.15)	0.351 (1.34)	0.8850	331.02**	2.21	0.0516
6	0.033* (4.33)	0.367 (1.59)	0.8877	332.10**	2.20	0.0727
7	0.030* (2.68)	0.344 (1.68)	0.8946	348.06**	2.25	0.0680
8	0.033* (4.14)	0.395 (1.94)	0.8643	254.82**	2.22	0.0930
9	0.037* (6.75)	0.224 (1.09)	0.8405	205.52**	2.32	0.0516
			R_2 - CORC			
1	0.058* (2.05)	0.713 (0.84)	0.9076	461.61**	1.97	0.0366
2	0.059* (2.26)	0.833 (1.13)	0.9119	476.05**	1.86	0.0462
3	0.055* (2.09)	0.852 (1.29)	0.9137	476.31**	1.92	0.0474

TABLE 5.2--Continued

Periods Ahead	Θ	λ	R^2	F	D-W	R^2(c-o)
4	0.059* (2.59)	0.931 (1.52)	0.9059	423.55**	2.04	0.0624
5	0.061* (2.98)	0.928 (1.59)	0.8902	348.59**	2.19	0.0662
6	0.068* (4.23)	0.952 (1.81)	0.8908	342.64**	2.12	0.0897
7	0.063* (3.19)	0.919 (1.91)	0.8885	326.60**	2.21	0.0849
8	0.069* (4.55)	0.752 (1.58)	0.8638	253.69**	2.20	0.0680
			R_3 - CORC			
1	0.088* (2.07)	1.45 (1.06)	0.9098	473.79**	1.92	0.0443
2	0.088* (2.22)	1.67 (1.40)	0.9139	488.43**	1.84	0.0589
3	0.085 (2.14)	1.69 (1.54)	0.9107	458.69**	1.96	0.0616
4	0.091* (2.66)	1.72 (1.69)	0.9039	413.78**	2.06	0.0738
5	0.094* (2.89)	1.71 (1.78)	0.8928	358.05**	2.15	0.0797
6	0.105* (4.51)	1.75 (1.96)	0.8856	325.23**	2.07	0.1041
7	0.097* (3.04)	1.35 (1.63)	0.8829	309.19**	2.17	0.0651
			R_4 - CORC			
1	0.119* (2.19)	2.55 (1.34)	0.9126	490.71**	1.87	0.0566

TABLE 5.2--Continued

Periods Ahead	Θ	λ	R^2	F	D-W	R^2 (c-o)
2	0.121* (2.51)	2.86 (1.67)	0.9129	481.87**	1.96	0.0749
3	0.115* (2.14)	2.77 (1.76)	0.9098	453.99**	1.98	0.0757
4	0.124* (2.60)	2.73 (1.87)	0.9043	415.76**	2.05	0.0962
5	0.128* (2.97)	2.72 (1.95)	0.8899	347.71**	2.14	0.0862
6	0.146* (4.88)	2.46 (1.85)	0.8787	304.27**	2.03	0.0983
			R_5 - CORC			
1	0.151* (2.20)	4.04 (1.62)	0.9128	492.07**	1.86	0.0719
2	0.154* (2.45)	4.23 (1.87)	0.9129	481.85**	1.88	0.0876
3	0.147* (2.12)	4.07 (1.95)	0.9103	456.56**	1.97	0.0884
4	0.161* (2.93)	3.98* (2.03)	0.9023	406.52**	2.05	0.0980
5	0.168* (3.21)	3.67 (1.92)	0.8855	332.62**	2.13	0.0929
			R_6 - CORC			
1	0.186* (2.24)	5.72 (1.81)	0.9133	495.24**	1.86	0.0842
2	0.188* (2.43)	5.84* (2.04)	0.9133	484.72**	1.88	0.0986
3	0.185* (2.43)	5.65* (2.11)	0.9092	450.57**	1.97	0.1000

TABLE 5.2--Continued

Periods Ahead	Θ	λ	R^2	F	D-W	R^2(c-o)
4	0.196* (2.81)	5.19* (2.03)	0.8991	392.13**	2.05	0.0976
			R_7 - CORC			
1	0.222* (2.30)	7.73 (2.00)	0.9140	499.25**	1.85	0.0966
2	0.224* (2.47)	7.79* (2.20)	0.9129	482.39**	1.88	0.1101
3	0.223* (2.49)	7.23* (2.17)	0.9074	440.95**	1.97	0.1041
			R_8 - CORC			
1	0.262* (2.38)	9.94* (2.14)	0.9137	497.30**	1.85	0.1071
2	0.264* (2.55)	9.58* (2.23)	0.9116	474.54**	1.89	0.1121
			R_9 - CORC			
1	0.304* (2.47)	12.13* (2.20)	0.9127	491.36**	1.85	0.1113

R^2(c-o), which is only 0.0340. This is the lowest R^2(c-o), while the highest is only 0.1121 for R_8 two periods ahead.

Examining the Cochrane-Orcutt results, the coefficients on risk are generally smaller than those reported in Chapters II and III. Also, the t-statistics on risk only become significant for R_6 through R_9. The coefficients are positive but less than one for R_1 and R_2, then they begin to increase from R_3 to R_9. Of special importance is the consistent significance of the constant term. This would indicate that other factors beside the measure of risk have explanatory power.

Conclusion

These results suggest that investors in corporate bonds are not naive, but they do perceive the problems of scale and variability and use appropriate measures. The results also lend support to the approach taken in Chapters II and III. Methodologically, this chapter has supplied proof by contradiction rather than the direct evidence of the earlier chapters. The nature of the proof has been directed toward the variable risk hypothesis itself rather than a test of any specific theory concerning the term structure, and it should be considered in that respect rather than as a test of the term or liquidity premium theories.

CHAPTER VI

CONCLUDING REMARKS AND SUGGESTIONS FOR FURTHER RESEARCH

Concluding Remarks

This dissertation has contributed to economic knowledge in the following manner. The dissertation was primarily intended as a test of the variable risk hypothesis. In terms of methodology, the approach to a measure of risk differed from that used by Bonomo and Jones. In so doing, additional support for this hypothesis was generated by showing that the variable risk hypothesis is not dependent upon the measure of risk.

In the process of testing the variable risk hypothesis by applying it to the term structure of interest rates, an attempt was made to relate the variable risk hypothesis to existing theories about term structure. It was found that this hypothesis was compatible with both the term premium and liquidity premium theories. In retrospect, the variable risk hypothesis might be more consistent with the term premium theory with its emphasis on interest-rate risk. Statistical tests were performed which lend support to both the variable risk hypothesis and these two theories.

Deriving a measure of risk based on acceptable theory is another point brought out in the dissertation. The introduction of a moving information set established the basis for the empirical measure of risk. The moving information set is a theoretical concept which justifies the use of more than a single point as the basis on which decisions were made, and it can be expanded to include different variables to be consistent with different theories of expectations formation.

Lastly, the dissertation has provided support for Friedman's emphasis on variability in his Nobel lecture. We have seen and should continue to see attempts to derive acceptable measures of risk to be used not only in academic empirical research but also in practical applied situations in the real world.

Suggestions for Further Research

The variable risk hypothesis can be applied to many areas where planning and uncertainty are a part of the decision-making process. Another direction for the analysis of this dissertation is to follow Kessel and examine the government securities market where financial assets can have as short a term to maturity as two weeks.

Another direction of research is to break down the measure of interest-rate risk into its components. Following Irving Fisher, we could postulate the following equation

$$\sigma_R^* = f(\sigma_r^*, \sigma_\pi^*) \ , \tag{6.1}$$

where

σ_R^* = nominal interest-rate risk (used here),

σ_r^* = real interest-rate risk, and

σ_π^* = inflation rate risk.

The problems associated with this approach are concerned with obtaining data on the real rate of interest, r, and, consequently, σ_r^*. Olsen does not consider any derivation such as equation (6.1), and it is a major flaw in his analysis. We chose not to pursue this line of approach here because it seemed more logical to establish the relevance of the variable risk hypothesis using the more broadly defined interest-rate risk first and then, in another research effort, establish the relevance of a more sophisticated measure of risk.

APPENDIX

Critical Values

Chapter	t 5% level	F 1% level (df)	D-W d_L	D-W d_U
2	2.01	7.31 (1,40)	1.50	1.59
3	2.01	7.31 (1,40)	1.50	1.59
4	2.01	2.89 (9,32)	1.23	1.79
5	2.01	7.31 (1,40)	1.50	1.59

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VARIABLE RISK AND THE TERM STRUCTURE

by

Paul J. Abbondante

(ABSTRACT)

The variable risk hypothesis states that if individuals do perceive a change in risk, and if this change is taken into account in their decision-making process, then it seems plausible to include some measure of risk as a variable in empirical studies where risk is a factor. Some reasonable measures of risk are proposed based on the concept of a moving information set where the information used to evaluate risk is changing over time. The resulting measure of risk is the moving coefficient of variation. The variable risk hypothesis is then applied to the term structure of interest rates. The empirical testing generates further support for the liquidity and term premium hypotheses, while a test of the segmented markets hypothesis using this measure of risk is not supportive.