EXPECTATIONS, RISK AVERSION, AND THE TERM STRUCTURE OF INTEREST RATES IN AUSTRALIA: AN ANALYSIS OF THE EFFECT OF ALTERNATIVE METHODS OF CONSTRUCTING YIELD CURVES ON THE RESULTS OF THE ERROR-LEARNING MODEL, AND OF THE EXTENT OF CENTRAL BANK CONTROL OVER THE YIELD CURVE.

by

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SUMMARY

This dissertation is an analysis of the effect of alternative methods of constructing yield curves on the results of the error-learning model devised by Meiselman (1962), and of the influence of expectations and risk aversion on the term structure of interest rates in Australia for the period 1954-68.

In chapter one, three alternative methods of constructing yield curves are outlined, namely, free-hand smoothing, linear interpolation, and regression analysis. It is argued that the third method is the most satisfactory, particularly when errors in the data are present and observations are relatively few.

A comprehensive history of the development of term structure theory preceding the work by Hicks (1939c) in <u>Value and Capital</u>, is presented in chapter two. Important contributions by writers who anticipated later work on term structure theory are emphasised. Attention is also paid to tracing the origins of the traditional expectations theory which is refined in Hicks' treatment in <u>Value and Capital</u>.

In chapter three, a theoretical analysis of the effect of risk aversion on the term structure highlights the

importance of transactors' availability periods for the slope of the yield curve. The analysis abstracts from expectations and transactions costs, and concludes that, until the length of and degree of certainty about availability periods on both sides of the market are specified, nothing can be said *a priori* concerning the slope of the yield curve.

The traditional expectations theory, from which Meiselman's error-learning model was developed, is discussed in chapter four. The assumptions of the theory, along with criticisms of these assumptions, and the relationship between the theory and the error-learning model, are examined.

The general results of the tests of the error-learning model are reported in chapter five. It is argued that the results support the importance of expectations in the Australian securities market, particularly when recognition is given to the effect on the term structure of the central bank's open market operations. The influence of expectations shows most strongly with respect to yields on securities with relatively short term to maturity, and it is these securities which are traded in an active private market that is relatively free of central bank control.

In chapter six, the three sets of results derived from the error-learning model using the three sets of yield curves are compared. The evidence suggests that the best results are obtained using yield data from curves constructed by regression analysis, the method which produces the smoothest yield curves. It is argued that it is preferable to use this method when the data contains significant imperfections, as is the case with the Australian data.

The use of smoothed curves is defended against criticism that such curves <u>ensure</u> good results from the error-learning model. If this criticism is valid, it could not be said that the error-learning model is a valid test of expectations where smoothed yield curve data is used. However, the evidence produced in chapter six throws doubt on the criticism and supports the validity of the error-learning model.

Evidence is produced in chapter seven concerning the existence of liquidity premiums in Australian yield curves. It is argued that the evidence supports the existence of a Hicksian "constitutional weakness" in the Australian securities market.

DECLARATION

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any University and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

F.A. Bloch

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INTRODUCTION

I.1 The Term Structure and Monetary Policy

The term structure of interest rates is a topic that has risen from the status of an academic curiosum during the first half of the twentieth century, to one that is in the battlefield of monetary policy in the latter half. While the topic aroused some debate in the nineteen-thirties, it was mainly treated as a by-product of interest-rate theory in general, an excursion to tie up the loose ends left dangling by the use of "the" interest rate in general equilibrium theory. However, the real world importance of the analysis was forcefully highlighted in the United States during the nineteen-fifties and -sixties when it was used to support two diametrically opposed monetary policies.

During the nineteen-fifties, the U.S. Federal Reserve Bank maintained an open market operations policy of "Bills Only". Based on a particular analysis of the term structure, this was a policy of restricting open market operations to treasury bills.[1] Then in 1961, the Kennedy

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1. For information on "Bills Only" refer Riefler (1958), Young and Yager (1960), Luckett (1960), Fand (1966), Van Horne (1966) and Bonello and Russell (1969).

Administration instituted "Operation Twist", a policy of conducting open market operations in <u>all</u> sectors of the market for government securities rather than just the short-term end. This policy was based on a quite different interpretation of the determinants of the structure of interest rates from that underlying "Bills Only".[2]

Despite its adoption by economic advisers to governments, the theory of the term structure has not yet been refined to the point where it can be said that there is a general consensus in academic circles on the relative importance of the major determinants. This is amusingly illustrated by Lutz (1967, p.210) when he notes that

> "one author believes he is able to refute the most widely accepted theory by appealing to the empirical evidence, while another thinks that the facts support it, and a third claims that the same empirical material that was used by the first supports rather than refutes this theory."

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2. The literature on "Operation Twist" is intimately bound up with the general analysis of the effects of variations in the supply of government securities on the term structure and hence covers a wide range of articles. A select few, in addition to those in footnote 1 above, are Okun (1963), Modigliani and Sutch (1966), Holland (1969) and Bierwag and Grove (1971).

The current state of term structure theory bears analogy with the state of monetary and fiscal policy in general, where major determinants of economic activity have been delineated but the relative importance of the variables is still hotly debated.[3] Similarly, with term structure theory the problem is now one of deciding <u>to what extent</u> expectations are important in determining the term structure compared with transactors' aversion to risk, and <u>to what extent</u> the government's open market operations affect the term structure.

"Fine-tuning" of term structure theory is continuing, both in the field of model formulation and empirical testing. Whether the day will eventually be reached when monetary policy has the advantage of a refined model of the term structure,on which a favourable consensus is held by academics, governments, and people close to securities markets is, however, another matter.

I.2 Theories of the Term Structure

Theories of the term structure of interest rates can be classified under three headings, namely, expectations, liquidity preference and market segmentation. Under the

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3. See, for example, Friedman (1970).

heading of expectations are those theories which postulate that market transactors base their portfolio decisions on their expectations of future rates alone. In selecting securities of particular terms to maturity, they will be influenced primarily by these expectations rather than by the risks that are associated with the uncertainty surrounding changes in future rates. Expectations may be formed concerning the course of future short-term rates, of future long-term rates, or of the whole complex of rates that are expected to rule in the future.

One of the earliest expectational theories is that formulated by Fisher (1930), and is referred to as the traditional expectations theory. The basic behavioral postulate of the theory is that market transactors form expectations concerning the future course of _short-term_ rates _over the long run_. It is assumed that transactors are profit-maximizers with uniform and confidently held expectations. Consequently, they base their portfolio decisions on expected returns over the long run, and have no _a priori_ preference for securities of any particular term to maturity. The theory predicts that, in equilibrium, the rate on any long-term loan will be equivalent to a geometric average of the short-term rates expected to rule over the life of the long-term loan. This theory is discussed further in chapter four below, and is the basis for the model tested in chapter five.

Another theory of the term structure that is based on expectations alone,employs a different behavioral postulate to that underlying the traditional expectations model. Instead of long-term forecasts of expected future short-term rates, this theory postulates that transactors make short-term forecasts of long-term rates or of all rates over the entire maturity spectrum. It is argued by Malkiel (1966) that the latter postulate is more realistic and in accordance with the opinions of those people who are close to the activities of securities markets.

Despite the different behavioral postulates of the two major expectational theories outlined above, the conclusions reached by both concerning the relationship between short-term and long-term rates at any point in time are the same: see the discussion in chapter four below (pp. 127-28). Similarly, whatever the particular structure of rates that may be observed at any time, it can be rationalised by either of the theories. For example, if short-term rates are less than long-term rates at a moment in time, the rationale would be that the market expects rates in general to rise in the future. An expected rise in future rates will, *ceteris paribus*, lead to a preference for short-term securities in order to avoid the impending capital loss on long-term securities if bought now. This is because a rise in rates in the future implies a fall in the future price of these long-term securities. The demand for short-term securities will drive up their price and so reduce their yield relative to yields on long-term securities. In the opposite case where short-term rates exceed long-term, both theories would predict that the market expects rates in the future to fall. Whether the process is explained in terms of expectations concerning future short-term rates, future long-term rates, or rates expected in the future on all terms, is irrelevant for the final outcome.

The liquidity preference theory is basically an extension of the expectations theories to allow for the effect of risk aversion on the term structure. The risk involved is the risk of loss due to unexpected future changes in rates, and not to any risk of borrower default. While allowing that the expectations of transactors concerning future rates play an important role in influencing their portfolio decisions, the theory postulates that aversion to risk leads to a state where, on the average, long-term rates exceed short-term rates. Where expectations alone influence the decision making, short-term rates will, on average, equal long-term rates provided only that rates are expected to rise as often and as far as they are expected to fall. However, the liquidity preference theory argues that, given expectations, an excess demand for short-term securities will exist which will drive up the price of short-term securities and so reduce their yield relative to long-term securities.

This theory is often ascribed to Hicks (1939c), but is more strictly due to Keynes (1930); see pp.66-70 below. Furthermore, it is the theory of liquidity preference that is discussed by Keynes in the _Treatise_ rather than that discussed in the _General Theory_. In the former, liquidity preference is a result of _uncertainty_ concerning future rate changes, whereas in the latter it is a result of _expectations_ of future rate changes, based on the concept of a normal level of rates. The theory of liquidity preference discussed here concerns the situation where transactors' uncertainty concerning future rate changes leads to an excess demand for short-term securities.

The excess demand for short-term securities is a result of a preference for short-term securities on the demand side of the market, and a preference for long-term securities on the supply side. Lenders of funds regard short-term loans as more liquid than long-term loans and so more available to meet their expected and unexpected needs. On the borrowing side of the market, borrowers are pictured as having a need for long-term funds due to the nature of the production process, and so prefer to issue long-term securities.

The gap between short- and long-term rates reflects the liquidity premium required by lenders in order to compensate them for the greater risk of holding long-term securities, and is a reflection of what Hicks (1939c, p.146) refers to as the market's "constitutional weakness" at the long-term end. So while transactors make portfolio decisions on the basis of their expectations concerning future rates, their decisions are tempered by considerations of the risk associated with uncertain future changes in rates. Liquidity preference is discussed further in chapters three and seven below.

The final group of theories focuses on market segmentation. In this case, expectations are regarded as having a negligible influence on decisions made by transactors concerning their portfolios. Transactors are influenced solely by considerations of risk, and so select securities of particular terms in such a way that risk is minimised. On the basis of their aversion to risk, transactors have definite preferences for particular terms with no motivation to transact outside these terms, so that the supply and demand for securities within a particular segment is independent of that for any other segment. The outcome is that the securities market becomes segmented into several sub-markets according to the term of securities.

An important implication of the segmentation of markets is that the monetary authorities can affect directly the term structure by the use of open market operations, that is, by varying the supply of government securities between segments of the market. For example, if the authorities wish to raise short-term rates in order, say, to attract capital inflow from overseas, and to lower long-term rates in order, say, to stimulate private domestic investment, they can do so in a segmented market by simultaneously issuing short-term bonds and buying long-term ones. The increase in supply of short-term bonds will cause an increase in their yield, while long-term yields will fall with the decrease in supply of long-term bonds.

The theory of market segmentation has been developed by Culbertson (1957), who argues that institutional impediments prevent the free flow of funds between market segments, so that expectations are important only in the *timing* of rate adjustments. Meiselman (1962) argues that the existence of market segmentation is not necessarily inconsistent with analysing a market *as though* it were comprised of transactors who were motivated primarily by their expectations of future rates. All that is required is that transactors in each segment of the market be willing to deal in securities at the margin of their segment on the basis of their expectations of future rates, and that all the segments in the market overlap. In this way, the overlapping segments effectively unify the market as a whole for the purpose of analysis, with the result that the term structure behaves *as if* it were determined by expectations alone.

Meiselman argues further, that analysing a segmented market as though it were dominated by expectations alone may be valid even if most transactors do not speculate at the margin of their segments. In this case the term structure may be determined by adequately-financed speculators in the market who are indifferent to risk and who hold uniform expectations. These speculators act so as to break down the segmentation and bring about a term structure that reflects their expectations of the future course of rates. Once again, the term structure will behave as if it were determined by transactors who base their portfolio decisions on their expectations of future rates. This implies that open market operations will have no lasting effect on the term structure; see the discussion in section 3.6.2 below.

The theory of market segmentation may be used to rationalise any term structure relationship (as were the pure expectational theories, see p. 5 above). Where short-term rates exceed long-term rates, for example, the argument is that preferences for particular terms on the supply and demand side of the market are, on the basis of risk aversion, consistent with supply and demand schedules that intersect at a lower price for short-term securities than for long-term ones. Any pattern of preferences consistent with this result can be postulated a priori, so that empirical investigation is required in order to determine whether the pattern postulated is really descriptive of the particular market under investigation. Market segmentation is discussed further in section 3.6 below.

I.3 Thesis Results

The major part of the thesis involves an analysis of the effects of alternative methods of constructing yield curves on the results of the error-learning model. (The error-learning model is an indirect test of the traditional expectations theory, and was devised by Meiselman (1962): see section 4.3 below). It is demonstrated that, despite criticism of the use of smoothing procedures for the construction of yield curves, such procedures are valid, at least with respect to the Australian data.

In order to show this, three separate methods are used to construct quarterly time-series of Australian yield curves. No such time-series have previously been available. The three methods used, namely regression analysis, free-hand smoothing and linear interpolation, are discussed in chapter one. It is argued in chapter six that the method of regression analysis is most suitable when the yield data contains significant imperfections, as is the case with the Australian data. An examination of the three sets of yield curves reveals that the curves constructed by linear interpolation and free-hand smoothing come to resemble the curves constructed by regression analysis as imperfections in the data are reduced over time.

The three separate time-series of yield curve data are used in tests of the error-learning model, and, as expected, the tests using data from the curves constructed by the best method, namely regression analysis, give the best results. However, the criticism that the use of data from smoothed curves necessarily ensures favourable results from the error-learning model is shown in chapter six to be inconsistent with the evidence. Some of the yield curves require extrapolation at the short-term end because of a paucity of observations below six months to maturity. Consequently, the time-series of three-month yields constructed by regression analysis are highly suspect as estimates of "true" yields. When these particular yields are used in tests of the error-learning model the results are poor, despite the fact that the yields come from smoothed curves.

The theory that favourable results from the error-learning model are due primarily to the presence in the model of one particular key rate is also examined in chapter six. As an indirect test of this theory, the model is modified in such a way that the influence of the particular rate referred to is reduced. Despite the modification, tests of the model still provide favourable results, suggesting that the error-learning model is a valid test of behavior based on adaptive expectations.

The results of the empirical tests in general are reported in chapter five, and they support the hypothesis advanced in the thesis that the central bank in Australia determines the term structure covering medium- and long-term securities, but that expectations of future rates determine the structure at the short-term end. This hypothesis is based on the nature of the Australian securities market over the test period. The market has been, and still is, relatively narrow by world standards, and so displays a high degree of sensitivity to the activities of the central bank. However, over the test period, an active private market in securities with terms ranging up to three and four years developed, assisted since the late 'fifties by the birth and growth of the official short-term money market. The active private market in short-term securities is less sensitive to central bank open market operations than are the less active markets in medium- and long-term securities. Thus, on the basis of this hypothesis, the influence of expectations should be felt most strongly at the short-term end of the term structure, and this is supported by the evidence of the tests for the period 1954-68.

Further evidence is provided by tests that are limited to the 1960-68 period. The increase in private trading during the 'sixties could be expected to strengthen the influence of expectations in the short-term market as well as to spill over to securities of slightly longer term. Both of these events are supported by the evidence presented in chapter five.

In providing evidence for the 1954-68 period as well as for the 1960-68 period, both annual and quarterly cross-section and time-series data are used. However, in order to allow tests using quarterly cross-section data, the problem caused by the presence of suspect three-month yields that were derived by extrapolation must be overcome. To this end, the error-learning model is modified so that the influence on the model of the suspect yields is minimised.

Evidence is produced in chapter seven in support of the presence of liquidity premiums in Australian yield curves. Three independent tests all support the finding that, in Australian rates over the period, there were liquidity premiums that increased in size with term but at a decreasing rate. It is argued that this evidence supports the liquidity preference theory, and so the existence of a "constitutional weakness" in the Australian securities market.

On the purely theoretical side, an analysis of the effect of risk aversion on the term structure of interest rates is presented in chapter three. The analysis stresses the importance of ascertaining the degree to which transactors on both sides of the securities market can determine the period of time for which they will have or require funds. It is argued that without such knowledge, nothing can be said *a priori* concerning the relationship between rates of different term, abstracting from all considerations other than the risk of loss due to uncertainty concerning future changes in rates.

The analysis of risk aversion combines the work on hedging behavior by Meiselman (1962) with the analysis of portfolio selection developed by Markowitz (1952) and Tobin (1958), and demonstrates how the work on liquidity by Joan Robinson (1951) is related to the present analysis. The implications of the analysis for the central bank's open market operations are discussed; it is concluded that in order that these operations should have *some* effect on the term structure, all that is required is a market that displays aversion to risk, whatever the particular form this aversion may take.

Much of the current debate concerning the term structure of interest rates is based on Hicks' *Value and Capital* (Hicks, (1939c)). However, many of the arguments involved in the debate have been discussed in some detail by earlier writers who have received little attention in the more recent literature. In chapter two, therefore, the various theoretical and empirical strands of the pre-*Value and Capital* discussion of the term structure are traced, and the importance of the contributions of Sidgwick (1887), Fisher (1896, 1906, 1907, and 1930), Kock (1929) and Keynes (1930 and 1936) are emphasised. The discussion in chapter two is, to the writer's knowledge, the most comprehensive of its kind available, and from it can be traced the development of the traditional expectations model leading up to Hicks' refinement of the model in Value and Capital.

The assumptions underlying the traditional expectations model and criticisms of the model are discussed in chapter four. In addition, the relationship between the traditional expectations model and Meiselman's error-learning model is made clear, as well as the relationship between the error-learning model (an adaptive-expectations model) and a model dealing with the formation of expectations.

CHAPTER ONE: CONSTRUCTION OF YIELD CURVES

1.1 Definition of the Term Structure

The term structure of interest rates refers to the variation in interest rates on loans according to the term to maturity of the loan. Other factors besides term to maturity also cause variations in interest rates between loans. Examples of these are

(1) transactions costs;

(2) the relative credit ratings of borrowers and hence the risk of default of payment of capital and/or interest;

(3) various forms of taxation concessions which make some securities more profitable than others.

The effect of these other factors are excluded from the present analysis which seeks to specify the variation in return to the investor that is due solely to the time period for which a debt is incurred. The term structure of interest rates thus refers to the relationship between yields to redemption and term to maturity on securities that are free of default risk. Default-free securities are those where the element of borrower riskiness has been minimised, so that the securities are homogeneous with respect to the credit rating of borrowers. In practice this usually means limiting the data to government securities, or to so-called high-grade corporate securities.

Yield to redemption is a measure of the average return offered by a security over its term to maturity and is identical with the internal rate of return. It is most commonly referred to simply as "the yield" and can be calculated from the following formula.

$$M.P. = \frac{C_1}{1+Y} + \frac{C_2}{(1+Y)^2} + \frac{C_3}{(1+Y)^3} + \ldots + \frac{C_n + R.V.}{(1+Y)^n} \quad (1.1)$$

M.P. is the current market price of the security, R.V. is its redemption value, C_1 to C_n are the regular coupon payments offered over the remaining n periods that the security has to run, and Y is the security's yield or internal rate of return. Thus, given a security's current market price, coupon rate, redemption value and term to maturity, its yield to redemption can be calculated from the above formula using an iterative process.[4]

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4. An actual example of this process has been worked out in Harcourt, Karmel and Wallace (1967, pp.161-64). A short cut is to use an approximation for equation (1.1) as has been done for the yields reported in table 1.3 in Bloch (1972).

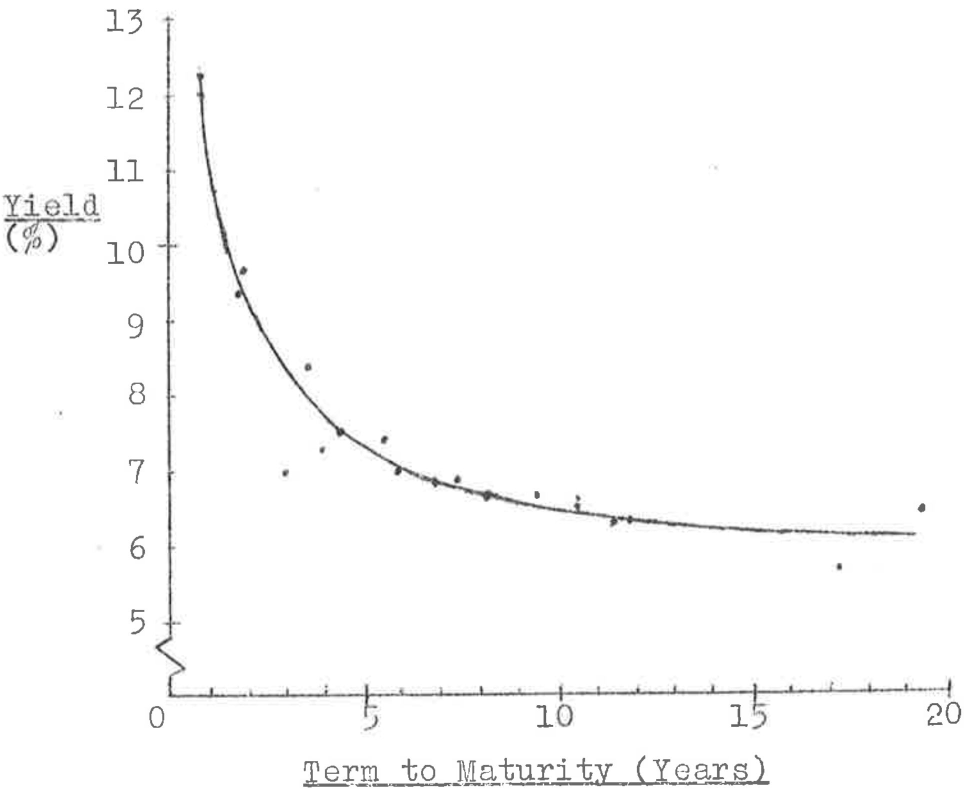
1.2 The Yield Curve

The term structure of interest rates that exists at a particular point in time can be described by what is known as a yield curve. Here the yields are plotted on the vertical axis and term to maturity on the horizontal axis. A smooth curve is then fitted to the points, either statistically or by free-hand. An example of such a yield curve is given in figure 1.1 on page 20 below. From the smoothed yield curves can be read off yields for regular term to maturity, and these yields can then be compiled in a yield table. However, no such consistent set of yield data has been published in Australia. All that is available are a few yield curves published from time to time by the Reserve Bank in its annual reports, and yields on a few select maturities published on a regular basis by the Bank in its Statistical Bulletin. The yield tables used for the empirical work in this thesis have been compiled from yields on commonwealth bonds by the writer for the period 1954-68, and are presented in Bloch (1972) along with the raw yield data from which they are derived.

Yield curves of various shapes have emerged over the last few decades, the most common (at least in the U.S.A. and Australia) being upward-sloping. As can be seen from table 1.1 on page 41 below, all of the fifty nine yield curves drawn for this thesis are upward-sloping, though thirty eight of these curves as drawn by regression analysis have downward-sloping sections as well. Downward-sloping curves have existed in earlier years of the twentieth century. An example is given in figure 1.1 below which is derived from table 1.3 in Bloch (1972) where yields for the period 1919-53 are presented. No attempt has been made to fit yield curves to all of this early bond data.

Figure 1.1

Yield Curve Constructed by Free-Hand
March 1931



Source: Commonwealth bond yields reported in the Official Record of the Stock Exchange of Melbourne.

From the whole spectrum of yields that go to make up a yield curve, it is convenient at times to select two hypothetical yields as representative of the whole. These are usually referred to as the short rate and the long rate. Where the relationship between these two rates is analysed in the following pages, it is to be thought of as a proxy for the relationship between all the rates that go to make up the term structure.

1.3 Problems in Constructing Yield Curves

The problems connected with the construction of yield curves can be conveniently discussed by employing the concepts of errors of the first type and errors of the second type as introduced by Masera (1970a). There are two main problems involved. First, it is necessary to ensure that the yields to redemption are for securities that are homogeneous in all respects except term to maturity. Therefore, other factors affecting yields such as transactions costs and credit ratings must be held constant in order to isolate the effect of term to maturity on yields. Failure to hold these other factors constant can lead to Masera's errors of the first type, where differences in yields caused by other factors are ascribed to term to maturity.

The second problem in the construction of yield curves comes in attempting to draw a curve through the scatter of yields plotted against term to maturity after eliminating errors of the first type. This leaves the way open for errors of the second type, where the particular curve selected may not correspond exactly to that which would emerge if a greater and greater number of securities, free of type-one errors and covering the entire maturity spectrum, were observed.

The two types of error described above are closely related. In order to minimise type-one errors, the range of securities selected for inclusion must be limited to those closely homogeneous in all respects other than term to maturity. This limits the number of observations and so raises the possibility of errors of the second type by making more difficult the actual drawing of the curves. However, if a wide range of securities is allowed in order to reduce errors of the second type, it will reduce the homogeneity of the sample and so increase errors of the first type. Hence the particular securities that are chosen to provide the basic data for the construction of yield curves must be carefully selected if both errors of the first and second type are to be minimised.

The problems concerning the construction of yield curves could be avoided in this thesis if a suitable set of curves using Australian data were already available. As mentioned above, however, no such curves are available, so that a significant part of the work for the thesis involves the construction of yield curves. There is little choice of securities from which to collect the basic data. Unlike the U.S., for example, there are no time-series of high-grade corporate bond yields available in sufficient volume to allow the drawing of yield curves. Such a time-series has been prepared in the U.S. by Durand (1942) and Durand and Winn (1947), and this is the basic data used by Meiselman (1962) in his tests of the error-learning model. Nevertheless, Commonwealth Government bonds are a homogeneous class of securities, and regular bond quotations are available from the stock exchanges. Moreover, the volume of government bonds has been far greater over the years than that of corporate bonds. In 1953, for example, commonwealth bonds represented 66.2 per cent of the market value of securities listed on the Melbourne Stock Exchange, whereas corporate debentures and notes accounted for only 2.4 per cent (Rose, 1969, p.55). Commonwealth bonds were chosen, therefore, to provide a time-series of yields.

1.4 Minimising Errors of the First Type

The major forms of type-one errors are as follows.

(1) Default risk,

(2) Government market controls,

(3) Taxation considerations with respect to coupon rates,

(4) Risk aversion with respect to coupon rates,

(5) Stock exchange listing imperfections,

(6) Optional call dates,

(7) Transactions costs.

Each of these will be looked at in turn.

1.4.1 Default Risk

Yields may differ between securities due to different degrees of default risk. The greater is the probability of risk of default, the greater is the return required by the lender. This factor has been held constant by using only commonwealth bonds to provide the basic data.

1.4.2 Government Market Controls

During the Second World War, the Commonwealth Government introduced capital issue controls and minimum bond prices in order to lower the cost of debt finance for defence purposes. As a result, bond yields for this period are influenced heavily by the official government controls. These controls were finally removed during December 1953, eight years after the war ended, by which time the economy had readjusted to a peace-time basis. In order to avoid a period when normal market forces were distorted, the time-series for the regression tests in the thesis begin at

March 1954, and yield curves are constructed for each quarter from that date. A further advantage of beginning at this time is that, prior to the middle 'fifties, there are only a limited number of securities recorded as outstanding for each quarter. By delaying the start until 1954, more cross-section data is available for the regression analysis, especially for the longer-term maturities.

1.4.3 Taxation Considerations with respect to Coupon Rates

There has been no study of the effect of taxation on bond yields in Australia, at least to the writer's knowledge. However, two considerations are clear enough. First, transactors were allowed a ten per cent tax rebate on coupon receipts from government bonds over the period 1942-68. This factor is held constant by ending the time-series at September 1968, allowing fifty nine yield curves to be drawn, one for each quarter from March 1954 to September 1968. Secondly, coupon payments received by transactors in Australia are subject to income tax whereas capital gains are not, at least for transactors not classified as share traders by the tax department. This factor leads to a preference for low-coupon, deep-discount bonds in order to minimise income tax, so that yields will be lower on securities carrying relatively lower coupon rates, as the tax saving replaces some of the yield. Thus, for a given term to maturity there will exist a direct relationship between yield and coupon. However, this direct relationship may be reversed when risk aversion is taken into account, so that the final relationship between yield and coupon is not clear on theoretical grounds.

1.4.4 Risk Aversion with respect to Coupon Rates

Given that two securities have the same yield and term to maturity but different coupon rates, a transactor may have a definite preference for one security or the other on the basis of his aversion to risk. This is because the security with the higher coupon rate is repaid proportionately faster than is that with the lower coupon. For example, assume that securities A and B each have a face value of $100 and a term to maturity of ten years, but coupon rates of five and six per cent respectively. In order to return a yield to redemption of five per cent each, their prices will have to be $100 and $107-72 respectively. This is summarised as follows.

	Term to maturity (years)	Coupon rate (%)	Face value ($)	Yield (%)	Price ($)
Security A	10	5	100	5	100
Security B	10	6	100	5	107.72

The proportion of the price repaid in each year for the first nine years is 5/100 or 5 per cent for security A, and 6/107.72 or 5.57 per cent for security B. Hence, security B with the higher coupon rate is repaid proportionately faster. This can be more clearly seen by examining the case where the transactor's budget is limited in both cases to $100. In this case, the repayment streams of the two securities are as follows.

	Years 1 to 9 ($)	Year 10 ($)	Yield (%)
Security A	5	105	5
Security B	100/107.72 x 6 = 5.57	(100/107.72 x 100) + 5.57 = 98.40	5

Again it can be seen that security B is repaid proportionately faster, returning relatively higher interim payments and a relatively lower final payment.

Given that securities A and B have the same yield and term to maturity, a transactor may still prefer one or the other on the basis of his aversion to risk. For example, he may incur a liability which requires annual interim payments and a lump-sum payment after ten years. In this case, either security will be a suitable investment to allow him to hedge against future interest rate changes in the manner described in chapter three below (see pp.90-94). Payment streams of both the asset and the liability will be matched in advance so that the net return is fixed over the ten years irrespective of any future changes in rates. However, if he incurs a liability which has an indefinite repayment stream, then as portfolio-selection analysis indicates (see pp. 96 - 99 below) he will, on the basis of his aversion to risk, prefer security B which returns the loan effectively faster.

Whether transactors will prefer low or high-coupon bonds when consideration is given to their aversion to risk will depend, therefore, on the nature of their commitments and the time period for which they have funds available for investment in securities. This matter is explored in more depth in chapter three below. The important thing to note here is that while taxation considerations suggest a direct relationship between yield and coupon rate as outlined in section 1.4.3 above, this relationship may be reversed by considerations of risk. Thus, the ultimate relationship is uncertain on theoretical grounds. Fortunately, the regression equations tested in section 1.5.3 below suggest that coupon rates have an insignificant effect on yields, so despite the theoretical relationship between yield and coupon, it has been ignored on empirical grounds.[5]

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5. Evidence on the relationship using U.S. data can be found in Wallace (1964) and Buse (1970b), and using U.K. data in Grant (1964b) and Fisher (1966 and 1967).

1.4.5 Stock Exchange Listing Imperfections

Imperfections in stock exchange listings encompass outdated quotes, listing errors, and temporary market distortions caused by large transactions in a narrow market. These problems are difficult to handle. The quarterly time-series of yield curves are for the last days of March, June, September and December, but some stock exchange quotes are not available for the last day of the quarter. In these cases, earlier quotes are given but with no indication as to the day to which they refer. Listing errors and temporary market distortions are also difficult to overcome, so that some errors of the first type can not be altogether prevented. Nevertheless, large errors are excluded by averaging the quotes from the Melbourne and Sydney Stock Exchanges as reported in the Exchanges' monthly reports. Quotes that differ by more than a tenth of a percentage point between Exchanges are excluded entirely.

1.4.6 Optional Call Dates

Where securities have optional call dates, the final redemption dates are uncertain, so that the yield to redemption for each of these securities is somewhat indeterminate. As the Treasury has the power to redeem these securities over a period of time, a definite maturity date can not be fixed, but it has been common for the Treasury in the past to redeem on the latest date. A rising trend in general interest rates over time as experienced since the Second World War encourages such a practice if the cost of the public debt is to be minimised. Therefore, the latest redemption date has been used here to determine the term to maturity of each security.

1.4.7 Transactions Costs

The most important transaction cost of dealing in commonwealth bonds is the brokerage charge. Details of brokerage charges are given in Bloch (1972, p. 3), and are of the order of a quarter of one per cent of the face value of the security. As the transactor is interested primarily in the net yield to be realised from a security, the yields need to be adjusted for brokerage charges. Such adjustments are in fact carried out by the stock exchanges, so that the net yield is listed in their monthly reports.

1.5 Minimising Errors of the Second Type

Given that the data is relatively free of errors of the first type, the next task is to construct, for each quarter, a yield curve from the cross-section data. There are three possible ways in which this can be approached, namely, free-hand smoothing, linear interpolation, and least-squares interpolation using ordinary regression analysis. All three approaches are employed here. This allows the error-learning model to be tested separately using data from each set of yield curves, and so an estimate can be made of the effect on the results of the particular method chosen for the construction of yield curves. Such an analysis is carried out in chapter six below.

1.5.1 Free-Hand Smoothing

This method was brought to prominence by David Durand (1942). From the scatter of bond yields plotted against term to maturity, Durand drew an envelope of the lowest yields for each term to maturity in order to eliminate any type-one errors from the high-grade corporate bond yields. He also restricted the curves to three basic shapes, smooth upward-sloping approaching an asymptote, horizontal, and smooth downward-sloping approaching an asymptote. Any irregular bumps were also treated as type-one errors and so ignored. After the free-hand construction, the data was then smoothed even further until the successive differences in yields between maturities became sufficiently regular.

There are two major disadvantages of Durand's method of smoothing. First, by restricting curves to just three basic shapes and so ignoring any bumps, the data is biased in favour of a pure expectations model such as the error-learning model, as irregular bumps and shapes may well be evidence of market segmentation. Secondly, by their nature, free-hand smoothed curves are unique to the drawer and so are unlikely to be reproduced by another person.

The curves constructed by free-hand smoothing in this thesis are different in two respects from Durand's. First, there is no restriction on the number of shapes allowed. Rather, the curve is drawn to follow the general direction of the observations, so that in some cases there are as many as four points of inflexion. Nevertheless, the presence of some errors of the first type are recognised as the free-hand smoothing does not simply interpolate between the observations as plotted, but rather outlines the curve that appears to give the best fit to the scatter of points. If the observations were all completely free of errors of the first type so that they could be regarded as "true" points, then a simple interpolation procedure would be required that produced a curve passing through all the "true" points. By contrast, the fitting procedure allows that all points are not necessarily "true", and so produces a curve that may or may not pass through any or all of the original observations.

Secondly, no attempt has been made to regularise the differences in yields between maturities by additional smoothing. Once the best general fit is obtained after allowing the curve to follow the general direction of the observations, no further adjustments are made. These two differences from Durand's method of fitting can be expected to react unfavourably on the tests of the error-learning model, based as it is on refined estimates of foward rates, and should be kept in mind when comparing the results in chapter five below with those reported by Meiselman.

Examples of yield curves drawn by free-hand smoothing can be found on pp.196-202 below. The quarterly yield table that is derived from the curves constructed by free-hand smoothing is presented in Bloch (1972, pp.131-60). Unfortunately, a paucity of observations of three-month yields constrained the first observation for each quarter to maturities of six months, as explained on pp. 159-60 below.

1.5.2 Linear Interpolation

Linear interpolation simply requires that successive observations be joined by straight lines to form a jagged graph, and has been used by Grant (1964a). Grant is critical of free-hand smoothing as used by Durand, claiming that it is highly "artificial" and unsuitable for the derivation of forward rates, as these rates are extremely sensitive to relatively small changes in spot rates. Grant introduced linear interpolation in order to allow a comparison of its effects on the error-learning model as compared with the effects of free-hand smoothing on the results as reported by Meiselman.

Masera (1970a, p.89), however, is critical of Grant's approach on the grounds that it ignores errors of the first type and stochastic error terms, as well as assuming with no reason that it provides correct yields. Linear interpolation assumes that the observations are completely free of type-one errors and simply interpolates between these observations, unlike both free-hand smoothing and least-squares regression analysis where the presence of some type-one errors are recognised. A similar argument applies to the stochastic errors.

Masera's last point, concerning the lack of reasoning supporting the ability of the linear interpolative method to produce correct yields, is not an easy one to answer. Given that the observations are free of errors of the first type, the particular method chosen to interpolate between these observations is, in the final analysis, purely a matter of subjective opinion, unless one wishes to impose a particular theory of the term structure on the problem. The problem being tackled here is the best way to draw yield curves so that a particular theory of the term structure can be analysed. If the theory is then used to justify one particular method of construction rather than another, the results of the tests of the theory are to a degree spurious, and due to the data used rather than the behavior postulated by the theory. Nevertheless, one can still argue with some justification that particular methods of construction are totally inconsistent with one or other of the theories. To use one of these methods would still bias the tests, but this time against the theory. Masera argues that linear interpolation is biased in this manner against any theory based on expectations, presumably because expectations would tend to lead to smooth curves.

Examples of curves drawn by linear interpolation can be found on pp.195-201 below. The quarterly yield table derived from linearly-interpolated curves is presented in Bloch (1972, pp. 162-91). Once again, the first observation for each quarter is the six-month yield.

1.5.3 Least-Squares Regression Analysis

Given that some errors of the first type are unavoidable due to limitations of the basic data, and that a jagged curve tends to be biased against expectational models, the method of linear interpolation can not be used with a high degree of confidence. Free-hand smoothing, on the other hand, is a highly personal method that derives curves which are unique to the drawer, making exact reproduction by other people unlikely. What is required is a method of construction that recognises the presence of type-one errors, is not biased in favour of any particular model of the term structure, and can be reproduced exactly by other people. The method that most closely meets these requirements is that of least-squares regression analysis, a method that has been used by D. Fisher (1966) and Masera (1970a).

In this method, errors of the first type are allowed for by making estimates of "true" yields corresponding to the observed yields. Interpolation is then carried out between estimated yields rather than the original sample yields. The fitting of yield curves by regression analysis, therefore, involves two independent processes carried out simultaneously; the estimation of the "true" yields (those free of type-one errors) corresponding to the sample yields, and the interpolation between these estimated yields. With free-hand smoothing, both the estimation of the "true" values and the interpolation are performed by eye in drawing the smoothed curve. With regression analysis, on the other hand, the "true" values are estimated by the method of least-squares, which at the same time gives a regression equation that can be used to interpolate between the estimated values.

The selection of the regression equation that gives the best fit to the points is still a subjective matter personal to the fitter. Nevertheless, the selection process can be carried out in a reasonably scientific manner that involves repeated testing. Furthermore, given the regression equation selected, other people can reproduce the curve.

In this thesis, ordinary least-squares regression analysis is used in three stages to construct the yield curves required for tests of the error-learning model. In stage one, preliminary regression tests are carried out on sample cross-section data in order to isolate significant independent variables. An equation containing these significant variables is then tested in stage two against the complete set of cross-section data required for the tests in chapter five. From the results of stage two, one or more regression equations are chosen as giving the best fit overall, and are used in stage three to construct the final yield curves. Each stage will now be discussed in more detail.

(1) Stage One

The basic data from which the yield curves are constructed comprise one set of cross-section yields for each quarter from March 1954 to September 1968. This gives fifty nine sets of cross-section data, with the number of observations in each set ranging from eighteen for the earliest to forty three for the latest, a wider maturity spectrum of securities coming on to the market in more recent years. The basic data, then, are a time-series of cross-section data, from which fifty nine yield curves are to be constructed.

As mentioned above, in deriving a regression equation for the purpose of fitting yield curves, it is desirable that it be chosen in such a way as to avoid bias in favour of any particular theory of the term structure. All that is required is a regression equation containing mathematical terms that adequately describe the shape of the yield curve. One way of deriving the required equation is to formulate an initial equation that contains all the likely mathematical terms describing the various shapes found in each cross-section, and then test this initial equation against a sample of cross-section yields. By examining the yield curves drawn by free-hand smoothing, some preconception can be formed as to the likely mathematical terms.

As a result of such an examination, the following initial equation is formulated.

$$Y = a + bX + cX^2 + dX^3 + eX^4 + f(\log X) + g(\log X)^2 + U \quad (1.2)$$

Y represents yield to redemption, a is a constant term, X is term to maturity, and U is a residual term. The dominance in the free-hand smoothed curves of a smooth upward-sloping curve approaching an asymptote suggests the likelihood of a logarithmic function, while the presence of several points of inflexion in some of the curves indicates the need for cubic and quartic terms. Finally, in the absence of apparent evidence of the need for more complex forms, a preference for mathematical simplicity restricts the equation to first-order functional relationships.

Having formulated the initial regression equation, the next step in stage one is to isolate the significant independent terms. This can be done against sample cross-section data in order to reduce computing costs. The sample is selected in such a way as to include all the basic shapes found over the complete time-series, so that terms which are significant for any one cross-section should show up as significant in the sample. In this way, the insignificant terms can be excluded before testing the regression equation against each set of cross-section data for the complete time-series.

Six sets of cross-section data emerge as having shapes that are representative of all those found in the complete time-series. These are reproduced in table 1.1, where it can be seen that the predominate shape is smooth upward-sloping approaching an asymptote, although in set (6) there is a point of inflexion early in the curve that is found in twenty of the fifty nine curves.

Before going on to the actual regression tests, it is convenient at this point to reintroduce the problem of coupon rates which was listed as a possible source of errors of the first type (see pp. 25-28 above). It was argued that the theoretical relationship between yield and coupon is uncertain, so that nothing has been done as yet to remove this potential source of type-one error. However, now that a regression equation is to be tested in order to isolate significant terms, the problem can be examined further by including terms involving coupon rates. An estimation can then be made of the significance of the effect of coupon rates on yields. If the effect is significant it can be held constant by including a term for coupon rates in the final regression equation, otherwise it can be ignored.

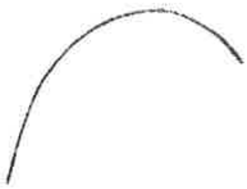
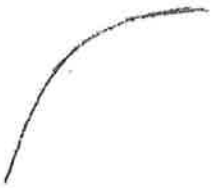
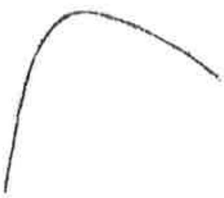
Equation 1.2 is expanded to include terms involving coupon rates in a manner similar to those involving term to maturity. This gives equation 1.3 as follows.

$$Y = a + bX + cX^2 + dX^3 + eX^4 + f(\log X) + g(\log X)^2 + hC + iC^2 + j(\log C) + k(\log C)^2 + U \qquad (1.3)$$

C represents the coupon rate. Equation 1.3 is tested against the six sets of sample data. The program used for the regression tests is given in Efroymson (1960). In brief, the independent terms in equation 1.3 are added to the regression in a step-wise fashion in order of their significance, and

Table 1.1

Results of Stage One
Preliminary Regression Results Using Sample Data

Date cross-section observed	General shape of cross-section	Number of times observed	Terms from equation 1.3 retained as significant
(1) March 1956		5	$Y = 4.31 - 0.45X + 3.37(\log X) + 1.40(\log X)^2 + 0.0004X^3$
(2) June 1956		1	$Y = 6.89 - 2.75X + 0.12X^2 - 0.01C^2 + 8.44(\log X) + 7.09(\log X)^2 - 0.0001X^4$
(3) Sept. 1957		21	$Y = 4.09 + 1.52(\log X) - 0.63(\log X)^2$
(4) Dec. 1957		9	$Y = 4.25 - 0.001X^2 + 1.16(\log X) - 0.44(\log C)$
(5) Dec. 1960		3	$Y = 5.28 + 0.008X^2 + 1.32(\log X) - 1.85(\log X)^2 - 0.0002X^3$
(6) March 1963		20	$Y = 3.78 + 0.08X + 0.52(\log X) - 0.48(\log X)^2$

accepted in a final regression equation if they reach the 0.10 level of significance. The criteria for goodness of fit in all cases is the correlation coefficient and significance tests. The results are given in table 1.1. In table 1.2 is a summary of the significant terms, and a clearer picture emerges as to the number of times that a particular term is reported as significant.

Table 1.2

Summary of Significant Terms from Table 1.1
(Significant terms denoted x)

Sample number	Regression terms									
	X	X^2	X^3	X^4	$\log X$	$(\log X)^2$	C	C^2	$\log C$	$(\log C)^2$
(1)	x		x		x	x				
(2)	x	x		x	x	x		x		
(3)					x	x				
(4)		x			x				x	
(5)		x	x		x	x				
(6)	x				x	x				

From table 1.2 it can be seen that the terms C and $(\log C)^2$ are not significant in any of the sample regressions, and so are eliminated. C^2 is significant only in sample number 2, and as this covers only one yield curve it is also eliminated. Similarly, log C is significant only in sample number 4 which covers only nine yield curves. As the ultimate aim is to derive one or two regression equations that adequately describe most of the shapes found in the time-series, log C is regarded as atypical and excluded. X^3 and X^4 are eliminated on the grounds that wherever they are significant (together covering only nine yield curves), the absolute values of their respective coefficients are negligible, thus indicating small explanatory powers. This left the following regression equation to be tested in stage two.

$$Y = a + bX + cX^2 + d(\log X) + e(\log X)^2 \qquad (1.4)$$

(2) Stage Two

Having derived a regression equation containing the significant terms, it is then tested over each and every set of cross-section data in the time-series. The results of these tests are presented in table 1.3. It can be seen that in twenty three of the fifty nine sets of cross-section data, every term in equation 1.4 is selected as significant at the 0.10 level of significance. In twenty cases, equation 1.4 less the term bX is chosen. Table 1.3 shows that no other expression is selected in more than five cases.

Table 1.3

Results of Stage Two
Selection of Significant Terms from Equation 1.4

Expressions containing significant terms	Number of times selected
$Y = a + bX + cX^2 + d(\log X) + e(\log X)^2$	23
$Y = a + cX^2 + d(\log X) + e(\log X)^2$	20
$Y = a + d(\log X) + e(\log X)^2$	5
$Y = a + bX + d(\log X) + e(\log X)^2$	4
$Y = a + cX^2 + d(\log X)$	4
$Y = a + bX + cX^2 + d(\log X)$	2
$Y = a + bX + d(\log X)$	1
	59

Consequently, the following two equations are chosen for the final step in the construction of yield curves.

$$Y = a + bX + cX^2 + d(\log X) + e(\log X)^2 \qquad (1.4)$$

$$Y = a + cX^2 + d(\log X) + e(\log X)^2 \qquad (1.5)$$

The final step in stage two is to test equations 1.4 and 1.5 against the remaining sixteen sets of cross-section data represented by the latter five expressions in table 1.3. This results in equation 1.4 being selected in fourteen of the sixteen cases. The final outcome of stage two, therefore, is that equation 1.4 is selected as giving the better fit to thirty seven of the fifty nine sets of cross-section data, with equation 1.5 covering the remaining twenty two sets.

(3) Stage Three

In stage three, equations 1.4 and 1.5 are regressed against the complete time-series of cross-section data, and estimates obtained for each quarter of the yields at regular term to maturity. These yields have been compiled in a yield table and are presented in Bloch (1972, pp.100-129). As with the yield tables compiled from the free-hand smoothed curves and linearly-interpolated curves, this table is the source of data for the empirical tests in chapter five below.

1.6 Summary

In this chapter has been presented an analysis of the construction of yield curves using the alternative methods of free-hand smoothing, linear interpolation and least-squares regression. It has been necessary to actually construct yield curves using Australian data for the empirical work involved in the thesis, as no such data is readily available. In chapter six below, the effects of the alternative methods on the tests of the error-learning model are analysed. It is concluded there that where significant errors of the first and second type appear in the data, the method of regression analysis is the most appropriate.

CHAPTER TWO: A HISTORY OF TERM STRUCTURE THEORY UP TO 1939

2.1 Introduction

Most of the recent literature on the term structure of interest rates takes Hicks' statement of the traditional expectations model in Value and Capital (Hicks, 1939c) as the major foundation of the topic,[6] although Fisher (1930) is sometimes given pre-eminence. Little has been written on earlier work concerning the term structure. In this chapter is presented a systematic account of the theoretical development of the term structure in the writings of economists preceding Hicks' work. The traditional expectations model itself is discussed in detail in chapter four below, as well as some of the later work on the term structure that followed Value and Capital.

2.2 J.B. Say, 1821

Reference to relative interest rates on loans of varying duration can be traced back at least as far as 1821 to Say's brief mention in a discussion of interest rates in general. He suggests that interest on short loans will be relatively

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6. For example, Meiselman (1962), Kessel (1965), Modigliani and Sutch (1966), Bierwag and Grove (1967), and Buse (1970a).

lower because of the "positive advantage of having capital readily at command." (1821, pp. 136-37). Say is concerned here only with the effect of risk aversion on the term structure and not at all with the effect of expectations. Furthermore, his brief discussion of risk aversion ignores several important factors. Risk aversion is discussed in detail in the following chapter, but some general points can be made here.

In stressing the importance of having capital readily at command, Say emphasises the lender's attitude to risk at the expense of the borrower's, an approach that is often repeated in later writings. Borrowers who require funds for investment in capital equipment, for example, are concerned with ensuring a ready source of funds over the life of the project. If the project is a relatively long one, the funds will be required over a longer period than where the project is expected to have a short life. Consequently, it is an empirical matter whether borrowers will prefer to borrow for short or long terms. In order for short rates to be lower than long rates as Say suggests, however, and given that lenders prefer short-term loans, it has to be shown that borrowers prefer long-term loans. This is the sort of analysis that is in fact undertaken by Keynes (1930) in his work on normal backwardation in commodities markets (see pp.66-70 below), and by Hicks (1939c) in his discussion of a "constitutional weakness" in debt markets (see pp. 101-3 below).

It can also be questioned whether in fact lenders do prefer short-term loans. A strong supporting argument could be made if a world without financial intermediaries is assumed. In such a world, the flow of funds is between primary borrowers and primary lenders, that is, between transactors who either lend or borrow but not both at the same time for the same period. From the lender's point of view, a short-term loan, negotiated if necessary for successive short terms, is obviously more readily available to meet both expected and unexpected future needs as they arise. The funds tied up in a long-term loan may not be available at all to meet an unexpected need if the borrower cannot repay the loan before the agreed maturity date.

However, with the development of financial intermediaries and with them the growth of negotiable instruments, a lender's capital that is invested in a long-term loan is often as readily available as funds invested in a short-term loan. The major uncertainty here now is not the availablity of funds as such, but rather the <u>price</u> at which they are available, that is, the price at which the security covering the long loan can be sold. This uncertainty is referred to in chapter three below as capital-uncertainty. There is also uncertainty connected with the stream of short-term loans, namely, uncertainty as to the interest income earned on future short-term loans. This is referred to as interest-uncertainty. The analysis in chapter three below suggests that preferences for one type of uncertainty over the other cannot be decided a priori, so that lenders' preferences for short or long loans requires empirical investigation.

The existence of negotiable instruments issued by governments is recognised by Say, so that his analysis can be considered to apply to a world containing financial intermediaries. Therefore, his stress on the importance of ready capital highlights capital-uncertainty at the expense of interest-uncertainty, an emphasis that is repeated frequently in the writings of later economists, for example, Sidgwick (1887), Fisher (1930) and Hicks (1939c), the latter arguing that, in the absence of an extra return for lending long, lenders will prefer to hold their money on deposit.

2.3 H. Sidgwick, 1887

Sidgwick has more to say on the relationship between short and long rates than does Say, and foreshadows many aspects of the analysis of the term structure that were to follow. He regards short and long rates as being determined by different forces, but connected via arbitrage and speculation. The short rate he regards as the price paid for the use of money, and the long rate as the price paid for the use of capital, an approach developed later by Marshall (1923) and Hawtrey (1938). Bankers, acting as financial intermediaries, are seen to prefer short loans because of the ready availability of these loans in meeting "exceptionally large payments" (1887, p. 246). Here again there is an emphasis on capital-uncertainty at the expense of interest-uncertainty. Sidgwick notes that a preference for short loans tends to depress short rates relative to long, and argues that the actual relationship between the rates over the ten-year period from 1869 to 1878 is the consequence of this pattern of preferences (p. 246n).

Another influence noted by Sidgwick is the trouble to the professional lender of continually supervising the investment of money for short periods, which tends to make for a downward-sloping yield curve. This observation foreshadows later work on transaction costs. He also anticipates later work on the cyclical nature of the term structure by arguing that, because money is more sensitive to the trade cycle than is capital, the short rate will also be more sensitive to the cycle than will the long rate. Thus, the gap between short and long rates caused by lenders preferring short loans, will vary over the cycle accordingly.

However, both rates will tend to move in the same direction due to arbitrage operations. For example, a fall in the short rate resulting from the effect of the trade cycle on the price of money, will make long loans more profitable at the margin. This will encourage a shift of funds to the long end of the market and so a subsequent decline in long rates.

Sidgwick does not make any reference to the effect of expectations on the term structure as such, but does mention the importance of expectations in discussing a tendency towards a uniform yield for all types of securities.

> "if any one prefers an investment that at present yields a lower interest than another, it is because he considers it safer or expects it to rise hereafter." Sidgwick (1887, pp. 260-61)

An example of this is where short loans at present yield less than long loans, but due to an expected rise in the general level of rates, a series of investments in short loans promises a greater return than a long loan covering the same time span. This brief mention of expectations foreshadows the work by Fisher (1930) in linking up expectations of future rates and the term structure.

It can be seen, therefore, that in a relatively brief discussion of the subject, Sidgwick is remarkably perceptive in outlining for further analysis the major determinants of the term structure.

2.4 I. Fisher, 1896, 1906, 1907, 1930

Irving Fisher is generally acknowledged as the founder of the traditional expectations model. In his 1896 work, he demonstrates that where a contract has different interest rates for different time periods, an "actuarial average" can be calculated which will yield the same present value for the contract as does the varying rates. He suggests that this concept has practical application in the case of government bonds, where the current yield to redemption can be considered an "actuarial average" of all the interest rates expected over the life of the bond.

In view of later controversy over the exact mechanism and behavioral implications of the expectations theory,[7] it is convenient to present Fisher's theory as falling into two segments, one which assumes the presence of certainty, the other not. It is clear that whenever Fisher refers to long rates as an average of expected future short rates, the setting is one of certainty.[8] His reference to the calculation

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7. See, for example, the discussion between Culbertson (1958) and Wehrle (1958), and that between Buse (1971), Kessel (1971), Roll (1971) and Wood (1971), and pp. 121-28 below.
8. This view is supported by Culbertson (1958, p. 608n).

of an "actuarial average" implies the presence of certainty. Another example occurs in Fisher (1930, p.70) where he describes a rate on a five-year contract as "a sort of an average of five theoretically existing rates, one for each of the five years covered." He gives the most complete statement of the relationship in his 1906 work, where he refers to a transactor who is contemplating the purchase of a 25-year bond with the intention of reinvesting the proceeds after twenty five years. Fisher suggests that if the transactor expects the average of rates on 25-year bonds purchased now and in twenty five years time to exceed the rate on a 50-year bond purchased now, the transactor will prefer the former option, that is, to purchase the stream of relatively shorter bonds. Conversely, if the average of the two shorter rates is less than the return on the 50-year bond, he will prefer the longer bond (Fisher, 1906, pp. 273-74).

That this discussion applies to a world of certainty is demonstrated by Fisher's observations concerning the investment behavior of insurance companies. Fisher suggests that the future income of insurance companies undertaking continual reinvestment is affected by changes in future rates, so that expectations of changes in rates are important. However, he goes on to add:

> "Insurance companies can only roughly take account of the changes, reckoning that the greater the likelihood of a rise, the better the policy of making temporary investments at high rates and the greater the likelihood of a fall, the better the policy of making permanent investments, even at moderately low rates." Fisher (1906, p. 274)

It seems then that in an uncertain world, Fisher sees transactors basing their decisions on their expectations of future rates, but not necessarily in accordance with the strict "actuarial average" model where forecasts of specific future rates are required. Rather, they form an opinion about the general future trend of rates. This is further evidenced by the observation that a 50-year bond yielding less than a 25-year bond can be explained "by the prevailing opinion that interest tends to fall," and his statement that "the investor puts no specific values on the individual yearly rates of interest" (Fisher, 1896, p. 29).

Fisher's analysis of the term structure under conditions of certainty and no transactions costs, is the birth of the traditional expectations model. Because of the idealised conditions that are assumed, it follows as a matter of logic that profit-maximizing transactors will base their portfolio decisions on their expectations of future rates as outlined in chapter four below. The precise algebraic formulation of the average is developed by Hicks (1939c) and Lutz (1940), and given empirical content by Meiselman (1962). Most writers, including Fisher himself, do not think that the model as it stands is a complete description of the relationships underlying the term structure. Adjustments are usually made to allow for the effects of risk aversion and transactions costs.

Fisher's analysis of risk aversion is similar to that presented by both Say and Sidgwick. The normal relationship between rates is regarded as being where short rates are lower than long rates due to the greater liquidity of short loans to the lender. Money invested in short loans is a "little like money on deposit, or ready money" (Fisher, 1930, p. 210) because it is available when needed. Hence, some of the interest on long securities is a compensation for the lesser availability of long loans, and yields on short securities are consequently lower on average than yields on long. As with Say and Sidgwick, Fisher's brief analysis of risk aversion centres on capital-uncertainty and neglects interest-uncertainty. It is Fisher, however, who deserves the credit for setting term structure theory on its feet by introducing the traditional expectations model, the blueprint for the work by Hicks (1939c) from which most later work developed.

2.5 F. Lavington, 1921, 1924

Lavington undertakes an analysis of the term structure that is much in the spirit of Sidgwick's work. After emphasising the greater liquidity of short loans to transactors when lending direct to primary borrowers, he suggests that the presence of financial intermediaries, by increasing the negotiability of long loans, reduces the difference in rates for different terms. He considers that only narrow markets and brokerage costs will be reasons for any normal gap between short and long rates, at least up until the 'twenties. In a later article (Lavington, 1924), he supports this argument with evidence that for many decades up to the end of World War One, the average of short rates over a period of years is substantially the same as the average of long rates. This he attributes to the effect of the stock exchange in giving many long loans the liquidity advantage of short loans.

In the later article, Lavington suggests that the 'twenties would see a new relationship between rates. The greater marketability of short loans coming on to the market, coupled with the greater observed fluctuation in prices of long securities over the previous two decades would be likely, he argues, to increase the relative preference for short loans and so make short rates on average lower than long.

Lavington's point about the greater fluctuation in prices on long securities is also mentioned by Kock (1929) and used in later portfolio-selection analysis in support of an upward-sloping yield curve as the norm, a topic discussed further in the next chapter. The reference concerning the greater marketability of short loans again emphasises capital-uncertainty.

Lavington also examines the cyclical movement of the term structure, presenting evidence that changes in short and long rates are connected to a common cause. Whereas Sidgwick views changes in short and long rates as originating from different causes, Lavington views these changes as due to a common factor, namely, the supply and demand for loanable funds with the latter more important. The supply and demand for loanable funds will vary over the trade cycle with demand varying most, and so initiate changes in both short and long rates. In a boom, for example, Sidgwick suggests that the demand for short loans will be more affected than that for long loans, leading to a larger rise in short rates than long despite arbitrage operations. However, as short and long rates are both affected by loanable funds, their <u>relative</u> profitability over the trade cycle should not change. Evidence for boom years, however, suggests that long loans increase their relative profitability compared with short loans during the upswing of the trade cycle. Lavington suggests this is due to the fact that, during boom years, businessmen switch their investments from consols to capital equipment in order to take advantage of the buoyant economic conditions. This tends to increase the yield on consols and will react on the short rate as well, but expectations of further investment switches will see yields on consols rising at a faster rate than necessary in order to keep the relative profitability of consols and short securities in balance.

On the basis of evidence of slumps that he had at the time of writing, the converse does not apply when rates are going down. That is, there is no evidence that consols decrease in relative profitability as businessmen switch from capital equipment to consols. Lavington postulates that this is due to the new relationship between average rate levels mentioned above, caused by the greater fluctuation in consol prices and so the lower capital-uncertainty on short loans.

2.6 A. Marshall, 1923

Marshall differs from both Sidgwick and Lavington in his view of the direction of causality between changes in short and long rates. He considers the long rate to be "the" rate of general equilibrium theory, determined by the supply and demand for capital investment, and while the short rate reflects money market activity, it is affected by changes originating in the long end of the capital market. Thus,

> "If the amount of capital has been increasing fast, then, in spite of a great widening of the field of investment, it forces down the rate of discount." Marshall (1923, p. 255)

This is the first suggestion that the long rate is the key rate in the term structure, and is supported later by Keynes (1936) and Malkiel (1962).

2.7 A.C. Pigou, 1927

The line of analysis adopted by Marshall is criticised by Pigou because of its implications for the central bank's discount policy. If short rates are determined by long rates while long rates are determined by the supply and demand for capital, the implication is that discount policy is constrained by these outside forces of supply and demand. Pigou suggests that this analysis ignores changes in the general level of prices. While agreeing that the discount rate is tied to the long rate, he says that it is the real rate of interest that is relevant here. The central bank can adjust the discount rate to any desired level, as changes in commodity prices will restore the previous relationship between the discount rate and the real rate on long loans.

Furthermore, Pigou suggests that the central bank can affect the real rate on long loans. Through its powers of credit creation, the bank can increase the supply of funds available for capital investment and so reduce the real rate of interest on both short and long loans. Thus the bank's powers are not limited by outside forces as suggested by Marshall.

2.8 K. Kock, 1929

The effectiveness of the central bank's discount policy is extensively explored by the Swedish economist Karin Kock, in a work that is devoted primarily to institutional organisations, particularly banks. She makes several important contributions to both the analysis of expectations and risk aversion.

As regards expectations, she appears to be the first writer to see the importance for term structure theory of the concept of a normal level of interest rates, a matter discussed later by Keynes (1936), Hicks (1939a), Robinson (1951), Malkiel (1962) and Modigliani and Sutch (1966). Because of the regular cyclical fluctuation in both short and long rates, transactors become accustomed to rates that regularly move up and down, so that a movement in one particular direction is not expected to continue for any length of time. Rather, they form an opinion of the average rate that rules over time and expect a regular fluctuation about this rate. Thus, if rates have been moving up for some time during an expansionary phase of the trade cycle, transactors will anticipate a downturn in the near future. They will prefer long securities, therefore, in order to benefit from the anticipated capital gains when rates fall, and so retard the upward movement in long rates.

Similarly, if rates have been moving downwards for some time, transactors will anticipate an upturn in the near future. This will make short securities more attractive than long because of the potentially higher yield, so that a shift into short securities will hamper the downward movement of long rates. The net result will be a greater cyclical swing in short rates than in long, strengthened by complementary action on the borrowing side of the market.

As the idea of a normal or average rate is the basis of these particular rate movements, Kock suggests that, provided the discount rate can influence other loan rates, the central bank can control the level of this normal rate by the use of the discount rate. The ability to do this will differ between markets in different countries.

Another matter first raised explicitly by Kock concerns the length of time for which transactors formulate their portfolio plans. She criticises Lavington for assuming implicitly that when people purchase long securities they intend to hold them as a long-term investment, unlike a short-term investment in short securities. She thinks it more likely that a transactor contemplating which type of security to purchase will view both as a short-term investment.

> "They use them (consols) for temporary investments of balances and the amount of the return depends therefore not only on the yield but also on the price at which they will be able to sell them." Kock (1929, p. 138)

The use of short planning periods is a theme developed for the theory of the term structure by Kaldor (1939), Robinson (1951), Kahn (1954), Culbertson (1957), Malkiel (1962), Michaelson (1965) and Wood (1969), and is discussed further on pp.127-28 below.

The other important contribution made by Kock is to the theory of risk aversion. She appears to be the first writer to acknowledge that the choice of maturity will be influenced by the average length of transactors' obligations, a theme developed later by Keynes (1930), Kahn (1954), Culbertson (1957), Meiselman (1962), Modigliani and Sutch (1966) and Masera (1969b), and discussed in depth in the next chapter.

A further influence she mentions is the greater observed fluctuation of prices on long loans for a given change in rates. This point is an important part of portfolio-selection analysis developed by Markowitz (1952) and Tobin (1958), and of the work by Malkiel (1962) on the mathematics of bond prices.

It can be seen from this brief review of her work, that Kock is responsible for first mentioning several matters in connection with the term structure, that later spawned much debate concerning the nature and effect of expectations and risk aversion on the structure of rates.

2.9 W.W. Riefler, 1930

Riefler takes up the point raised by Lavington and Kock concerning the greater observed fluctuation of prices on long loans for a given change in rates, as part of a discussion on the stability of long rates relative to short. He observes that short and long rates in the U.S. for the period 1919-28 tend to move together, but with long rates exhibiting the greater stability, a phenomenan also discussed by Keynes (1936), Kalecki (1939), Hicks (1939a) and Malkiel (1962).

Riefler advances two reasons to explain the greater stability of long rates. The first is to do with the point raised by Kock concerning the arithmetic of bond prices.

Turning the point the other way round, a given change in the price of a security has less effect on its yield as its term to maturity lengthens.

> "When these maturities are relatively short, fluctuations in the current prices of the securities are reflected in more nearly equal fluctuations in the calculated yield, but when yields are calculated on long maturities - on, for example, the typical twenty-year bond frequently used as a base in calculations of bond yields - relatively large changes in the current quotations from these securities produce relatively small movements in their calculated yield to maturity." Riefler (1930, p. 120)

The second reason he gives is based on the traditional expectations theory. Riefler appears to be the first writer to make use of the theory as it stands in describing real world events, and is followed in this by Williams (1938), Lindahl (1939), Kalecki (1939) and Meiselman (1962). As the model predicts that the long rate is an average of expected short rates over the life of the long loan, a temporary increase in short rates is not fully matched by increases in long rates.

> "the current yield on bonds, in consequence, is not directly comparable with the current yield on short-term loans, but rather with the average expected return on short-term loans over a similar period of years with the result that lenders might reasonably prefer a long-term bond yielding five per cent in times of high money rates to a short-term loan yielding seven." Riefler (1930, p. 121)

This argument is supported later by Kalecki (1939, p. 112), and relies on the assumption that the market's expectation of future short rates is inelastic with respect to changes in the current short rate, a topic which is widely discussed in later writings, for example, Keynes (1930 and 1936), Hicks (1939a), Lutz (1940), Marx (1942), Riefler (1958), Wood (1964), Van Horne (1965b and 1966), and Fand (1966).

2.10 J.M. Keynes, 1930, 1936

Keynes is the first to outline in any detail the relationship between the production and financial sectors of the economy as they impinge on the term structure. His treatment of this in the Treatise (1930) is still the most detailed account in existence even today. In the Treatise he postulates that the normal slope of the yield curve will be upward, based on his analysis of normal backwardation in commodities markets. Keynes' position here is that, because of the nature of the technological processes used, capital-uncertainty will dominate for the economy as a whole. Unlike Say, Sidgwick and Fisher, who concentrate solely on capital-uncertainty, Keynes recognises the presence of interest-uncertainty but suggests that on balance, capital-uncertainty prevails. The state of technology is such that the most productive methods tend to be those roundabout processes that employ relatively long-lived assets such as land, buildings and other physical assets. These long-lived assets have useful lives that are longer on average than the term for which transactors wish to invest their funds in securities. To quote Leijonhufvud (1968, p. 302),

> "In Keynes' grand conception, the basic function of 'finance' in modern systems is to reconcile the desire of households to be 'liquid' with the technological necessity for the system as a whole to carry vast stocks of 'physically illiquid' capital goods."

The result of this preference for roundabout processes, is that for the economy as a whole, the average period for which transactors have funds available for investment in securities will be less than the average term to maturity of all securities on the market. As is shown in the next chapter, this result implies that capital-uncertainty will dominate for the market as a whole, so that given expectations and transactions costs, the yield curve will slope upward. This conclusion abstracts from any idea of the presence in the securities market of adequately-financed speculators acting as marginal transactors to remove the upward bias, a possibility discussed by Meiselman (1962, p. 10).

The experience of downward-sloping yield curves in the past Keynes attributes to a change in technological considerations. These downward-sloping curves are usually observed during economic upswings, the upswings being due to Schumpetarian-type innovatory booms. In such times, it becomes more profitable to employ less roundabout processes in production, leading to the use of shorter-lived assets and so securities with shorter terms to maturity. Eventually, these securities will have terms to maturity that are, on average, less than the time for which funds are available, so that interest-uncertainty will come to dominate the market resulting in a downward-sloping yield curve.

Keynes' treatment of expectations in the General Theory (1936) changes from that in the Treatise (1930). In the Treatise he postulates that the central bank, by operating on the discount rate, can affect the long rate and so the level of investment spending on capital goods, whereas this ability is viewed with much less enthusiasm in the General Theory. In the earlier work, the key rate is the long rate determined by expectations of future long rates. It is connected to all other rates in the yield curve by profitability considerations, as a very low long rate and a very high short rate, given expectations, gives investment in long loans a high opportunity cost. The data presented by Keynes for the period 1919-29 suggests that there is a surprisingly close relationship between discount rates and yields on consols, even closer than expected by considerations of profitability, given the imperfections in the market.

In the *Treatise*, Keynes ascribes this close relationship to a chain of belated and imperfect reactions from one end of the market to the other. From among the total maturity spectrum represented by the market's outstanding securities, different transactors will prefer different terms, and these preferences will overlap in such a way as to connect the whole maturity spectrum from end to end. Thus, a rise in short rates will cause a ripple in the yield curve as it affects first transactors in the short end, then those further along the yield curve, and so on. Keynes is supported later in this by Meiselman (1962, pp. 52-54).

The argument is carried a step further by Keynes when he proposes that not only do happenings in the short end eventually ripple their way along to the long end, but that these happenings themselves affect transactors' expectations of future long rates. There is little other evidence available on which transactors can formulate their expectations of future rates, and current changes in short rates will, therefore, be given significant weight. In other words, expectations of future rates will be elastic with respect to changes in current short rates. The implication of all this is that monetary policy, acting primarily on the short end of the market, is thought in the *Treatise* to be an effective way of influencing activity in the long end.

The position in the General Theory is different. Keynes postulates there that the long rate is not overly responsive to changes in the short rate. Rather, the long rate can be thought of as

> "a highly conventional.......phenomenon. For its actual value is largely governed by the prevailing view as to what its value is expected to be. Any level of interest which is accepted with sufficient conviction as likely to be durable will be durable." Keynes (1936, p. 203)

Keynes suggests that only if changes in short rates are made gradually so that transactors can become accustomed to the new levels, will transactors' expectations change permanently or durably. Sharp changes in various directions will not be considered durable, and so expectations will be inelastic with respect to these changes in short rates. Therefore, monetary policy which aims to influence the long rate by working on the short rate will require a considerable time lag before it becomes effective. This is a much more pessimistic outlook concerning the elasticity of expectations than that adopted in the Treatise. Culbertson (1957, p. 486) attributes this change in outlook to a reluctance of long rates to decline in the 'thirties.

2.11 J.B. Williams, 1938

Williams supports Irving Fisher's presentation of the long rate as an average of expected future short rates.

> "Long-term interest rates are not a genus wholly distinct from short-term interest rates, and they are not determined separately from short-term rates by independent considerations. Rather, long-term rates are only a thing derived, an average of a special kind, a mere figure of substitution that can be used in place of the series of short-term rates for the years covered. Williams (1938, p. 60)

As with Keynes before and Hicks (1939c) after, Williams compares the bond market with the commodities market, and is one of the first writers to develop the importance of the forward rate for the term structure. These forward rates can be considered market forecasts of expected future short rates, and like any other forecasts in the presence of uncertainty, subject to error.

> "It is not maintained of course, that the future rates so calculated will necessarily come to pass; it is merely asserted that such rates are implicitly forecast by the bond prices in question, and that such a forecast by the bond market is an interesting fact in itself, worthy of criticism as to its plausibility like any other forecast made by the securities market." Williams (1938, p. 124)

It can be seen that, like Riefler, Williams is applying Fisher's traditional expectations model, as framed in a world of perfect certainty, to the real world of imperfect foresight. He goes even further and derives market forecasts of short rates for the period 1937-60 as implied by the 1937 yield curve. This approach differs from that of Kock who proposes a model where expectations are formed concerning the whole spectrum of rates for the next period, rather than of short rates alone over several periods. It differs also from Hicks (1939c) who bases his work on the traditional expectations model but allows for the presence of risk aversion. Hicks' model includes risk premiums as part of the forward rates, so that these forward rates are biased estimates of future spot rates, a matter investigated in depth by Kessel (1965) and Cagan (1969), and in chapter seven below. As the risk premiums increase with term to maturity, the normal slope of the yield curve will be upward. Williams is critical of this argument on the grounds that downward-sloping yield curves have been observed many times in the past, and that the net risk on long loans will be zero,

> "for the hope of temporary appreciation is balanced against the fear of temporary depreciation." Williams, (1938, p. 341)

Apparently, Williams thinks that transactors give the same weight to an equal chance of loss or gain, that is, that they are indifferent to risk.

2.12 F.R. Macaulay, 1938

Like Williams, Macaulay recognises the presence of implied future rates in yield curves. Moreover, he is the first to conduct a test of the traditional expectations model using evidence independent of that implied by the yield curves themselves. He finds that the pronounced seasonal variation in call-money rates as quoted on the New York Stock Exchange, is anticipated by movements in ninety-day rates as the model predicts. However, he finds little evidence of successful forecasting elsewhere, though he is careful to point out that evidence of unsuccessful forecasting does not necessarily mean that forecasting is not attempted. Rather, it may just mean that the uncertainty involved leads to inaccurate forecasts. Neverthless, he suggests that the forecasting implied by the data is so bad that it raises doubts whether forecasting is really attempted at all beyond the very near future. However, Lutz (1940, p. 41n) has since shown that Macaulay misinterprets some of the evidence, which, when correctly interpreted, actually strengthens the case for accurate forecasting.

Few writers followed Macaulay's lead in devising an <u>independent</u> test of the traditional expectations model until Meiselman (1962) devised the error-learning model and started a spate of empirical tests that continues solidly to the present time.

Macaulay introduces the concept of "duration" to describe the true length of a loan. He points out that the number of periods to maturity is only one aspect of a security's repayment plan, so that consideration should be given to other repayment features involved over the life of the loan. An obvious theoretical factor apart from term that affects the duration of a loan is the level and frequency of coupon payments, as most bonds and debentures in practice carry equal and regular coupon payments. The effect of coupon rates on yields is discussed in chapter one above (see pp. 25-28), where it is shown that the final effect is uncertain when both risk aversion and taxation effects are considered. In the empirical work carried out for this thesis, term to maturity is used in lieu of duration, as the tests carried out in chapter one above suggest that the effect of coupon rates on relative yields in Australia is, in practice, slight.

2.13 R.G. Hawtrey, 1938, 1939

Hawtrey disputes Keynes' contention in the *Treatise* that monetary policy, working through the discount rate, can affect the long rate and so the level of economic activity, despite the fact that Keynes himself modifies this position in the *General Theory*. The attack by Hawtrey in his 1938 work is launched on two fronts. First, he questions whether changes in the short rate will significantly affect the long rate. Here he adopts the argument first put forward by Sidgwick that the two rates are determined by different causes; the long rate by the supply and demand for capital, and the short rate by conditions in the money market. While there are similar movements in the two rates due to such common causes as wars and depressions, these similarities are very limited, especially those due to expectations. He suggests that transactors can only forecast up to a maximum of two years ahead, and views the securities market as being effectively segmented into short and long ends with little overlap.

The close correspondence that Keynes finds between short and long rates is, Hawtrey suggests, due to the particular years chosen. To demonstrate this, Hawtrey presents data over a much longer period of time which reveals little correlation between movements in short and long rates.

As D.H. Robertson (1940) points out, Hawtrey's model of the trade cycle is intermediate between those of Hicks (1939a) and Lavington. Whereas Hicks views the long rate as relatively stable over the cycle, Hawtrey finds a clear cyclical movement. Like Lavington, Hawtrey attributes the cyclical movements in short and long rates to a common cause, namely, changes in the demand for loanable funds. However, whereas Lavington sees these movements connected by expectations of future investment switches leading to amplified movements in long rates, Hawtrey suggests that the evidence shows that short and long rate movements do not always synchronise, so that often when short rates change long rates do not.

Hawtrey's second frontal attack on Keynes, questions whether the level of economic activity is affected primarily by changes in capital spending that result from changes in the long rate as suggested by Marshall and Keynes. Hawtrey regards it as more likely that the economy is primarily affected by changes in stocks resulting from changes in the short rate. Thus, the question of whether changes in the short rate affect changes in the long rate is irrelevant for monetary policy, as changes in the short rate alone will be sufficient to achieve the desired results.

Following some comments from Hicks (1939a), Hawtrey discusses in some detail in his 1939 article the elements determining the long rate. The effect of the short rate on the long rate he sees as minimal, due to the inability of the market to forecast more than a few months ahead. Rather, he takes the eclectic stance that there exist many influences on the long rate.

> "The actual movements of the long-term rate of interest are the result of many forces. It would not be possible to obtain statistical evidence of the operation of any of these unless the effects of the others could be eliminated." Hawtrey (1939a, p. 152)

To the extent that expectations are important in linking the long rate with the short rate, Hawtrey regards it as expectations of future <u>long</u> rates. On this general point he is in sympathy with Marshall and Keynes. But unlike Hicks (1939a) who postulates that expectations of future long rates will be a function of past short rates, Hawtrey argues that <u>any</u> persistent tendency in the capital market will affect expectations of future long rates.

2.14 J.R. Hicks, 1939

In a review of Hawtrey's 1938 work, Hicks (1939a) criticises the contention that short and long rates will have common movements over the trade cycle. The evidence presented by Hicks suggests that the long rate, unlike the short rate, is remarkably insensitive to the cycle. He postulates that this is due to the fact that the current long rate is primarily a function of the normal level of the long rate as viewed by market transactors, a stance first taken by Kock and developed later by Malkiel (1962) and Modigliani and Sutch (1966). This normal level is a function of the average of past short rates, and this by nature tends to change rather slowly over time. The short rate will be one of the rates affecting the long rate, but its effect is relatively insignificant.

Consequently, Hicks agrees with Hawtrey that monetary policy, by operating on the short rate, will have little effect on the long rate, but differs in his view of the determinants of the long rate. It is interesting to note that the empirical results reported in chapter five below support Hicks' contention that expectations are inelastic with respect to the current rate due to the concept of a normal rate (see pp. 145-47 below).

Hicks modifies his presentation in Value and Capital, where he suggests that people formulate expectations not only about the future long rate but about the whole spectrum of rates expected in the future, from short to long. This means that a model of the term structure can be developed wholly in terms of expectations of future short rates or of future long rates, whichever is preferred, as the results will be consistent in either case. Accordingly, Hicks elects to present his model of the term structure in Value and Capital in terms of expectations concerning future short rates.

2.15 E. Lindahl, 1939

Lindahl, in the tradition of Kock, Riefler, Keynes, Hicks and Hawtrey, is concerned with the ability of the central bank to exert an influence over the term structure. Like Riefler and Williams, he regards the long rate as being primarily a function of expected short rates. This means that one channel by which the central bank can influence long rates is by making announcements concerning its policy on future short rates. In addition, open market operations will be a successful channel through which the term structure can be affected for three reasons.

(1) The market displays an aversion to risk. Whilst not making this explicit, he refers the reader to Kock's book for an analysis of the risk factor. It will be remembered that Kock was one of the first writers to consider the effect of the average length of transactors' obligations on their portfolio preferences. Where maturity preferences exist independently of expectations, variations in the supply of securities can affect the term structure as discussed in chapter three below.

(2) The market's supply and demand for securities is subject to a budget constraint, so that theoretically, the central bank with the backing of the government can exert complete control over the term structure.

(3) While speculators can be expected to reduce the effectiveness of open market operations, they are averse to risk and so will not completely neutralise the bank's efforts, a point taken up again by Robinson (1951, p. 97).

Based on his analysis of the term structure, Lindahl goes on to analyse the implications for the general price level, and concludes that the long rate has a more permanent effect on the price level than does the short rate. Lindahl thus postulates a market that is very sensitive to the central bank's monetary policy, with both expectations and risk aversion assisting the bank's efforts to control the term structure.

2.16 M. Kalecki, 1939

Kalecki agrees with Hicks (1939a) concerning the relative insensitivity of the long rate to the business cycle, and bases his support on statistical evidence for the period 1853-1932. He explains the apparent stability of the long rate in terms of the traditional expectations model, where the long rate is an average of expected short rates. These expectations are relatively inelastic with respect to changes in the current short rate, being determined rather by the most recent average position of short rates. Therefore, changes in short rates have only minor repercussions on the long rate. Once again this analysis is consistent with the results reported in chapter five below, where the evidence suggests that expectations of future rates in Australia are formed by an extrapolation of past rates with weights that decline more than exponentially for rates further into the past.

Kalecki appears to be one of the first writers to propose that, on the basis of risk aversion and transactions costs alone, the yield curve will slope downward. He recognises the dual concepts of capital- and interest-uncertainty, and says that on balance, the interest-certainty and lower transactions costs associated with consols will be preferred to the capital-certainty of bills.

2.17 N. Kaldor, 1939

Kaldor is critical of the argument that the expected short rate is a function of the average of past rates, on the grounds that it is a "boot straps" theory that requires an explanation of how past rates are determined before it is complete. However, he suggests that the notion of a normal long rate is important in explaining the relative stability of long rates compared with short. Therefore, he proposes that the long rate is a function, not of past rates, but of expected future short rates along the lines outlined by the traditional expectations model. The "boot straps" criticism he claims is avoided by suggesting that the current short rate is not dependent on expected future rates but on the current supply and demand for cash balances.

Robinson (1951, p. 101n) argues that Kaldor still does not escape the "boot straps" criticism that he apparently fears so much. She says that one of the main determinants of the demand for money is expectations concerning the future course of the long rate, and this links up the circularity in Kaldor's argument again. She suggests that the "boot straps" criticism is unavoidable when dealing with the term structure.

> "The price of any long-lived object with low carrying costs is strongly influenced by expectations about what its price will be in the future. If the rate of interest is hanging by its boot straps, so is the price of Picasso's paintings." Robinson (1951, pp.102-3)

Kaldor criticises Hawtrey's contention that the market is effectively segmented, with expectations having little influence on any relationship that does exist between short and long rates. If a situation prevails where short rates exceed long rates for long enough so that the present level of short rates comes to be regarded as normal, then transactors will eventually switch their funds from the long end of the market to the more profitable short end.

Because of the connection between short and long rates, Kaldor suggests that bank rate can not be freely used for monetary policy purposes, as it may react unfavourably in some circumstances on employment. For example, a relatively high short rate that lasts for some time due to the efforts of the authorities may come to be regarded as normal and so lead to an increase in long rates. This will then lead to a decrease in investment and so unemployment. Kaldor concludes that as the short rate can only be increased temporarily if unemployment is to be avoided, the use of bank rate by the monetary authorities can not secure a stable level of income. This is because if the rate is to be lowered when unemployment threatens, it will have to be kept high at other times to allow the drop, so affecting the rate regarded as normal.

2.18 Summary

It can be said in summary that by 1939 all of the important variables that appear in later work on the term structure have been identified. From then on, most writers are concerned with developing models that emphasise the relative importance of these variables, though empirical tests remained scanty until Meiselman (1962) encouraged a rush that continues today. An awareness of this early work seems essential for a proper treatment of the issues being hotly debated today.

In the next chapter a detour is taken in order to analyse the effect of risk aversion on the term structure, before returning to examine the traditional expectations model in more detail as well as some criticisms of it by later writers.

CHAPTER THREE: RISK AVERSION

3.1 Introduction

In this chapter, the effect of risk aversion on the term structure of interest rates is analysed. The risk referred to is that experienced by transactors in securities markets as a result of uncertainty as to future changes in interest rates, and not to any fear of default by the borrower. Furthermore, expectations and transactions costs are taken as given, so that it is solely the desire to avoid risk that is analysed here, and not the trade-off between expected return and risk.

Much of the literature on the term structure discusses risk aversion in the context of either hedging behavior,[9] or portfolio analysis based on utility maximization, as developed by Markowitz (1952) and Tobin (1958).[10] There has been little attempt to relate the two approaches,[11] or to show how the concepts of capital-uncertainty and income-uncertainty, as introduced by Robinson (1951), fit into the analysis. Masera (1969b) has made a start in this direction, and his work is extended in this chapter.

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9. For example, Meiselman (1962) and Modigliani and Sutch (1966).

10. For example, Bierwag and Grove (1967) and Grossman (1967).

11. Some discussion on the relationship can be found in Culbertson (1957 and 1958), Wehrle (1958), Michaelson (1965), Telser (1967) and Masera (1969b).

It is suggested below that the analysis of risk aversion is clarified by first dividing transactors into two types, namely, those with definite availability periods and those with indefinite availability periods. The more general case of partially indefinite availability periods is then examined, and the conclusion is reached that, abstracting from transactions costs and expectations of future rates, the normal slope of the yield curve can not be determined *a priori*. Evidence is necessary concerning the length and relative importance of definite compared with indefinite availability periods for both the supply and demand side of the securities market. Finally, the implications of the analysis for a central bank's open market operations is discussed.

3.2 Capital-Uncertainty and Interest-Uncertainty

The relationship between capital and income is one which has generated much discussion in the literature, although it still can not be said that complete agreement about the relationship has been reached.[12] Despite this ambiguous relationship, Joan Robinson has adapted these concepts to a generalised discussion of liquidity in her article on

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12. Refer, for example, Parker and Harcourt (1969).

the rate of interest (Robinson, 1951, p.94).

Capital-uncertainty she defines as uncertainty as to the future capital value of an asset due to future changes in the rate of interest. She defines income-uncertainty as "uncertainty as to the income that a sum of money now committed to the asset will yield in the future." But if one adopts the simplistic stance that income represents the change in the value of capital over time, it follows that capital-uncertainty and income-uncertainty are opposite sides of the same coin, as it were. However, Robinson does not pursue this line of argument, and simply suggests instead that various assets contain these qualities in varying degrees, and selects a few as illustrative of the rest. In this way she contrasts bills (short-term) and bonds (long-term).

> "The difference between them arises from uncertainty. In a world where past experience has been that interest rates vary from time to time there is uncertainty about future interest rates, in the sense that, whatever an individual may believe about the most probable future course of interest rates, he does not hold his belief with perfect conviction. An owner of wealth who buys a bill today knows what his capital will be in three months' time, but he is uncertain what interest he will then be able to get by re-investing it. If he buys a bond, he knows his income for as long as he likes to hold the bond, but he is uncertain about what his capital will be worth at any date in the future.

"Perfectly good bills thus offer negligible capital-uncertainty, but relatively high income-uncertainty, while perfectly good bonds offer perfect certainty of income, but relatively high capital-uncertainty."
Robinson (1951, pp. 95-96)

From the above description it may help to clarify the issue if the term income-uncertainty is replaced by the term interest-uncertainty, so that the estimation of income as such can still include part of the anticipated change in the future value of capital if desired. In this way it is the <u>interest</u> payments received from the long-term security that is known for as long as the security is held, and not necessarily total <u>income</u>.

The coupling of capital-uncertainty with long securities and interest-uncertainty with short, can only be justified where the expressions "long-term" and "short-term" are related to transactors' availability periods, as will be demonstrated in the following section.

3.3 Availability Periods

The concept of an availability period can be thought of as that period of time for which a transactor in the securities market has funds available for the purchase of securities, or requires funds by the sale of securities. The importance of this concept for the theory of the term structure seems to have been recognised first by Kock (1929).

For some transactors the availability period will be known with a high degree of certainty, but not for others. A life insurance company, for example, can if it wishes statistically determine within certain confidence limits what proportion of a year's premiums will be required for cash payments in particular years in the future. Consequently, it could arrange to have definite sums of money available for the purchase of securities for specified periods of time.

Similarly, a widow in many cases will have a definite sum of money available for investment over the remainder of her life. Other transactors in the market, however, will be highly uncertain as to the period of time for which they will require funds, or have funds available for dealing in the market; others again will fall somewhere in between these two cases of a high and a low degree of certainty.

Where a transactor has a definite availability period, it does not necessarily follow that a short-term security as generally understood will subject him to interest-uncertainty, or a long-term one to capital-uncertainty. A three-month bill, for example, may subject one transactor to interest-uncertainty but another to capital-uncertainty, depending on their respective availability periods. If a lender (borrower) has funds definitely available for longer than three months, then the bill will subject him to interest-uncertainty. Conversely, if the funds are available for less than three months the bill will subject him to capital-uncertainty, as the lender (borrower) will be uncertain as to the amount for which he can sell (repurchase) the bill when the funds are required.

It is suggested, therefore, that the concepts of capital-uncertainty and interest-uncertainty can only be coupled in general with long and short securities respectively, where the terms "long" and "short" are explicitly defined in relation to availability periods. In this way, a long security will be one which has a term to maturity that exceeds the transactor's availability period and hence will subject that particular transactor to capital-uncertainty. A short security will have a term to maturity less than the transactor's availability period, and so will subject him to interest-uncertainty. Where availability periods are indefinite, then both capital- and interest- uncertainty will prevail, the former becoming relatively more important as term to maturity increases.

In examining the effect of availability periods on risk-averting behavior, it is convenient to begin with two extreme cases, namely, where completely definite and completely indefinite availability periods exist. The more general case of some indefiniteness will then be examined.

3.3.1 Definite Availability Periods

Transactors with definite availability periods can be further subdivided into two groups, hedgers and non-hedgers, according to whether or not they have liabilities as well as assets. Each of these cases will be looked at in turn.

(a) Hedgers

In order to qualify as a hedger, a transactor must have both assets and liabilities. Hedging, in the context of risk aversion, has been aptly described by Meiselman (1962, p.8).

> "Hedging is achieved by having essentially the same item on both sides of one's balance sheet. The hedging mechanism operates through the identical response of an asset and an offsetting liability to the contingency hedged against so that the net worth remains unchanged with respect to that contingency. To hedge against interest rate fluctuations, a transactor who acquires an asset must finance it with a liability that has a repayment stream matching the expected payments stream of the asset. Similarly, a transactor who incurs a liability can hedge against the consequences of a change in rates by acquiring an asset whose payments stream matches the liability's payment stream. In this way both sides of the balance sheet will respond alike to a given change in interest rates."

The example given above of a life insurance company is also that of a hedger as Meiselman points out (1962, p. 8).

> "A life insurance company has long-term liabilities in the form of commitments to deliver funds, on the average, in the distant future. The life insurance company can hedge against interest rate shifts by acquiring long-term assets..."

In order to avoid both capital-uncertainty and interest-uncertainty, and hence to preserve net worth, (as distinct from maximizing net worth), an exact match of the payments stream of assets and liabilities must be made. If, for example, a three-year liability is financed by a five-year asset, the asset will have to be sold at the end of the third year at an unknown price in order to repay the liability. Capital-uncertainty will prevail and the net worth in three years time will be uncertain. If, on the other hand, the liability is financed by a stream of one-year securities, the interest to be received in the second and third years is not known, so that interest-uncertainty prevails. As the asset's value at any point in time depends on the present value of the future net receipts, including interest receipts, this uncertainty concerning future interest receipts means that the asset's value in each year will also be uncertain.

Thus, where either capital-uncertainty or interest-uncertainty prevail, the net value of the balance sheet is subject to change over the availability period and is, therefore, uncertain, so that hedging must be imperfect. In order to hedge perfectly, in the sense that the net value is preserved,[13] the payments stream of assets and liabilities must be perfectly matched.

In the context of hedging behavior, the availability period will be that period for which a transactor in the market has a payment stream in relation to his assets (if he is a borrower in the market), or to his liabilities (if he is a lender). Where this availability period is known with certainty, the hedger can avoid risk, as Meiselman points out, by selecting a security with a term to maturity that matches the term of his definite availability period. As a result, both sides of his balance sheet will be unaffected by any changes in interest rates that occur over the period, and his net worth will, therefore, be constant.

Note that in order to hedge perfectly, one needs to have a definite availability period, otherwise a perfect match on the opposite side of the balance sheet can not be made. Note also, that even with a definite availability period, a perfect matching may not be possible due to an imperfect securities market. That is, a security may not be available that has the required payments stream (in the case of a lender), or there may be no demand for a security with the desired payments (in

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13. Houthakker (1968) points out that hedging is not solely an action for avoiding risk. However, this analysis abstracts from all considerations other than aversion to risk.

the case of a borrower), so that some risk remains. Nevertheless, the implications of hedging behavior for the term structure are much the same whether perfect matching is possible or not.

It follows from the description of hedging behavior above, that if a hedger has a relatively short availability period he will have a preference for short securities as a result of his aversion to risk, and _vice versa_ for a transactor with a long availability period. Thus, in a world of universal hedging and definite availability periods, the overall preference for short- and long-term securities, and hence the general slope of the yield curve, can only be determined _a priori_ if the weighted average availability period for each side of the market is known. For example, if it is known that relatively short availability periods tend to dominate the lenders' side of the market, while the borrowers' side is dominated by relatively long availability periods, it can be predicted that, _on the basis of risk aversion alone_, the yield curve will slope upward due to an excess demand for short securities driving short yields below long yields.

Where the average availability periods in such a world are not known, however, nothing can be said _a priori_ about the slope of the yield curve. The issue can only be resolved by empirical analysis. The same considerations apply in a market not comprised solely of hedgers but dominated by them in terms of the supply of and demand for funds.

(b) Non-Hedgers

Hedgers need not be the only transactors with definite availability periods. There may be some people on the lenders' side of the market, for example, who have funds available for a definite period of time but no offsetting liabilities. An example of this is a person with idle funds awaiting the purchase of a consumer durable at a definite date in the future. The widow also may have no liabilities. Furthermore, the private sector of the economy as a whole will be a net lender of funds where the government is a significant borrower. Transactors in this category can not hedge against changes in interest rates in the sense used above, as there is no liability payments stream to be matched. Nevertheless, risk can still be avoided by purchasing a security with a term to maturity that matches the lender's availability period. In this way, both the interest received over the period, and the amount of capital received at the end of the period will be known with certainty. That is, there will be no capital-uncertainty or interest-uncertainty.

If a security with a term to maturity longer than the availability period is purchased, there will be some capital-uncertainty, as the security will have to be cashed before maturity at an uncertain price. Interest-uncertainty will exist where a security with a term to maturity less than the availability period is purchased, as the transactor will be uncertain as to the interest he can earn on reinvestment.

It follows that a transactor with a definite availability period and no liabilities, and acting on risk aversion alone, will select securities of particular term to maturity on the basis of his availability period, as is the case with the hedger. Once again, therefore, the general slope of the yield curve can only be determined _a priori_ once the average availability period is known.

Definite availability periods are a prerequisite for the existence of market segmentation, where transactors have definite preferences for securities of particular term, or terms within a particular maturity range. These preferences delineate the market into segments according to term, so that one group of transactors may prefer securities with terms ranging from three to six years, another may prefer terms of ten to fifteen years, and so on. Given this range of preferred terms, transactors will not deal in any others, thus foregoing the chance of a higher return. The relationship between market segmentation and liquidity preference is discussed in section 3.6 below.

The argument so far has been that, in a world comprised solely of risk-averting transactors with definite availability periods, be they hedgers or non-hedgers, the general slope of the yield curve can not be determined _a priori_ until the average availability period for each side of the market is known. In the next section, the case of completely indefinite availability periods is examined.

3.3.2 Indefinite Availability Periods

An indefinite availability period is one where the transactor is _vague or uncertain_ as to the time-period for which he will have or require funds, rather than the situation where the time-period is unlimited. Where a risk-averting transactor has an indefinite availability period, his aversion to capital-uncertainty compared with interest-uncertainty is not immediately obvious. Whereas the transactor with a definite availability period can avoid both types of uncertainty by matching term to maturity and availability period, the transactor with an indefinite availability period has to weigh one type of uncertainty against another when selecting securities of particular term. However, extending the analysis along these lines tends to be unfrüitful, so that a more generalised approach to risk aversion is necessary. This appears to have been recognised first (in connection with term structure theory) by Culbertson (1957, pp. 492-93).

Where there is no independent evidence available concerning transactors' preferences for particular maturities, it becomes necessary to take account of such characteristics as the behavior of relative prices and yields on securities of different term, and to analyse the maximizing behavior of market transactors with respect to their portfolios. This particular trail has been blazed by Markowitz (1952) and Tobin (1958), and has come to be known as portfolio-selection analysis. It relates specifically to the case where the transactor's availability period is uncertain.

Portfolio-selection analysis is based upon a study of mean expected yields from alternative portfolios of securities. Risk aversion is explicitly allowed for by considering the probability dispersion of yields around these means. It is usual in the analysis to postulate that transactors compare alternative portfolio opportunities over a time-horizon equal to that set by a one-period security.[14]

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14. Refer Bierwag and Grove (1967) and Grossman (1967).

Wood (1969, p. 524) points out that such a time-horizon is the rational one for a transactor wishing to maximize his returns over any period, a point that can be traced back to at least Robinson (1951, p. 95n). Given this time-horizon for comparing alternative portfolio opportunities, and using Tobin's approach to portfolio-selection, it is a well-known result that the variance of the money value of a bond portfolio increases with term.[15]

A risk-averting transactor with funds to invest in securities for an indefinite period of time will thus be able to select the term of security that minimises his risk. By using portfolio-selection analysis, rather than an indeterminate comparison of capital- and interest-uncertainty, it is clear that a portfolio of one-period securities is subject to the least variance in money value. Therefore, in a market comprised of transactors with indefinite availability periods, there will exist a demand for one-period securities with no demand at all for securities of other terms.

Exactly the same analysis applies to the supply side of the market. Suppliers of securities requiring funds for

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15. See, for example, Grossman (1967).

uncertain periods of time can best avert risk by minimising the money variance of their portfolios. Once again this implies a preference for one-period securities, so that there will exist a preference for one-period securities only. The net result, therefore, will be a flourishing market in one-period securities to the exclusion of all else, with no term structure, no yield curve, and just "the" interest rate of general equilibrium theory.

3.3.3 Partially Indefinite Availability Periods

It has been shown that where the securities market is dominated by risk-averting transactors with definite availability periods, the normal slope of the yield curve can only be determined by empirical analysis. Where indefinite availability periods dominate, however, the yield curve will be non-existent, the only yield being that on one-period securities. What if the market contains a mixture of definite and indefinite? Many combinations can be imagined. For example, it may be that definite availability periods of relatively long term dominate the demand side of the market with completely indefinite on the supply side, or *vice versa*: or a mixture of definite and indefinite may occur on each side of the market or on one side only. However, Masera (1969b, pp. 254-57) has shown that where a mix of definite and indefinite availability periods exist in the market, the normal slope of the yield curve is still indeterminate _a priori_.

A more general case in the real world than a mixture of totally definite and totally indefinite availability periods, is where transactors have _some_ idea concerning the length of time for which they have or require funds for dealing in the market, but are not completely sure. To the extent they are uncertain both suppliers and demanders will, on the basis of their risk aversion, prefer one-period securities. But to the extent that they are certain, their preference will depend on the length of their availability periods, and so be indeterminate. Hence, the final outcome will depend on the _degree of their certainty_, and so still be a matter which can only be resolved by empirical analysis.

The conclusion reached is that until it can be determined statistically how certain both suppliers and demanders of securities are concerning their availability periods, the very existence of the yield curve can not be determined _a priori_. The existence of yield curves in the real world is not necessarily evidence against the dominance of uncertain availability periods on both sides of the market. This analysis has abstracted from transactions costs and expectations, either of which may account for the existence of yield curves quite independently of aversion to risk.

Furthermore, should it be the case that there exists a high degree of <u>certainty</u> about availability periods on one or both sides of the market, then the slope of the yield curve will still be indeterminate until the average lengths of these availability periods are known.

3.4 Some Opinions about the Real World

3.4.1 Definite Versus Indefinite Availability Periods

Many writers have given their impressions as to the most likely situation in the real world, some of which are discussed in chapter two above, but in most cases they give little supporting evidence. Perhaps the most famous is Hicks (1939c) with his hypothesis of a "constitutional weakness" in debt markets. Based on armchair analysis but apparently derived from Keynes (1930), Hicks argues that a weakness exists in the long end of the market due to a preference by lenders for short securities while borrowers prefer long. This excess demand for short securities results in liquidity premiums being paid on long securities in order to attract funds to the long end of the market, so that an upward-sloping yield curve prevails.

The rationale behind Hicks' model appears to be a mixture of definite and indefinite availability periods on opposite sides of the market. On the borrowing side, Hicks postulates the presence of hedgers with long availability periods.

> "They may be embarking on operations which take a considerable time to come to fruition; or they may merely be laying down plans for continuous production, in the form of a long series of planned inputs and outputs, which it will not be easy to break off at any particular point. These persons will want to hedge their future supplies of raw materials. They will have a strong propensity to borrow long." Hicks (1939c, p. 146)

Hicks does not say explicitly whether he considers these hedgers with fairly definite availability periods to be the dominant transactors on the borrowing side or not, but moves on to the lenders' side where his analysis becomes more scanty. Lenders are portrayed as having preferences for short securities, because

> "if no extra return is offered for long lending, most people (and institutions) would prefer to lend short, at least in the sense that they would prefer to hold their money on deposit in some way or other." Hicks (1939c, pp. 146-47)

This type of reasoning can be supported by portfolio-selection analysis, assuming that most lenders have indefinite availability periods. Alternatively, Johnson (1971, pp. 86-87) suggests that Hicks views the typical lender as a bank, with short-term liabilities and hence a preference for short-term securities. However, the two interpretations are consistent if it is assumed that banks act to translate their depositors' indefinite availability periods (and hence their depositors' preferences for short-term deposits) into a demand for short-term securities.

It is suggested, therefore, that the Hicksian analysis can be supported by postulating a market where the borrowing side is dominated by hedgers with long and fairly definite availability periods, and hence a preference for long securities; and a lending side dominated by transactors with indefinite availability periods and hence a preference for short securities. The result is an excess demand for short securities, leading to an upward-sloping yield curve.

Keynes (1930) is more informative on his reasons for postulating an upward-sloping yield curve. Drawing on his analysis of normal backwardation in commodities markets, he suggests that the economic system as a whole will display an excess demand for short securities. As discussed in chapter two above (see pp. 66-68), Keynes regards the nature of technology to be such that firms prefer more roundabout methods in production to less, so that the system's physical assets tend to be long-lived. As individuals have relatively shorter lifetimes, there will be a demand for long-term funds (at a uniform rate of interest) that can not, on balance, be satisfied, so that an upward-sloping yield curve prevails.

This type of analysis provides an answer to such critics as Bailey (1964, p. 554) and Meiselman (1962, pp. 14-17), both of whom argue that in practice such hedging behavior can as well lead to a downward-sloping curve. Of course, Keynes' assumptions still need empirical support before the matter can be satisfactorily resolved.[16]

An important work based on hedging behavior is that of Modigliani and Sutch (1966). They base their analysis on the supposition that each transactor has a definite maturity preference or "preferred-habitat" as they call it. This concept is identical to the concept of an availability period, as illustrated by the following passage from their work.

> "Suppose that a person has an _n_-period habitat; that is, he has funds which he will not need for _n_ periods and which, therefore, he intends to keep invested in bonds for _n_ periods."
> Modigliani and Sutch (1966, p. 183)

In this setting, they develop a model incorporating expectations based on the work of DeLeeuw (1965). Tests of the model show it to have good explanatory powers,[17] thereby indirectly supporting the presence of definite

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16. Further details of Keynes' approach can be found in Houthakker (1968) and Leijonhufvud (1968).

17. See, however, Kessel (1967), Wallace (1967b) and Hamburger and Latta (1969).

availability periods.

Culbertson (1957) is generally regarded as a strong proponent of a hedging-type approach to risk aversion. This does not, however, stand up to close scrutiny, It is clear that he regards expectations as an unimportant determinant of the term structure, but concerning risk aversion he is very clear on the point that there will be some transactors with fairly definite availability periods, while others will have indefinite periods and so require a more generalised risk analysis than the former (1957, pp. 492-93). Thus a hedging analysis will be relevant for some transactors but not others.

On the opposite side to writers favouring a hedging-type analysis of risk aversion based on definite availability periods, are those who argue that such hedging behavior is relatively unimportant. Usually, however, they provide as little supporting evidence as their opponents. Michaelson (1965, pp. 460-61) for example, argues that hedging behavior is "special and empirically unimportant", so that a mean-variability approach" is required, as used in portfolio-selection analysis. Unfortunately, he fails to produce any evidence to support his contention other than his own general impressions.

One writer who does produce evidence on the matter is

Walker (1954). In a study of U.S. Government interest rate policy during World War Two, Walker finds that large shifts occurred in the average maturity of transactors' holdings of government securities. He ascribes this to a change in expectations brought about by the government's war-time stabilisation policy. However, Kessel (1967, pp. 594-95) argues that such large shifts are evidence against the "preferred-habitat" theory, based as it is on definite maturity preferences.

It does not follow, of course, that evidence of *any* change in transactors' maturity preferences is necessarily evidence against definite availability periods or the "preferred-habitat" theory. Except in the case of market segmentation, a transactor's preference for securities of particular term to maturity is a function, not only of his aversion to risk, but also of his expectations of future changes in rates. Hence, a shift in maturity preferences may reflect a change in transactors' expectations, as Walker suggests in his study, rather than the absence of "preferred-habitats". Kessel argues, however, that such *large* shifts as observed by Walker are unlikely to occur where preferences for particular habitats, based on risk aversion, are at all strong.

In a manner similar to Michaelson, Kessel concludes that the theories of hedging behavior are based on forces that have a "relatively minor effect, if any, on the term structure when compared with liquidity preference and expectations" Kessel (1967, p. 594).

3.4.2. Speculation

Another variation to the analysis of risk aversion is that adopted by such writers as Robinson (1951) and Meiselman (1962), who argue that it is adequately-financed speculators who finally determine the slope of the yield curve. They see speculators as marginal transactors with sufficient funds to minimise yield differentials caused by the market's aversion to risk. For the purpose of the present analysis, the speculators are constrained to performing arbitrage, as it is assumed that expectations are given. For example, if there is an excess demand for securities of short term, speculators can profit (given expectations) by lending long-term and borrowing short-term. Whether the ultimate slope of the yield curve will still be upward, or whether it will become horizontal depends on whether speculators also display any aversion to risk.

Meiselman (1962, p. 10) argues that speculators are risk-indifferent, and so base their portfolio decisions entirely on their expectations of future interest rates. Thus, given expectations, a market containing these risk-indifferent marginal transactors can be expected to display a horizontal yield curve with no *a priori* bias at all.

Robinson (1951, p. 97) differs from Meiselman in arguing that speculators are risk averse, so that there will still exist an *a priori* bias in the yield curve. Furthermore, she suggests that the usual case will be where speculators, along with the rest of the market, display a preference for capital-certainty, so that a bias will exist towards an upward-sloping yield curve. As one expects speculators to have indefinite availability periods, their capital-consciousness is supported by portfolio-selection analysis.

3.5 Conclusion

The outcome of the above discussion is that, abstracting from transactions costs and expectations of future rates, nothing can be said *a priori* about the normal slope of the yield curve. However, if evidence can be produced concerning the length and relative importance of definite compared with indefinite availability periods, then empirical statements can be made concerning particular markets.

In chapter seven below, the results of a series of tests for the existence of liquidity premiums in Australian yield curves are presented. The evidence supports the contention that, for the period 1954-68, the yield curves contain positive liquidity premiums as an increasing function of term to maturity. Such ex post evidence is consistent with the existence of a "constitutional weakness" in the Australian securities market, along the lines proposed by Hicks (1939c).

3.6. Postscript: Liquidity Preference, Market Segmentation, and Open Market Operations

3.6.1 Liquidity Preference and Market Segmentation

Liquidity preference is a term that strictly can be used to describe any market situation where transactors display an aversion to risk. However, it is generally used in the context of the Hicksian model of the term structure,[18] and for purposes of exposition it is convenient to restrict the term to the market situation where liquidity premiums form an increasing function of term to maturity, as outlined in the introduction to this thesis. Expectations are assumed to be an important influence on portfolio decisions. Abstracting from expectations and transactions costs, the yield curve will slope upward as the result of the market's aversion to risk.

Liquidity preference is consistent with the existence of

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18. Refer Kessel (1965, p. 41) and Malkiel (1966, pp. 24-28).

definite availability periods, as pointed out on pp. 101-3 above. It is assumed that transactors will move outside their preferred periods if liquidity premiums are paid in compensation for the extra risk involved. It is here that one distinction can be drawn between liquidity preference and market segmentation. In a segmented market, investors do not transact outside their preferred terms, that is, there is no trade-off between risk and return.

Expectations are unimportant in a segmented market, so that supply and demand in each segment is completely independent of that in other segments. This means that liquidity premiums do not arise at all. In order for yields to be registered on a wide range of maturities, therefore, the supply and demand for securities must also be widely spread, unless transactions costs encourage investors to transact outside their preferred periods.

It can be seen that definite availability periods are consistent with both liquidity preference and market segmentation, and that expectations are important in the former market but not the latter. Another difference in the two market situations concerns the ordering of the supply and demand schedules for each registered market yield. With liquidity preference, the schedules must be ordered such that a smooth upward-sloping yield curve results. No such ordering is required with market segmentation, however, as the yield curves may take any shape.

3.6.2 Open Market Operations

As mentioned in the introduction to this thesis, the U.S. Government has, at various times in the past, used open market operations in an attempt to influence the term structure in the U.S. The results reported in chapter five below support the contention that the central bank in Australia has exerted an influence over the term structure in Australia. Various empirical tests have been carried out concerning the effect of open market operations on the term structure, but no definite concensus has emerged.[19] However, in most cases, there has been some evidence of an exogenous influence on the term structure, and while this has apparently been due to variations in the supply of government securities, the strength and permanency of the influence is uncertain.

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19. For example, refer Okun (1963), Wallace (1964), Scott (1965), Modigliani and Sutch (1966), Malkiel (1966), Dewald and Bush (1968), Hamburger and Latta (1969), Bierwag and Grove (1971), and Taylor (1971)

There has been confusion in the literature concerning the market conditions that are necessary for open market operations to have an influence on the term structure. Struble (1969, p. 233), for example, suggests that open market operations have no influence on the term structure in a market that displays liquidity preference.

> "Both the pure expectations theory and the version of this theory which contends that liquidity preference is partly responsible for the establishment of maturity yield differentials, agree on one vital point: that the maturity structure of outstanding debt does not affect the maturity structure of yields."

If, as Struble suggests, the maturity structure of outstanding debt has no influence on the term structure, then variations in the supply of government securities will also have no effect on the term structure. However, Struble is wrong in claiming that liquidity preference renders the maturity structure of outstanding debt unimportant for the term structure.

Open market operations will be totally ineffective in changing the yield curve only where the market displays no aversion to risk at all, so that transactors with uniform and confidently-held expectations dominate. In such a market, the demand schedules for securities of each term are infinitely elastic at the respective rates of interest that equate yields for each and every holding period, as implied by the traditional expectations theory.[20] Therefore, an increase in the supply of securities of <u>any</u> term is taken up by the market (assuming no constraint on funds), so that in equilibrium, the structure of rates remains the same as before the increase in supply occurred, though at a higher level overall. This also assumes that the change in the supply of government securities does not itself cause a change in expectations.

With liquidity preference, by contrast, the demand schedules for each term are not infinitely elastic because of the effect of risk aversion. Transactors are paid a premium in order to compensate them for the extra risk involved in transacting outside their preferred terms. Variations in the supply of government securities will have an affect on the magnitude of these premiums and so on the shape of the yield curve. For example, if expectations are given so that the yield curve slopes upward, the central bank can lower the level of long rates by purchasing long securities. The decrease in supply of long-term securities will reduce the premiums at the long end of the market, and

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20. See chapter four below, and Malkiel (1966, pp. 187-88) who gives a geometric analysis of holding-period yields.

so reduce the long rate.

It is argued, therefore, that the evidence of an exogenous influence on the term structure is not surprising, as all that is required for open market operations to exert <u>some</u> influence on the term structure, is a market that displays an aversion to risk, whatever the particular form it may take. Whether the market displays liquidity preference or market segmentation, the yields on various terms will be responsive to changes in both supply and demand schedules for the respective terms. Open market operations will be totally ineffective only where the market displays no aversion to risk at all.

It may be that uniform and confidently-held expectations are dominant in the market, at least for an important group of transactors, with yields affected to only a minor degree by risk aversion: but to the extent that risk aversion is present at all, open market operations will have <u>some</u> effect on the term structure.

A further implication of the analysis is that the existence of definite or indefinite availability periods is irrelevant for this general conclusion. The type of availability period will have an effect on the shape of the yield curve, and hence on the particular <u>area of the curve</u> where open market operations are conducted, but not on the overall effectiveness of these operations.

CHAPTER FOUR: EXPECTATIONS

4.1 Introduction

As can be seen from chapter two above, most of the writers on term structure theory up to 1939 regard expectations of future rates as playing an important role in influencing transactors' portfolio decisions. However, considerable debate emerged concerning the particular rate or rates that are forecast, as well as the length of the planning period over which transactors make their decisions, and this debate continues today.

Fisher (1930) formulates the traditional expectations theory in terms of long-term forecasts of future short rates, and is supported by Riefler (1930), Williams (1938), Lindahl (1939), Hicks (1939c) and Meiselman (1962). An alternative formulation, first proposed by Marshall (1923) and given support by Keynes (1930), Hawtrey (1939) and Robertson (1940), views transactors as making long-term forecasts of the long rate. More recent work on the term structure proposes a third alternative, whereby short-term forecasts are made of <u>all</u> rates in the maturity spectrum, a view first proposed by Kock (1929) and later supported by Robinson (1951), Malkiel (1962) and Wood (1971). In the following section, these alternative theories will be discussed in conjunction with the traditional expectations model.

4.2 The Traditional Expectations Model

This model can be traced back to Fisher (1896) but is more formally presented by Hicks (1939c)[21] and Lutz (1940). Before outlining the model in detail, some simple notation is introduced.[22] Let F refer to expected or <u>future</u> rates, R to actual or <u>spot</u> rates, and r to implied or <u>forward</u> rates. Let prescripts refer to the period in which a rate is expected to be realised, the first subscript to the term of the loan, and the second subscript to the period in which the rate is recorded on the market. Thus, ${}_{t+1}F_{1,t}$ refers to the one-period spot rate expected as at time t to prevail during period $t+1$. ${}_{t}R_{2,t}$ refers to the two-period spot rate ruling in the market at time t. ${}_{t+1}r_{1,t}$ refers to the one-period forward rate implied by the yield curve at time t to apply during time $t+1$.

The concept of an implied or forward rate requires clarification. From the spot rates ${}_{t}R_{1,t}$, ${}_{t}R_{2,t}$, ${}_{t}R_{3,t}$, ... ${}_{t}R_{n,t}$ [23] which make up the yield curve as observed at

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21. Note, however, that Hicks supported a modified version of the model (see pp. 101-2 above).
22. The notation is based on Meiselman (1962, p. 19).
23. As the prescript for R values is the same as the second subscript in all cases, the prescripts will be omitted from R values from here on.

time t, a rate can be derived that is determined at time t on money to be delivered in the future, and this is the forward rate.[24] For example, if the spot rate on two-year loans ($R_{2,t}$) is 5 per cent per annum, and the spot rate on three-year loans ($R_{3,t}$) is 7 per cent, then (using simple interest for illustrative purposes) the rate determined today on a one-year loan to commence two years from now (${}_{t+2}r_{1,t}$) is 11 per cent per annum ($(3 \times 7) - (2 \times 5)$). That is, at the margin, a transactor can simultaneously sell a two-year security and purchase a three-year security, thereby effectively investing in a one-year loan to start in two years time.

Arbitrage operations ensure that forward rates are positive. If $R_{3,t}$ is 3 per cent per annum, for example, while $R_{2,t}$ is 5 per cent, so that ${}_{t+2}r_{1,t}$ is -1 per cent ($(3 \times 3) - (2 \times 5)$), an assured profit can be made (ignoring transactions costs) by selling three-year securities and purchasing two-year securities. These arbitrage operations will continue until such discrepancies are eliminated and forward rates become positive again.

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24. This concept is analagous with, and indeed derived from, the "futures" rates applicable to commodities markets: refer Hicks (1939c, pp. 144-52).

The traditional expectations model postulates that the spot rate on a security at time t ($R_{n,t}$) is an average of the one-period future rates (${}_{t}F_{1,t}$, ${}_{t+1}F_{1,t}$, ${}_{t+2}F_{1,t}$, ... ${}_{t+n-1}F_{1,t}$) expected over the life of the security. This is because a transactor with funds available to invest for n periods has a choice of investing in an n-period security or n one-period securities. If the latter prospect offers a higher return, then he will purchase the latter as will other transactors with the same expectations, thus lowering the yield on one-period securities until the returns from both investments are brought into equality.

For example, if $R_{3,t}$ is 5 per cent while ${}_{t}F_{1,t}$ is 4 per cent, ${}_{t+1}F_{1,t}$ is 5 per cent and ${}_{t+2}F_{1,t}$ is 7 per cent, then, using simple interest again, a transactor with funds to invest for three periods can earn an average of 5 per cent per period on the three-period security and 5.3 per cent on the one-period securities. Under these circumstances there will be a preference for one-period securities that will last until relative prices adjust sufficiently to bring the average returns into equality. When this happens, the three-period rate will be an average of the three one-period rates.

The exact nature of this average depends on the assumptions made concerning the repayment streams of the securities. The general formula derived by Hicks (1939c, p. 145) assumes that all payments of interest and principal are made when the n-period security matures, and is equivalent to the following equation.

$$(1 + R_{n,t})^n = (1 + {}_tF_{1,t})(1 + {}_{t+1}F_{1,t})\ldots\ldots(1 + {}_{t+n-1}F_{1,t}) \qquad (4.1)$$

By comparison, Lutz (1940, p.37n) gives a formula that assumes that only the principal is left invested in the contract until maturity, with interest payments being withdrawn. In this case, the formula is as follows.[25]

$$(1 + R_{n,t}) = \frac{(1 + {}_tF_{1,t})(1 + {}_{t+1}F_{1,t})(1 + {}_{t+2}F_{1,t})\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1 + {}_{t+n-1}F_{1,t})}{\left[(1 + {}_{t+1}F_{1,t})(1 + {}_{t+2}F_{1,t})\ldots(1 + {}_{t+n-1}F_{1,t})\right] + \left[(1 + {}_{t+2}F_{1,t})\ldots(1 + {}_{t+n-1}F_{1,t})\right]\ldots + (1 + {}_{t+n-1}F_{1,t}) + 1} \qquad (4.2)$$

Before looking at the assumptions underlying the model, two implications can be noted. First, forward rates (${}_{t+j}r_{1,t}$)

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25. For the derivation of these formulae, refer Conard (1959, pp. 304-7).

will equal expected rates ($_{t+j}F_{1,t}$). If the forward rate on a one-period loan due two years from now ($_{t+2}r_{1,t}$), for example, is greater than the one-period rate expected to rule at that time ($_{t+2}F_{1,t}$), then transactors will anticipate a profit by entering the forward market. By undertaking to repay at the present forward rate a sum of money at the end of period $t+2$, a profit can be made by borrowing the funds with which to repay the loan at the lower spot rate expected to rule during that period ($R_{1,t+2}$). This sort of activity will continue until forward rates are brought into equality with their respective expected rates. This means that the expected rates are implied by the yield curves themselves in the form of forward rates. It is solely a matter of arithmetic that the forward rates ($_{t+j}r_{1,t}$) can be derived from the yield curve, but the traditional expectations model gives behavioral content to these forward rates by equating them with expected future rates ($_{t+j}F_{1,t}$).

The second implication of the model is that the return per period (or holding-period yield as it is usually called), is the same irrespective of the period of time for which funds are invested, or of the term of securities held. If this is not so, then securities will be bought and sold in the manner described above until any differences in holding-period yields are eliminated.

4.2.1 Assumptions

The assumptions underlying the traditional expectations model are as follows.

(1) Transactors in securities markets are profit-maximizers.

(2) Dominant transactors (in terms of funds) have uniform expectations concerning future movements in interest rates, and these expectations are held with complete confidence.

(3) Transactions costs are zero.

(4) Transactors maximize their returns over a time-period at least as long as the longest term of security outstanding.

Assumption (1) is necessary in order to ensure that transactors act to equalise holding-period yields and bring forward rates into equality with expected rates. Assumption (2) ensures that transactors are willing to invest in securities on the basis of expected return only (complete confidence), and that the forward rates are predictions of the future rates expected by the market (uniform expectations). It is necessary for transactions costs to be zero in order that holding-period yields are equated on securities of different term, while assumption (4) ensures that the long rate will be a geometric average of expected future short rates.

4.2.2 The Necessity for Additional Assumptions

Most writers accept that, on the basis of the four assumptions above, the conclusions of the model follow in a logical fashion. One writer who disagrees is Wood (1969), who argues that a further assumption is necessary, namely,

> (5) "investors, when selecting their optimal portfolio at a given point in time, consider themselves bound to hold each security purchased until maturity." (p. 522)

Wood argues that, if this further assumption is not made, the model may give sub-optimal results.

The essence of Wood's argument, is that where transactors use one-period planning horizons, rates expected more than one-period into the future are not taken into account in making investment decisions. Given this, expectations of the next-period's long rate <u>may be inconsistent</u> with expectations of future short rates. Therefore, unless a transactor is constrained, when purchasing securities, to hold these securities until maturity, a situation may arise where he can gain a larger return by investing solely on his expectations of next-period's rates, rather than on rates expected over several periods.

This criticism of the traditional expectations model sparked a debate in the March 1971 issue of the <u>American</u>

Economic Review, where Wood's article is challenged by Buse, Kessel and Roll, with a reply by Wood. The main argument centres on the distinction between equilibrium and disequilibrium conditions, with the challengers asserting that the inconsistency between expectations of next-period's long rate and of future short rates, is a disequilibrium situation that will eventually be removed in the movement towards equilibrium. However, Wood replies that disequilibrium situations are the rule rather than the exception, so that the model leads to sub-optimality most of the time, unless assumption (5) above is added.

Masera (1969b) has also challenged Wood's article on similar grounds to the later challenge in the American Economic Review. After claiming that Wood has confused equilibrium and disequilibrium conditions, Masera suggests that Wood's confusion arises from a misinterpretation of causality. Wood asserts that the condition that the long rate is an average of future short rates implies that holding-period yields must be equal irrespective of the term of securities held. However, Masera suggests that the causality operates in the opposite direction. That is, in order to have equilibrium, expected holding-period yields must be equal, implying that the long rate must be an average of expected short rates. And assumptions (1) to (4) above ensure that expected holding-period yields must be equal, as described above.

Wood has not replied to this criticism, and when combined with the main challenge in the American Economic Review, it appears that the case is still to be made for the need of an additional assumption in the model.

4.2.3 Uniform Expectations

Most of the criticismsof the traditional expectations model are aimed at the realism of the underlying assumptions, in particular, assumptions (2) and (4). The assumption of uniform expectations has been criticised by Kahn (1954) and Luckett (1959). Kahn suggests that the equality of expected short rates with corresponding spot long rates, applies only to the marginal transactor. Furthermore, this transactor may view the market's expectations as different to his own, so that he may invest in a manner inconsistent with that predicted by the model.

The same point is made by Luckett in criticising Lutz's (1940) formulation of the model. However, Meiselman (1962) argues that the presence of a group of transactors with uniform expectations and adequate finance, can cause the term structure to behave as if all the transactors in the market have uniform expectations. Meiselman postulates that such a group is present in the form of speculators.

Culbertson (1957, p. 496) doubts whether speculators do have uniform expectations, and considers that the importance of speculative activity will vary from market to market. Kane and Malkiel (1967) report that in a mail survey of U.S. banks, life insurance companies, and non-financial corporations, they found a wide diversity of expectations concerning future rate changes. However, Michaelson (1965) finds evidence to support uniform expectations in a test involving U.S. short-term securities. Also, in interviews with Australian share brokers, money market dealers and other such transactors, the writer has found the overwhelming opinion to be that expectations tend to be uniform, due to the relative smallness of the Australian securities market, and the suggestion that it is a "gossipy" one where news travels fast.

It does seem unlikely that there exists in fact a market composed of transactors, all of whom hold identical expectations. Therefore, the question becomes whether there exists an important body of transactors, with adequate finance and uniform expectations, who effectively determine the term structure. As can be seen from the few cases quoted above, opinion on this question differs, so that more empirical research is needed before the matter can be resolved satisfactorily.

4.2.4 Completely Confident Expectations

The assumption that expectations are held with complete confidence is needed to eliminate the possibility that uncertainty may cause transactors to prefer securities of particular term on the basis of risk aversion, and so distort the relationship between long rates and expected future short rates. There is widespread agreement that many transactors do suffer uncertainty and an aversion to risk, but again, Meiselman (1962) argues that speculators who dominate the market are risk-indifferent, and so cause the term structure to behave as if the whole market itself is risk-indifferent.

Meiselman also points out that even if individual transactors display risk aversion, it does not necessarily follow that the market as a whole will also display risk aversion. Transactors who hedge their assets and liabilities, and so restrict their speculation to a small range of securities, may form overlapping segments covering the whole maturity spectrum. Again the outcome is the same as if transactors have complete confidence in their expectations, and so invest in all maturities on this basis.

Meiselman is the exception rather than the rule in his approach to the effect of risk aversion on the yield curve. Most writers express the opinion that risk aversion will have some effect on the term structure whether speculation is important or not. Some of these opinions can be found in chapter two above. In chapter seven below, evidence is produced that is consistent with the importance of risk aversion in the Australian securities market. Hence, it is argued that the traditional expectations model does require modification for the existence of risk aversion.

4.2.5 Length of Transactors' Planning Horizons

Another criticism of the model concerns the assumption that forecasts of future rates are made over a time-horizon extending long into the future. Many writers, for example, Kock (1929), Kaldor (1939), Harrod (1948), Robinson (1951), Kahn (1954), Culbertson (1957), Malkiel (1962), Dorrance (1963), Michaelson (1965), Lutz (1967) and Wood (1969), suggest instead that transactors make forecasts of all rates over short-term planning horizons.

Nevertheless, Malkiel (1966, pp. 73-77) shows that the implications concerning the relationship between short and long spot rates are the same whichever behavioral postulate is used. He demonstrates that, implicit in the prices expected to rule in the next period using a short-term planning period, are streams of expected short rates.

> "That is, we shall show that given any set of expected prices for next year, there is a unique stream of future one-year rates that is consistent with it .... Thus, even though the two approaches start from very different behavioral assumptions, the final results of the two approaches are indistinguishable." Malkiel (1966, p. 75)

Luckett (1967) argues that the results are distinguishable in the sense that, because of the different behavioral assumptions involved, the one-period forward rates implied by the yield curve at any time can only be equated with expected rates in the model based on long planning horizons. But Hicks (1967, p. 94n) points out that the market's expectations concerning next period's prices, may still be based on its expectations of future short rates over the long run, a possibility noted also by Wood (1969, p. 525n). This implies that forward rates under such circumstances can still be regarded as equal to expected rates in both models.

It can be seen from the above review, that debate on the traditional expectations model has ranged far and wide, with most of the major issues being a matter for empirical analysis. In the following section, an indirect test of the model is discussed.

4.3 The Error-Learning Model

4.3.1 Introduction

The error-learning model was devised by Meiselman (1962) in order to provide an operational test of the traditional expectations theory. Previously, most tests of the theory had relied on the assumption of perfect foresight, and so compared forward rates at time t with the corresponding spot rates that are realised at time $t+j$. As mentioned above on pp. 116-20, at time t the yield curve contains implicit forward rates which the theory postulates are also unbiased estimates of the expected spot rates for periods $t+1$, $t+2$, $t+3$, and so on. If transactors have perfect foresight and act solely on their expectations of future rates, then forward rates will forecast accurately future spot rates. However, when transactors make forecasts under conditions of imperfect foresight, errors are likely to occur, so that differences between forward rates and corresponding spot rates may reflect imperfect foresight rather than the absence of forecasts.

In order to make the traditional expectations theory operational, Meiselman devised a test that does not rely on the assumption of perfect foresight. His model is based on the manner in which expectations are revised, rather than on how they are formed. That is to say, the model is not directly concerned with expectations as to the level of future rates at any point in time, but rather with how expectations change over time as a result of present happenings. As Telser (1967, pp. 551-53) shows, this formulation is a variation of the Cagan-Friedman model of adaptive expectations. In section 4.4 below, the derivation of the error-learning model from a model based on expectations of the level of future rates is shown.

In the error-learning model, it is assumed that transactors revise their expectations of future rates whenever they find past expectations to be in error. These revealed errors in past forecasts can be quantified by the difference between the n-period forward rate at time $t-1$ that refers to the n-period spot rate at time t, and the corresponding n-period spot rate that comes to pass. These forecast-errors will lead to a revision in expectations of future spot rates that are applicable to periods later than t. The revision in expectations can be quantified by the changes in forward rates between periods $t-1$ and t. Therefore, there should exist a correlation between the revealed errors in past forecasts and the revision in future forecasts (as embodied in changes in forward rates).

4.3.2. Algebraic Representation of the Model

(1) Forward Rates

Forward rates can be estimated by using the following general formula, which is derived from Keynes (1936, p. 169) and Hicks (1939c, p. 145).

$$_{t+j}r_{n,t} = \sqrt[n]{\frac{(1 + R_{j+n,t})^{j+n}}{(1 + R_{j,t})^{j}}} - 1 \qquad (4.3)$$

$_{t+j}r_{n,t}$ refers to the n-period forward rate as implied by the yield curve at time t, and applicable to the period $t+j$. For example, $_{1975}r_{3,1970}$ is the three-year forward rate applicable to 1975 as implied by the yield curve at the beginning of 1970, and can be calculated as follows.

$$_{1975}r_{3,1970} = \sqrt[3]{\frac{(1 + R_{8,t})^{8}}{(1 + R_{5,t})^{5}}} - 1$$

This method of calculating forward rates assumes that all coupon payments are zero or made at redemption date (see pp. 118-19 above), and that transactions costs are zero. The regression results in chapter one above (see pp. 40-43) indicate that even where coupon payments are present, their effect on the term structure is slight, while Wallace (1964) has shown that the effect of regular coupon payments on the above formula is small, so that the formula is a good approximation even where regular coupons are paid, as is the case with government bonds.

The error-learning model is conveniently expressed in terms of one-period forward rates, for which the formula is as follows.

$$_{t+j}r_{1,t} = \frac{(1 + R_{j+1,t})^{j+1}}{(1 + R_{j,t})^{j}} - 1 \qquad (4.4)$$

From the yield curve at time t can be derived a whole series of these one-period forward rates $_{t+1}r_{1,t}$, $_{t+2}r_{1,t}$, $_{t+3}r_{1,t}$, ... $_{t+j-1}r_{1,t}$ (where j is the term of the longest security outstanding at time t), representing the one-period spot rates expected to rule during periods $t+1$, $t+2$, $t+3$, ... $t+j-1$.

(2) The Error-Learning Model

The independent variable in the model is the revealed error in the market's forecast. This is represented by the difference between the market's forecast at time $t-1$ of the one-period spot rate expected to rule during period t ($_{t}r_{1,t-1}$), and the corresponding spot rate which comes to pass ($R_{1,t}$). The error in the market's forecast is expressed as follows.

$$R_{1,t} - {}_{t}r_{1,t-1}$$

As a result of this revealed error in their past forecasts, transactors revise their expectations of future rates. In the absence of any such revision, ${}_{t+j}r_{1,t-1}$ and ${}_{t+j}r_{1,t}$ will be equal. Thus, the revision term is as follows.

$$ {}_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} $$

The complete functional relationship between forecast-error terms and revision terms is as follows.

$$ {}_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} = f(R_{1,t} - {}_{t}r_{1,t-1}) \qquad (4.5) $$

The sense of this, is that if the market had expected this period's one-period spot rate to be 5 per cent, when in fact it is 6 per cent, then the market's expectation of other future rates will be revised upward by some fraction or multiple of 1 per cent, representing the revealed error in the forecast spot rate.

Equation 4.5 can be reduced to the following form.

$$ \Delta\, {}_{t+j}r_{1,t} = f(E_t) \qquad (4.6) $$

E_t is an abbreviation for the revealed forecasting error. If a linear relationship is assumed for equation 4.5, equation 4.6 can be expressed as follows.

$$ \Delta\, {}_{t+j}r_{1,t} = a_j + b_j E_t \qquad j = 1,2,3,\ldots\ldots \qquad (4.7) $$

The addition of a residual variable in order to recognise the presence of other influences on forward rates, gives as follows.

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j \qquad j = 1,2,3,\ldots \qquad (4.8)$$

The relationship expressed in equation 4.8 can be tested using least-squares regression analysis. The results of such tests using annual and quarterly data is reported in the following chapter.

4.4 Expectations Concerning the Level of Rates

Jacob Mincer (1969) has shown that the error-learning model is consistent with models that deal with expectations concerning the level of rates. The basic model outlined by Mincer is based on a linear extrapolation of current and past rates, with several variations according to the individual weights placed on the past observations. In this way, the expected value of future short rates is obtained by a weighted average of current and past values of short rates. Thus the general formula for a one-period forecast is as follows.[26]

$$_{t+1}F_{1,t} = \sum_{j=0}^{\infty} \beta_j R_{1,t-j} \qquad (4.9)$$

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26. Mincer's variables for the forecasted value (Y^*) and past value (Y) have been replaced here by F and R respectively.

As an example of a particular derivative of this general case, Mincer gives the following formula for a linear extrapolation that involves exponential forecasting, that is, where the weights for the current and past values of spot rates decline geometrically into the past.

$$ {}_{t+1}F_{1,t} = \beta \sum_{j=0}^{\infty} (1 - \beta)^{j} R_{1,t-j} \qquad (4.10) $$

He then goes on to demonstrate that this particular formulation is consistent with the following adaptive expectations model.

$$ {}_{t+1}F_{1,t} - {}_{t}F_{1,t-1} = \beta(R_{1,t} - {}_{t}F_{1,t-1}) \qquad (4.11) $$

It can be seen that the model depicted in equation 4.11 differs from that in equation 4.5 (the Meiselman model), in that in the former, the particular time-period relevant to the forecast shifts forward, whereas in the latter it is stationary.

Mincer also demonstrates that other adaptive expectations models are consistent with linear-extrapolation models where the relevant weights do not decline exponentially into the past. To demonstrate this, he uses the following time-series which originates as a linear function of independent random shocks, with zero means and common variance for all ε.

$$R_{1,t} = \varepsilon_t + \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} \qquad (4.12)$$

In the case of the time-series depicted in equation 4.12, <u>all</u> linear forecasts imply adaptive behavior, although the model in equation 4.11 above relates only to the case of linear forecasts with weights that decline exponentially into the past. The adaptive model relating to the general case is as follows.

$${}_{t+1}F_{1,t} - {}_{t+1}F_{1,t-1} = \beta_1 (R_{1,t} - {}_{t}F_{1,t-1}) \qquad (4.13)$$

In the case of exponential forecasting, equations 4.11 and 4.13 are equivalent, that is, ${}_{t+1}F_{1,t-1} = {}_{t}F_{1,t-1}$, as the same expectations are held for any span into the future.

From equation 4.13 can be derived the error-learning model using different revision coefficients for different spans into the future.

$${}_{t+k}F_{1,t} - {}_{t+k}F_{1,t-1} = \gamma_k (R_{1,t} - {}_{t}F_{1,t-1}) \qquad (4.14)$$

γ_k is a function of the weights β_1 , β_2, ... β_k, in equation 4.9. There are as many distinctive adaptive equations 4.14 as there are distinct parameters w_i in equation 4.12. Hence, the values of the γ_k as revealed by empirical tests can give evidence as to the particular form of equation 4.9 involved. That is, the results of the error-learning model can be used to say something about how transactors actually form their expectations concerning the level of rates in the future. Thus, it is clear that the error-learning model can be used to provide evidence on how expectations are revised from time to time, and on how these expectations are formed in the first place.

The pattern of declining γ_k found in the empirical tests reported in chapter five below, is consistent with a linear extrapolation of past rates with weights that decline more than exponentially (refer Mincer, p. 91). It is interesting to note, that this particular pattern of linear extrapolation is consistent with the hypothesis that transactors form expectations concerning the normal level of rates, an hypothesis which has been advanced by Kock (1929), Keynes (1936), Hicks (1939a), Robinson (1951), Malkiel (1962) and Modigliani and Sutch (1966). Further evidence concerning the formulation of expectations by Australian transactors will be discussed in the following chapter.

CHAPTER FIVE: TESTS OF THE ERROR-LEARNING MODEL

5.1 Introduction

In this chapter, the error-learning model is tested using Australian data. The basic model tested is that described in equation 4.8: see p. 134 above. Annual and quarterly data are used for both cross-section and time-series over the test period 1954-68. Furthermore, three sets of yield curve data are used, being those derived from yield curves constructed by regression analysis, free-hand smoothing and linear interpolation respectively. The construction of these yield curves is discussed in chapter one above.

5.2 Results of Tests using Annual Cross-Section and Time-Series Data

5.2.1 Introduction

The first series of regression tests involves annual time-series and cross-section data in order to allow a comparison of the results with those obtained by Meiselman (1962, ch. 2). Meiselman restricted his tests to annual data because of the limitations of the Durand data on which the tests were based. Durand's yield curves had been estimated on an annual basis since 1900, but his quarterly time-series did not start until 1952.[27] In order to allow sufficient observations for the regression tests, Meiselman used annual data for the period 1901-54. His results are reprinted below in table 5.4.

5.2.2 Calculation of Forward Rates

The one-year forward rates required for the tests of the error-learning model were calculated using equation 4.4: see p. 132 above. The calculation was made separately for the three sets of yield data derived from the yield curves constructed by regression analysis, free-hand smoothing and linear interpolation. In order to obtain an impression of the effect on the results of the different methods of construction of yield curves, the results from each set of data are compared one with another.[28]

The data requirements of the error-learning model, are a consistent cross-section of forward rates estimated separately over a number of yield curves, that is, a time-series of cross-section forward rates. As explained on pp. 24-25 above, the limitations of the basic data restrict the time-series to the fifteen-year period 1954-68. In terms

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27. The data used by Meiselman can be found in Durand (1942), Durand and Winn (1947), Durand (1958) and The Economic Almanac (1953).

28. This matter is taken up in chapter six below.

of equation 4.4 therefore, subscript t will run from one (1954) to fifteen (1968) for the annual time-series.

The extent of the cross-section will be limited to the shortest yield curve in the whole time-series. This happens to be the 1954 yield curve, where the longest bond outstanding has thirteen years to maturity. Consequently, the estimation of one-year forward rates from each of the yield curves is restricted to an upper limit of twelve years into the future. In terms of equation 4.4, subscript j will run from one to twelve for the annual cross-section. The calculation of forward rates using annual data can be summarised as follows.

$$ {}_{t+j}r_{1,t} = \frac{(1 + R_{(j+1),t})^{j+1}}{(1 + R_{j,t})^{j}} - 1 \qquad \begin{array}{l} t = 1,2,\ldots 15 \\ j = 1,2,\ldots 12 \end{array} \qquad (5.1) $$

5.2.3 Tests of the Error-Learning Model, 1954-68

Having calculated the annual time-series of one-year forward rates, the error-learning model can be tested by regression analysis based on the following equation.

$$ {}_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} = a_j + b_j (R_{1,t} - {}_{t}r_{1,t-1}) + U_j \qquad (5.2) $$

$$ t = 2,3,\ldots 15 $$
$$ j = 1,2,\ldots 11 $$

This results in eleven regressions each with fourteen observations. The results are given for the three sets of yield data in tables 5.1 to 5.3.

Table 5.1

Relations Between Annual Changes in One-Year Forward Rates (classified by maturity) and One-Year Forecast-Errors, 1954-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
1	0.0040 xx (0.0014)	0.7625 x (0.1839)	0.7674
2	0.0034 xx (0.0012)	0.5999 x (0.1627)	0.7289
3	0.0027 (0.0013)	0.4777 x (0.1656)	0.6399
4	0.0022 (0.0014)	0.3840 x (0.1780)	0.5285
5	0.0019 (0.0014)	0.3136 (0.1888)	0.4323
6	0.0017 (0.0015)	0.2607 (0.1936)	0.3623
7	0.0016 (0.0015)	0.2220 (0.1928)	0.3155
8	0.0016 (0.0014)	0.1951 (0.1884)	0.2865
9	0.0018 (0.0014)	0.1762 (0.1858)	0.2640
10	0.0020 (0.0015)	0.1670 (0.1931)	0.2423
11	0.0023 (0.0017)	0.1637 (0.2191)	0.2109

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Table 5.2

Relations Between Annual Changes in One-Year Forward Rates (classified by maturity) and One-Year Forecast-Errors, 1954-68

Data from Free-Hand Smoothed Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
1	0.0023 (0.0014)	0.6446 x (0.1844)	0.7104
2	0.0023 (0.0015)	0.4986 x (0.1986)	0.5868
3	0.0022 (0.0014)	0.4180 x (0.1856)	0.5450
4	0.0022 (0.0015)	0.3280 (0.1975)	0.4324
5	0.0021 (0.0014)	0.2982 (0.1868)	0.4186
6	0.0014 (0.0015)	0.2108 (0.2006)	0.2903
7	0.0018 (0.0013)	0.2129 (0.1726)	0.3355
8	0.0015 (0.0014)	0.2103 (0.1840)	0.3134
9	0.0024 (0.0012)	0.2708 (0.1577)	0.4441
10	0.0011 (0.0012)	0.1836 (0.1670)	0.3025
11	0.0012 (0.0013)	0.1344 (0.1749)	0.2165

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Table 5.3

Relations Between Annual Changes in One-Year Forward Rates (classified by maturity) and One-Year Forecast-Errors, 1954-68

Data from Linearly-Interpolated Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (b) (standard error in brackets)	Regression (c) coefficient (standard error in brackets)	Correlation coefficient
1	0.0025 (0.0017)	0.5273 x (0.2193)	0.5702
2	0.0008 (0.0021)	0.5002 x (0.2671)	0.4755
3	0.0023 (0.0016)	0.2500 (0.2109)	0.3238
4	0.0012 (0.0019)	0.1325 (0.2412)	0.1566
5	0.0010 (0.0017)	0.1551 (0.2211)	0.1985
6	0.0029 (0.0016)	0.2624 (0.2009)	0.3528
7	0.0002 (0.0024)	0.2404 (0.3139)	0.2159
8	0.0031 (0.0017)	0.2837 (0.2207)	0.3478
9	0.0008 (0.0015)	0.1872 (0.1877)	0.2767
10	0.0008 (0.0010)	0.0057 (0.1253)	0.0131
11	0.0021 (0.0010)	0.2121 (0.1256)	0.4382

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

5.2.4 Analysis of Results

It can be seen that the explanatory power of the model is best using data from yield curves constructed by regression analysis. The general results are least favourable using data from the yield curves constructed by linear interpolation. This suggests that the smoother the yield curves, the better are the results from the error-learning model. However, even the tests using data from linearly-interpolated yield curves give some results in favour of expectations.

While the results in general are not overwhelmingly favourable for the traditional expectations theory, they do give some evidence in support of the importance of expectations. In the case of table 5.1, it can be seen that the first four regressions have significant b coefficients. That is, the annual forecast-errors are significant determinants of revisions in annual forward rates for periods of up to four years into the future. The corresponding figures for tables 5.2 and 5.3 are three years and two years respectively.

Furthermore, the significance of the regression coefficients tends to decline in a regular manner, the greater is the number of years later than t to which the relevant forward rates are applicable. A regression of the regression coefficients from table 5.1 against j, where j

runs from one to eleven, produces a correlation coefficient of -0.923. This indicates that the revisions in forward rates are connected to each other in a systematic manner, as predicted by the traditional expectations theory.

The decline in the regression coefficients indicates that the annual revision in one-year forward rates becomes less sensitive to one-year forecast-errors, the further the period to which the forward rates refer lies ahead. For example, the forward rates applicable to one year into the future are more sensitive to current one-year forecast-errors, than are forward rates applicable to ten years into the future.

The correlation coefficients in table 5.1 also decline systematically as j increases. All are positive and decline from a high of 0.7674 to a low of 0.2109. The corresponding figures for tables 5.2 and 5.3 are highs of 0.7104 and 0.5702, and lows of 0.2165 and 0.0131 respectively, but the decline in each is not as systematic as in table 5.1.

The decline in the regression and correlation coefficients is not necessarily evidence that expectations concerning the distant future are less important than those concerning the near future. Mincer (1969, pp. 103-4) has shown that a declining pattern of <u>correlation</u> coefficients in connection with the error-learning model is consistent with a model of expectations based on a linear extrapolation of past spot rates, that is, a model concerned with how expectations are formed. Where expectations of <u>all</u> future rates are based on a linear extrapolation of past rates, the correlation coefficients obtained from the error-learning model can be expected to decline.

Furthermore, as mentioned in chapter four above (see p. 137), a declining pattern of <u>regression</u> coefficients is consistent with a linear-extrapolation model where the weights decline more than exponentially into the past.

It follows therefore, that the decline in the regression and correlation coefficients obtained from the error-learning model, are not necessarily evidence that expectations of the distant future are less firm than near-term expectations. Indeed, the <u>decline</u> in the regression coefficients provides evidence as to the manner in which expectations are formed in the Australian market. That is, the error-learning model has produced evidence not only of the way in which expectations are <u>revised</u>, but also of how expectations are <u>formed</u>. Of course, the regression coefficients which are not significant can not be used as part of the evidence supporting the importance of expectations.

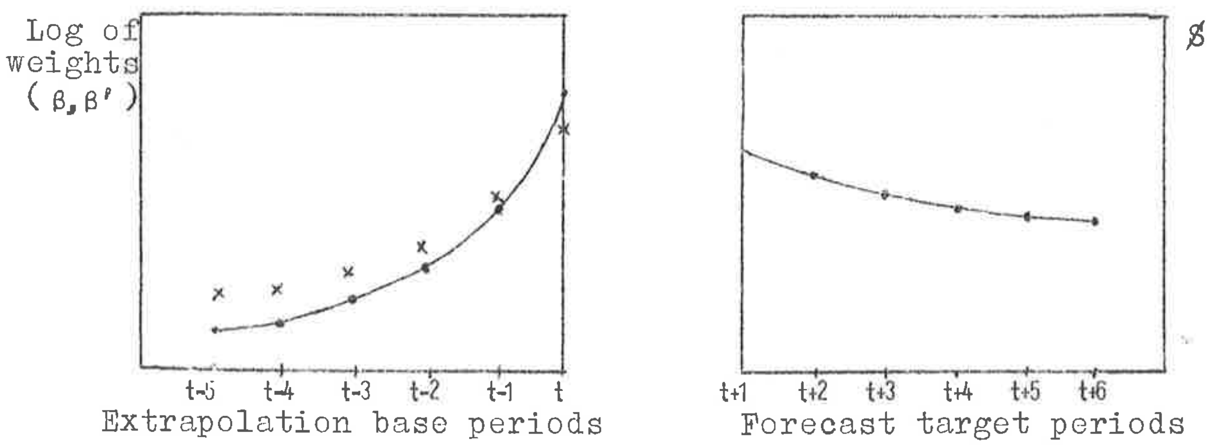
The above results are also consistent with the assumption that Australian transactors are influenced by the idea of a "normal" rate of interest, a concept discussed on pp. 61-62 above. Where the weights assigned to past rates decline more than exponentially, it implies that forecasts of rates extending further and further into the future trace out a path towards the position of normalcy. This is illustrated in figure 5.1, taken from Mincer (1969, p. 95).

Figure 5.1

The Relationship Between Pattern of Weights and Multiperiod Forecasts

Pattern of weights (declining more than exponentially)

Multiperiod forecasts implied by weight pattern



Note: In the left panel, the solid line shows β, the weights in forecasting one period ahead; the crosses show β′, the weights in forecasting two spans ahead.

These results can be compared with Meiselman's.

5.2.5 Meiselman's Results

As mentioned above, Meiselman carried out a test of the error-learning model using private-bond yield data compiled by Durand. Meiselman's results, reprinted in table 5.4, give stronger support for the traditional expectations model than do the results reported in tables 5.1 to 5.3. All of the *b* coefficients in table 5.4 are significant, while the correlation coefficients range from a high of 0.952 to a low of 0.590.

It would seem, therefore, that expectations of future rates play a stronger role in influencing the portfolio decisions made by transactors in U.S. securities markets than is the case with Australian transactors. However, one important difference between the securities market in Australia as compared with the U.S. must be considered before such a conclusion can be drawn. The Australian market has always been much narrower than the U.S. market, both in the range and volume of securities traded.[29] Furthermore, the Australian central bank and Commonwealth Treasury have tended to dominate trading, and this is particularly

29. Refer Spray (1964), Arndt and Harris (1965, pp. 94-95 and ch. 7) and Rose (1969, chs. 3 and 9).

Table 5.4

Relations Between Annual Changes in One-Year Forward Rates (classified by maturity) and One-Year Forecast-Errors, 1901-54, as reported by Meiselman (1962, p. 22)

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (standard error in brackets)	Regression coefficient(b)	Correlation coefficient
1	0.00 (0.02)	0.703 x	0.952
2	0.00 (0.03)	0.526 x	0.867
3	-0.01 (0.04)	0.403 x	0.768
4	-0.03 (0.04)	0.326 x	0.682
5	-0.02 (0.04)	0.277 x	0.642
6	-0.01 (0.03)	0.233 x	0.625
7	-0.02 (0.03)	0.239 x	0.631
8	0.01 (0.03)	0.208 x	0.590

(a) Number of years later than t to which forward rate refers.
(b) Standard errors not reported. Significant coefficients marked x, but level of significance not reported.

true of the bond market.[30]

This dominance of the bond market has allowed the monetary authorities to exert a strong influence over the level and structure of interest rates, so overshadowing the influence of private transactors whether their actions be motivated by expectations or other factors. This is particularly true of rates on securities of longer than four years to maturity, a point discussed in more detail below (see pp. 176-77).

Consequently, while expectations may be an important determinant of private transactors' investment decisions, the term structure itself from around four years to maturity onwards is determined primarily by the monetary authorities. Before the overall importance of expectations for the term structure in Australia over the test period can be decided, therefore, the influence of the monetary authorities on the term structure must first be removed. As yet, the error-learning model has not been successfully adapted to allow such an investigation.

Another factor affecting the test results concerns the quality of the test data. The earlier part of the time-

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30. Refer Arndt and Harris (1965, ch. 7), Rose (1969, chs. 3 and 10) and Lewis and Wallace (1971).

series of Australian bond yields can be expected to contain relatively large errors of the first and second type as compared with, say, the period 1960-68. The Australian capital market remained narrow by world standards until the nineteen-sixties, and even during the nineteen-fifties the data available for the construction of yield curves was not completely satisfactory. Tests limited to the nineteen-sixties are carried out below (see pp. 178-84).

Another difference between the Australian and U.S. tests is the number of observations involved in the regressions. The time-series used by Meiselman ran over fifty five years, compared with fifteen years for the Australian data. The Australian data before 1954 is most unsuitable for the statistical analysis that is involved with the error-learning model. Consequently, the Australian time-series can not be extended to a length that is comparable with that for the U.S. data.

In order to increase the number of observations and so obtain a better comparison with Meiselman's results, a first approach is to take more frequent observations within the test period. This has been done below by utilising quarterly yield curves rather than annual, and so observing quarterly changes in one-year forward rates. Whether this results in a comparable increase in degrees of freedom for the regression tests depends on whether the observations are independent. This can be evaluated by means of the Durbin-Watson test on the regression residuals.

Another important advantage of using quarterly time-series data, is that it allows a test of the error-learning model for the shorter period 1960-68, and so provides evidence for the hypothesis developed in sections 5.5.4 to 5.5.6 concerning the influence of the central bank in Australia over the term structure.

5.3 Results of Tests using Annual Cross-Section and Quarterly Time-Series Data.

5.3.1 Introduction

In order to increase the observations for the regression tests, the revision in one-year forward rates can be tabulated on a quarterly basis rather than on an annual basis. That is, the cross-section of forward rates remains on an annual basis in order to conform with Meiselman's test, but the time-series of these revisions is now on a quarterly basis. Similarly, the forecast-error term for the error-learning model will be in terms of one-year forward rates, but as revealed each quarter rather than annually. This means that the yield curves for each March are compared in order to calculate the revisions in annual forward rates, as are the curves for June, September and December. In this way, the number of observations is increased four-fold.

5.3.2 Calculation of Forward Rates

The cross-section of forward rates remains the same as for the tests in section 5.2 above, so that j in equation 4.4 continues to run from one to twelve. However, the annual revisions are now observed quarterly, so that t will run from one to fifty nine. The formula is as follows.

$$ {}_{t+4j}r_{1,t} = \frac{(1 + R_{(j+1),t})^{j+1}}{(1 + R_{j,t})^{j}} - 1 \qquad \begin{matrix} t = 1,2,\ldots 59 \\ j = 1,2,\ldots 12 \end{matrix} \qquad (5.3) $$

These one-year forward rates for the quarterly time-series have been calculated for the three sets of yield curves, and are reported in Bloch (1972, pp.229-348).

5.3.3 Tests of the Error-Learning Model, 1954-68

The regression equation used for testing the error-learning model using one-year forward rates and quarterly time-series is as follows.

$$ {}_{t+4j}r_{1,t} - {}_{t+4j}r_{1,t-4} = a_j + b_j(R_{1,t} - {}_{t}r_{1,t-4}) + U_j \qquad (5.4) $$

$$ t = 5,6,7,\ldots .59 $$
$$ j = 1,2,3,\ldots .11 $$

This results in eleven regressions each with fifty five observations. These results are shown separately for each set of yield data in tables 5.5 to 5.7.

5.3.4 Analysis of Results

The increase in the number of observations for the regression tests results in an increase in the number of significant regression coefficients and in the levels of the correlation coefficients for each set of data. In table 5.5, for example, it can be seen that every regression coefficient is significant, while the correlation coefficients range from a high of 0.9045 to a low of 0.2611. However, the regressions display strong signs of autocorrelation. As can be seen in table 5.5, the Durbin-Watson statistic for each of the eleven regressions is far below the crucial value of 1.53. This indicates that the observations are not independent so that the results are spurious to some degree.

The regression results using annual time-series data reported in table 5.1 do not display any signs of autocorrelation. Hence, the use of quarterly time-series in order to increase the number of observations available, has not made the results any more comparable with Meiselman's results because of the presence of autocorrelation. This particular problem is overcome in the next section, where three-month forward rates are substituted for one-year forward rates.

Table 5.5

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Forecast-Errors (observed each quarter), 1954-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+4j}\, r_{1,t} = a_j + b_j E_t + U_j$$

j [(a)]	Constant term[(b)] (standard error in brackets)	Regression coefficient[(c)] (standard error in brackets)	Correlation coefficient	Durbin-Watson test[(d)]
1	0.0038 xx (0.0004)	0.8262 x (0.0535)	0.9045	0.39 x
2	0.0031 xx (0.0004)	0.6225 x (0.0550)	0.8410	0.41 x
3	0.0024 xx (0.0004)	0.4702 x (0.0554)	0.7591	0.46 x
4	0.0018 xx (0.0005)	0.3563 x (0.0572)	0.6499	0.51 x
5	0.0015 xx (0.0005)	0.2724 x (0.0602)	0.5277	0.51 x
6	0.0013 xx (0.0005)	0.2129 x (0.0629)	0.4218	0.50 x
7	0.0013 xx (0.0005)	0.1743 x (0.0643)	0.3487	0.48 x
8	0.0014 xx (0.0005)	0.1530 x (0.0650)	0.3079	0.47 x
9	0.0017 xx (0.0005)	0.1480 x (0.0669)	0.2908	0.46 x
10	0.0020 xx (0.0006)	0.1569 x (0.0742)	0.2790	0.45 x
11	0.0025 xx (0.0007)	0.1794 x (0.0911)	0.2611	0.43 x

(a) Number of years later than *t* to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.
(d) Regressions displaying signs of autocorrelation are marked x. The crucial lower bound of the Durbin-Watson statistic below which autocorrelation is significant is 1.53.

Table 5.6

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Forecast-Errors (observed each quarter), 1954-68

Data from Free-Hand Smoothed Yield Curves

$$\Delta_{t+4j}\, r_{1,t} = a_j + b_j E_t + U_j$$

j [a]	Constant term [b] (standard error in brackets)	Regression coefficient [c] (standard error in brackets)	Correlation coefficient
1	0.0026 xx (0.0005)	0.7357 x (0.0590)	0.8634
2	0.0013 xx (0.0006)	0.4122 x (0.0700)	0.6287
3	0.0018 xx (0.0006)	0.3443 x (0.0689)	0.5659
4	0.0019 xx (0.0006)	0.2591 x (0.0693)	0.4569
5	0.0020 xx (0.0005)	0.2472 x (0.0644)	0.4661
6	0.0019 xx (0.0005)	0.2642 x (0.0604)	0.5150
7	0.0020 xx (0.0005)	0.2604 x (0.0567)	0.5336
8	0.0015 xx (0.0005)	0.2246 x (0.0631)	0.4396
9	0.0016 xx (0.0005)	0.1859 x (0.0609)	0.3870
10	0.0013 xx (0.0005)	0.1430 x (0.0569)	0.3262
11	0.0011 xx (0.0005)	0.0815 (0.0605)	0.1819

(a) Number of years later than *t* to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Table 5.7

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Forecast-Errors (observed each quarter), 1954-68

Data from Linearly-Interpolated Yield Curves

$$\Delta_{t+4j} r_{1,t} = a_j + b_j E_t + U_j$$

(a) j	Constant term[b] (standard error in brackets)	Regression coefficient[c] (standard error in brackets)	Correlation coefficient
1	0.0033 xx (0.0006)	0.7347 x (0.0665)	0.8349
2	0.0008 (0.0008)	0.3964 x (0.0888)	0.5226
3	0.0020 xx (0.0007)	0.2771 x (0.0821)	0.4205
4	0.0019 xx (0.0009)	0.2423 x (0.1008)	0.3135
5	0.0017 xx (0.0008)	0.3531 x (0.0861)	0.4908
6	0.0039 xx (0.0007)	0.3963 x (0.0858)	0.5357
7	0.0018 (0.0010)	0.3292 x (0.1142)	0.3681
8	0.0013 (0.0010)	0.0561 (0.1135)	0.0677
9	0.0011 (0.0007)	0.1552 x (0.0835)	0.2473
10	0.0013 xx (0.0006)	0.1468 x (0.0707)	0.2742
11	0.0008 (0.0007)	0.0440 (0.0768)	0.0784

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

5.4 Results of Tests using Quarterly Cross-Section and Time-Series Data

5.4.1 Introduction

So far the tests of the error-learning model have been based on one-year forward rates. The argument has been that transactors make forecasts of future one-year rates, and that revisions in these forecasts are revealed by revisions in one-year forward rates. However, there is no apparent reason why transactors' forecasts should be restricted specifically to one-year rates.

In terms of the traditional expectations model as developed by Fisher (1930), transactors make long-period forecasts of the one-period rate, but the actual unit period itself is not specified. Hicks (1939c, p. 145) makes the convenient assumption that the unit period is one week, with decisions made on Monday and held for the remainder of the week. Nevertheless, he suggests that expectations will be formed concerning the future course of <u>all</u> rates in the maturity spectrum (1939c, p. 152).

It follows, therefore, that in terms of the error-learning model, the particular unit period chosen for the forward rates can vary. Forecasts of future one-year spot rates, for example, will be reflected in one-year forward rates, forecasts of future five-year spot rates in five-year forward rates, and so on. Revisions in all forward rates can be expected whenever errors are discovered in past predictions. A reduction in the unit period to three months, therefore, will allow an increase in the number of regression observations, while leaving the error-learning model consistent with the traditional expectations model.

Unfortunately, the bond yield data available does not allow a complete test using three-month forward rates. For the period 1954-68 there is a paucity of yield observations on securities of less than six months to maturity. In the fifty-nine quarterly sets of cross-section data, a third contain no observations for terms as low as three months to maturity: see Bloch (1972, pp. 52-97).

Under these circumstances, the three-month spot rate required for calculating three-month forward rates can be obtained only by either extrapolation of the yield curve, or the use of three-month yields on securities other than government bonds. The latter possibility presents a problem in that securities selected as a substitute for government bonds must be comparable in terms of errors of the first type. Clearly, to avoid differences caused by different levels of default risk (see pp. 17-18), the securities would require the Commonwealth Government's backing. The only three-month yield data of this kind available in

Australia, apart from bond yields, are yields on treasury notes, but these are only available on a consistent basis from 1963, and in any case are relatively insensitive to market forces. As for obtaining three-month yields by extrapolation of bond yields at the very short-term end of the maturity spectrum, such a process must be regarded as, at best, highly suspect.

Because of the difficulties of deriving a consistent set of representative three-month yields over the test period, the quarterly yield tables derived by free-hand smoothing and linear interpolation do not include a three-month spot rate: see Bloch (1972, pp.250-332). However, in order to allow a test of the error-learning model using quarterly cross-section and time-series data, a three-month yield was derived by extrapolation for the yield curves constructed by regression analysis. The use of these suspect three-month yields in tests of the error-learning model also provides evidence concerning the controversy over the effect on the model of employing data from smoothed yield curves, a matter investigated in chapter six below.

5.4.2 Calculation of Forward Rates

Three-month forward rates are calculated from equation 4.4. As the time-series spans fifty nine quarters, subscript t will run from one to fifty nine. The cross-section of yields available in March 1954 spans fifty four quarters, and this limits the estimation of three-month forward rates to fifty three quarters into the future. Hence, subscript j will run from one to fifty three, and the calculation for the regression analysis data is as follows.

$$ {}_{t+j}r_{1,t} = \frac{(1 + R_{(j+1),t})^{j+1}}{(1 + R_{j,t})^{j}} - 1 \qquad \begin{matrix} t = 1,2,\ldots 59 \\ j = 1,2,\ldots 53 \end{matrix} \qquad (5.5) $$

For the freehand data and the linearly-interpolated data, j will run from two to fifty three due to the absence of a three-month spot rate in each curve. These three-month forward rates are reported in Bloch (1972, pp.198-332).

5.4.3 Tests of the Error-Learning Model, 1954-68

Regression equation 5.6 below describes the test of the error-learning model using solely quarterly data. As it requires the three-month spot rates ($R_{1,t}$), the test has been carried out using only regression analysis data.

$$ {}_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} = a_j + b_j(R_{1,t} - {}_{t}r_{1,t-1}) + U_j \qquad (5.6) $$

$$ t = 2,3,\ldots 59 $$

$$ j = 1,2,\ldots 52 $$

This results in fifty two regressions each with fifty eight observations. The results are reported in table 5.8.

Table 5.8

Relations Between Quarterly Changes in Three-Month Forward Rates (classified by maturity), and Quarterly Forecast-Errors, 1954-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
1	-0.0012 (0.0010)	0.1192 (0.0877)	0.1786
2	-0.0009 (0.0009)	0.0340 (0.0831)	0.0546
3	-0.0006 (0.0008)	0.0147 (0.0743)	0.0264
4	-0.0004 (0.0007)	0.0138 (0.0660)	0.0280
5	-0.0002 (0.0007)	0.0192 (0.0592)	0.0434
6	0.0000 (0.0006)	0.0270 (0.0539)	0.0668
7	0.0001 (0.0005)	0.0352 (0.0499)	0.0937
8	0.0002 (0.0005)	0.0427 (0.0469)	0.1207
9	0.0003 (0.0005)	0.0503 (0.0449)	0.1482
10	0.0004 (0.0005)	0.0565 (0.0433)	0.1718
11	0.0004 (0.0005)	0.0623 (0.0422)	0.1937
12	0.0005 (0.0005)	0.0674 (0.0412)	0.2133
13	0.0005 (0.0004)	0.0714 x (0.0405)	0.2292
14	0.0006 (0.0004)	0.0745 x (0.0399)	0.2421
15	0.0006 (0.0004)	0.0770 x (0.0393)	0.2529
16	0.0007 (0.0004)	0.0797 x (0.0388)	0.2648

Table 5.8 (Cont.)

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
17	0.0007 (0.0004)	0.0804 x (0.0381)	0.2713
18	0.0007 (0.0004)	0.0816 x (0.0377)	0.2780
19	0.0007 (0.0004)	0.0818 x (0.0371)	0.2829
20	0.0007 (0.0004)	0.0810 x (0.0364)	0.2846
21	0.0007 (0.0004)	0.0814 x (0.0359)	0.2902
22	0.0007 (0.0004)	0.0793 x (0.0353)	0.2877
23	0.0007 (0.0004)	0.0776 x (0.0348)	0.2859
24	0.0007 (0.0004)	0.0764 x (0.0342)	0.2866
25	0.0007 (0.0004)	0.0735 x (0.0336)	0.2804
26	0.0007 (0.0004)	0.0705 x (0.0332)	0.2730
27	0.0006 (0.0004)	0.0680 x (0.0326)	0.2682
28	0.0006 (0.0004)	0.0641 x (0.0323)	0.2568
29	0.0006 (0.0003)	0.0609 x (0.0318)	0.2482
30	0.0006 (0.0003)	0.0569 x (0.0315)	0.2352
31	0.0005 (0.0003)	0.0521 x (0.0312)	0.2181
32	0.0005 (0.0003)	0.0481 (0.0309)	0.2036
33	0.0005 (0.0003)	0.0429 (0.0308)	0.1827
34	0.0005 (0.0003)	0.0391 (0.0305)	0.1689
35	0.0004 (0.0003)	0.0321 (0.0307)	0.1384
36	0.0004 (0.0003)	0.0285 (0.0307)	0.1232

Table 5.8 (Cont.)

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
37	0.0004 (0.0003)	0.0232 (0.0309)	0.0998
38	0.0003 (0.0003)	0.0155 (0.0313)	0.0660
39	0.0003 (0.0003)	0.0110 (0.0318)	0.0464
40	0.0003 (0.0004)	0.0042 (0.0324)	0.0173
41	0.0002 (0.0004)	-0.0017 (0.0334)	-0.0070
42	0.0002 (0.0004)	-0.0085 (0.0343)	-0.0331
43	0.0001 (0.0004)	-0.0141 (0.0356)	-0.0530
44	0.0001 (0.0004)	-0.0213 (0.0372)	-0.0764
45	0.0001 (0.0004)	-0.0283 (0.0389)	-0.0968
46	0.0000 (0.0005)	-0.0355 (0.0410)	-0.1151
47	0.0000 (0.0005)	-0.0419 (0.0433)	-0.1283
48	-0.0001 (0.0005)	-0.0497 (0.0458)	-0.1433
49	-0.0001 (0.0005)	-0.0571 (0.0487)	-0.1548
50	-0.0001 (0.0006)	-0.0635 (0.0519)	-0.1612
51	-0.0002 (0.0006)	-0.0718 (0.0553)	-0.1709
52	-0.0002 (0.0007)	-0.0788 (0.0592)	-0.1752

(a) Number of quarters later than t to which forward rate refers.

(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.

(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

5.4.4 Analysis of Results

The results reported in table 5.8 are very weak indeed. Despite the fact that twenty of the fifty two regressions have significant regression coefficients, the values of the correlation coefficients never exceed 0.2902. Furthermore, the last twelve regressions report regression coefficients with the wrong sign.

These weak results are undoubtedly due to the presence of the highly suspect three-month spot rates (R_1) in both parts of the forecast-error term ($R_{1,t} - {}_t r_{1,t-1}$),

$$\left[\text{where } {}_t r_{1,t-1} = \frac{(1 + R_{2,t-1})^2}{1 + R_{1,t-1}} - 1 \right]$$

If a valid test using quarterly data is to be carried out, the error-learning model must be modified in such a way that the influence of the three-month spot rate is minimised.

The traditional expectations theory postulates that expectations are consistent throughout the yield curve, so that expectations concerning one particular future rate are linked with expectations of all other future rates. This postulate was supported by the test of the regression coefficients on pp. 144-45 above. If this is the case, then good results should still be obtained from the error-learning model by substituting the revealed error in the <u>one-year</u> spot rate, say, ($R_{4,t} - {}_t r_{4,t-1}$), for the suspect error-term involving the three-month rate. That is, the revision in three-month forward rates should be connected to revealed errors in one-year spot rates as well as to revealed errors in three-month spot rates.[31] In this way, the suspect three-month spot rates can be apparently removed from the regression tests.

Unfortunately, this is not the case. Any forward rate, of whatever unit period, that relates to a spot rate expected in three-months' time involves the three-month spot rate: or, more generally, any forward rate at time t that relates to period $t+1$ (${}_{t+1}r_{n,t}$) involves ${}_{t}R_{1,t}$, as shown by the following general formula for multi-period forward rates (derived from equation 4.3).

$$ {}_{t+1}r_{n,t} = \sqrt[n]{\frac{(1 + R_{(n+1),t})^{n+1}}{1 + R_{1,t}}} - 1 \qquad (5.7) $$

The three-month spot rate is involved in the estimation of the six-month forward rate relating to three-months' time (${}_{t}r_{2,t-1}$), the one-year rate (${}_{t}r_{4,t-1}$), the ten-year rate (${}_{t}r_{40,t-1}$) and so on. This means that any test of the error-learning model that includes a forecast-error term involving a quarterly comparison of forward rate and spot rate,

31. According to Meiselman (1962, p. 31), the error term is only a proxy for changes in "the" interest rate.

whatever the unit period of the forward rate, requires the three-month spot rate in order to estimate the relevant forward rate.

Nevertheless, the importance of the three-month spot rate is less for a forecast-error term based on the one-year forward rate ($R_{4,t} - {}_{t}r_{4,t-1}$), than it is for one based on the three-month forward rate ($R_{1,t} - {}_{t}r_{1,t-1}$). It can be argued, therefore, that the distortion introduced by a suspect R_1 value can be reduced by using an error term other than that based on R_1. The results of the following section tend to confirm this.

5.5 Results of Tests using Annual and Quarterly Cross-Section Data, and Quarterly Time-Series Data

5.5.1 Introduction

In this section, a forecast-error term based on the one-year forward rate - but as revealed quarterly - is substituted for one based on the three-month rate, while retaining the three-month unit period for the revision term.

5.5.2 Calculation of Forward Rates

As the revision terms are the same as those used in section 5.4, the only new calculation involves the forecast-error terms. This new calculation uses the following formula which is derived from equation 5.7 above.

$$_{t+1}r_{4,t} = \sqrt[4]{\frac{(1 + R_{5,t})^5}{1 + R_{1,t}}} - 1 \qquad t = 1,2,\ldots 59 \qquad (5.8)$$

5.5.3 Tests of the Error-Learning Model, 1954-68

The regression equation for this section is as follows.

$$_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} = a_j + b_j (R_{4,t} - {}_t r_{4,t-1}) + U_j \qquad (5.9)$$

$$t = 2,3,\ldots 59$$

$$j = 1,2,\ldots 52$$

This results in fifty two regressions, each with fifty eight observations. The results for the regression analysis data are reported in table 5.9.

5.5.4 Analysis of Results

The results in table 5.9 are consistent with those reported in table 5.1 which are based on annual data. The first fifteen regressions contain significant regression coefficients, as do another fifteen towards the end of the table. The first fifteen regressions involve forecasts reaching nearly four years into the future, and the annual tests reported in table 5.1 contain significant regression coefficients for the first four regressions, also covering a span of four years into the future.

Table 5.9

Relations Between Quarterly Changes in Three-Month Forward Rates (classified by maturity), and One-Year Forecast-Errors (observed each quarter), 1954-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term(b) (standard error in brackets)	Regression coefficient(c) (standard error in brackets)	Correlation coefficient	Durbin-Watson test(d)
1	0.0016 xx (0.0003)	1.1278 x (0.0667)	0.9144	1.55
2	0.0022 xx (0.0004)	0.9978 x (0.0768)	0.8665	1.95
3	0.0022 xx (0.0003)	0.8662 x (0.0739)	0.8429	1.98
4	0.0021 xx (0.0003)	0.7476 x (0.0701)	0.8186	1.90
5	0.0018 xx (0.0003)	0.6432 x (0.0678)	0.7853	1.79
6	0.0016 xx (0.0003)	0.5529 x (0.0671)	0.7405	1.67
7	0.0014 xx (0.0003)	0.4744 x (0.0675)	0.6843	1.58
8	0.0012 xx (0.0003)	0.4058 x (0.0685)	0.6207	1.53 x
9	0.0010 xx (0.0003)	0.3476 x (0.0698)	0.5541	1.52 x
10	0.0009 xx (0.0003)	0.2965 x (0.0708)	0.4881	1.53 x
11	0.0007 xx (0.0003)	0.2524 x (0.0719)	0.4246	1.57
12	0.0006 (0.0003)	0.2148 x (0.0726)	0.3678	1.62
13	0.0005 (0.0003)	0.1834 x (0.0730)	0.3184	1.67
14	0.0004 (0.0003)	0.1545 x (0.0731)	0.2716	1.72
15	0.0003 (0.0003)	0.1318 x (0.0731)	0.2342	1.77
16	0.0003 (0.0003)	0.1128 (0.0728)	0.2028	1.81

Table 5.9 (Cont.)

j [a]	Constant term [b] (standard error in brackets)	Regression coefficient [c] (standard error in brackets)	Correlation coefficient	Durbin-Watson test
17	0.0002 (0.0003)	0.0960 (0.0721)	0.1752	1.84
18	0.0002 (0.0003)	0.0826 (0.0716)	0.1524	1.86
19	0.0002 (0.0003)	0.0727 (0.0708)	0.1360	1.88
20	0.0001 (0.0003)	0.0632 (0.0698)	0.1202	1.88
21	0.0001 (0.0003)	0.0588 (0.0689)	0.1133	1.89
22	0.0001 (0.0003)	0.0537 (0.0677)	0.1053	1.88
23	0.0001 (0.0003)	0.0508 (0.0667)	0.1013	1.87
24	0.0001 (0.0003)	0.0502 (0.0655)	0.1018	1.86
25	0.0001 (0.0003)	0.0495 (0.0644)	0.1021	1.83
26	0.0002 (0.0003)	0.0512 (0.0634)	0.1073	1.81
27	0.0002 (0.0003)	0.0536 (0.0622)	0.1144	1.80
28	0.0002 (0.0003)	0.0554 (0.0612)	0.1200	1.77
29	0.0002 (0.0003)	0.0604 (0.0601)	0.1332	1.76
30	0.0003 (0.0003)	0.0645 (0.0592)	0.1441	1.74
31	0.0003 (0.0003)	0.0679 (0.0584)	0.1537	1.73
32	0.0003 (0.0003)	0.0742 (0.0575)	0.1699	1.72
33	0.0004 (0.0003)	0.0797 (0.0570)	0.1837	1.73
34	0.0004 (0.0003)	0.0854 (0.0561)	0.1994	1.74
35	0.0004 (0.0003)	0.0909 (0.0560)	0.2121	1.74
36	0.0005 (0.0003)	0.0972 x (0.0557)	0.2270	1.77
37	0.0005 xx (0.0003)	0.1039 x (0.0556)	0.2423	1.81

Table 5.9 (Cont.)

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient	Durbin-Watson test
38	0.0005 xx (0.0003)	0.1079 x (0.0561)	0.2489	1.83
39	0.0006 xx (0.0003)	0.1161 x (0.0567)	0.2641	1.87
40	0.0006 xx (0.0003)	0.1198 x (0.0577)	0.2674	1.94
41	0.0007 xx (0.0003)	0.1272 x (0.0593)	0.2756	1.96
42	0.0007 xx (0.0003)	0.1309 x (0.0610)	0.2756	2.01
43	0.0007 xx (0.0003)	0.1357 x (0.0633)	0.2756	2.05
44	0.0008 xx (0.0003)	0.1418 x (0.0662)	0.2750	2.08
45	0.0008 xx (0.0003)	0.1457 x (0.0696)	0.2692	2.10
46	0.0009 xx (0.0003)	0.1483 x (0.0736)	0.2599	2.13
47	0.0009 xx (0.0004)	0.1521 x (0.0782)	0.2516	2.13
48	0.0009 xx (0.0004)	0.1560 x (0.0830)	0.2435	2.14
49	0.0010 xx (0.0004)	0.1567 x (0.0887)	0.2299	2.14
50	0.0010 xx (0.0004)	0.1588 x (0.0949)	0.2183	2.14
51	0.0011 xx (0.0005)	0.1609 (0.1015)	0.2072	2.13
52	0.0011 xx (0.0005)	0.1613 (0.1090)	0.1939	2.12

(a) Number of quarters later than t to which forward rate refers.

(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.

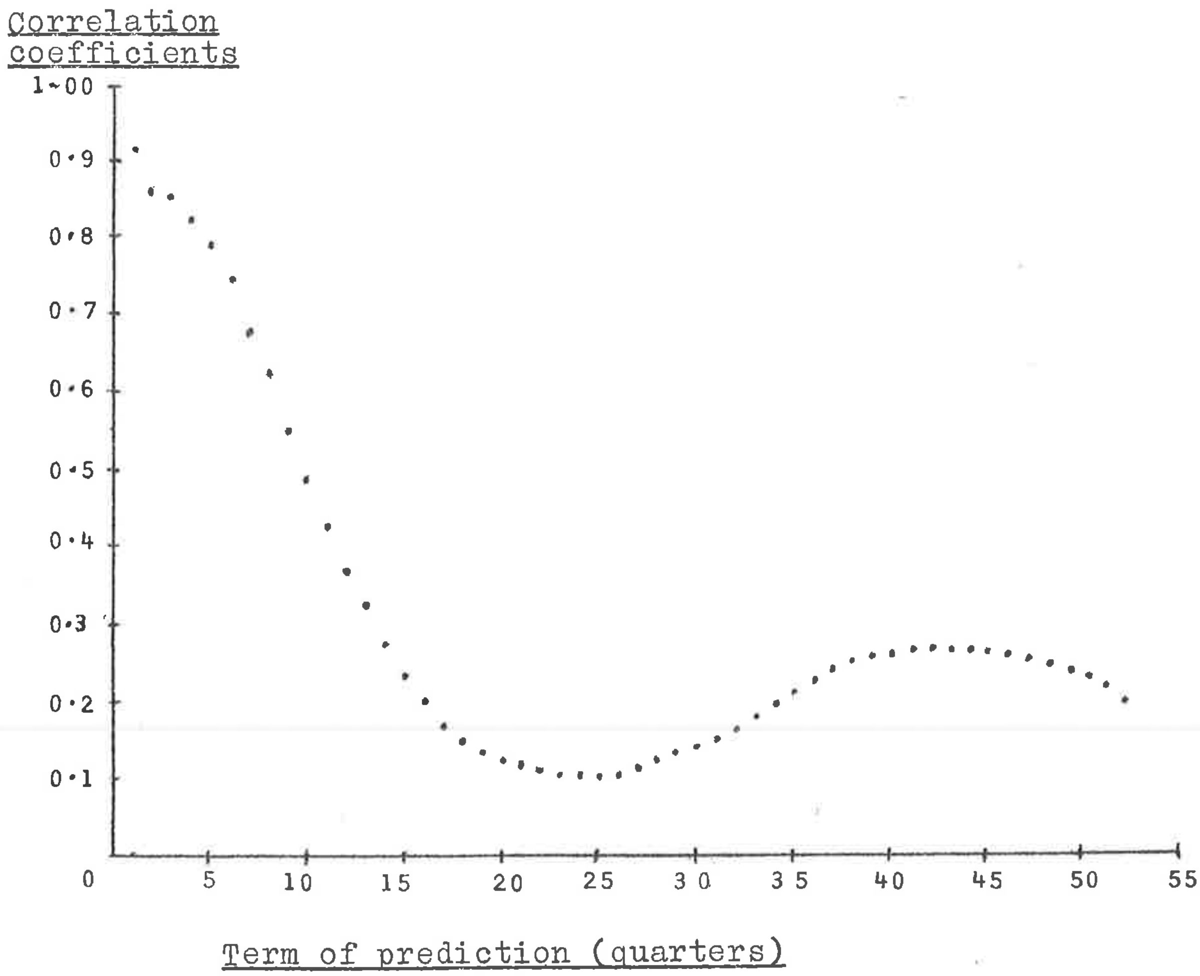
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

(d) Regressions displaying signs of autocorrelation are marked x. The crucial lower bound of the Durbin-Watson statistic below which autocorrelation is significant is 1.54.

The correlation coefficients in table 5.9 decline in a systematic manner, from 0.9144 for the first regression to 0.1013 for the twenty third regression. Following this, they rise consistently again to a level of 0.2756 for the forty third regression, and then decline again. The pattern of the level of the correlation coefficients in table 5.9 is described in figure 5.2.

Figure 5.2

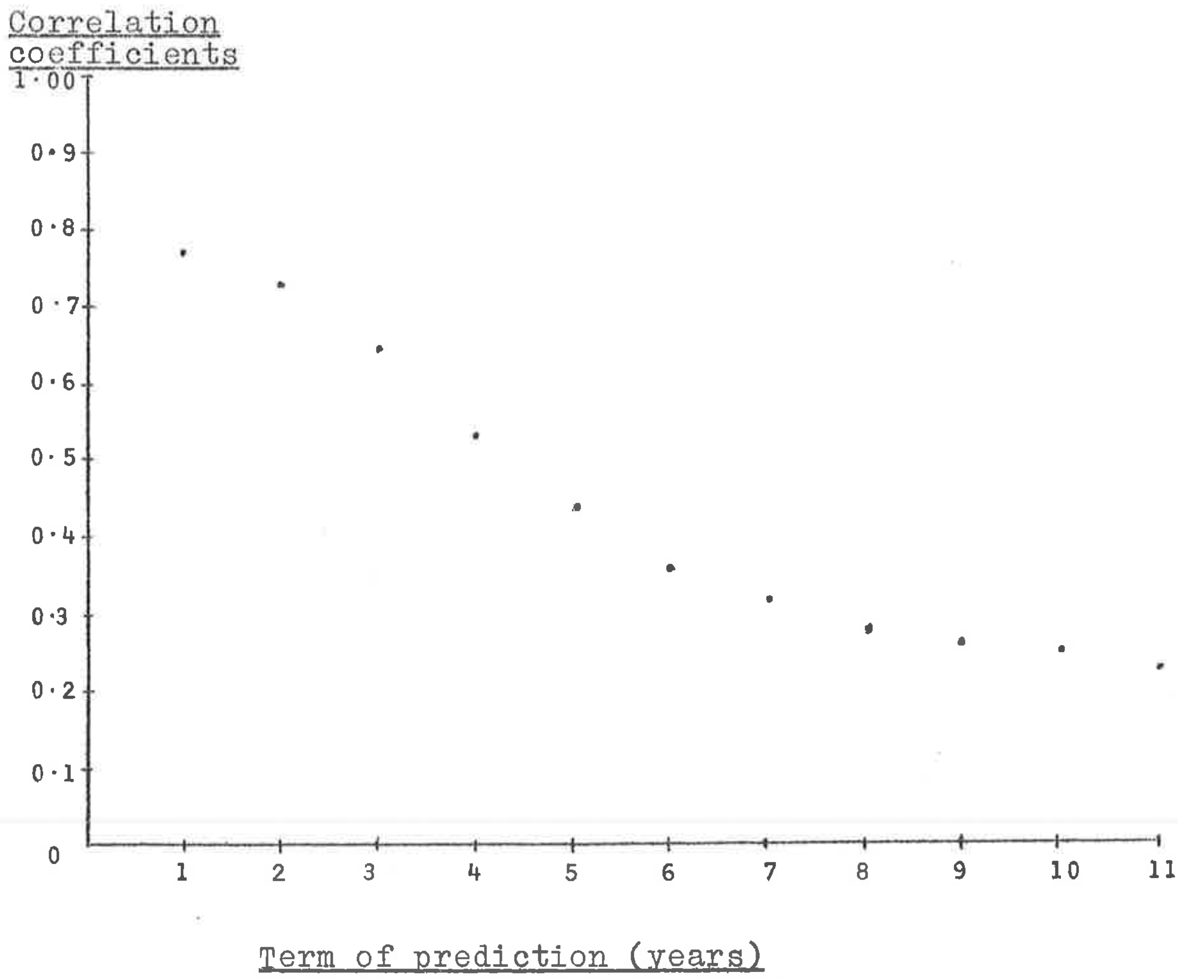
Graph of the Correlation Coefficients from Table 5.9 according to Term of Prediction



The correlation coefficients in table 5.1, by comparison, do not display any tendency to turn upward, as demonstrated in figure 5.3.

Figure 5.3

Graph of the Correlation Coefficients from Table 5.1 according to Term of Prediction



It seems likely that the cyclical movement in figure 5.2, along with the significant regression coefficients in table 5.9 for terms thirty six to fifty, are not indicative of expectations but rather are due to the presence of sampling fluctuations. Bartlett (1946) has demonstrated that a cyclical movement in the pattern of correlation coefficients may be obtained from any linear autoregressive time-series, where the value of the regression coefficients becomes absolutely small.

The interpretation of correlation coefficients depends on two independent factors, namely, "the appropriateness of the theoretical scheme assumed and the magnitude of sampling fluctuations"(Bartlett, 1946, p. 27). Bartlett demonstrates that when the values of the regression coefficients become small, the correlation coefficients may not approach zero as expected, but rather may undergo a cyclical fluctuation. This is due to the fact that when the regression coefficients are small, the sampling properties of the correlation coefficients depend on the variance and covariance of the standard errors.

It can be seen from table 5.9, that the upturn in the correlation coefficients occurs at $t = 24$, when the value of the regression coefficient is 0.0502 and <u>declining</u>. The regression coefficients do move up again starting at $t = 26$, but as soon as they reach 0.1418 at $t = 44$ and continue to rise, the correlation coefficients turn down again. This contrary movement in the two coefficients, therefore, is probably due to the sampling fluctuations mentioned by Bartlett. Whether the upturn in the regression coefficients starting at $t = 26$ is also a sampling property, however, is not clear. It does seem unlikely though, that the upturn is indicative of transactors' expectations. For example, the pattern of significant regression coefficients in table 5.9 would suggest that predictions reaching up to fifteen quarters into the future, along with predictions spanning quarters thirty six to fifty, are sensitive to forecast-errors, while predictions spanning sixteen to forty-nine quarters into the future, along with quarters fifty one and fifty two, are not. Such behavior by transactors seems most unlikely on common sense grounds, and is inconsistent with the results reported in table 5.1.

The substitution of three-month forward rates for one-year forward rates in the error-learning model, has largely overcome the problem of spurious results caused by auto-correlation. Of the fifty-two values for the Durbin-Watson statistic reported in table 5.9, only three are below the critical value and then only marginally. This suggests that quarterly predictions of three-month forward rates are independent of each other over time.

The evidence from tables 5.1 and 5.9 suggests that predictions of future rates up to approximately four years into the future are sensitive to current prediction-errors. However, it does not necessarily follow that transactors do not make forecasts for longer periods than this. Rather, it could be that the influence of the central bank in the bond market effectively masks the effect of expectations on the yield curve over all but the shortest end of the curve.

Support for this argument can be found in the presence over the test period of an active private market in short-term bonds of up to three years to maturity, where the influence of the central bank was less than for other maturities where no comparable market existed. The development of the short-term money market during the nineteen sixties allowed such a market to develop to the stage where, according to a private paper prepared by the Reserve Bank, the private dealers had a turnover of short-term securities that was several times larger than that of the bank itself. Consequently. it would be harder for the central bank to manipulate rates at the shorter end of the yield curve, than it would be for other areas which are subject to much less private trading. In the medium- and long-term areas of the bond market where trading is not as active, the bank would have a much stronger influence on yields. As Rose (1969, p. 157) points out in discussing the bond market,

> "most of this activity is in short-dated bonds. Despite the institutional framework, the secondary (bond) market in medium amd long-dated issues is relatively narrow, and is characterised by discontinuous trading."

The conclusion that emerges from the above discussion, is that while the results in tables 5.1 and 5.9 support the importance of expectations for only approximately four years into the future, the influence of the central bank over the medium and long-term areas of the yield curve overshadows the presence of expectations for periods longer than four years into the future. Additional evidence on this matter is gained by limiting the tests to the 1960-68 period.

During the period 1954-60, the Australian capital market was still shaking off the effects of war-time restrictions. In addition, the volume and breadth of securities (including commonwealth bonds) coming on to the capital market tended to increase significantly during the nineteen-sixties.[32] Therefore, the influence of behavior based on expectations should show out more strongly during the 'sixties, reflecting the decline in the relative importance of the central bank.

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32. Refer Arndt and Harris (1965, pp. 94-5 and 203-8), Rose (1969, ch. 3) and Bloch(1972, table 1.4, pp. 53-97).

The growth of the capital market saw a decline in the relative size of the transactions of the central bank compared with the market as a whole,[33] while the Commonwealth Government adopted a more flexible interest rate policy.[34]

Furthermore, it could be expected that the increase in market activity probably applied, to some extent, over the whole range of the term structure, so that the effect of expectations should show through over a longer forecast-period than the four years reported for 1954-68.

5.5.5 Tests of the Error-Learning Model, 1960-68

The regression equation is now as follows.

$$_{t+j}r_{1,t} - {}_{t+j}r_{1,t-1} = a_j + b_j(R_{4,t} - {}_tr_{4,t-1}) + U_j \qquad (5.10)$$

$$t = 26, 27, 28, \ldots 59$$

$$j = 1, 2, 3, \ldots\ldots 52$$

This results in fifty two regressions each with thirty four observations. The results for the regression analysis data are reported in table 5.10.

5.5.6 Analysis of Results

As a result of limiting the time-series to the 1960-68 period, the values of the correlation coefficients for each

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33. Refer Rose (1969, p. 155).

34. Refer Arndt and Harris (1965, pp. 203-8), and Lewis and Wallace (1971, p. 10).

Table 5.10

Relations Between Quarterly Changes in Three-Month Forward Rates (classified by maturity), and One-Year Forecast-Errors (observed each quarter), 1960-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+j} r_{1,t} = a_j + b_j E_t + U_j$$

(a) j	Constant term(b) (standard error in brackets)	Regression coefficient(c) (standard error in brackets)	Correlation coefficient	Durbin-Watson test(d)
1	0.0020 xx (0.0003)	1.1920 x (0.0567)	0.9656	1.72
2	0.0027 xx (0.0003)	1.1062 x (0.0658)	0.9478	1.89
3	0.0027 xx (0.0003)	0.9905 x (0.0640)	0.9393	1.84
4	0.0025 xx (0.0003)	0.8783 x (0.0617)	0.9293	1.75
5	0.0022 xx (0.0003)	0.7756 x (0.0608)	0.9141	1.66
6	0.0020 xx (0.0003)	0.6853 x (0.0611)	0.8927	1.58
7	0.0018 xx (0.0003)	0.6052 x (0.0621)	0.8647	1.52
8	0.0016 xx (0.0003)	0.5336 x (0.0635)	0.8296	1.47
9	0.0014 xx (0.0003)	0.4720 x (0.0648)	0.7900	1.44
10	0.0012 xx (0.0003)	0.4173 x (0.0658)	0.7464	1.43
11	0.0011 xx (0.0003)	0.3688 x (0.0667)	0.6990	1.44
12	0.0009 xx (0.0003)	0.3266 x (0.0673)	0.6513	1.46
13	0.0008 xx (0.0003)	0.2908 x (0.0675)	0.6057	1.48
14	0.0007 xx (0.0003)	0.2572 x (0.0675)	0.5588	1.51
15	0.0006 (0.0003)	0.2298 x (0.0674)	0.5163	1.53
16	0.0005 (0.0003)	0.2055 x (0.0671)	0.4761	1.56

Table 5.10 (Cont.)

j [(a)]	Constant term [(b)] (standard error in brackets)	Regression coefficient [(c)] (standard error in brackets)	Correlation coefficient	Durbin-Watson test
17	0.0005 (0.0003)	0.1840 x (0.0663)	0.4405	1.59
18	0.0004 (0.0003)	0.1663 x (0.0658)	0.4077	1.60
19	0.0003 (0.0003)	0.1513 x (0.0654)	0.3784	1.62
20	0.0003 (0.0003)	0.1369 x (0.0644)	0.3519	1.64
21	0.0003 (0.0003)	0.1285 x (0.0639)	0.3352	1.64
22	0.0002 (0.0003)	0.1181 x (0.0632)	0.3138	1.67
23	0.0002 (0.0003)	0.1116 x (0.0628)	0.2996	1.68
24	0.0002 (0.0003)	0.1058 x (0.0620)	0.2887	1.69
25	0.0002 (0.0003)	0.1018 (0.0620)	0.2788	1.69
26	0.0002 (0.0003)	0.1004 (0.0615)	0.2774	1.72
27	0.0002 (0.0003)	0.0973 (0.0617)	0.2688	1.76
28	0.0002 (0.0003)	0.0967 (0.0614)	0.2684	1.78
29	0.0002 (0.0003)	0.0979 (0.0613)	0.2719	1.81
30	0.0002 (0.0003)	0.1001 (0.0615)	0.2765	1.82
31	0.0002 (0.0003)	0.0992 (0.0622)	0.2715	1.87
32	0.0002 (0.0003)	0.1036 (0.0623)	0.2820	1.90
33	0.0002 (0.0003)	0.1057 (0.0630)	0.2844	1.95
34	0.0002 (0.0003)	0.1085 x (0.0632)	0.2903	1.98
35	0.0003 (0.0003)	0.1134 x (0.0639)	0.2995	2.00
36	0.0003 (0.0003)	0.1175 x (0.0645)	0.3066	2.03
37	0.0003 (0.0003)	0.1213 x (0.0647)	0.3145	2.09

Table 5.10 (Cont.)

j [a]	Constant term [b] (standard error in brackets)	Regression [c] coefficient (standard error in brackets)	Correlation coefficient	Durbin-Watson test
38	0.0003 (0.0003)	0.1257 x (0.0655)	0.3213	2.09
39	0.0003 (0.0003)	0.1315 x (0.0660)	0.3324	2.12
40	0.0004 (0.0003)	0.1341 x (0.0667)	0.3351	2.16
41	0.0004 (0.0003)	0.1401 x (0.0670)	0.3465	2.14
42	0.0004 (0.0003)	0.1458 x (0.0678)	0.3591	2.18
43	0.0004 (0.0003)	0.1483 x (0.0676)	0.3607	2.20
44	0.0005 (0.0003)	0.1542 x (0.0680)	0.3740	2.19
45	0.0005 (0.0003)	0.1604 x (0.0680)	0.3851	2.18
46	0.0005 (0.0003)	0.1614 x (0.0677)	0.3868	2.20
47	0.0005 (0.0003)	0.1676 x (0.0675)	0.4012	2.17
48	0.0005 (0.0003)	0.1705 x (0.0680)	0.4078	2.17
49	0.0006 (0.0003)	0.1731 x (0.0670)	0.4103	2.14
50	0.0006 (0.0003)	0.1795 x (0.0670)	0.4278	2.14
51	0.0006 (0.0003)	0.1804 x (0.0670)	0.4295	2.10
52	0.0006 (0.0003)	0.1845 x (0.0670)	0.4376	2.06

(a) Number of quarters later than t to which forward rate refers.

(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.

(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

(d) Regressions displaying signs of autocorrelation are marked x. The crucial lower bound of the Durbin-Watson statistic below which autocorrelation is significant is 1.39.

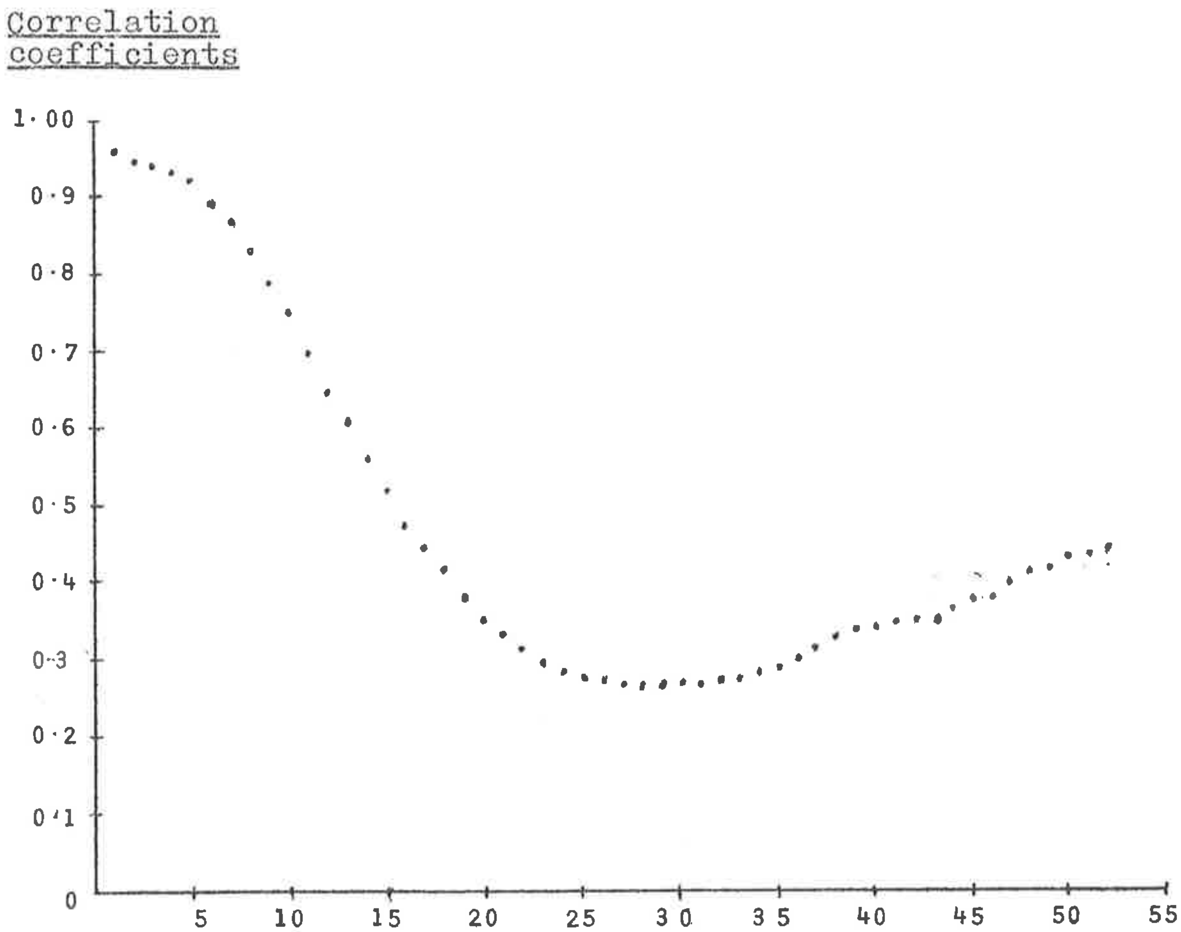
of the fifty two regressions have risen. There is no evidence of autocorrelation in any of the residuals. This supports the contention that the influence of expectations on the term structure in general has become more important in recent years as a result of the growth of the capital market and the decline in relative importance of the central bank.

The other important point to note from table 5.10 as compared with table 5.9, is that the number of early regressions reporting significant regression coefficients increases from the first fifteen to the first twenty four. This evidence is not inconsistent with the hypothesis that the growth of the bond market during the nineteen sixties saw the active market in short-dated bonds spreading to bonds of longer term to maturity, along with relatively less control over yields by the central bank. Consequently, the expectations of private transactors in the bond market show up as significant for forecast-periods of up to six years into the future, compared with four years for the 1954-68 period.

The correlation coefficients from table 5.10 do not decline consistently throughout the entire term of prediction: see figure 5.4 below. Once again it seems probable that, as with figure 5.2, the upturn in the graph is due to the presence of sampling fluctuations, as are the significant

Figure 5.4

Graph of the Correlation Coefficients from Table 5.10 according to Term of Prediction



Term of Prediction (quarters)

regression coefficients for regressions thirty four to fifty two in table 5.10. A possible alternative explanation of these significant regression coefficients, is that they are due to transactors' expectations dominating the relevant section of the yield curve. However, this section approximates the maturity range of eight to thirteen years, and, to the writer's knowledge, there is no evidence of an active market for bonds of these maturities that is relatively free from central bank control.

5.6 Summary

In this chapter has been presented a series of tests of the error-learning model. The results using annual data for the period 1954-68, while giving some support to the traditional expectations model, do not compare favourably with Meiselman's results based on U.S. data. Tests using annual cross-section and quarterly time-series were carried out in order to increase the observations for the regressions, but the tests suffer from the presence of autocorrelation of the regression residuals. This problem was overcome by the use of quarterly time-series data, but a paucity of observations of three-month spot rates prevented a proper test.

Consequently, a test was devised incorporating a forecast-error term based on one-year forward rates, observed quarterly. The results of this test support the general findings of the annual tests, indicating the significance of market forecasts based on expectations of future rates of up to four years into the future.

In order to examine whether the influence of the central bank in the bond market had prevented forecasts for longer periods from determining the relevant sections of the term structure, a more limited test period, 1960-68, was examined, with the result that the significant period increased from four to six years into the future. As the bond market became more active in the 'sixties, this result is consistent with the argument that the influence of the central bank over bond yields has declined for securities of longer and longer term to maturity.

CHAPTER SIX: CONSTRUCTION OF YIELD CURVES AND THE ERROR-LEARNING MODEL

6.1 Introduction

An important finding which emerges from the results reported in chapter five, concerns the effect of different methods of construction of yield curves on the tests of the error-learning model. A debate has been carried on in the literature concerning the most appropriate method of construction of the yield curves that are used in tests of the error-learning model: see Grant (1964a and 1964b), D. Fisher (1964), (1966) and (1967), Buse (1967a and 1967b) and (1968), and Wallace (1969).

Grant (1964a) criticises the Meiselman (1962) results on the ground that they are based on suspect data. In particular, Grant considers that the smoothing of yield curves by Durand is "artificial", and makes the results of the tests of the error-learning model as reported by Meiselman highly suspect. Estimates of forward rates are extremely sensitive to relatively small changes in the values of spot rates, and Grant argues that the smoothing process adopted by Durand is not conducive to accurate estimates of spot rates. Consequently, the forward rates derived from these spot rates are suspect, as are the results of the error-learning model. Grant employs yield curves constructed by linear interpolation of U.K. data as the basis for a test of the error-learning model. The results give little support to the traditional expectations model.

Grant's results are questioned by Fisher and Buse. Fisher (1964) argues that linear interpolation does not allow for the effect of varying coupon rates on yields. That is, the use of linear interpolation ignores the presence of errors of the first type caused by varying coupon rates: see chapter one, pp. 25-28 above. Yet it is assumed in the calculation of forward rates that are required for tests of the error-learning model, that regular coupon payments are zero. Hence, while a smoothing process may or may not compensate for the coupon effects, linear interpolation does not.

This criticism by Fisher can be extended to cover <u>all</u> errors of the first type, and not solely those that are due to the presence of varying coupon rates. Fisher carries out a test of the error-learning model employing yield curves that are constructed by free-hand smoothing of U.K. data, and obtains results that are favourable to the traditional expectations model.

Buse (1967a) also obtains favourable results from the error-learning model using smoothed U.K. yield curves.

However, he argues that whether or not smoothing is correct theoretically, the use of smoothed curves ensures good results from the error-learning model, provided only that short rates fluctuate more than long rates and in the same direction. The good results are due to the pattern of forward rates associated with any smoothed yield curves, a pattern which approximates the shape of the yield curve itself.

As a test of his hypothesis, Grant jumbles up the smoothed yield curves into a random order and reruns the regression tests of the error-learning model. The results show higher values for the regression coefficients and coefficients of determination than those obtained from the tests employing chronologically-ordered yield curves. Buse concludes as follows.

> "The Meiselman model is consistent with any set of smoothed yield curves in which the short and long rates move together but in which short rates show a greater variability. The correct chronological order is not vital to the result. The model cannot, therefore, be considered a useful test of the expectations theory because it does not discriminate between the behavior of investors acting on Meiselman postulates and alternative formulations which are consistent with the same pattern of observed rates. The consistency and strength of the correlations may or may not be relevant. Meiselman results would be implied by any set of yield curves, even if the type of investor behavior which Meiselman assumes dominates the yield curve did not exist." Buse (1967a, p. 61)

Wallace (1969) has since shown that Buse's contention that correct chronological order of the yield curves is not vital to the results from the error-learning model, is based on "an irrelevant and incorrect comparison of coefficients of determination" (p. 524). Wallace suggests that comparisons of predictive power should be based on comparisons of mean-square prediction errors, rather than of coefficients of determination. When he ran such a test he found that the chronologically-ordered yield curves gave the better predictions - a finding that is in direct contrast to Buse's conclusions.

Wallace suggests that the production of high values for the coefficients of determination using randomly-ordered yield curves as reported by Buse, is due to the presence of the one-period spot rate in all the experiments. No matter how the curves are ordered, this rate at time t ($R_{1,t}$) is used as an explanatory variable of the yield curve at time t. Consequently, it may be that the explanatory power of this variable alone is enough to ensure high values of the coefficients of determination.

The questions raised above concern first, whether smoothing is preferable to linear interpolation in the construction of yield curves, and secondly, whether high values of regression coefficients and coefficients of determination in tests of the error-learning model are assured by the use of smoothed curves, in which short and long rates move in the same direction with short rates having the greater variability. Evidence from the tests in chapter five concerning these two questions are reported in the following sections.

6.2 Smoothing versus Linear Interpolation

Techniques for constructing yield curves are described in chapter one above. It is pointed out there (pp. 33-35) that linear interpolation involves the implicit assumption that observations are completely free of type-one errors. These errors are discussed in chapter one above, and it is apparent that they are present in the data that is used for the regression tests in chapter five. As mentioned by Fisher (1964, p. 413) in connection with coupon rates, a smoothing process may or may not reduce these errors of the first type, but linear interpolation does not. Evidence on this matter is produced by comparing the results of the regression tests in chapter five for the 1954-68 period, with that presented below for 1960-68.

In tables 5.5 to 5.7 on pp. 155-57 above are reported the results of tests of the error-learning model using quarterly time-series and annual cross-section data, the results in each table being based on a different set of yield curves. These three sets of results are not as close together as are those for tables 6.1 to 6.3 below which contain the results of comparable tests for the period 1960-68. It is suggested that this is due to the closer conformity of the three sets of yield curves in the latter part of the complete time-series as compared with the former.

As a wider range of bond maturities became available in the nineteen-sixties, the scatter of observations available for the construction of yield curves came closer together. Consequently, less interpolation is necessary between observations, so reducing errors of the second type. Furthermore, errors of the first type are reduced as the market becomes more perfect. This reduction in type-one and type-two errors allows the yield curves constructed by linear interpolation and free-hand smoothing to become <u>more and more smooth</u>.

The end result, therefore, is that as the time-series comes to an end, the curves constructed by linear interpolation and free-hand smoothing <u>come more and more to resemble those constructed by regression analysis</u>. In order to illustrate this, the yield curves for the months of March 1954, 1958, 1962, and 1968, using the three sets of data, are graphed in figures 6.1 to 6.8 below. The data used can be found in Bloch (1972, tables 2.1 to 2.3).

Table 6.1

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Forecast-Errors (observed each quarter), 1960-68

Data from Regression Analysis Yield Curves

$$\Delta_{t+4j} r_{1,t} = a_j + b_j E_t + U_j$$

j [a]	Constant term [b] (standard error in brackets)	Regression coefficient [c] (standard error in brackets)	Correlation coefficient
1	0.0033 xx (0.0003)	0.8379 x (0.0368)	0.9731
2	0.0027 xx (0.0003)	0.6699 x (0.0437)	0.9434
3	0.0022 xx (0.0004)	0.5494 x (0.0486)	0.9027
4	0.0018 xx (0.0004)	0.4625 x (0.0514)	0.8579
5	0.0015 xx (0.0004)	0.3999 x (0.0533)	0.8121
6	0.0013 xx (0.0004)	0.3552 x (0.0551)	0.7675
7	0.0013 xx (0.0005)	0.3247 x (0.0571)	0.7261
8	0.0012 xx (0.0005)	0.3046 x (0.0594)	0.6896
9	0.0013 xx (0.0005)	0.2931 x (0.0617)	0.6614
10	0.0014 xx (0.0005)	0.2876 x (0.0638)	0.6417
11	0.0015 xx (0.0005)	0.2882 x (0.0658)	0.6313

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Table 6.2

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Forecast-Errors (observed each quarter), 1960-68

Data from Free-Hand Smoothed Yield Curves

$$\Delta_{t+4j} r_{1,t} = a_j + b_j E_t + U_j$$

j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
1	0.0031 xx (0.0004)	0.8507 x (0.0451)	0.9616
2	0.0016 xx (0.0005)	0.5435 x (0.0672)	0.8323
3	0.0016 xx (0.0004)	0.5090 x (0.0541)	0.8681
4	0.0019 xx (0.0004)	0.4835 x (0.0568)	0.8449
5	0.0020 xx (0.0004)	0.4549 x (0.0543)	0.8412
6	0.0017 xx (0.0004)	0.4403 x (0.0561)	0.8247
7	0.0018 xx (0.0004)	0.3704 x (0.0552)	0.7797
8	0.0013 xx (0.0005)	0.3339 x (0.0631)	0.7008
9	0.0013 xx (0.0005)	0.2878 x (0.0624)	0.6506
10	0.0011 xx (0.0005)	0.2191 x (0.0657)	0.5266
11	0.0008 (0.0006)	0.2142 x (0.0724)	0.4813

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Table 6.3

Relations Between Annual Changes in One-Year Forward Rates (observed each quarter) classified by maturity, and One-Year Fore-cast-Errors (observed each quarter), 1960-68

Data from Linearly-Interpolated Yield Curves

$$\Delta_{\ t+4j}r_{1,t} = a_j + b_j E_t + U_j$$

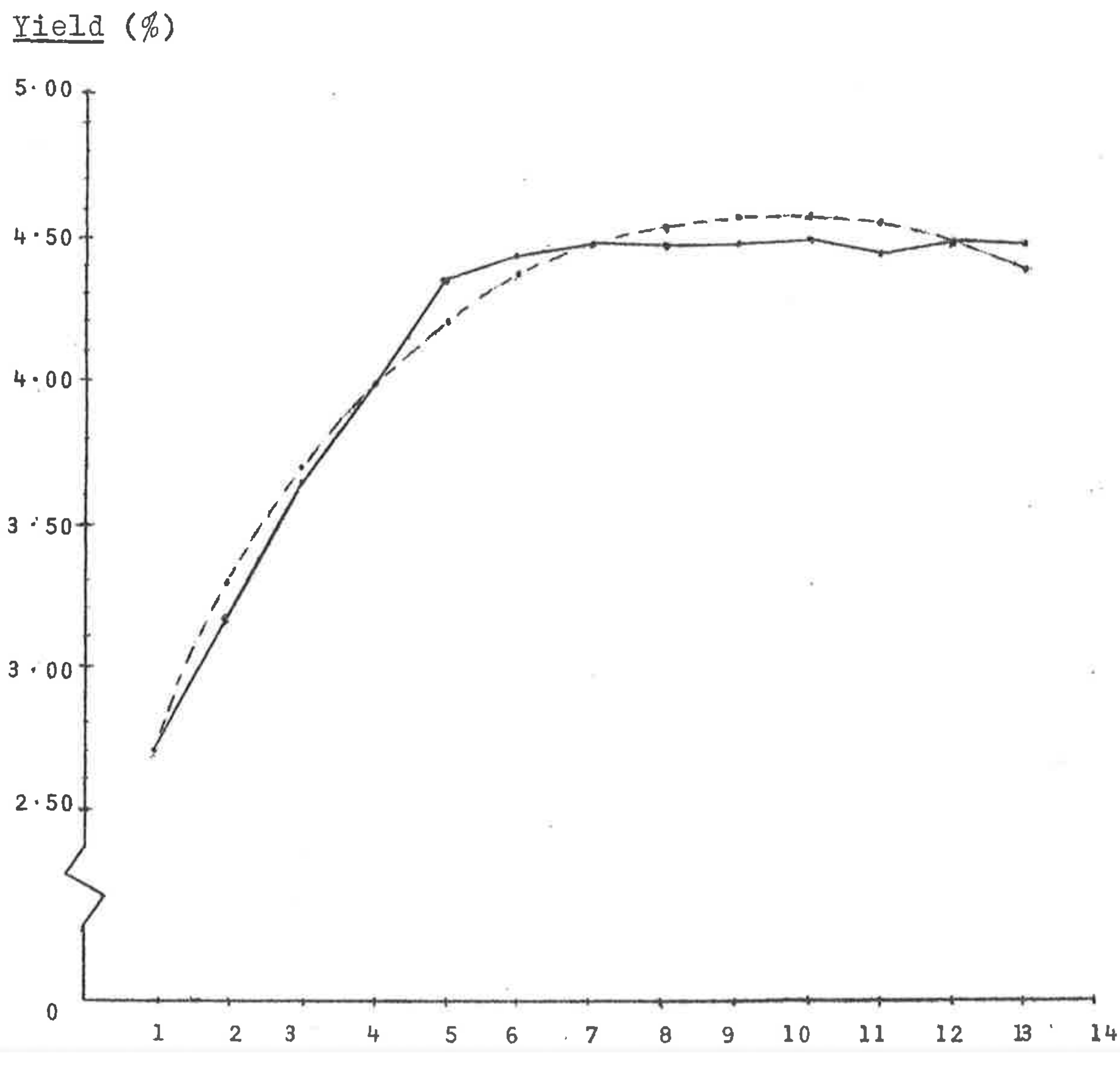
j (a)	Constant term (b) (standard error in brackets)	Regression coefficient (c) (standard error in brackets)	Correlation coefficient
1	0.0036 xx (0.0006)	0.8322 x (0.0676)	0.9163
2	0.0013 (0.0008)	0.4914 x (0.0925)	0.7022
3	0.0017 xx (0.0007)	0.4119 x (0.0814)	0.6846
4	0.0022 xx (0.0006)	0.5407 x (0.0760)	0.7972
5	0.0013 (0.0007)	0.4704 x (0.0852)	0.7157
6	0.0032 xx (0.0007)	0.3857 x (0.0797)	0.6684
7	0.0011 (0.0009)	0.3929 x (0.1112)	0.5484
8	0.0019 (0.0011)	0.3647 x (0.1314)	0.4582
9	0.0012 (0.0008)	0.2019 x (0.0935)	0.3721
10	0.0007 (0.0005)	0.1559 x (0.0637)	0.4138
11	-0.0001 (0.0008)	0.1248 (0.0916)	0.2453

(a) Number of years later than t to which forward rate refers.
(b) Significant terms at the 5 per cent level of confidence using a two-tail test are marked xx.
(c) Significant terms at the 5 per cent level of confidence using a one-tail test are marked x.

Figure 6.1

Yield Curves Constructed by Regression Analysis and Linear Interpolation

March 1954

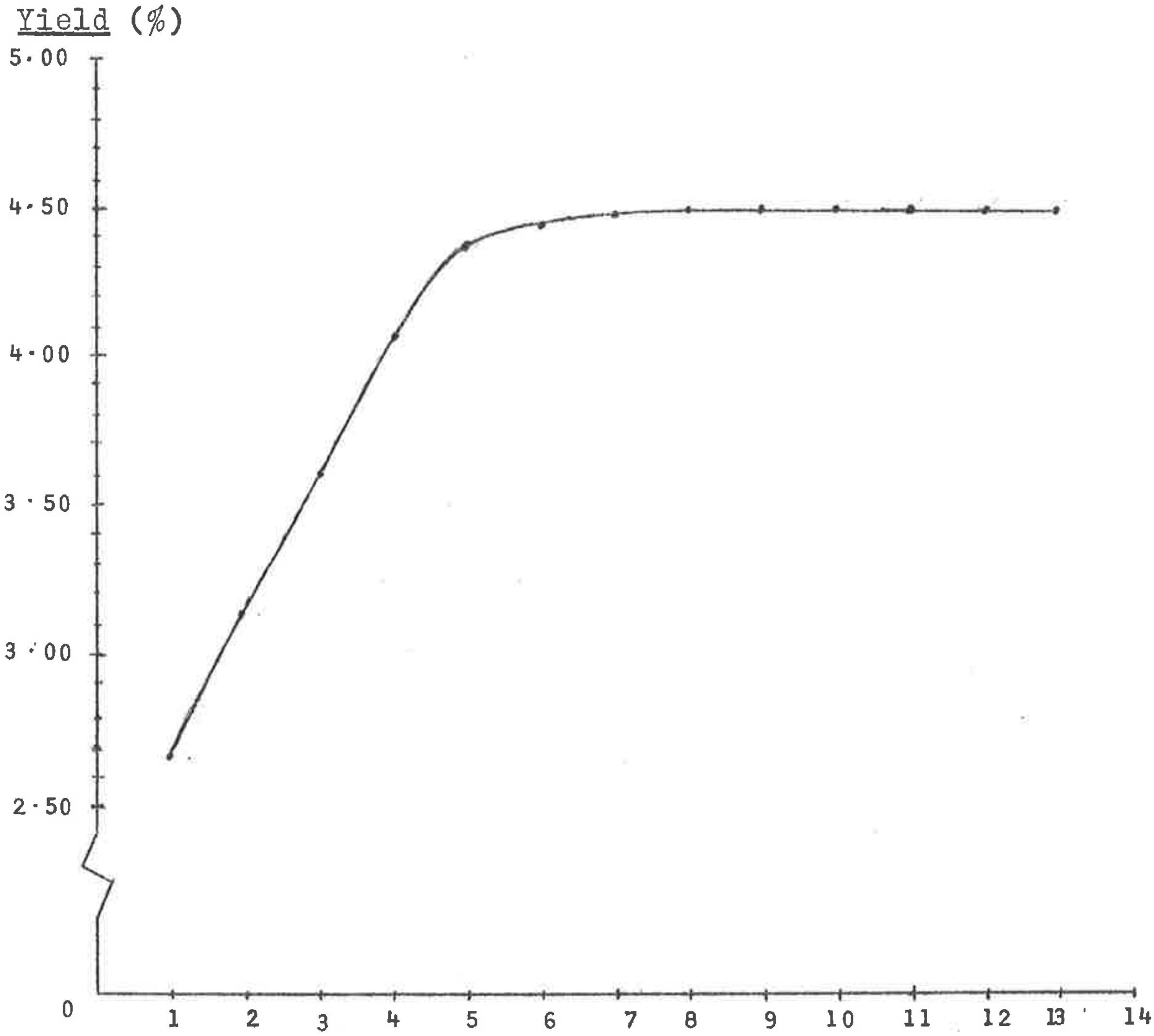


Note: The regression analysis curve is represented by the broken line and the linearly-interpolated curve by the solid line.

Figure 6.2

Yield Curve Constructed
by Free-Hand Smoothing

March 1954

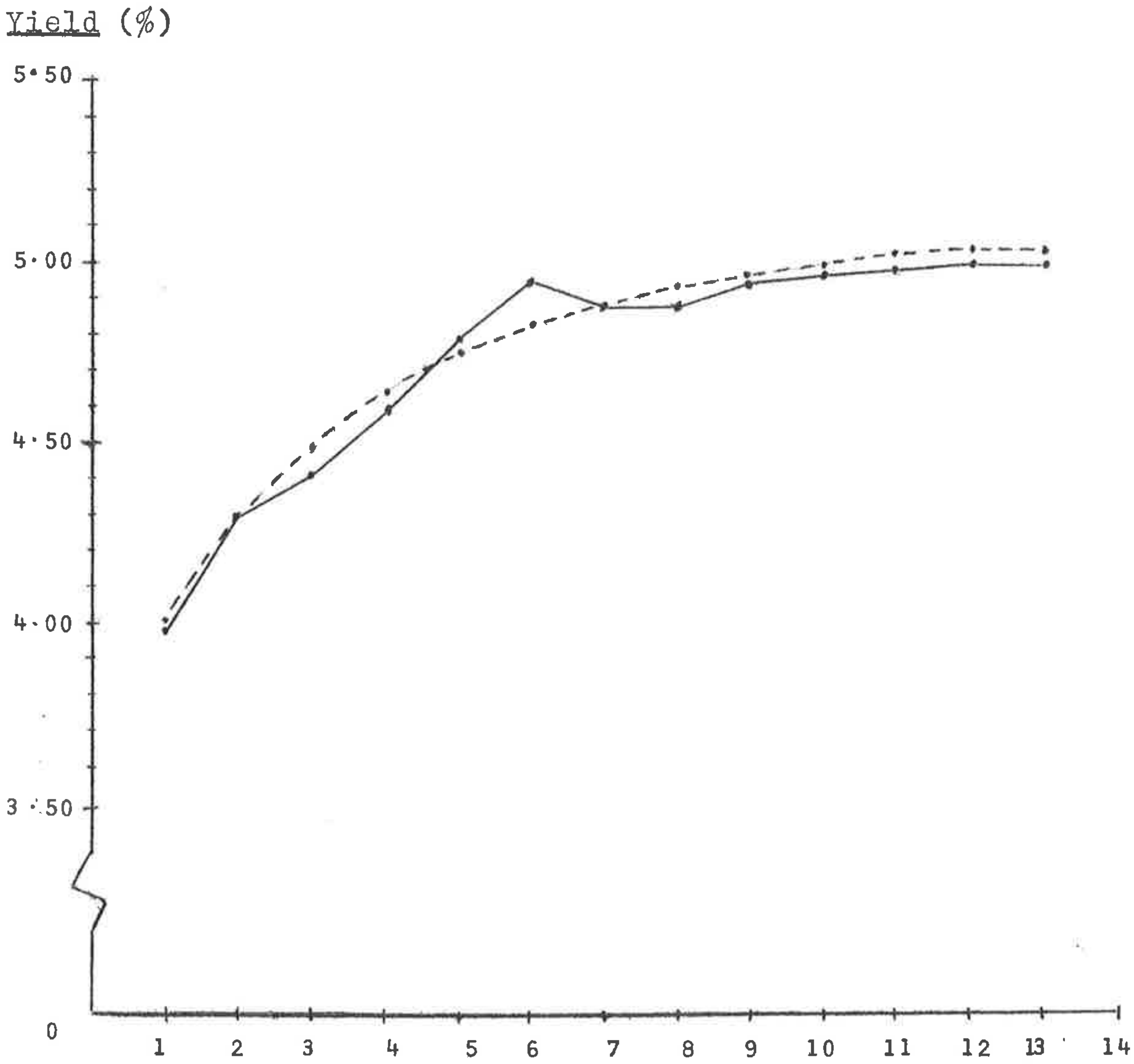


Term to Maturity (Years)

Figure 6.3

Yield Curves Constructed by Regression Analysis and Linear Interpolation

March 1958



Note: The regression analysis curve is represented by the broken line, and the linearly-interpolated curve by the solid line.

Figure 6.4

Yield Curve Constructed by Free-Hand Smoothing

March 1958

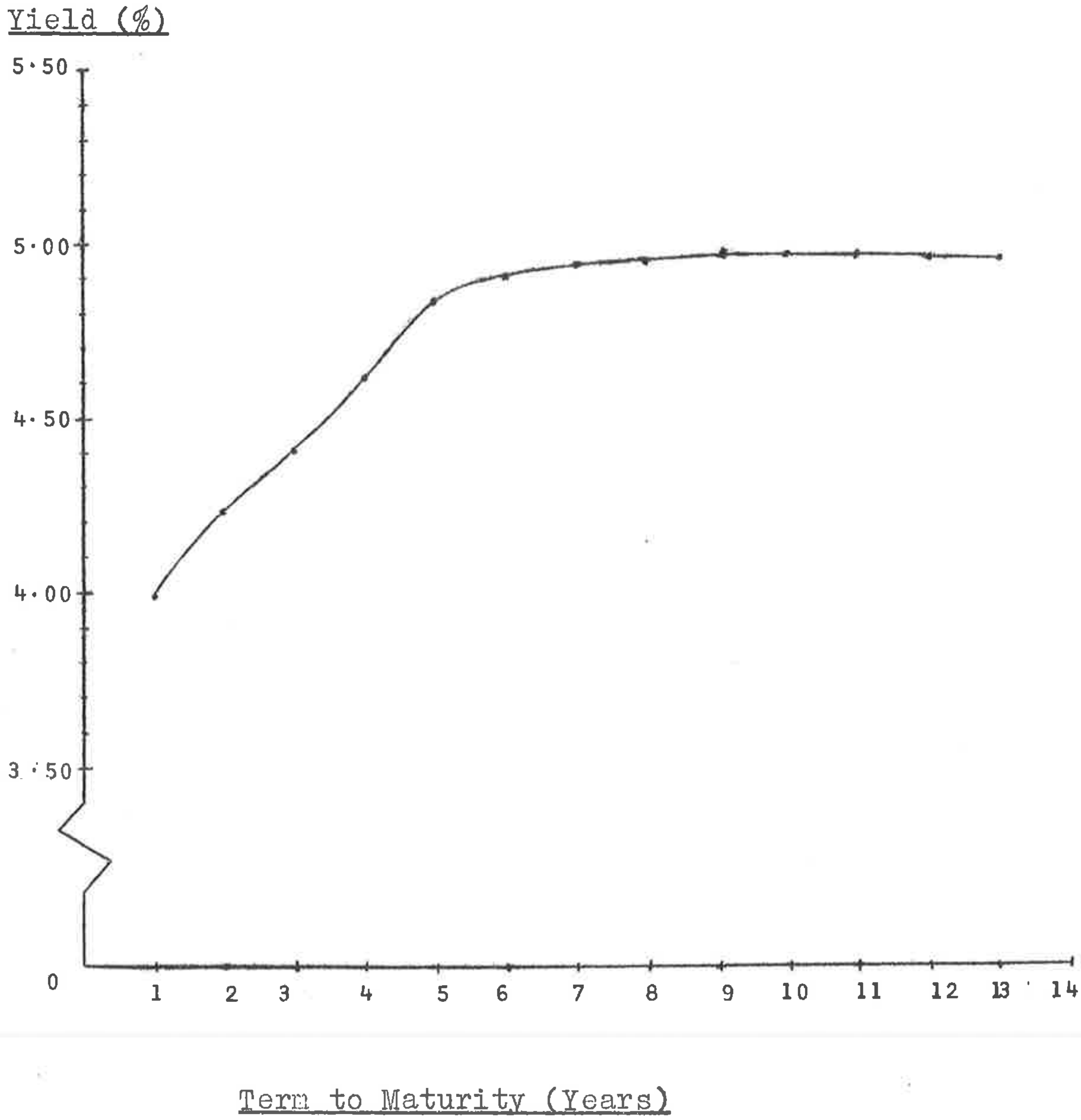
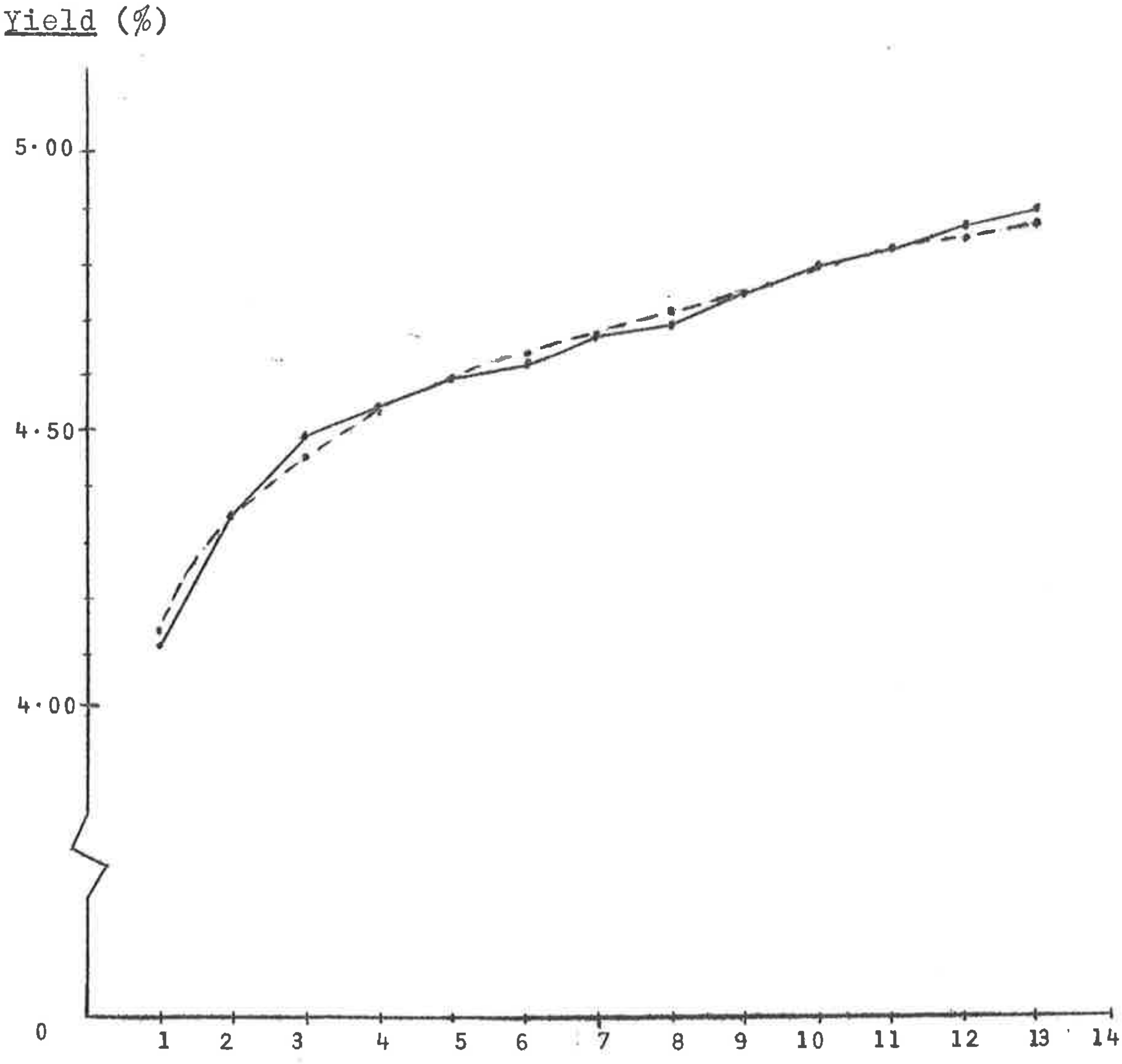


Figure 6.5

Yield Curves Constructed by Regression Analysis and Linear Interpolation

March 1962



Note: The regression analysis curve is represented by the broken line, and the linearly-interpolated curve by the solid line.

Figure 6.6

Yield Curve Constructed
by Free-Hand Smoothing

March 1962

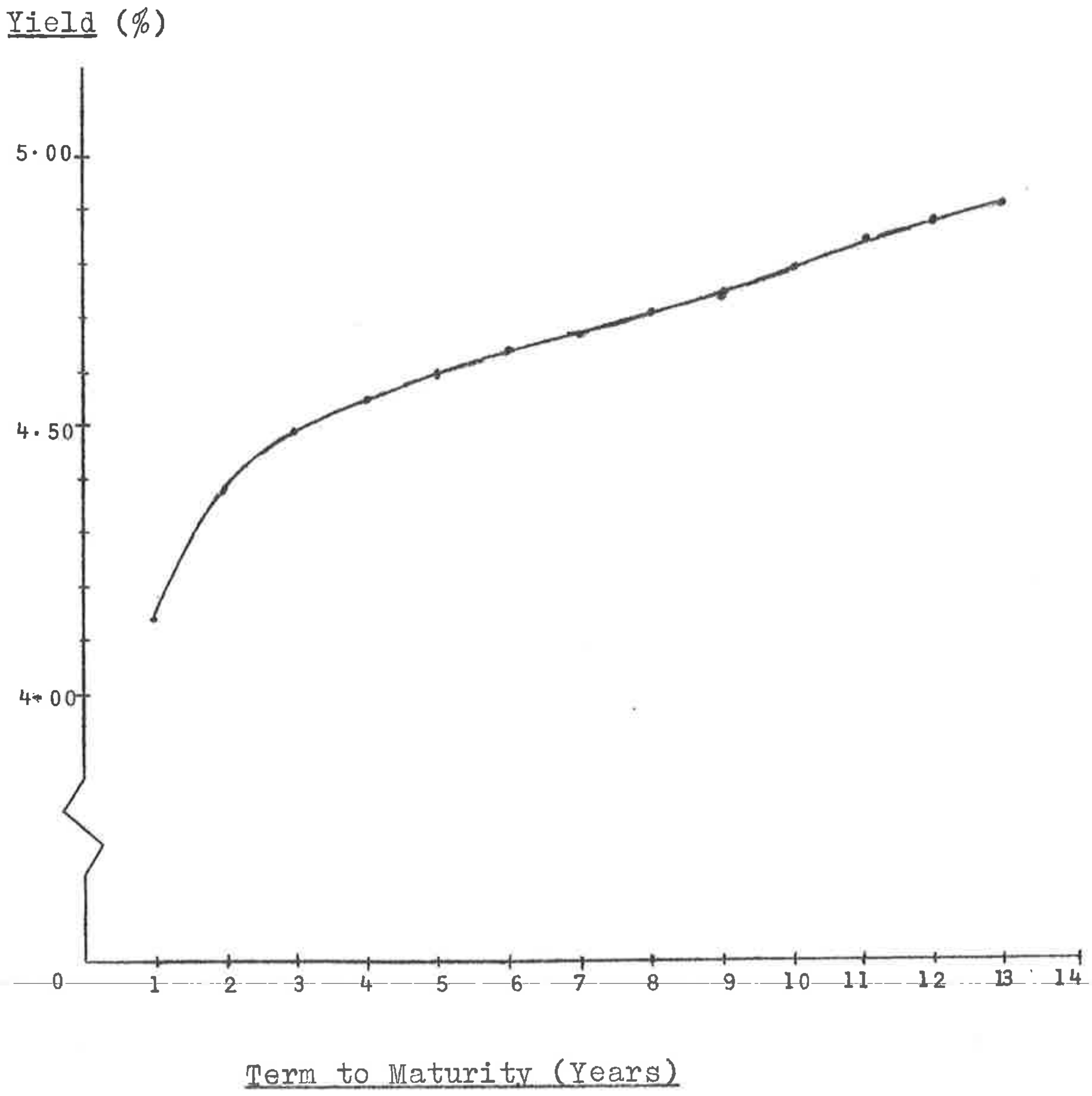
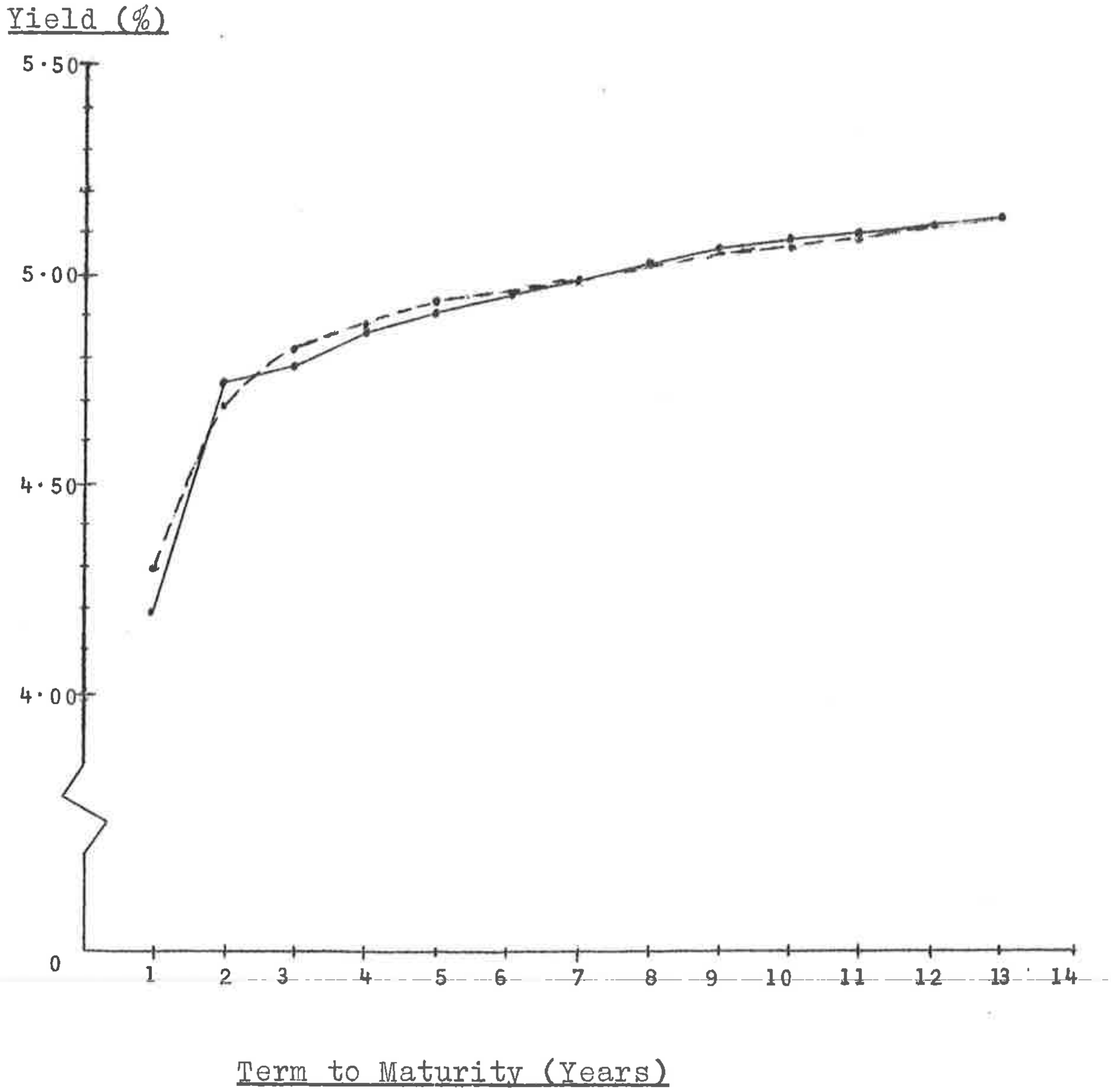


Figure 6.7

Yield Curves Constructed by Regression Analysis and Linear Interpolation

March 1968

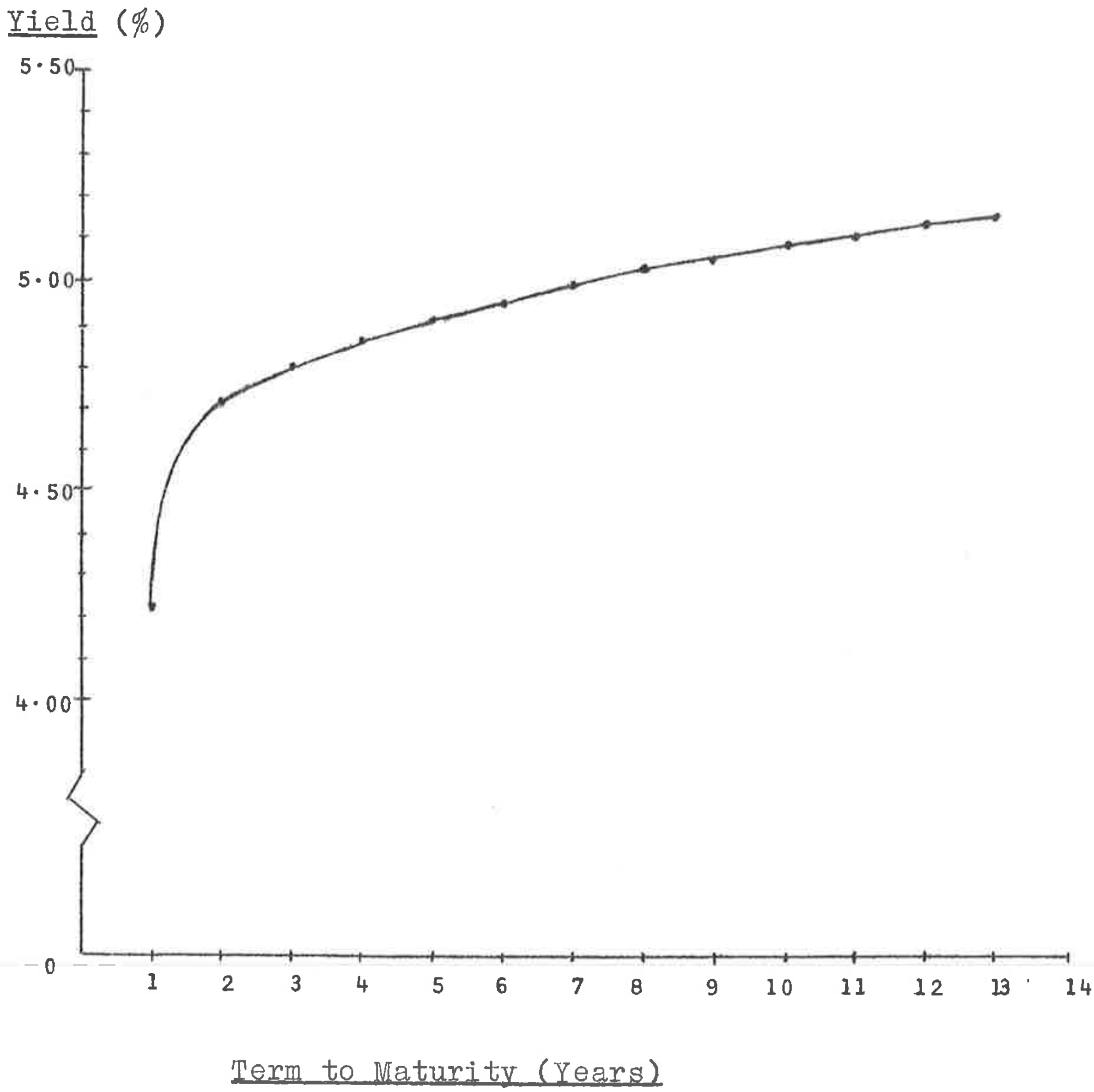


Note: The regression analysis yield curve is represented by the broken line, and the linearly-interpolated curve by the solid line.

Figure 6.8

Yield Curve Constructed by Free-Hand Smoothing

March 1968



It can be seen that the three types of yield curves become increasingly similar over the test period. Whereas the linearly-interpolated yield curves appear quite jagged early in the time-series, by 1968 they closely resemble the curves constructed by regression analysis. These results demonstrate the inadvisability of constructing yield curves in a manner that allows the curves to follow closely the raw observations, where these observations are known to contain errors of the first type and potential errors of the second type. In particular, the use of linear interpolation to construct yield curves for the earlier years of the time-series is most questionable.

It follows that the results of the tests of the error-learning model are more suspect <u>for these reasons</u>, when based on yield curves constructed by linear interpolation, than are those results based on curves constructed by regression analysis. Whether or not it can be concluded that the results from the latter tests can be held with more confidence <u>overall</u>, depends on the strength of Buse's argument that <u>any</u> smoothed curves that are used as basic data for the error-learning model will provide favourable results, provided only that short and long rates move together, with short rates showing the greater variability. This argument is examined in the following section.

6.3 Smoothed Curves and the Error-Learning Model

In chapter five above (see pp. 158-67) are reported the results of a test of the error-learning model using quarterly cross-section and time-series data. It will be recalled that the first observation (R_1) in two-thirds of the yield curves used for the test was obtained by extrapolation and so regarded as highly suspect as an estimate of the "true" value. If Buse's argument holds, then despite these suspect R_1 values, the test of the error-learning model should still have produced good results, because the data comes from a time-series of yield curves where short and long rates move together, and where the fluctuation is greatest in short rates. This can be seen from figure 7.2 on p. 214 below. However, as indicated in table 5.8, the results are very poor. It is argued, therefore, that these results are inconsistent with Buse's argument, and that they lend support to the validity of the error-learning model.

One further possible criticism of the error-learning model needs to be examined before it can be concluded that the model is a valid test of the traditional expectations theory. Wallace (1969), in criticising Buse (1967a), comments that the production of high values of the coefficients of determination in the tests run by Buse, may have been due primarily to the presence of the R_1 values in the forecast-error term of all the tests. That is, the explanatory power of the one-period spot rate alone may be sufficient to ensure high values of the coefficients of determination. If this is the case, it implies that the good results obtained from the error-learning model are not necessarily due to the type of behavior proposed by Meiselman.

Evidence concerning this matter is provided by the results in section 5.5 above (see pp. 167-75). In order to overcome the problems caused by the presence of suspect R_1 values in the quarterly data, the error-learning model was reformulated by employing a forecast-error term based on the one-year spot rate (R_4) rather than on the three-month rate (R_1), while leaving the dependent term expressed in terms of three-month forward rates (see equation 5.9 on p. 168). The three-month spot rate is still involved in the forecast-error term via the one-period forward rate (see pp. 166-67), but obviously its importance is much reduced compared with its influence in the forecast-error term used for the tests in section 5.5 (see equation 5.6 on p. 161).

According to Wallace's argument, minimising the influence of the R_1 values may well have resulted in poor results for the regression tests reported in table 5.9 (pp. 169-71). However, as discussed in section 5.5.4, the results give good support for the existence of the type of behavior that is postulated by Meiselman, especially when the influence of the central bank in Australia over the yield curve is recognised. Whilst minimising the influence of the R_1 values in the error-learning model is not sufficient evidence to invalidate Wallace's theory, as some spurious correlation may remain, these results do give some indirect evidence on the matter.

6.4 Summary

In this chapter the validity of the use of smoothing procedures for the construction of yield curves has been discussed. Evidence has been produced to demonstrate the advisability of smoothing when large errors of the first type and potential errors of the second type are present, as is the case with the early Australian data.

In addition, a criticism of the error-learning model by Buse (1967a) has been examined, and evidence produced that contradicts his argument. In particular, it has been shown that smoothed curves of the type described by Buse do not necessarily ensure good results from the model.

A further criticism of the error-learning model, this time by Wallace (1969), that good results from the model depend on the presence of R_1 values, is given an indirect test that throws doubt on the validity of the criticism. It is concluded that the ability of the model to give a valid test of the type of behavior proposed by Meiselman and by the traditional expectations theory, is supported by the evidence produced in this chapter.

CHAPTER SEVEN: LIQUIDITY PREMIUMS IN AUSTRALIAN YIELD CURVES

7.1 Introduction

In this chapter is presented a series of tests concerning the existence of liquidity premiums in Australian yield curves over the test period 1954-68. The traditional expectations model as outlined above (see pp. 116-20) postulates that forward rates are unbiased estimates of expected future spot rates. It will be recalled from chapter three above (see pp. 101-3) that Hicks (1939c) modified the traditional expectations theory in order to allow for the presence of liquidity premiums in the term structure.

Hicks suggests that liquidity premiums are an increasing function of term to maturity, and represent a compensation to lenders for the risk involved in lending money for other than the shortest period. That is, the longer the period for which a loan is made, the greater is the premium required to compensate the lender for the risk of unexpected changes in rates in the future. Because borrowers prefer long loans, the debt market suffers from a "constitutional weakness", a state where, with given expectations and an equality of short and long rates, there is an excess supply of long securities and an excess demand for short securities. Liquidity premiums will be paid on long securities in order to attract funds to the long end of the market. As a result, forward rates will no longer be unbiased estimates of expected future rates, but rather will overstate expected rates by an amount that reflects these positive liquidity premiums.

Hicks' theory of a "constitutional weakness" in debt markets is similar to Keynes'(1930) work on normal backwardation, whereby positive liquidity premiums again lead to an upward-sloping yield curve. Nevertheless, it is shown in chapter three above, that even if the debt market does display an aversion to risk, nothing can be said *a priori* about the *sign* of liquidity premiums unless the relative importance and length of definite compared with indefinite availability periods is known.

Ex post evidence concerning the existence of liquidity premiums in Australian securities markets is presented in the following tests.

7.2 Constant Terms in the Error-Learning Model.

The first test is based on the results of the regression tests of the error-learning model presented in chapter five. The existence of significant constant terms in the regression equation $\Delta_{t+j} r_{1,t} = a + bE_t$, may be evidence of the presence of liquidity premiums. If the revision in forward rates

$\Delta_{t+j}r_{1,t}$ contains a significant constant factor a which is independent of the error term bE_t, then the constant factor may reflect the presence of liquidity premiums. That is, if forward rate revisions do not respond solely to revealed errors in past forecasts, it implies that other factors besides expectations may be an important influence on forward rates. And if such a factor is constant when forward rates are revised in response to revealed forecast-errors, this factor may reflect the presence of liquidity premiums that are insensitive to revealed errors.

It can be seen from tables 5.1 to 5.3, 5.9 and 5.10 on pp. 141-3, 169-71, and 179-81 above, that all of the constant terms are positive. The absence of negative terms could be indicative of the presence of positive liquidity premiums. Furthermore, the constant terms are significant in the regressions relating to the shorter end of the yield curve. In table 5.10, for example, the first fourteen constant terms are significant. The first fourteen regressions relate to bonds of up to approximately four years to maturity. It is argued in chapter five above that this is the approximate area of the yield curve which has been most sensitive to private trading over the 1960-68 period. Therefore, forward rates derived from this section of the yield curve are most likely to reflect the investment behavior of private transactors as compared with that of the central bank.

Consequently, if liquidity premiums are present, they can be expected to show most clearly in the regressions relating to the first few years of the maturity spectrum, and this is the case with the results reported in table 5.10. A similar case can be made for the results reported in tables 5.1 to 5.3 and 5.9. The appearance of significant constant terms in table 5.9 for the last sixteen regressions is probably due to the problem of sampling fluctuations referred to in chapter five above (see pp. 174-75).

The finding of positive and significant constant terms supports the existence of positive liquidity premiums in Australian yield curves. Similar supporting evidence using both U.S. and U.K. data has been reported by Wallace (1964), Van Horne (1965a) and Buse (1967a). Meiselman's results (1962, p. 22), however, have both positive and negative constant terms, all of which are insignificant, but Wood (1963) has demonstrated that this is not <u>necessarily</u> inconsistent with the existence of liquidity premiums. The absence of significant constant terms, while necessary, is not sufficient evidence for the absence of liquidity premiums, as Wood shows that insignificant constant terms can be generated even where liquidity premiums exist.

In the next section, a test is carried out in order to determine whether these premiums are a function of term to maturity in the manner suggested by Hicks.

7.3 Average Yield Curve, 1954-68

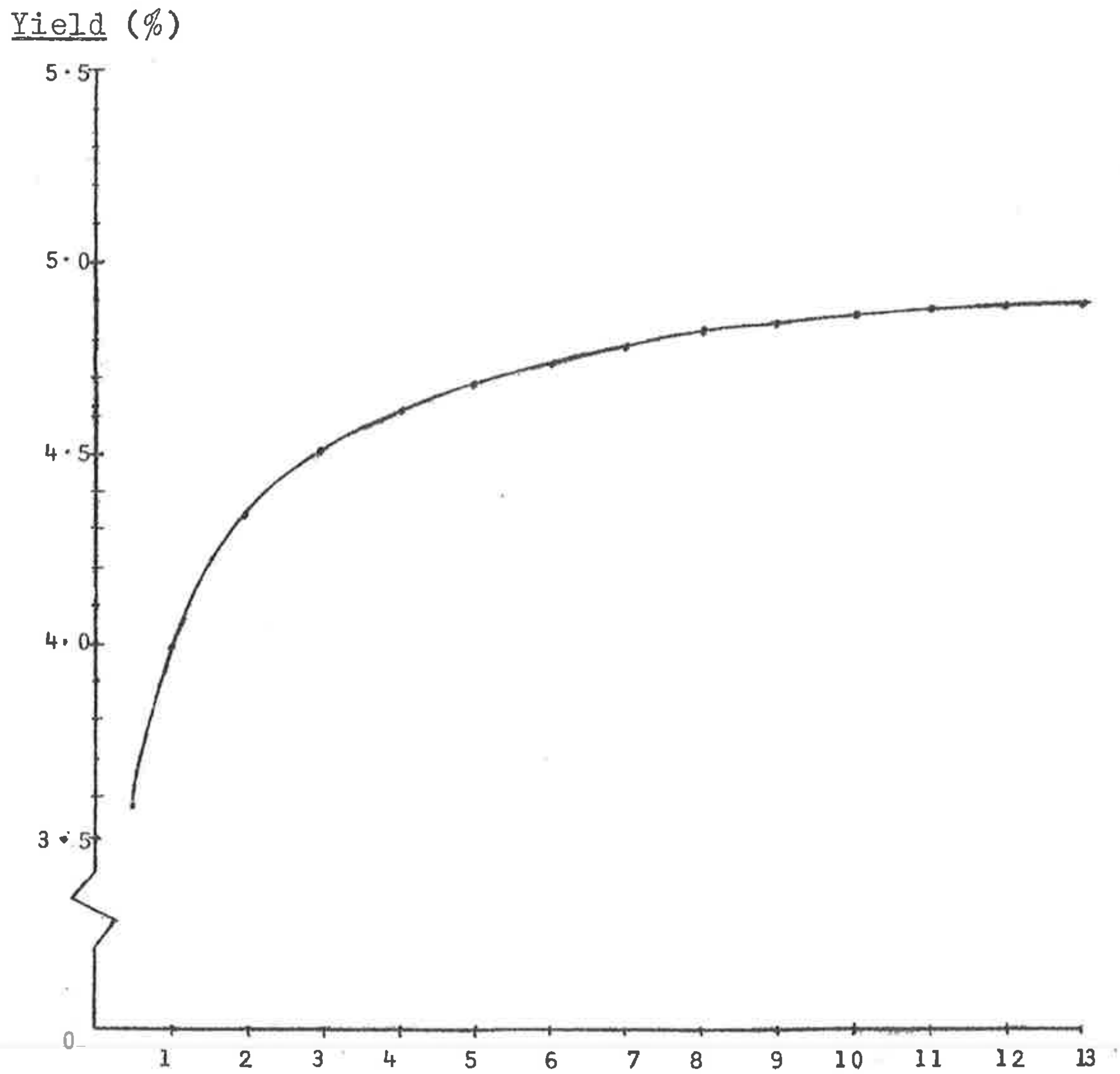
A test for liquidity premiums devised by Kessel (1965, pp. 17-18) is based on the shape of the average yield curve over the complete time-series. An average yield curve for the fifteen years from 1954 to 1968 is computed by averaging separately all the yields on one-year securities, two-year securities, and so on up to thirteen-year securities. The resulting yield curve is shown in figure 7.1.

According to the traditional expectations theory, an upward-sloping yield curve reflects the market's expectation that interest rates in general will rise in the future. With respect to figure 7.1, therefore, the explanation would be that for the period 1954-68 as a whole, the market had anticipated a rise in the general level of interest rates. A simple test of this proposition can be made by employing ex post data on rate movements over the period. The actual trend of rates is shown in figure 7.2 below, and neither the two-year nor the ten-year bond rate displayed any obvious upward trend over the period.

It could be argued, therefore, that to the extent that

Figure 7.1

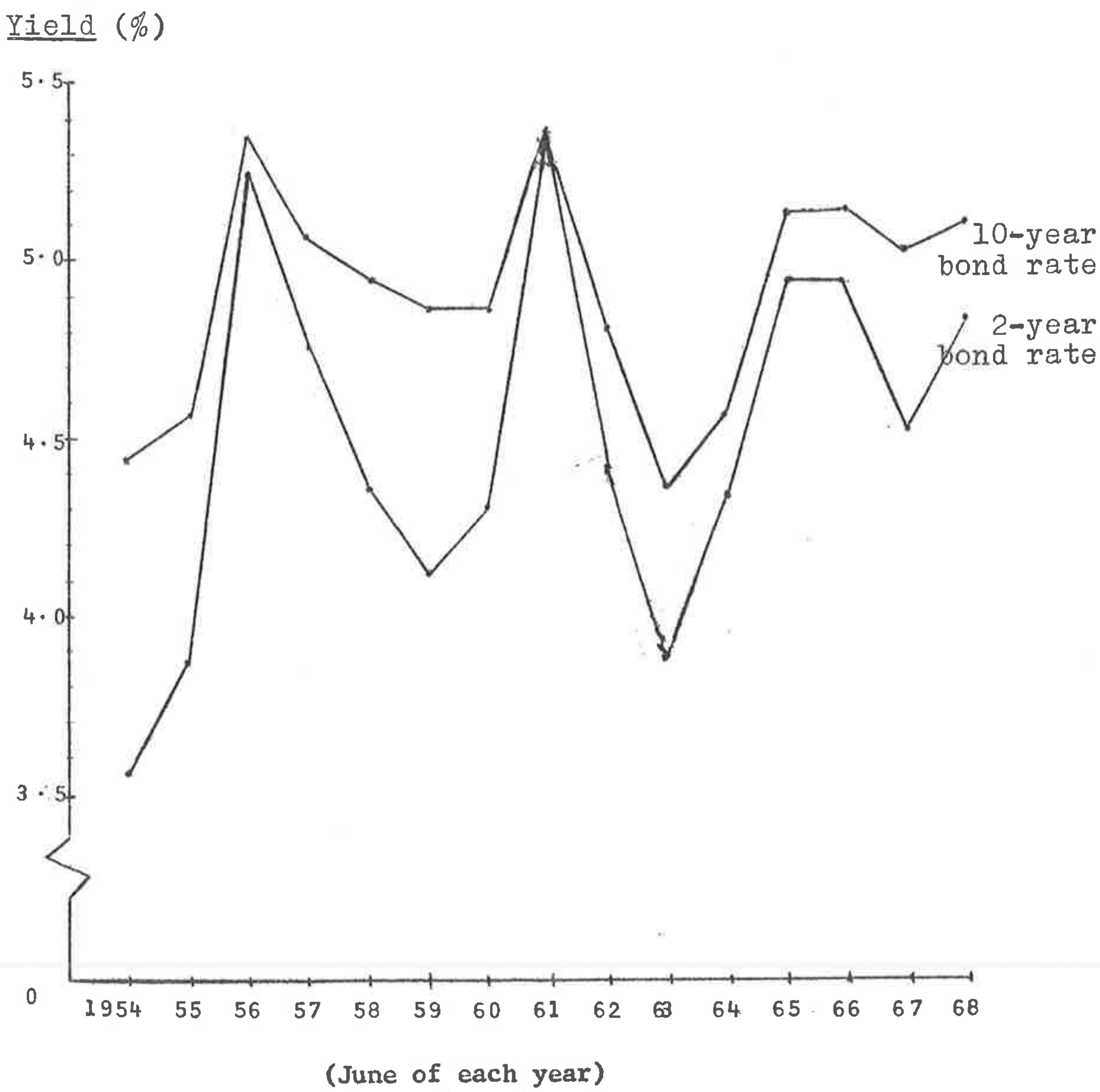
Average Yield Curve for the Period 1954-68
Regression Analysis Data



Term to Maturity (years)

Figure 7.2

Trend of Selected Interest Rates in Australia for the Period 1954-68



Source: Reserve Bank of Australia, Statistical Bulletin.

expectations of future levels of rates are based on recent past levels, figure 7.2 gives little support to the hypothesis that transactors expected a general rise in rates over 1954-68. An alternative explanation of the general upward-slope in figure 7.1 is that it is due to the presence of positive liquidity premiums, the premiums increasing in absolute size with term to maturity, but at a declining rate.

7.4 Forecast-Error Term Bias

Another test for liquidity premiums also based on Kessel (1965, pp. 18-19) concerns the frequency of high estimates of future rates as revealed by the forecast-error term in the error-learning model. If positive liquidity premiums exist, forward rates should be high estimates of future rates, so that the difference between forward rates (${}_{t}r_{1,t-1}$) and corresponding spot rates ($R_{1,t}$) will, on average, be positive. This means that the forecast-error terms should have significantly more minus signs than plus signs, and their average should be negative.

In table 7.1 is reported the forecast-error terms relating to the results in table 5.1 (p.141) based on equation 5.2 (p.140) ; the forecast-error terms for table 5.9 (pp. 169-71) based on equation 5.9 (p.168) are reported in table 7.2. It can be seen from table 7.1, that of the

Table 7.1

Forecast-Error Terms Relating to Table 5.1 (based on equation 5.2)

$t^{(a)}$	$R_{1,t}$	${}_t r_{1,t-1}$	$R_{1,t} - {}_t r_{1,t-1}$
1	0.0347	0.0419	-0.0072
2	0.0419	0.0494	-0.0075
3	0.0411	0.0538	-0.0127
4	0.0400	0.0489	-0.0089
5	0.0362	0.0455	-0.0093
6	0.0408	0.0421	-0.0013
7	0.0434	0.0473	-0.0039
8	0.0402	0.0498	-0.0096
9	0.0344	0.0450	-0.0106
10	0.0410	0.0391	0.0019
11	0.0461	0.0456	0.0005
12	0.0453	0.0510	-0.0057
13	0.0405	0.0509	-0.0104
14	0.0428	0.0466	-0.0038

(a) t represents the yearly observations from September 1955 to September 1968.

Table 7.2

Forecast-Error Terms Relating to Table 5.9 (based on equation 5.9)

$t^{(a)}$	$R_{4,t}$	${}_tr_{4,t-1}$	$R_{4,t} - {}_tr_{4,t-1}$
1	0.0295	0.0310	-0.0015
2	0.0299	0.0328	-0.0029
3	0.0304	0.0354	-0.0050
4	0.0294	0.0348	-0.0054
5	0.0336	0.0365	-0.0029
6	0.0347	0.0386	-0.0039
7	0.0351	0.0453	-0.0102
8	0.0383	0.0410	-0.0027
9	0.0421	0.0440	-0.0019
10	0.0419	0.0474	-0.0055
11	0.0406	0.0518	-0.0112
12	0.0427	0.0452	-0.0025
13	0.0438	0.0484	-0.0046
14	0.0411	0.0464	-0.0053
15	0.0402	0.0468	-0.0066
16	0.0402	0.0436	-0.0034
17	0.0403	0.0424	-0.0021
18	0.0400	0.0425	-0.0025

Table 7.2 (Cont.)

t [a]	$R_{4,t}$	${}_t r_{4,t-1}$	$R_{4,t} - {}_t r_{4,t-1}$
19	0.0386	0.0419	-0.0033
20	0.0364	0.0414	-0.0050
21	0.0373	0.0399	-0.0026
22	0.0362	0.0397	-0.0035
23	0.0369	0.0379	-0.0010
24	0.0392	0.0392	0.0000
25	0.0391	0.0411	-0.0020
26	0.0408	0.0410	-0.0002
27	0.0531	0.0440	0.0091
28	0.0523	0.0595	-0.0072
29	0.0496	0.0555	-0.0059
30	0.0434	0.0528	-0.0094
31	0.0408	0.0467	-0.0059
32	0.0415	0.0440	-0.0025
33	0.0414	0.0441	-0.0027
34	0.0402	0.0439	-0.0037
35	0.0386	0.0438	-0.0052
36	0.0386	0.0409	-0.0023
37	0.0351	0.0415	-0.0064
38	0.0344	0.0370	-0.0026
39	0.0343	0.0363	-0.0020

Table 7.2 (Cont.)

t [a]	$R_{4,t}$	${}_t r_{4,t-1}$	$R_{4,t} - {}_t r_{4,t-1}$
40	0.0342	0.0358	-0.0016
41	0.0394	0.0361	0.0033
42	0.0410	0.0436	-0.0026
43	0.0413	0.0435	-0.0022
44	0.0467	0.0443	0.0024
45	0.0460	0.0492	-0.0032
46	0.0461	0.0483	-0.0022
47	0.0458	0.0501	-0.0043
48	0.0461	0.0498	-0.0037
49	0.0451	0.0507	-0.0056
50	0.0453	0.0482	-0.0029
51	0.0412	0.0491	-0.0079
52	0.0409	0.0444	-0.0035
53	0.0410	0.0438	-0.0028
54	0.0405	0.0436	-0.0031
55	0.0419	0.0437	-0.0018
56	0.0431	0.0466	-0.0035
57	0.0437	0.0487	-0.0050
58	0.0428	0.0478	-0.0050

(a) t represents the quarterly observations from June 1954 to September 1968.

fourteen error terms involved, only two are positive, while the average error is -0.0063. Of the fifty eight error terms in table 7.2, only three are positive, while the average error is -0.0034. Both average error terms are significant at the 5 per cent level of confidence.

Meiselman argues that errors in forecasts do not necessarily contradict the theory that forward rates are unbiased estimates of future rates. Forecasts may be inaccurate yet still determine the term structure. However, there should be no mean bias present in that case, but a mean bias is revealed by the results in tables 7.1 and 7.2. This evidence may well be indicative of the presence of liquidity premiums.

7.5 Summary

In this chapter has been presented a series of tests for the existence of liquidity premiums in Australian yield curves. The conclusion reached is that positive liquidity premiums do exist, and that they increase in size with term to maturity, though at a decreasing rate. These results are consistent with the existence in Australia of a "constitutional weakness" in debt markets, especially when combined with the favourable results reported in chapter five concerning the importance of expectations.

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