# THE TERM STRUCTURE OF INTEREST RATES

# AND TREASURY BILL MARKET

# EFFICIENCY IN

# TANZANIA


By

ELLINAMI JOHN MINJA

Bachelor of Commerce
University of Dar es Salaam
Dar es Salaam, Tanzania
1991

Master of Business Administration
University of Nairobi
Nairobi, Kenya
1996

Certified Public Accountant
National Board of Accountants and Auditors
Dar es Salaam, Tanzania
1996



Submitted to the Faculty of the Graduate College of the
Oklahoma State University in partial fulfillment
of the requirements for the Degree of
DOCTOR OF PHILOSOPHY
December, 2003

THE TERM STRUCTURE OF INTEREST RATES

AND TREASURY BILL MARKET

EFFICIENCY IN

TANZANIA

Dissertation Approved

Dissertation Chair

Dean of the Graduate College

ACKNOWLEDGEMENT

This study has been made possible by a number of individuals and institutions to each of whom I am indebted and would like to express my gratitude. I owe my greatest debt to Dr. Frank Steindl, the chair of the dissertation committee for his invaluable assistance through guidance and constant advice. His many efforts, devotion of time and encouragement are highly appreciated. Special thanks go to the other members of the committee, Drs. James R. Fain, Thomas F. Gosnell, Jr., and Dr. Dan S. Rickman who read and provided input and guidance in preparing the drafts. My thanks also go to faculty and members of staff of the department of Economics and the University as a whole for creating and maintaining an enabling environment throughout my studies.

I am grateful to institutions that provided funds to support my studies: the Fulbright/IIE program; the Department of Economics at OSU; African Economic Research Consortium and the OSU Foundation. I am indebted Dr. Keith Willett, Dr. William Lyakurwa and AERC staff, and other officers and individuals in these organizations for their immeasurable kindness and assistance.

To my colleagues and friends especially Ng'wanza: You've always been around. To my family for understanding and sacrifice: Ritha, your love and support has been abundant through the ups and downs of life; Imani, and Sia, you have been a great source of inspiration. And to my parents, brothers and sisters for always asking, "When are you coming back?"

And for every step that I have taken in my life God has always been with me.

TABLE OF CONTENTS

LIST OF TABLES

Table Page



LIST OF FIGURES

Figure Page

**Nomenclature**

**Abbreviations and symbols**

| | |
|---|---|
| BOT | Bank of Tanzania |
| LSPY | Lowest Successful Price Yield |
| TZS | Tanzanian Shilling |
| WAY | Weighted Average Yield |
| $i$ | Nominal yield (or nominal interest rate) |
| $\Phi$ | Real yield (or real interest rate) |
| $\Pi$ | Inflation rate |
| $\theta$ or $\alpha$ | Term (or maturity) premium |

**Definitions**

| | |
|---|---|
| Forward inflation rate: | The ex-post inflation rate for the next $n$ periods |
| Headline inflation: | The change in the overall consumer price index covering both food and non-food prices. |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Studies on the term structure of interest rates have generally focused on two issues: (1) the slope of the yield curve and (2) whether long-term instruments attract a maturity premium over the short-term instruments. In some studies attempts have been made to use the term structure of interest rates to test for market efficiency – specifically for government securities (Hambuger and Platt (1975), Phillips and Pippenger (1976), Pesando (1978, 1979), Mishkin (1980) and Godbout et al (2002)). The argument for using the term structure to test for market efficiency is that if a data set is consistent with a given term structure theory, then the market producing that data is efficient. The ability of a data set to support the theory is assessed in terms of the presence of a term premium and/or a slope significantly different from zero. While a significant slope is amenable to other factors such as the trend of the economy, a significant term premium does not necessarily offer sufficient evidence to accept most of the term structure theories.

In the absence of a biased relative demand between short- and long term instruments, the premium is solely accounted for as compensation to the buyers of long-term instruments for loss of liquidity and uncertainty over the life of the instruments. However, the premium may be absent in the presence of a well-developed secondary market where there are no transaction costs – as assumed in most studies.[1] This is because

[1] A study by Shen and Starr (1998) suggests that modeling the term structure of interest rate will reveal the existence of a term premium if transaction costs are explicitly incorporated in the modeling process or that, in

the holders can easily obtain liquidity by selling the instruments in this market. These two features – the ability of the secondary market to minimize the liquidity risk and the assumption of no transaction costs – are common in most studies since they use interest rates based on yields to maturity for debt instruments in the secondary market. Even where primary market yields are used, such as in Godbout et al. (2002), the instruments do end up being traded in the secondary market since they are quoted in this market.

Though government securities – on which the term structure of interest rates is generally based – have secondary markets in most countries, there exist a number of economies, particularly in the developing world, where they do not have an organized secondary market. On the other hand, while the auction systems in these economies are comparable to those where secondary markets exist, very little exists in the literature on the structure of the yields from primary market in these economies and whether these markets are efficient.

One implication of using primary market data, in the absence of secondary market, is that the primary market may be generating limited information to test for market efficiency. For example, while it is possible to have yields to maturity or holding period returns based on daily prices observed in the secondary market, primary market auctions, and hence the observed yield, are held once a week or even less frequently. In addition, with the presence of a secondary market, several prices are observed for each issued instrument, but only one price – that obtained in the auction – is observed when there is no secondary market. All these factors create the need to use additional information that is not directly accrued to the market to test its efficiency. Fama (1975) and Carr, Pesando

---

reality, transaction costs do not exist. The latter is likely to be the case in a situation where there is no secondary market since investors are expected to hold the instruments until they mature.

and Smith (1976), among others, have used the relationship between inflation expectations and nominal interest rates for this purpose. Fama (1975) argues that

> "... If the inflation rate is to some extent predictable, and if the one-period equilibrium expected real return does not change in such a way as to exactly offset changes in the expected rate of inflation, then in an efficient market there will be a relationship between the one-period nominal interest rate observed at a point in time and the one-period rate of inflation subsequently observed. If the inflation rate is to some extent predictable and no such relationship exists, the market is inefficient: in setting the nominal interest rate, it overlooks relevant information about future inflation" (pp.269).

One condition that enhances inflation predictability is a central bank that primarily focuses on inflation targeting.

### 1.2 Statement of the Problem and Objectives of the Study

It can be argued that the pricing process of treasury securities in the primary market and hence the nature and structure of the yields are different from situations where the securities have secondary markets. Theoretically, the most obvious effect of the absence of a developed secondary market is the presence of greater liquidity risk. The fact that investors hold securities until they mature and hence incur no transaction costs implies that when there is no secondary market, the yields obtained in an efficient primary market display term premia that are statistically significant. In addition, where inflation targeting exists, these yields are also expected to reflect inflation expectations.

This study examines the pricing process of treasury bills in Tanzania and how it is related to the term structure of interest rates and the notion of market efficiency. It uses the biased expectations theory of the term structure of interest rates and the theory of market efficiency to derive a representation of the behavior of the yields to maturity obtained from Treasury bill auctions. The understanding of market efficiency and investors' rationality is enhanced by an examination of how the yields are influenced by inflation expectations. The study addresses and tests two main issues:

1. Using yields from treasury bills auctions to estimate the parameters of the term structure of interest rate models and test for market efficiency.
2. Modeling the yields to establish whether they reflect inflation expectations.

Both the yield-to-maturity obtained from the lowest successful price bids (LSPY) and the yields based on weighted average price (WAY) are used separately to establish which yield produces more satisfactory results.

The study focuses on the short end of the maturity spectrum of the term structure of interest rates with the yields and inflation rates covering periods of not more than one year. Shorter-term yields have been viewed as being more reliable indicator of markets' expectation and having the advantage of conforming more closely to the likely policy horizons of central banks (Browne and Manasse, 1989). These issues are addressed and tested using yields obtained from the results of weekly Treasury bill auctions for three maturities – 91-days, 182-days and 364-days – as well as three- and six-months inflation rates.

## 1.3 Significance of the Study

The general significance of this study derives from its introduction and use of a new set of data in understanding the term structure of interest rates and testing for primary market efficiency. The data are also different in the sense that they come from a situation where treasury bills do not have secondary market and the central bank employs inflation targeting. While the Bank of Tanzania (BOT), which is the central bank of Tanzania, has been auctioning treasury securities since 1993, there has not been an organized secondary market for the securities[2]. On the other hand, monetary policy in Tanzania is geared towards monitoring inflation with inflation targeting being the central bank's primary policy objective since 1995.

Of particular significance is the use of the yields to maturity obtained from the lowest successful price bids (LSPY) and comparing the results with those from the yields based on weighted average price (WAY). The BOT uses a discriminatory pricing auction system where successful bidders pay their respective bid prices which makes the WAY the reported market yield. The WAY is the yield implied by the weighted average price obtained in a particular auction, which in turn is computed by weighing all successful bid prices by their respective amounts. With discriminatory pricing system bidders obtain different yields: those quoting the lowest successful price obtain the highest yield in a particular auction while those quoting the highest bid price end with the lowest yield. The former group quotes a price that is "just right" to ensure an allocation while the latter is quoting a price that is "too much". It may be argued that bidders quoting the lowest successful price, and hence earning the LSPY, are likely to be the better-informed traders.

They also seek to exploit any arbitrage opportunities arising from existence of market imperfections, which, in the long run, enhances market efficiency. Thus, the LSPY may be of greater consequence in testing for market efficiency and may also reflect more satisfactory inflation expectations than WAY. In this study both the LSPY and WAY are used to estimate the parameters of the term structure of interest rate equations and modeling the yields to establish whether they reflect inflation expectations. A comparison is then made for the results from the two yields. This approach is somehow different from the one used in a study by Godbout et al. (2002) who also used the yield obtained by the lowest successful price but in a different context. In their study, they used the dispersion between the yield obtained by the lowest and highest prices to examine whether there is a link between the dispersion and the term structure model. They found that the term structure model was likely to fail in weeks where yields are highly dispersed and, in their view, this "lend credence to the belief that something unusual happens to the [Canadian] Treasury bill market whenever there is a large degree of dispersion in auction yields" (p. 9). Since the dispersion is a product of both lowest and highest prices, this study focuses on one aspect of the dispersion and assesses its link with the term structure model.

To the BOT, this study serves as an initial assessment of their auction system which uses discriminatory prices, rather than a single uniform price, in allocating securities to bidders. The results on market efficiency can be used as a basis for analyzing the integrity of the auction process and whether there is a need to revise the rules governing the auction of the securities. In general, the exploratory nature of the study forms the basis for

---

[2] A decision was made in 2002 to list government securities – both treasury bills and bonds – in the Dar-es Salaam Stock Exchange. So far, the process is not yet complete.

understanding the term structure of interest rates in Tanzania and open the door for more researches in this area.

## 1.4 An Overview

This dissertation consists of five chapters. The preceding discussion in this first chapter involves background information to the study, the statement of the problem, the objectives of the study and the importance of the study. The second chapter provides a review of the pertinent literature to the study. Attention is paid to the information content of the term structure of interest rates, modelling of the term structure, the relationship between nominal interest rate and inflation expectation as well as the use of the term structure model and the Fisher hypothesis to test for market efficiency. In this chapter a review of some previous results is made as well as giving an overview of the institutional characteristics of the Treasury bill market.

The third chapter discusses the research design used in the study. It focuses on developing the equations to be estimated and the data used in the study. Chapter four covers data analysis, the findings and their interpretation. The last chapter gives a conclusion and summary of the discussion. The chapter also highlights the limitations of the study as well as suggesting areas for further research.

CHAPTER 2

# LITERATURE REVIEW

## 2.1 The Information Content of the Term Structure of Interest Rates and Market Efficiency

In general, the term structure of interest rates focuses on the relationship between short term and long-term interest rates assuming constant individual risk. Holding individual risk constant is achieved by using government securities. Understanding the term structure of interest rates for a particular economy serves a number of purposes. First, the term structure is important in describing the transmission mechanism of monetary policy. Godbout et al. (2002) argue this from the view that the monetary authorities have the greatest influence over the shorter-term interest rates (through policy instruments such as open market operations and repurchase agreements) than the longer-term rates. On the other hand, it is the longer-term rates that are more relevant to investment and consumption decisions. Thus, the term structure provides for the link between the policy instruments used by monetary authorities and longer-term rates and in turn the link with investment and consumption. It is important, however, to bear in mind that different theories of the term structure have different implications on whether the link between monetary policy and any particular long-term interest rate holds and how direct the link is. Engsted (1994), for example, points out that if the expectations hypothesis of the term structure holds, there is a stable one-to-one relationship between short- and long-term interest rates. This implies, for instance, that while the monetary authority can change the short- and long-term interest rates by altering the relative supplies of short- and long-term bonds, this will not permanently 'twist' the relationship in the term structure.

A second point in the use of the term structure of interest rates is as an alternative indicator of monetary policy. The suggestion that there may exist some problems in interpretation of monetary aggregates in some countries (Browne and Manasse, 1989) makes monetary aggregates less reliable indicator of monetary policy. As a result, the term structure of interest rates is used in addition, or as an alternative, to monetary aggregates in gauging monetary policy.

A third significance is related to the first two and it arises from empirical evidences linking the term structure with economic variables such as interest rates, inflation, and economic activity. While there is a relationship between the term structure and the trend of the economy (Gray, 1973; Luckett, 1967; and Campbell, 1995) it has been found that the term structure is a useful predictor of inflation (Mishkin, 1990; Frankel and Lown, 1994), real economic activity (Estrella and Hardouvelis, 1991; Harvey, 1997); and future short-term interest rates (Mankiw, 1986; Campbell and Shiller, 1987, 1991; Mishkin, 1988). On the ability of the yield curve to forecast real economic activity, studies in the US and Canada indicate that the yield curve forecasts economic growth more accurately than models based on time series or on the index of leading indicators (Harvey, 1997). A steeper yield curve implies faster future growth in real output while a flatter yield curve implies slower future growth in real output (Estrella and Hardouvelis, 1991). A study by Mishkin (1990) found that at longer maturities, the term structure of interest rates could be used to help assess future inflationary pressure. This was despite some of the data rejecting the Fisher effect and even indicating – in some cases – a negative correlation of the slope of the real term structure with the slope of the nominal term structure. Similar results, with some improvement in the predictive power, have also been observed on shorter maturities ranging from 3 to 12 months (Frankel and Lown, 1994).

Finally, analyzing the term structure of interest rates using yields from auctions is important for regulatory purposes, the choice of the auction system as well as serving as one of the indicators of the integrity of the auction process and hence market efficiency. The latter derives not only from the fact that market participants seek to exploit arbitrage opportunities that may be present between different maturities but also that markets are occasionally subject to "squeeze" and manipulations. A paper by the Bank of Canada (1998) points out the extent to which "... specific issues [of government securities] trade off of the theoretical yield curve" as one of the indicators of a possible squeeze in the market. Thus, where the yield curve deviate significantly from its theoretical path, there may be a need to look at the market's regulatory framework. One example is when the U.S. the Treasury began to experiment with uniform-price auctions, in early 1990s, to address the problem of possible collusion among bidders. And when a decision was made in 1998 to switch from discriminatory price system to uniform price, it was argued that the aim was to make some improvements in the efficiency of market operations based on a study showing that the new system produces a broader distribution of auction awards (Pulizzi and Nicholson, 1998).

## 2.2 The Term Structure of Interest Rates and Market Efficiency: Theoretical Models

### 2.2.1 Modeling the Term Structure of Interest Rates

To understand better the approach to be used in testing the issues in this study, a summary of literature related to modeling the term structure of interest rates and testing for market efficiency is presented. These two aspects are essentially interrelated since the test for market efficiency is also based on a particular model of the term structure of interest rates. The basic hypothesis in the structure of interest rates is that it is primarily determined by expectation of the future course of short-term interest rates. This is the essence of the expectation theory and its derivatives. It hypothesizes that the yield on a long-term instrument is some average of the current one-period rate (the short-term rate) and short-term rates expected to occur over the life of the long-term instrument. Technically the expectation theory implies that the expected gross annual yield for a long-term instrument equals the geometric average of the gross yields for short-term instruments. This can be presented as

$$(1+I_{n,t})^n = (1+i_{1,t})\prod_{j=1}^{n-1}(1+E_t i_{1,t+j}) \qquad (2.1)[3]$$

Where $I_{n,t}$ is the yield for an instrument with $n$ period maturity at time t,

$i_{1,t}$ is the yield for a one period instrument at time t, and

[3] For consistency $i$ is used to denote nominal yield, and $\Pi$ the inflation rate. In addition the terms yield, rate of return and interest rate will be assumed to have the same meaning.

$E_t i_{1,t+j}$ is the expected yield for a one period instrument in period t+j.

The "expected" yields are used since future short-term yields are unobservable at time $t$ but it is assumed that market participants estimate them with some degree of accuracy. In addition $E_t$ indicates that this expectation is formed at time $t$ based on relevant information available to the market participants at this time. The equation above represents the pure (unbiased) expectation theory and is based on two assumptions. First, investors view all securities that have the same liquidity, risk, information costs, and tax treatment as perfect substitutes. This implies that investors care about returns but not the length to maturity. Secondly, investors are able to re-invest the proceeds from short-term obligations at the expected (future) short-term rate. The two assumptions imply that for a given holding period, investors starting with the same initial investment end with the same terminal value irrespective of the length to maturity of the securities they hold. They also imply that there are no systematic arbitrage opportunities in the market. Equation (2.1) can be written in logarithm form as

$$n\ln(1+I_{n,t}) = \ln(1+i_{1,t}) + \sum_{j=1}^{n-1}\ln(1+E_t i_{1,t+j}) \qquad (2.2)$$

In general, for a value $i$ that is small relative to 1, $\ln(1+i)$ is approximately equal to $i$. Since interest rates are generally small relative to 1, this approximation gives

$$I_{n,t} = \tfrac{1}{n}(i_{1,t} + \sum_{j=1}^{n-1} E_t i_{1,t+j}) \qquad (2.3)$$

This approximation is widely used in term structure studies (from the earlier work of Meiselman, 1962) and does not seem to affect the results.

In reality, however, instruments of all maturities may not have identical liquidity and risks and may, in fact, appeal to different groups of market participants. Consequently the general representation found in most literature is that the holding-period returns for instruments of different maturities differ by a constant premia. This extends equation (2.3) to;

$$I_{n,t} = \tfrac{1}{n}(i_{1,t} + \sum_{j=1}^{n-1} E_t i_{1,t+j}) + \theta \qquad (2.4)$$

Where θ is a constant term premium

While it is prudent to assume that this premium varies monotonically with the length to maturity, it is often assumed that for a given maturity, the premium is constant. This has been a very important assumption in testing for the plausibility of the theory and the existence of market efficiency (see, for example, Hamburger and Platt, 1973; Phillips and Pippinger, 1976; Pesando, 1978 and 1979; and Godbout et al. 2002).

In general, equation (2.4) represents biased expectations and identifying it with a particular term structure theory depends on how to account for the premium. Cox et al. (1981) is perhaps the most prominent work that has attempted to explain the expectation theory from different viewpoints based on at least three distinct propositions. Other studies have adopted more restrictive approaches: Mishkin (1980) accounts for the premium based on the existence of preferred maturity aspect only; Roll (1970) terms the relationship 'stationary variant of the market segmentation hypothesis'; Modgliani and Shiller, (1973) consider the relationship a variation of the expectations theory that recognizes the presence of a term premium; and Meiselman (1962) views it as the expectations theory that depends on risk aversion. The many different versions of expectations theory are partly responsible for problems encountered in the interpretation of empirical works on the term structure theories. In this study, both liquidity preference and market segmentation are considered the main factors behind the premium and the theory is simply referred to as a biased expectations theory. The postulate in the biased expectation theory used here, and flowing from the works cited above, is that each market participant has a preferred maturity, liquidity, risk tolerance, and tax exposure – in other words, habitat – for securities. With government securities having zero default risk and assuming no tax treatment differentials, the premium in the term structure is only based on preference for liquidity and/or instruments of a particular maturity. Thus, the premium is explained by two sub- theories – the expectations with liquidity preference and the existence of preferred maturity. The expectations with liquidity preference aspect believes that the term structure reflects the expectation of the future path of interest rates as well as liquidity premium. The liquidity premium recognizes that there is a price risk associated with long-term instruments and market participants must be compensated for assuming this risk. Hicks (1946) is probably the first author to discuss the liquidity preference side of the premium. He argued that since borrowers typically undertake long-term projects they prefer to issue long-term securities so as to hedge against the risk of fluctuating in interest costs and probably to take advantage of the increased flexibility resulting from using funds borrowed on long-term basis[4]. On the other hand, lenders prefer to hold short-term securities to maintain liquidity and avoid the fluctuation in portfolio value associated with holding long-term securities. Thus, investors prefer to hold short-term instruments (with a low expected return) but will hold long-term instruments if they are paid a premium to compensate for the loss of liquidity.

[4] This should not be considered as a very important argument in the term structure since the term structure uses yields on instruments issued by the government, which has objectives that are sometimes different from that of a private borrower.

Conversely, borrowers are willing to pay a premium for the longer liquidity and increased flexibility in using funds borrowed on long-term basis. Long-term instruments are also viewed as poorer money substitutes hence calling for higher yield to compensate for the 'non-pecuniary' return earned by short-term instruments when serving as money substitutes. With liquidity preference being considered independently, the premium in equation (2.4) is always positive and it rises monotonically with the term to maturity.

Accounting for the premium based on the preference for a particular maturity originates from Modigliani and Sutch (1966) who viewed the premium as a reflection of the time dimension of the investment objective. That is, the rate of time preference or desire to consume at a particular point of time determines the investment horizon of investors which, in turn has a major influence on the term premium. A latter refinement by Cox et al. (1981) considers risk aversion rather than the time dimension as the key determinant. In both, the general argument is that market participants have a range of maturities – as determined by risk aversion attitude or the time dimension of investment objective – in which they prefer to operate. The preferred maturity ranges, or habitats, affect the demand and supply of instruments of different maturities. Assuming discrete and non-overlapping maturity ranges[5], the relative demand position in a given maturity segment determines the yield for the instrument of that particular maturity. In the presence of excess demand in a given segment, a risk premium is needed to induce market participants to move from their preferred habitat to "less preferred" habitat, hence bringing about equilibrium in all market segments. Thus, with the premium being determined by the market forces – in relative terms – its sign in equation (2.4) can be

[5] This is the key assumption that distinguishes Modigliani and Stuch's view from Hicks'. Hicks argued that the maturity ranges overlap so that there is a continuum of excess demand for funds along the term axis.

positive or negative. If, for example, buyers have a strong preference for long-term instruments while sellers' preference is predominantly in short-term borrowing, then the relative demand for short-term instruments is lower than the one for long-term instruments. In this situation short-term instruments would presumably attract a premium to account for the uncertainty that the buyers are exposing themselves to by buying short-term rather than long-term instruments. The implication of the preference for a particular maturity is that the shape of the yield curve is affected by changes in the supply and demand for instruments of a particular maturity. It is worthwhile to note that the two aspects of the preferred habitat theory are not unrelated. For example, if buyers have a strong preference for short-term instruments while sellers' preference is in issuing long-term instruments, the preferred maturity aspect results into excess demand in the short-term instruments and consequently long-term instruments having a yield premium over short-term instruments. On the other hand a strong preference for short-term instruments implies that they are more liquid than long-term instruments hence justifying the premium based on the liquidity preference theory.

With the two aspects of the preferred habitat theory implying that the sign of the premium is not determined unambiguously the question here is: What is the most likely sign when equation (2.4) is modeled using yields from the primary market? It has to be noted that two conditions have to be satisfied for the premium to be negative. First, the relative demand for long-term instruments has to be *higher* than the one for short-term instruments creating excess demand for long-term instruments. Secondly, the risk premium that buyers demand to move from their preferred long-term maturity range to short-term maturity outweighs the liquidity premium that short-term instruments attract over long-term instruments. The absence of the second condition means that the liquidity premium is dominant while the absence of the first condition means that the premiums resulting from liquidity preference and the existence of preferred maturity range reinforce each other. In both situations a positive premium results. In this study it is hypothesized that long-term instruments command a premium over short-term instruments (i.e. $\theta$ in equation 2.4 is positive) and that this premium is significantly different from zero. This hypothesis is based on some arguments and assumptions. First, it has often been argued that the liquidity part account for most of the premium particularly for treasury bills. For example, using the bid-ask spread as a proxy for liquidity premium, Shen and Starr (1998) show that the liquidity premium is priced in the bill market and account for a substantial portion of the term premium, sometimes to the exclusion of a risk premium in the term structure. With the liquidity premium being the dominant component it is likely that it will offset any negative premium arising from existence of a biased relative demand. Second, assuming that market participants have a preference for a particular maturity, the premium arises only when there are relative demand imbalances in the markets. However, if there are very large relative demand imbalances the yield curves may not give the correct information about the future course of short-term interest rates – a potential for the breakdown of the term structure relationship. Also, in the absence of "abnormal" market or economic conditions such as recession and a prolonged biased risk preference, primary markets for government securities can be assumed to experience a balanced relative demand particularly since the supply is assumed to be fixed: and even when there is excess demand for one maturity segment such phenomena is unlikely to exist for a prolonged period of time. This is in line with findings that segmentation effects seem to be sufficiently small (Browne and Manasse, 1989) and may imply that, taken on its own, the effect of preference for a particular maturity does not lead to a significant term premium. This is even more critical in the treasury bill market where the deviation – measured in time – that market participants take from their preferred maturity is small. As a result, the premium asked for a switch, say, from six-months to three-months, is also likely to be very small. Thus, the biased expectations hypothesis used here postulates that the term premium is positive and is time invariant.

### 2.2.2 Expectations Formation and Rational Expectations

The key issue in equation (2.4), which has taken central stage in modeling the term structure of interest rates, is how the expectations on future short-term interest rates are formed. Expectations are not directly observable though they are generally viewed as being formed on the basis of available information. However, the nature of this information and whether direct data exist to compute market participants' expectations make it difficult to formulate explicitly a model for expectation formation. Consequently, the type of information and the way it is incorporated in the term structure modeling process has evolved over time.

The early studies considered short-term interest rates expectations based on past short-term interest rates and explicitly incorporated this in the modeling process (Modigliani and Sutch (1966), Modigliani and Shiller (1973), and Dobson et al (1976)). Nelson (1972) decomposed expectations into two components. The first is the expectation conditional on the history of the spot-rate sequence while the second is a random disturbance. In effect, the latter component represents information other than that from historical spot rates. From Nelson's general proposition, variants of interest rate expectations can be inferred. For example, expectations for one-period interest rate one period into the future could take the form $E_t i_{1,t+1} = i_{1,t} + \epsilon_t$ (static expectation) or $E_t i_{1,t+1} = i_{1,t} + \lambda(i_1^* - i_{1,t}) + \epsilon_t$ where $i_1^*$ is the "normal" interest rate and $\lambda$ the adjustment coefficient (regressive mechanism that adjusts to "normal" interest rate) or $E_t i_{1,t+1} = \Sigma w_j i_{1,t-j} + \epsilon_t$ for j = 0 to n (weighted average of present and past short-term rates)[6]. In general, expectations in the early studies contained both regressive and extrapolative elements and long-term rates were viewed as a distributed lag of past and present short-term rates. The main weakness of the expectation formation process in these studies is that it considers present and past short-term rates as the *only* relevant information in estimating future short-term rates. Sargent (1972), for example, does not only emphasize the need for expectations to be future oriented but also identifies money supply, price level, rate and composition of income as factors influencing future interest rates. There are also questions regarding the existence of a long run (or normal) value of *i*, whether interest rate return to this value and the time it takes for this to happen.

While the *observed* forward rates have also been used where available (Mishkin 1988) most studies have used the rational expectations assumption. The concept, which gained significant importance following the contribution by Modigliani and Shiller (1973), is based on the assumption that economic agents have perfect foresight and the expected short-term rates fully reflect all the information available, and which is relevant as soon as it becomes available. It implicitly posits that market participants use a model that leads to

[6] Dobson et al (1976) contains a good summary of econometric models of expectations formation based on the use of *past* interest rates

random forecasting errors. As a result the relation between the expectations and the actual has the form

$$E_t\, i_{1,t+1} = i_{1,t+1} + \varepsilon_{t+1} \qquad (2.5)$$

Where $\varepsilon_{t+1}$ is a random error term

The random error term is assumed to be independent and identically distributed with a zero mean and a constant variance.

With an assumption on yield expectations in place, it is now possible to develop an equation for the relationship between one- and two-period yields based on equation 2.4. Considering a one period (forward) expectation, the relationship between two- and one-period yields is specified as:

$$I_{2,t} = \tfrac{1}{2}(i_{1,t} + E_t i_{1,t+1}) + \theta_1 \qquad (2.6a)$$

Where $i_1$ and $I_2$ are one- and two-period yields respectively, and

$\theta_1$ is a one-period forward liquidity premium.

This can be rewritten as

$$2I_{2,t} = i_{1,t} + E_t i_{1,t+1} + 2\theta_1 \qquad (2.6b)$$

Substituting equation (2.5) into equation (2.6b) gives

$$2I_{2,t} = i_{1,t} + i_{1,t+1} + \varepsilon_{t+1} + 2\theta_1 \qquad (2.7a)$$

Rearranging gives

$$i_{1,t} + i_{1,t+1} = -2\theta_t + 2I_{2,t} - \varepsilon_{t+1} \tag{2.7b}$$

Equation 7b is estimable and can be written as a linear approximation of the forecasting error (as in Godbout et al 2002) *or* based on the spread (as in Mankiw and Miron 1986). In this study the latter approach is used since it also represents a form of the Meiselman's error-learning cycle. Subtracting $2i_{1,t}$ from both sides of equation (2.7b) and dropping the maturity subscript (for convenience) gives

$$i_{t+1} - i_t = -2\theta_t + 2(I_t - i_t) - \varepsilon_{t+1} \tag{2.8a}$$

In a linear regression form, equation 2.8a is written as

$$i_{t+1} - i_t = \alpha + \beta(I_t - i_t) - \varepsilon_{t+1} \tag{2.8b}$$

Equation 2.8(b) states that the expected one period change in the short-term yield (the left hand side) is a linear function of the current yield spread between long- and short-term yield and that the spread is a forecast of change in the short-term yield. This implies that the coefficient β is a variation of the slope of the yield curve[7] hence making this relationship more appropriate in modeling than that implied by equation 2.7(a). The

[7] Strictly speaking, this is not the slope of the yield curve though it is often referred to as such. In a two period model such as equation 8b it represent the rate of change of the short-term rate per a unit change in the spread between long- and short-term rate

relationship in equation 2.7(a) can be misleading by suggesting that the current and expected short-term yields have separate effectson the current long-term yields. In addition, equation 2.8(b) involves differencing which is useful in ensuring data stationarity. Notice that this equation contains both the general expectations theory and the hypothesis of rational expectations meaning that rational expectations is an integral part of the expectations theory. If the theory as defined in equation 2.8(b) holds, then it is expected that $\beta$ should be positive and not significantly different from 2 and, based on the earlier arguments, $\alpha$ is expected to have a negative sign and significantly different from zero.[8]

The plausibility of the approach used to develop the testable model above has been employed in a number of studies. Mankiw and Miron (1986) used three-month and six-month yields for short- and long-term yields respectively, and found that the theoretical relation implied by equation 2.8(b) holds for yields (in the US) particularly when interest rate targeting was not in use. A latter study by Mishkin (1988) also found the relationship implied by equation 2.8(b) is useful in predicting movements in the short-term interest rate several months into the future.

### 2.2.3 Market Efficiency

The efficiency of a market is related to the way in which prices are set in the market and the information used in setting these prices. It is based on assumptions such as zero transaction costs, free information that becomes available to everyone at the same instant

[8] Recall that a negative sign for $\alpha$ implies that long-term instruments command a premium over short-term instruments – a positive $\theta$ in equation (2.4) – and vice versa.

and symmetric market rationality. In general, a market is deemed efficient if prices fully reflect all the available relevant information as it becomes available. A number of approaches can be used to gauge the efficiency of the market for government securities. First, one can use an approach that is similar to the one used in the market for stocks. In this market, efficiency is primarily characterized by existence of a random walk in stock prices. The random price behavior implies that successive holding period returns, such as daily returns, are also random. For the term structure of interest rates, equation (2.4) can be used to explain the relationship between two successive yields. In period t-1 the equation is rewritten as

$$I_{n,t-1} = \tfrac{1}{n}(i_{1,t-1} + \sum_{j=0}^{n-2} E_{t-1} i_{1,t+j}) + \theta \qquad (2.9)$$

Subtracting equation (2.9) from (2.4) gives

$$I_{n,t} - I_{n,t-1} = \tfrac{1}{n}(E_t i_{1,t+n-1} - i_{1,t-1} + \sum_{j=0}^{n-2}\{E_t i_{1,t+j} - E_{t-1} i_{1,t+j}\}) \qquad (2.10)$$

The term in the brackets after the summation sign are the expected one-period rates in time $t+j$ with the expectation for the first being formed at time $t$ and for the second at time $t$-$1$. Under rational expectations the relation $E_t\, i_{1,t+j} = E_{t-1}\, i_{1,t+j} + \varepsilon_{t+j}$ holds. This reduces equation (2.10) to

$$I_{n,t} - I_{n,t-1} = \tfrac{1}{n}(E_t i_{1,t+n-1} - i_{1,t-1}) + \varepsilon_{t+j} \qquad (2.11)$$

As $n$ increases, such as for a long term bond, 1/n becomes smaller while $E_t i_{1,t+n-1} - i_{1,t-1}$ is also small. The combined effect is to reduce equation (2.11) to approximately

$$I_{n,t} - I_{n,t-1} = \varepsilon_{t+j} \tag{2.12}$$

This implies that in an efficient treasury securities' market consecutive yields of long-term instruments display random walk behavior - just like for stocks. This also suggests that if the market for long-term instruments is efficient then the variation in long-term interest rates is due to expectations only. Pesando (1978 and 1979) tested for the relationship in equation (2.12) using Canadian data and found that the random walk characteristic does exist for long-term interest rates. He, however, cautions that there is no guarantee that short-term rates in an efficient market will conform to the random walk behavior. Hambuger and Platt (1975) also cast doubt on the usefulness of this approach for short-term interest rates, though they noted that the time series process of the U.S. Treasury bill rates is "not far from being a random walk". It is possible that the randomness observed is attributable to factors other than simply a market that is efficient. For instance, Kugler (1988) observes that the randomness of Treasury yields in part of Mankiw and Miron's (1986) study was for post-1915 yields – a period in which interest rate targeting was being employed in the US leading to stabilization/smoothening of interest rates. Ironically, Mankiw and Miron (1986) found that the expectations hypothesis, particularly the presence of significant term premium, failed for the data after 1915. It was also noted earlier that the use of the random walk approach to test for market efficiency is valid as long as the current change in the short rate has a low correlation with past short rates (Mishkin, 1980, pp. 410) and term premiums do not vary with time

(Pesando 1979, pp. 458). Using primary market data is also susceptible to the limitations that a wider time gap between yield observations may have on the random walk behavior.

The second approach for testing market efficiency is based on a test for joint hypothesis involving (1) testing for a particular model of interest rates and (2) testing for efficiency of the market based on the specified model. Market efficiency and rational expectations are related on the basis that, in forecasting future interest rates, market participants rationally employ all available information. Thus, this approach uses the basic term structure relationship (such as the one implied by equation 2.4) to test for the presence of efficiency. In effect it views the underlying term structure theory and efficient [bond] market theory as complementary rather than alternative hypotheses. That is, if the data support the theory then the market that generated the data is efficient. This approach, which was used by Modigliani and Shiller (1973), is simple in the sense that there is no need to develop a separate model to test for efficiency. It is also reinforced by the rational behavior of market participants in an efficient market. That is, since the market participants have the opportunity to buy any of the offered maturity groups, the current and expected future yields in the different groups influence the prices quoted by the bidders, which in turn determine the yields. Consequently, the relationship among the yields, as contained in, say, the biased expectations theory is one of the factors that can be used to gauge market efficiency. The implication of using a variation of the expectations hypothesis based on rational expectations is that in an efficient market there is no exploitable regularity in the past movement of interest rates and there are no arbitrage opportunities. Essentially, this tests at least the weak form of market efficiency.

## 2.3 Interest Rates and Inflation

Both the Fisher hypothesis and rational expectations point out to the existence of a positive relationship between inflation and nominal interest rates. On the other hand, the causality in the relationship is not a straightforward issue. While the information contained in the term structure is useful in predicting inflation (Mishkin, 1990; and Frankel and Lown, 1994), current inflation can also be used to predict nominal interest rates. The essence of the Fisher hypothesis and hence the effects of inflation upon the nominal interest rate is that lenders allow for the expectations of inflation-induced decrease in the real value of the principal. This leads to a relationship of the form

$$i_t = r + E_t \pi_{t+1} \tag{2.13}$$

Where $i_t$ is the one-period nominal interest rate,

$r$ is the real interest rate, and

$E_t \pi_{t+1}$ is the expected inflation rate for the next period.

Like future interest rates, $E_t \pi_{t+1}$ is unobservable and its estimation is possible if economic agents possess information to form inflation expectations. The information includes past inflation rates, money supply, price level, rate and composition of income (Sargent, 1972). If the monetary authority employs inflation targeting and it is credible and consistent, the periodic inflation targets are also likely to be the main, and possibly the only factor used in forming inflation expectations. Using the rational expectation assumption, the actual inflation rate observed in the future is used to represent the expected inflation such that

$$E_t\pi_{t+1} = \pi_{t+1} + \varepsilon_{t+1} \qquad (2.14)$$

Substituting (2.14) into (2.13) and writing as an estimable equation gives

$$i_t = \phi + \lambda\pi_{t+1} + \varepsilon_{t+1} \qquad (2.15)$$

The coefficient Φ represents the real interest rate – which is hypothesized to be positive and significant – while the coefficient λ is, theoretically, not significantly different from unity. This relationship was proposed and used by Yohe and Karnosky (1969) who sought to explain fluctuations in nominal interest rates solely in terms of variations in price expectations. The model was further tested and supported – to a lesser extent – by Pesando (1976) using Canadian data despite the fact that there was no indication that the Canadian monetary authority employed inflation targeting - at least for the period in focus. Wallace and Warner (1993) also found that inflation and interest rates are cointergrated hence supporting both the Fisher effect and the expectations theory. These findings suggest that looking at how the treasury bills prices are influenced by inflation expectations enhances understanding of the structure of the interest rates, market efficiency and investors' rationality.

## 2.4 Institutional Characteristics of the Treasury Bill Market

Treasury securities are often used by central banks to manage money supply and government debt. In auctions, treasury securities are sold to bidders using uniform price or multiple prices[9]. The latter can either be 'discriminatory' or a combination of discriminatory and uniform prices. In the uniform-price system all successful bidders pay the same price, which is the lowest price that clears the market in which the securities are sold, while under discriminatory price system bidders pay their respective bids – hence the common name pay-your-bid system. In the latter, the successful bidders are listed, starting with the highest bid price, down to the lowest successful bid price. In addition, various combinations of discriminatory and uniform prices are used by some central banks. One combination is that used by the Bank of Spain where, for winning bids above the average winning bid, buyers are charged the average winning bid, otherwise they pay their respective bids. It is important to note that the different systems produce different official yields. For example, in the uniform-price system the yield obtained in each auction is based on a single price, while under multiple-price system the yield is obtained as the weighted average of the yields of all successful bids. This may impact on the relevance of some additional information such as the dispersions obtained in the auctions – i.e. the difference between the yield implied by highest and the lowest successful prices – and the yield obtained by lowest successful bids in modeling the term structure as well as testing for market efficiency.

Since its creation in 1966, the BOT has been selling treasury securities on behalf of the Government of Tanzania. Prior to 1993, selling of these securities was based on some predetermined prices hence giving the buyers a predetermined yield. This was due mainly to the fact that most of the potential buyers were government owned institutions and the financial system was heavily regulated. In 1992 Tanzania liberalized its financial sector by

[9] The choice of the system to use is essentially the decision of the Treasury, which is the issuing authority. For example, while the US uses the uniform price system Canada uses the multiple prices system.

allowing private institutions in the banking industry. In line with this, the BOT changed its system of selling securities to an auction system based on the use of multiple prices. The BOT has been auctioning treasury bills since August 1993. Initially, the auctions were held fortnightly but from mid-1994 auctions have been held on weekly basis. Different maturity groups have been offered: 35 days, 91 days and 182 days were offered up to early December 1994 while 91 days, 182 days and 364 days have been sold thereafter. In the last week of May 2002 the BOT started issuing the 35-day bills again. The 35- and 91-day Treasury bills are used for liquidity management purposes, while the 182, and 364-day treasury bills (together with two-year and recently introduced five-year Treasury bonds) are used for Government debt management.

To auction government securities, the BOT uses a multiple-price, sealed-bid auction system. It involves the BOT announcing, about one week prior to the auction, the amount of debt it plans to sell and inviting bids from prospective buyers subject to a minimum bid size with bid prices quoted per 100 Tanzanian Shillings (TZS). Eligible bidders can submit multiple competitive sealed bids only: noncompetitive bids are not allowed. Successful bids are then awarded on the discriminatory pricing basis. Based on the successful bids, the weighted average price, for each maturity group is computed and in turn used to compute the annualized weighted average yield. In addition, after each auction, the BOT releases some information that may be considered an important input to bidders in subsequent auctions. The information includes total amount subscribed, highest and lowest bid prices received, minimum successful price and the face value of the amount sold. In the first years of the auction system, particularly the 1993 to1996 period, the yields produced in the auctions fluctuated widely (Figure A1.1 and Tables A1.1 to A1.3 in Appendix 1). In this period, though both the yields and inflation rates (Figure A1.2) were high, the yields were significantly higher that the inflation rate and experienced wider fluctuations. In the recent years, however, both inflation and the yields have been low and they also experience smaller fluctuations. Its noteworthy observing that longer maturing bills have higher yields in almost all auctions implying that the auctions have been producing upward slopping yield curves.

In January 1999, the BOT introduced the primary dealership system.[10] In this system investors with bids valued at TZS 100.0 million or more are allowed to participate in the auctions directly while those with bids valued at less than TZS 100.0 million are expected to channel their bids through primary dealers. The primary objective was to simplify the issuance and administration of government securities, and to facilitate the development of the secondary and inter-bank trading market, thereby enhancing efficiency in liquidity management. It was expected that primary dealers, particularly commercial banks, would buy securities for "on-selling" to their in-house clients since the securities are neither listed nor allowed to be sold on the over-the-counter market of the stock exchange. It was also expected that the REPO market – between the BOT and the primary dealers and among financial institutions – would also help to enhance the liquidity of treasury securities. However, the expectations have not been realized as the original buyers resell only a negligible proportion of the securities. In 2000, for example, out of securities worth Tanzanian Shillings (TZS) 321.6 billion bought by primary dealers, only securities

[10] Currently there are 18 registered primary dealers. However it may be considered that the pool of investors capable of submitting bids of TZS 100 million has the 18 registered banks, 11 non-bank financial institutions and about 80 bureaux as the front-runners. Recent data based on October 2002 to February 2003 auctions indicate that, on average, the treasury bills buyers are made up of deposit money banks (75%), pension funds and insurance companies (20%) and non-bank financial institutions (5%) (BOT Monthly Economic Reviews, November-December 2002, March 2003)

worth TZS 1.07 billion, about 0.3 percent, were transacted in the secondary market (BOT Monetary Policy Statement, June 2001).

It is argued that the institutional factors of the auction process can affect the ability the market to fully exploit arbitrage opportunities (Godbout et al. 2002) as well as the distribution of auction awards (Pulizzi and Nicholson, 1998). Between uniform price auction and pay-your-bid auction, studies have shown that uniform price tend to yield higher revenues to the issuer (Heller and Lengwiler 1998) and produce higher dispersions of bids but low price volatility overtime (Godbout et al. 2002). In general, the auction system used as well as the multiples in which bids come impact not only the issuer's cost of borrowing but also has effect on the performance of the expectations theory of the term structure and the market efficiency (Godbout et al. 2002). It is not the primary purpose of this study to carry out a critical evaluation of auction systems. However, understanding the auction system that produce the yields used in this study is important in the interpretation of the results.

# CHAPTER 3

## MODELLING PROCEDURE AND DATA

### 3.1 The Methodology

In this study a period is defined in terms of three months with the yields to maturity on 91-, 182-, and 364-day Treasury bills representing one-, two- and four-period yields respectively. These will also often be referred to as three-month, six-month and one-year yields respectively.

Using the approach applied in equations (2.5a) through (2.8b), the equation for the relationship between three- and six-month yields is

$$i_{1,t+1} - i_{1,t} = \alpha + \beta(I_{2,t} - i_{1,t}) + z_t \tag{3.1}$$

Where $i_1$, and $I_2$ are yields to maturity on 91-, and 182-day Treasury bills respectively. The expectations horizon in this equation is three months and the error term $z_t$ is realized three months latter. Thus, using equation 2.5 and denoting the short-term interest rate expectations error as $\epsilon_{t+1} = E_t i_{t+1} - i_{t+1}$, the error terms in the equation has the form $z_t = \epsilon_{t+1}$.

The relationship between six- and twelve-month yields is essentially a two period model but with expectations horizon of six months. Its equation is given as

$$i_{2,t+2} - i_{2,t} = \alpha + \beta(I_{4,t} - i_{2,t}) + z_t \tag{3.2}$$

Where $i_2$, and $I_4$ are yields to maturity on 182-, and 364-day Treasury bills respectively. The error term is realized six months latter and has the form $z_t = \epsilon_{t+2}$. The coefficient $\beta$ in both 3.1 and 3.2 is expected to be positive and not significantly different from 2.

A similar approach to the one used above is used to develop an estimable equation for the relationship between three- and twelve-month yields. However, some few manipulations are involved to make the spread between the short- and long-term yields the independent variable. It starts with an equation similar to 2.4 with the general formulation being

$$I_{4n,t} = \tfrac{1}{4}(i_{1,t} + E_t i_{1,t+1} + E_t i_{1,t+2} + E_t i_{1,t+3}) + \theta \qquad (3.3a)$$

This is rearranged as

$$i_{1,t} + E_t i_{1,t+1} + E_t i_{1,t+2} + E_t i_{1,t+3} = 4I_{4,t} - 4\theta \qquad (3.3b)$$

Subtracting $4i_{1,t}$ from both sides and imposing the rational expectations assumption gives

$$i_{1,t+3} + i_{1,t+2} + i_{1,t+1} - 3i_{1,t} + \varepsilon_{t+1} + \varepsilon_{t+2} + \varepsilon_{t+3} = -4\theta + 4(I_{4,t} - i_{1,t}) \qquad (3.3c)$$

Writing as an estimable equation and using $z_t$ to represent the sum of the error terms gives

$$i_{1,t+3} + i_{1,t+2} + i_{1,t+1} - 3i_{1,t} = \alpha + \beta(I_{4,t} - i_{1,t}) + z_t \qquad (3.3d)$$

The error term $z_t$ is realized in installments – three-, six and nine-months latter – making nine months the longest expectations horizon in this equation. The coefficient β is expected to be positive and not significantly different from 4.

Three things are common in equations 3.1, 3.2 and 3.3d. First, the independent variable is the yield spread between longer- and shorter-term yield observable at time *t*. Second, the error terms represent the sum of expectation errors for future short-term yields and is realized over the expectations horizon in the respective equation. Third, based on the discussion in Chapter 2, α, which represents the term premium, is expected to be negative and significantly different from zero. Assuming the term premium increases monotonically with maturity, then the longer the expectations horizon the higher the absolute value of $\alpha$.

The relationship between inflation and nominal interest rates is tested using the 91-day and 182-day yields only. The equations are

$$i_{1,t} = \phi + \lambda \pi_{1,t+1} + \varepsilon_t \tag{3.4}$$

$$i_{2,t} = \phi + \lambda \pi_{2,t+2} + \varepsilon_t \tag{3.5}$$

Where $i_{1,t}$ and $i_{2,t}$ are the yields on 91- and 182-day treasury bill respectively, and $\pi_{1,t+1}$ and $\pi_{2,t+2}$ are the change in price level for the next three and six months.

With a real yield that is constant o

ver the length to maturity, $\Phi$ is expected to be positive and significant. If the Fisher effect – that nominal interest rates move one-for-one with inflation – holds, then the coefficient $\lambda$ should not be significantly different from unity. On the other hand, if $\lambda$ is only significantly different from zero it will suggest that the yields contain significant information about inflation expectations even when the Fisher effect does not hold on one-to-one basis.

## 3.2 Data Type and Sources

The data used in this study are the annualized yields obtained from weekly Treasury bill auctions and the month-to-month inflation rates both of which are published by the BOT. The overall sample for the term structure and testing for market efficiency consists of 264 weekly yield curve observations from June 1998 (auction 216) through January 2003 (auction 479). The choice of the sample period is dictated by two main factors. First, the sample period starts about five years after the BOT started using the auction system to allow reasonable time for the market to experience smooth operations. This is key to the imposition of a rational expectations assumption. It is highly likely that the phenomenon of treasury bills buyers having expectations that are not rational was prevalent at the onset of the auction system. However, this phenomenon would be expected to disappear or at least fall to insignificant levels in the long run. Second, for consistency, the sample covers a period where most of the trading was through primary dealers and where all the three maturities have been on issue simultaneously. This is also the period where the BOT has been maintaining a comprehensive data bank of auction results that made it possible to compute the LSPY used in this study. For each of equations 3.1, 3.2 and 3.3d, the sample is the longest possible that can be extracted from the overall sample period based on the requirements for the specific equation. It is noteworthy pointing out that the auction system used by the BOT makes the WAY the reported yield. The LSPY is not directly reported but the lowest successful price is included in the information release after each auction. For the purpose of this study, this price is used to compute the LSPY for each auction using the same approach as that used by the BOT when computing WAY from the weighted average price[11]. The lowest successful price would have been the price on which the official yield is based if the uniform price system was in use. In addition, this price can be viewed as the one paid by the better-informed buyers who are focusing on buying the Treasury bills while at the same time avoid paying a price that is too much. These buyers consider all available information and try to exploit any market imperfections that may arise from information asymmetry.

The annualised three- and six-month inflation rates are computed by compounding and annualising one-month seasonally adjusted headline inflation rates. Headline inflation is the change in the overall consumer price index covering both food and non-food prices (see also Figure A1.2 in appendix 1 for the different indices). Annualisation and compounding is necessary because the one-month rates published by the BOT are "month-to-month" rates that are not annualised. To synchronize the yields and inflation rates, the relationship between the yields and inflation rates is tested using the yields observed at a date close the beginning of each calendar month for the period from June 1998 to July 2002. This allows for matching Treasury bill maturities with the duration used in computing monthly inflation.

[11] With bid size of TZS 100, the annualized yields are computed as $Yield = \frac{100 - P}{P} * \frac{365}{D} * 100$

where *Yield* represents WAY or LSPY
P is the weighted average price and lowest successful price for WAY and LSPY respectively and D is the days to maturity.

# CHAPTER 4

# EMPIRICAL RESULTS

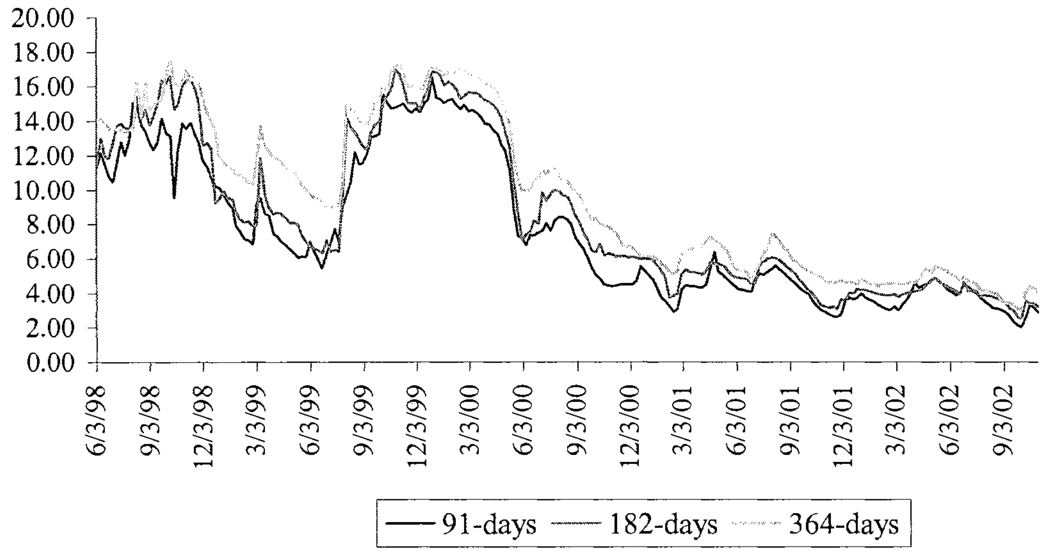
## 4.1 An Overview of the Data Used

The yield and inflation rate data for June 1998 to January 2003 are plotted in figures 4.1 to 4.3. In general a declining trend is observed. This is largely explained by the commitment of the central bank to lower inflation from more than 30 percent in 1995 to about 5 percent in the early 2000s (see figure A1.2 in Appendix 1). Reforms in the financial sector have also enhanced competition in the Treasury bill market.

The data plots suggest that yields obtained in the earlier auctions were more volatile than those in the more recent auctions. For both WAY and LSPY an evident change in the level and volatility occurs around May/June 2000. The BOT's publications (Monthly and Quarterly Economic Reviews) do not offer an insight as to the cause of the wide fluctuations in yields particularly in the June 1999 to May 2000 period. There was no change in the BOT's management and, interestingly, deposit rates and indicators such as exchange rates and inflation rates did not experience such wide fluctuations.

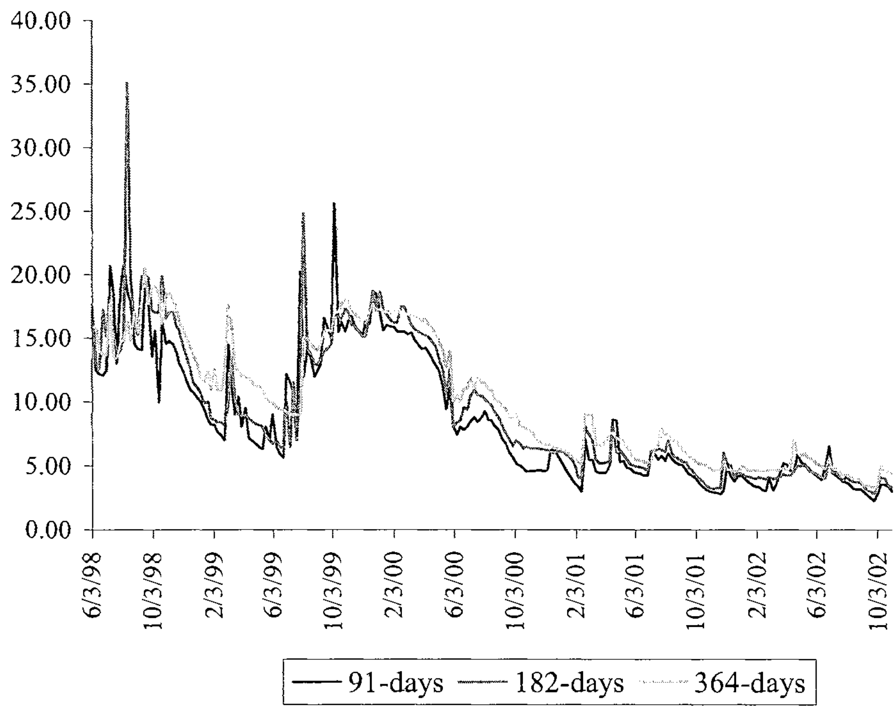
A Chow test was used to establish whether the underlying process is the same across all observations in the sample. The test was based on the time series nature of the data to determine the evidence of a structural shift over time. The most significant statistics were found to be present on May 31 2000 (auction 341). The F statistics at this date were 72.29, 58.72 and 92.84 for 91-, 182- and 364-day Treasury bills respectively giving insignificant $p$-values. This evidence is the criteria used to split the data into two sub-samples.

Figure 4.1: Yields based on the weighted average prices (WAY)




Source: Bank of Tanzania

Figure 4.2: Yields obtained by lowest successful prices (LSPY)




Source: Bank of Tanzania and own computations

Tables 4.1 and 4.2 present summary statistics for the two sub-samples. Splitting the data has lowered the volatility substantially resulting into the sub-samples having standard deviations that are substantially lower than the standard deviations for the entire sample (columns 2, 5, and 8). On the other hand, the June 1998 to May 2000 period still has standard deviations that are significantly larger (columns 3, 6, and 9) than those in the June 2000 to October 2002 period (columns 4, 7, and 10) for both WAY and LSPY. It is interesting to note that the coefficients of variation, which measure volatility in relative terms, are higher in the June 2000 to October 2002 period than in the June 1998 to May 2000 period. Lower volatility for the sub-samples also has some effects in estimation of the coefficients with initial tests showing that the split data is more homoscedastic compared to that for the entire sample period.

Table 4.1: Summary statistics for weighted average yields (WAY)

| Maturity | | *91- days* | | | *182- days* | | | *364- days* | |
|---|---|---|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| Sample Period (yr:m) | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 |
| N | 230 | 105 | 125 | 230 | 105 | 125 | 230 | 105 | 125 |
| Low | 2.02 | 5.45 | 2.02 | 2.54 | 6.32 | 2.54 | 3.00 | 8.97 | 3.00 |
| High | 16.52 | 16.52 | 8.42 | 16.96 | 16.96 | 10.00 | 17.62 | 17.62 | 11.21 |
| Mean | 7.65 | 11.43 | 4.47 | 8.51 | 12.53 | 5.14 | 9.68 | 13.98 | 6.07 |
| Standard Deviation | 4.19 | 3.11 | 1.44 | 4.50 | 3.35 | 1.71 | 4.55 | 2.55 | 2.00 |
| Coefficient of Variation | 0.55 | 0.27 | 0.32 | 0.53 | 0.27 | 0.33 | 0.47 | 0.18 | 0.33 |

Source: Bank of Tanzania and own computations

Table 4.2: Summary statistics for lowest successful price yields (LSPY)

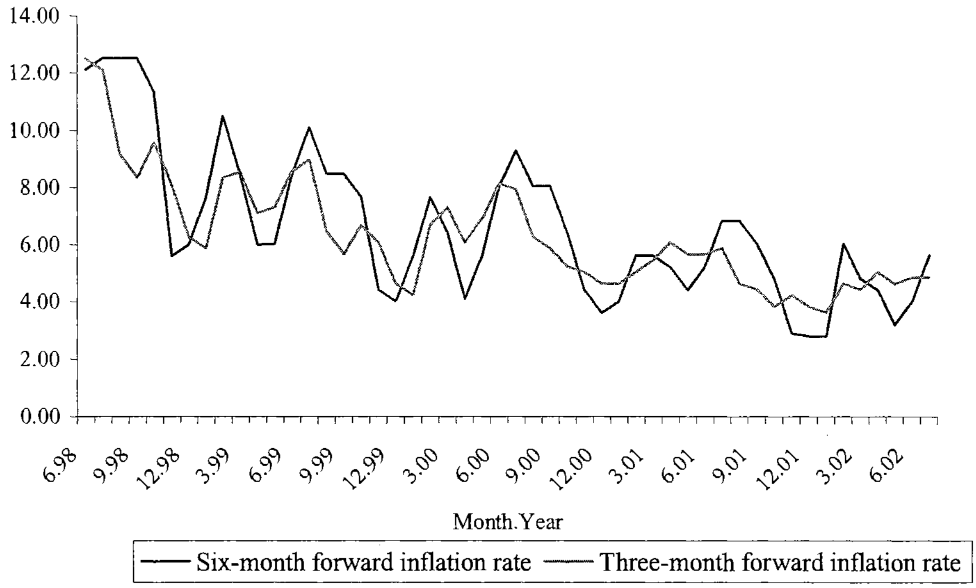
| Maturity | | *91- days* | | | *182- days* | | | *364- days* | |
|---|---|---|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| Sample Period | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 |
| N | 230 | 105 | 125 | 230 | 105 | 125 | 230 | 105 | 125 |
| Low | 2.26 | 5.61 | 2.26 | 2.81 | 6.39 | 2.81 | 3.30 | 8.96 | 3.30 |
| High | 25.60 | 25.60 | 9.23 | 35.11 | 35.11 | 10.96 | 20.54 | 20.54 | 11.89 |
| Mean | 8.62 | 13.09 | 4.87 | 9.32 | 13.88 | 5.49 | 10.14 | 14.67 | 6.33 |
| Standard Deviation | 5.03 | 3.93 | 1.62 | 5.31 | 4.41 | 1.86 | 4.84 | 2.85 | 2.10 |
| Coefficient of Variation | 0.58 | 0.30 | 0.33 | 0.57 | 0.32 | 0.34 | 0.48 | 0.19 | 0.33 |

Source: Bank of Tanzania and own computations

The plot of 3- and 6-month forward inflation rates (Figure 4.3) shows a declining trend and volatility level that does not change substantially throughout the sample period. Table 4.3 also shows that splitting the sample lowers the standard deviation in the second part of the sample (columns 4 and 7) but not in the first part (columns 3 and 6). Unlike the WAY where 3-month yields are always lower than 6-month yields, three-month inflation rates are not always lower than six-month inflation rates. Based on the coefficient of variations, the relative volatility for the yields seems to be comparable for the split data. However, while the averages show that 6-month yields are higher than 6-month inflation rates in both sub-samples, (columns 6 and 7 in Tables 4.1 and 4.3), the 3-month yields are higher than 3-month inflation rates in the first sub-sample (columns 3 Tables 4.1 and 4.3) but not in the second.

Though the shift in the inflation rate is not as evident as that for the yields, splitting the data into two parts was done using the same cut off as that for the yields for comparison purposes. The limited number of observations in the sub-samples calls for attention in interpreting the resulting estimates, particularly the standard errors. The use of small samples is not uncommon. In generating yield curve estimates, Gray (1973) based the estimates on sample size ranging from 22 to 44. Though no mention is made of specific adjustments, it is prudent to assume that the standard errors of the estimates are adjusted to account for the properties of small samples.

Figure 4.3: Annualized inflation rate 3- and 6-month into the future




Source: Bank of Tanzania and own computations

Table 4.3: Summary statistics for forward inflation rates

| | | *3-months* | | | *6-months* | |
|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Sample Period | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 | 98.6-02.10 | 98.6 – 00.5 | 00.6-02.10 |
| N | 50 | 25 | 25 | 50 | 25 | 25 |
| Low | 2.80 | 4.01 | 2.80 | 3.62 | 4.23 | 3.62 |
| High | 12.52 | 12.53 | 9.27 | 12.51 | 12.51 | 7.92 |
| Mean | 6.62 | 8.01 | 5.24 | 6.32 | 7.58 | 5.06 |
| Standard Deviation | 2.64 | 2.71 | 1.71 | 1.98 | 1.97 | 0.92 |
| Coefficient of Variation | 0.40 | 0.34 | 0.33 | 0.31 | 0.26 | 0.18 |

Source: Bank of Tanzania and own computations

## 4.2 Initial Data Analysis

The data were analyzed using the SAS statistics software. First a regression using maximum likelihood method was used to estimate the parameters for the equations developed in chapter 3 for the entire data set and for the sub-samples. The robustness of the initial estimates was primarily based on testing the resulting error terms for the presence of autocorrelation and heteroscedasticity[12]. The Durbin-Watson statistic was used to test for the presence of autocorrelation while White's test and the Breusch-Pagan statistic are used to test for conditional heteroscedasticity. In all tests the significance level is set at 10 percent. For the entire sample, the residuals for the term structure equations showed the presence of autocorrelation – notably first order – for both WAY and LSPY. On the other hand, all three equations were found to have heteroscedastic residuals when WAY is used but not when using LSPY. In addition, a plot of the residuals from WAY estimates against time shows that the variances are not constant; they decrease over time. Based on the split data, autocorrelated residuals are found in all of the initial estimates while heteroscedasticity is found in two sub-samples when using WAY and in one sub-sample when using LSPY. For all possible combination of the term structure relations none has residuals that are neither autocorrelated nor heteroscedastic. For the relationship between the yields and inflation, the observation on autocorrelation and heteroscedasticity is somehow different. Of the 18 relationships (based on sample type, yield type and equations 3.4 to 3.6) three have residuals that are neither autocorrelated nor heteroscedastic while only one has residuals that are both autocorrelated and heteroscedastic.

[12] Only the adjusted estimates, on which the discussions are based, are presented in the findings

The findings of autocorrelated and heteroscedastic residuals are an unsurprising phenomenal since the equations are base on the use of rational expectations. This is coupled with the fact that the yields and inflation rates are not only a set of jointly distributed random variables indexed in time but also are essentially time series realized from a stochastic process. As a result, the error terms in the estimated equations are realized at a latter period and hence the serial correlation. Addressing the problems takes the following approach. A model whose variables are indexed on time can be presented as

$$Y_t = \alpha + \beta X_t + z_t \tag{4.1}$$

where the error term, $z_t$, behave as a time series variable. This implies that $z_t$ contains information about $Y_t$ and needs to be identified and modeled as an autoregressive integrated moving average (ARIMA) process. If $z_t$, is identified as having a $j^{th}$ order autocorrelation it can be expressed as

$$z_t = \varepsilon_t - \varphi_1 z_{t-1} - \ldots - \varphi_j z_{t-j} \tag{4.2}$$

This gives an autoregressive model [AR(j)] of a form

$$Y_t = \alpha + \beta X_t - \varphi_1 z_{t-1} - \ldots - \varphi_j z_{t-j} + \varepsilon_t \tag{4.3}$$

Heteroscedastic variance implies that the error term $\epsilon_t$ in equation 4.3 is not independent of $X_t$. However, the variance is unknown and must be estimated from the data. If $\epsilon_t$ is assumed to be exponential heteroscedastic, then the variance has a form

$$\varepsilon_t = \sqrt{h_t e_t} \tag{4.4}$$

Where $h_t = w + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}^2 + \sum_{m=1}^{p} \gamma_m h_{t-m}$

The resulting model is an exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model that combines a $j^{th}$ order autoregressive error model with the GARCH(p,q) variance model. These adjustments are used to re-estimate the equations with the adjustment for each data set being based on the initial findings for autocorrelation and heteroscedasticity.

The order of autocorrelation was determined by using BACKSTEP (backward elimination) option in the SAS code rather than simple AR identification. The equations were estimated using different lag length specifications ranging from 2 to 13. Higher level of lag-length specification (beyond lag 13) was avoided as it was found not to change the parameter estimates significantly. On the other hand, particular attention was paid to lags 4, 7 and 13 in case of the presence of seasonal pattern in the data. Adjustment for conditional heteroscedasticity was based on ARCH model and, where appropriate, exponential GARCH model was used based on an assumption that the variance has an exponential form. The GARCH specification is restricted to GARCH (1,1) or lower. The main focus was on algorithms that converge, stable parameter estimates and estimates that have the least autoregressive residuals.

### 4.3 Results on the Term Structure and the Forecasting Power of the Spread

The results for the term structure estimates adjusted for the presence of autocorrelation and heteroscedasticity are presented in tables 4.4 to 4.6. The results are discussed in two parts with the first part covering the findings on the term-premium and the second covering the slope of the yield curve and the forecasting power of the spread.

### 4.3.1 The Term Premium

Table 4.4 shows that, based on the entire sample, α is of the expected sign and significantly different from zero for both WAY and LSPY only in the relationship using three- and twelve-month yields (columns 3, and 7). This supports the presence of a positive maturity premium for WAY (at 1 percent) and LSPY (at 10 percent). In addition, the relationship using six- and twelve-month LSPY indicates the presence of a positive maturity premium at 10 percent (column 6).

A clearer picture is revealed by the split data. For the June 1998 through May 2000 period, the yields do not show the presence of a term premium (α is not significant) for any of the three equations irrespective of the type of yields used (columns 2, 4 and 6 in tables 4.5 and 4.6). Term premium is also absent for the June 2000 through October 2002 period when six-month yields are used as long-term yields (column 3 in tables 4.5 and 4.6). When 12-month yields are used as long-term yields both WAY and LSPY have term premium that are significant. The LSPY fare better than WAY with both term premia being significant at a 1 percent (columns 5 and 7 in tables 4.6). The presence of significant term premia means the hypothesis that longer maturing bills are riskier cannot be rejected. This is of significant importance in the absence of secondary market where buyers face increased uncertainty as they hold the bills until they mature. The assumption of monotonically increasing term premium also seem to hold whereby the equations with 9-month expectation horizon (columns 5 Table 4.5 and 4.6) have term premia that are larger, in absolute terms, than those for equations with 6-month expectations horizon (columns 7 Table 4.5 and 4.6).

Table 4.4: Regression of the change in short-term yields on the spread between long- and short-term rates for the entire sample period (98.6 – 02.10)

| Yield type | | WAY | | | LSPY | |
|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Months (s,l) | (3,6) | (3,12) | (6,12) | (3,6) | (3,12) | (6,12) |
| N | 230 | 204 | 217 | 230 | 204 | 217 |
| α | 0.002<br>(0.003) | -0.044*<br>(0.013) | -0.018<br>(0.019) | -0.0073<br>(0.01) | -0.08***<br>(0.047) | -0.023***<br>(0.0137) |
| *β* | 0.317*<br>(0.047) | 1.999*<br>(0.158) | 0.8780*<br>(0.127) | 0.3782*<br>(0.0655) | 2.62*<br>(0.158) | 1.0453*<br>(0.0842) |
| D.W | 1.7695 | 2.0197 | 1.6218 | 1.9881 | 2.0650 | 2.1162 |
| $R^2$ | 0.0661 | 0.3695 | 0.1843 | 0.1318 | 0.5974 | 0.42 |

s = months for short-term yield, l = months for long-term yield

Standard errors are in parentheses
*, **, *** Significant at 1, 5, and 10 percent respectively

Table 4.5: Regression of the change in short-term yields on the spread between long- and short-term rates using WAY

| Months (s,l) | (3,6) | | (3,12) | | (6,12) | |
|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Period (yr.m) | 98.6–00.5 | 00.6-02.10 | 98.6–00.5 | 00.6-02.5 | 98.6–00.5 | 00.6-02.7 |
| N | 105 | 125 | 105 | 99 | 105 | 112 |
| $\alpha$ | -0.006 | -0.004 | -0.086 | -0.109* | -0.002 | -0.015** |
| | (0.018) | (0.0056) | (0.08) | (0.01) | (0.01) | (0.006) |
| $\beta$ | 0.34** | 0.41* | 2.656* | 2.0934* | 0.584* | 0.768* |
| | (0.13) | (0.091) | (0.2235) | (0.192) | (0.103) | (0.1254) |
| D.W | 1.8792 | 2.0143 | 1.5968 | 1.5662 | 2.0025 | 2.0599 |
| $R^2$ | 0.0612 | 0.1423 | 0.2969 | 0.4697 | 0.1708 | 0.2588 |

s = months for short-term yield, l = months for long-term yield

Standard errors are in parentheses
*, **, *** Significant at 1, 5, and 10 percent respectively

Table 4.6: Regression of the change in short-term yields on the spread between short- and long-term yields using LSPY

| Months (s,l) | (3,6) | | (3,12) | | (6,12) | |
|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Period (yr.m) | 98.6–00.5 | 00.6-02.10 | 98.6–00.5 | 00.6-02.5 | 98.6–00.5 | 00.6-02.7 |
| N | 105 | 125 | 105 | 99 | 105 | 112 |
| α | -0.013<br>(0.0152) | -0.0074<br>(0.0049) | -0.1<br>(0.078) | -0.059*<br>(0.0206) | -0.032<br>(0.028) | -0.015*<br>(0.005) |
| *β* | 0.3593*<br>(0.094) | 0.7149*<br>(0.128) | 2.6698*<br>(0.209) | 2.0358*<br>(0.2787) | 1.0563*<br>(0.084) | 0.5877*<br>(0.138) |
| D.W | 1.9941 | 1.9241 | 2.0048 | 1.8238 | 2.0251 | 2.0260 |
| $R^2$ | 0.1289 | 0.1591 | 0.6186 | 0.3584 | 0.6115 | 0.0004 |

s = months for short-term yield, l = months for long-term yield

Standard errors are in parentheses

*, **, *** Significant at 1, 5, and 10 percent respectively

The absence of term premia in the June 1998 through May 2000 period is consistent with both the level effect (Nelson, 1972) and volatility effect (Browne and Manasse, 1989; Longstaff and Schwartz, 1992; Brenner et al.; 1996). Tables 4.1 and 4.2 show that both the level and volatility of the yields in this period are higher than in the June 2000 through October 2002 period. Nelson (1972) found that, other things being equal, the term premium should be less, the higher the interest rate while Longstaff and Schwartz (1992) observed that the change in the short-term rate depends on both the level of the current short-term rates and their volatility. High absolute variability in this case is likely to affect the predictability of short-term rates hence making them less useful in forecasting long-term rates.

### 4.3.2 The Slope of the Yield Curve and the Forecasting Power of the Spread

In all but one equation, $\beta$ is positive and significantly different from zero at 1 percent. The exception is for the 3-months expectation horizon using WAY (Table 4.5 column 2), which is significant at 5 percent. The coefficient is also larger under LSPY than under WAY in all but two equations (columns 5 and 7, Table 4.5 versus columns 5 and 7, Table 4.6). The significance of this coefficient implies that there is a positive relationship between long- and short-term yields and that the current spread between long- and short-term yields is useful in the prediction of future short-term yields.

Overall, the relationship between the spread and change in short-term yields seems to hold better over longer maturity [(3,12) and (6,12)] than shorter maturity [(3,6)] and that the slope is greater under LSPY than under WAY. The former stands in contrast to

Browne and Manasse (1989) who found that the forecasting ability of the term structure fades as yields on assets of increasingly distant maturities are employed as long-rates. On the other hand, however, the presence of significant term premia for equations with 6- and 9-months expectations horizon but not for those with 3-months expectations horizon as well as monotonically increasing term premia support the argument that the longer the maturity the higher the term premium. Thus, the term premium is not only related to the time-to-maturity but also to the length of the expectations horizon.

For all equations, the coefficients of the yield curves though positive and significant, fall short of the hypothesized values. This has been a common observation in most term structure studies. Such observation should be construed to imply that although the data do not fully confirm the expectations theory, the slope of the yield curve does contain substantial information on the path of the short rate. Mankiw and Miron (1986) argue that a slope that is significant but short of the hypothesized values is sufficient to convey the basic message. That is, the yield-spread variation is related to subsequent movement in short-term yields and does forecast part of the expected change in the short-term yields. In addition, one has to bear in mind that the slope is susceptible to the trend of the economy and the extent to which short-term rate expectations are used in forecasting long-term rates. The predictive power of the spread, however, does not seem to get much support from the equations' R-squares, which are small. Though small $R^2$s have been observed in a number of studies on term structure of interest rates (see for example Shiller, 1973; Mankiw and Mirron, 1986; Mishkin, 1988; and Kugler, 1988), they call the theory into question especially with slopes that fall short of the hypothesized values.

Mankiw and Mirron (1986), for example, found small $R^2$ mainly in cases where the expectations theory is rejected.

### 4.4 Results on Interest Rate and Inflation

This section focuses on testing the Fisher effect based on both three- and six-month yields and forward inflation rates. Tables 4.7 to 4.9 present the results for the estimates adjusted for the presence of autocorrelation and heteroscedasticity.

For the entire sample (Table 4.7), the Fisher effect equations suggest the presence of positive real interest rate with $\Phi$ being of the expected positive sign and significantly different from zero. On the other hand the coefficient of the inflation rate, $\lambda$, is not significantly different from zero suggesting that the yields, and by implications the bidders, do not take inflation expectations into account.

Like the term structure equations, the split data provide clearer results. A positive and significant real yield is observed in all sub-samples when WAY is used with $\Phi$ that is positive and significantly different from zero (Table 4.8). The same is observed when LSPY are used except for the six-month Fisher effect model for the June 2000 to July 2002 period (column 5, Table 4.9). In all samples, the coefficient for inflation rate, $\lambda$, is significantly different from zero for the June 2000 to July 2002 period for both yields with LSPY having higher coefficients.

Table 4.7: Relationship between yields and expected inflation for the entire sample period

| Yield type | WAY | | LSPY | |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |
| Model | Fisher effect (3-month) | Fisher effect (6-month) | Fisher effect (3-month) | Fisher effect (6-month) |
| N | 50 | 50 | 50 | 50 |
| Φ | 0.0880*<br>(0.025) | 0.0927**<br>(0.035) | 0.1*<br>(0.03) | 0.116*<br>(0.040) |
| λ | -0.1494<br>(0.123) | -0.1327<br>(0.254) | -0.0782<br>(0.249) | -0.2768<br>(0.38) |
| D.W | 1.9964 | 1.6513 | 2.4520 | 2.3037 |
| $R^2$ | 0.0337 | 0.0064 | 0.0021 | 0.0032 |

Standard errors are in parentheses
*, **, *** Significant at 1, 5, and 10 percent respectively

Table 4.8: Relationship between WAY and expected inflation

| Model | Fisher Effect (3 months) | | Fisher Effect (6 months) | |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |
| Period (yr.m) | 98.6–00.5 | 00.6-02.7 | 98.6–00.5 | 00.6-02.7 |
| N | 24 | 26 | 24 | 26 |
| Φ | 0.1383* (0.025) | 0.015** (0.006) | 0.132* (0.014) | 0.0258* (0.008) |
| λ | -0.354*** (0.186) | 0.6031* (0.111) | -0.239 (0.178) | 0.4466* (0.118) |
| D.W | 1.209 | 1.515 | 1.349 | 1.019 |
| $R^2$ | 0.148 | 0.563 | 0.0785 | 0.0616 |

Standard errors are in parentheses
*, **, *** Significant at 1, 5, and 10 percent respectively

Table 4.9: Relationship between LSPY and expected inflation

| Model | Fisher Effect (3 months) | | Fisher Effect (6 months) | |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |
| Period (yr.m) | 98.6–00.5 | 00.6-02.7 | 98.6–00.5 | 00.6-02.7 |
| N | 24 | 26 | 24 | 26 |
| $\Phi$ | 0.126*<br>(0.023) | 0.0161**<br>(0.0066) | 0.117*<br>(0.033) | -0.008<br>(0.014) |
| $\lambda$ | 0.091<br>(0.271) | 0.656*<br>(0.1209) | 0.1047<br>(0.4279 | 1.3*<br>(0.277) |
| D.W | 1.253 | 1.833 | 1.556 | 1.548 |
| $R^2$ | 0.0049 | 0.5615 | 0.003 | 0.49 |

Standard errors are in parentheses
*, **, *** Significant at 1, 5, and 10 percent respectively

Overall, the Fisher effect holds in the June 2000 to July 2002 period, though not on one-to-one basis. This is the period where both the inflation rates and the yields are low and experience low fluctuations. Again this suggests that the predictability of future inflation rates is enhanced with low inflation rates and low volatility. Also, the LSPY seem to provide better results supporting the idea that bidders quoting the minimum successful price are more informed: they not only consider inflation rate but the also consider any available information including the existence of market imperfections.

One argument is useful in explaining why the Fisher effect model based on the yields and inflation observed in Tanzania fail to holds on one-to-one. Inflation is an aggregate measure and the resulting number does not have the same effect on all economic agents. Some facts about the weights in the headline inflation and the Treasury bill buyers help to explain this. First, this study has used the headline inflation which covers both food and non-food prices. The weight of food items in the basket used in computing headline inflation in Tanzania is 71.2 percent. Second, banks, which account for more than 75 percent of the trading volume in the Treasury bill market, lend mainly to manufacturers and traders in the non-food sector. They are also the key players in the foreign currency market. Third, deposit rates offered by banks are low and for some time they have been below the inflation rate. For example, in the period from October 2000 through April 2002, savings deposit rates were below the headline inflation rate (BOT Monthly Economic Report, April-May 2002, pp.12), while for the June 2002 through March 2003 period, both savings deposit rates and time deposit rates were below the headline inflation (BOT Monthly Economic Report, April 2003). The combined effects of these facts suggest that the inflation rates used here may be less useful to both depositors and the banks. Thus, the Treasury bill buyers may be relying more on other numbers such as the non food inflation and the change in the value of the local currency. This argument is somehow supported by the BOT which, in its 2001 monetary policy statement, stated that its policy focus is on the consumer price index excluding food prices (the non-food inflation) rather than the overall (headline) inflation.

"... This is because food prices are mainly affected by non-monetary factors like droughts, floods etc. which monetary policy cannot control. ... Thus the Non-food Inflation rate is a measure of price movements, largely caused by policy factors. It is an important measure, which monitors more accurately, the effectiveness of monetary policy on inflation (BOT, Monetary Policy Statement, June 2001 pp.6).[13]

The similarity between the observations when testing the expectations theory and those from the relationship between the yields and inflation is attributable to a number of factors. First, there is the increase in the credibility of the central bank starting from the new Bank of Tanzania Act in 1995 and significantly enhanced by the appointment of a new Governor in 1998. The inclusion in the new Act of a provision for controlling inflation as the principal objective of the BOT had effects on both the inflation and the yields. Second, the failure by the yields to reflect fully inflation may be related to the objectives of treasury bills buyers. Most of the Treasury bill buyers are depository institutions buying Treasury bills for their own accounts rather than for selling to their clients. In this case, one of their main considerations is the margin between the yields and the deposit rates, which are also considered to be short-term rates. For most part of the sample period these rates have not only been low but have also been below the inflation

[13] Since non-food inflation data is only available from 1999, headline inflation was used throughout the sample period to ensure consistency.

rate (BOT Monthly Economic Review, April-May 2002, April 2003). This provides a room for the bidders to be 'competitive' and submit bids that result to low yields but which are above the deposit rate. Low yields, particularly for short-term bills, are also likely to be acceptable when the bills are used as a temporary store of funds. Finally, it seems that Treasury bill buyers consider inflation when it is low but when it is high they tend to ignore it. This is probably because high inflation rates are also likely to be characterized by high absolute variability, which makes future inflation rates less predictable and, in effect, less useful predictor of nominal yields.

### 4.5 Comparison of WAY and LSPY Results

Earlier, it was argued that bidders quoting the lowest successful price are likely to be more informed and they also seek to exploit any arbitrage opportunities arising from existence of market imperfections. In the long run, the presence, in a market, of participants seeking to exploit arbitrage opportunities enhances efficiency. Thus, it is expected that the yields earned by this group of bidders, the LSPY, produce more satisfactory results than the WAY. To a large extent this is supported by the findings in this study. Comparison of the results in tables 4.4, 4.5 and 4.6 shows that, in the estimating the term structure equations, LSPY has term premia that are significant at higher level of confidence; the yield curves have higher slope in seven of nine cases; and the equations have higher $R^2$s in seven of the nine cases. The initial estimates (before adjustments) also showed that models estimated using the LSPY had residuals that were more independent of the explanatory variable. The two yields do not produce different results across the different term structure estimations. In addition to not showing significant term premium for the June 1998 through May 2000 period both do not show significant term premium for short expectation horizon (three months) for the June 2000 through October 2002 period.

The superiority of the result from the LSPY over those from the WAY can also be used to support the argument that bid shading is not a common practice in the treasury securities auction. Studies have shown that the use of discriminatory pricing system in sealed-bid auctions tends to encourage bidders to deliberately lower their bids below the true values they place on the item being auctioned (Chari and Webber, 1992; Nautz and Wolfstetter, 1997; Laffont, 1997). This practice – known as bid shading – is intended to ensure that a bidder pays the least price when awarded the auctioned item. This is because the price paid by a bidder depends on that bidder's bid and bidders do not want to pay a price that is too much. In a market where bid shading is prevalent it may be expected that the lowest successful prices contain little information about the true valuation of the securities hence making LSPY less useful in term structure estimation. The findings in this study suggest that this may not be the case in Tanzania.

While it is not possible to stop bid shading, mechanisms can be put in place to ensure that the lowest successful price is not affected much by the practice. Restriction on the ability of bidders to submit multiple bids and having minimum bid price are some of the measures that can be used to limit the effect of bid shading. The LSPY results suggest that the BOT has some mechanisms in place and somehow they are effective. For example, a cursory look at the after-auction data shows that in several occasions the BOT award securities of amount smaller than those offered even when an offer is oversubscribed. While having such mechanisms in place is useful, care needs to be taken to ensure that they do not adversely affect the efficiency of the market.

### 4.6 Plausibility of the Underlying Theories and Market Efficiency

Breaking the theory into separate components does help understanding the implications of the results in relation to the biased expectations theory. First, the theory is split into the term premium part and the pure expectations part. The premium component has to do with the perceived riskness of the longer-maturing bills while the pure expectations component is related to the slope of the yield curve. The pure expectations element is further analyzed as emanating from two aspects that are also the underlying assumptions. The first is the use of short-term yields – both present and forecasted – to derive long-term yields. The second is the evolution of short-term yields where rational expectations are present. This implicitly posits that market participants use a model that leads to random forecasting errors.

The significant term premium observed in this study does not necessarily lead to the overall acceptance of the biased expectations theory. It only tells that for the sample period Treasury bill buyers considered longer-maturing bills riskier than shorter-maturing bills. The riskness, in this case, is most likely due to the fact that buyers face increased uncertainty as they held the bills longer (until they mature) in the absence of a secondary market. The premium may also reflect that long-term bills lack the non-pecuniary yield earned by short-term bills. That is, lower yield for short-term bills are likely to be acceptable if short-term bills are used as a temporary store of funds, probably, while waiting for better investment opportunities. In Tanzania primary dealers are mainly banks and they may be willing to accept lower yields as long as they are above deposit rates. Observing a significant term premium, however, gives some indication of market efficiency. In the absence of a secondary market Treasury bill buyers are expected to demand a premium when buying longer-maturing bills, if the market is efficient.

The combined effect of the two aspects of the pure expectation part is that if the short-term yields were the sole determinants of the long-term yields and evolved in a manner that is rational, then there would be no arbitrage opportunities in the market. The joint hypothesis nature of the theory is probably the key factor responsible for the rejection of the theory because the two aspects are rarely examined in isolation. Following the view held by Sargent (1972) that it is difficult to maintain both that only expectations about short-term rates determine the yield curve and that expectations are rational in the sense of efficiently incorporating available information, an attempt is made here to develop a theoretical analysis of the two aspects separately. Thus, the failure of the data to confirm fully the expectations theory – specifically the absence of a slope that is equal to the hypothesized value – is analyzed by looking at each aspect separately while assuming that the other aspect holds.

The observation in this study of yield curves with slopes that are significantly below the hypothesized values is interpreted as follows. First, short-term yields, assuming that they are the sole determinant of long-term yields, evolve in a manner that is not rational. Having a yield curve that has a slope that is lower than hypothesized value while maintaining that only short-term yields are used to derive long-term yields implies that market participants' expectations consistently overstate future short-term rates. As a result the current long-term rates are also overstated while the ex-post future realization of the short-term yields are below the expectations. Arbitrage opportunities exist and, assuming no other assets, investors are better off by buying long-term bills and holding them to maturity rather that buying and rolling over short-term bills. The idea that a market consistently overestimates future short-term yields is highly unlikely since market participants can be expected to adjust their forecasts based on the realized forecasting errors. Also, consistent overestimation indicates a problem with the expectations formation process – which precludes the rational expectations assumption – while arbitrage opportunity can only exist for short time as market forces work to wipe out possible profits. Consequently, in the long run, if short-term yields are used as the *sole* determinant of the long-term yields, there are no arbitrage opportunities in the market and the coefficients of the yield curves would be equal to the hypothesized values.

The second part of the interpretation is that market participants do not consider the expected short-term yields as the *sole* determinant of long-term yields. Short- and long-term yields may, in fact, bear little direct relationship even though both may be determined from closely related information. This allows for the slope of the yield curve to be different from the hypothesized value and is the key to the interpretation of negative slopes that have been observed when recession is expected.

The separate analysis shows that the rejection of the expectations theory of the term structure is more related to the rejection of the former aspect – that the current and expected short-term yields are the *sole* determinant of long-term yields – rather than the latter – that expectations on short-term yields are rational. The idea that short-term yields are used to determine long-term rate but are not the sole determinant has a number of implications. First, it does not preclude the rational expectations assumption. Maintaining rational expectations is, rather, related to existence of short-term rates that are highly predictable (Mankiw and Mirron, 1986). One issue that most studies seem to conveniently avoid is the simultaneity of the short- and long-term yields observed at a given point of time. The expectations hypothesis assumes that, at time t, the *current* short-term yield is known and this yield, together with the expected future short-term yields, are used to determine the long-term yield. This assumption has a weakness in the sense that both the short- and the long-term yields observed at time t are simultaneously determined. In a given auction, for example, bidders do not know the yield on a 91-day bill when deciding the bid price for a 364-day bill. Both yields are known after the auction. Thus, when deciding the bid price for a longer maturing bill, the current short-term yield is, at best, an expectational value. It follows that the assumption on expectations needs to extend to what is considered the current short-term yield. This, of course, does not change the results, particularly under rational expectation assumption, but helps to clear any misconception that the current short-term rate is observed before the current long-term rate.

Second, it recognizes that other factors have a direct influence on the long-term rates. For example, the assumption of absence of arbitrage opportunities inherent in the expectations theory invariably assumes that the next best investment alternative is found in the same market for government securities and there are no other assets. That is, over the duration of the longer-term bills, the series of shorter-term bills represent the best alternative investment considering, among other things, the desired portfolio risk. In practical however, the investor has other alternatives carrying the same total risk or having the same effect on the investor's portfolio. Nelson (1972) points out the failure of the theory to recognize this. He argues that there is a need to generalize the concept of risk to account for the relationship of returns from contracts in the bond market with those from nonbond assets in the participant's portfolio. Finally, recognizing that long-term yield is influenced by other factors allow for the slope of the yield curve to also capture the impact of the demand and supply forces.

Is the Tanzanian primary market for Treasury bills efficient? To a large extent the evidence provides an indication of the conformance of the Treasury bill market to the weak form conditions of market efficiency at least for the June 2000 to October 2002 period. First, significant term premium are observed in all term structure equations for both WAY and LSPY. That is, in an efficient market, buyers of longer-term instruments will demand a premium if they know that they have to hold them until they mature. Second, the spread between the current long- and short-term yields has ability to predict future change in the short-term yields. Finally, the yields reflect inflation though not on one-on-one basis. In general, assuming that the low volatility displayed in the more recent yields and inflation rates continue, the conclusion is that the market efficiency is improving with time.

### 4.7 Implications on the Cost of Government Borrowing

The objective of auctioning government securities is twofold in nature. First the government wants to ensure that the instruments offered for sale are sold and the intended amount is raised. Second it wants to minimize the interest it pays on the debt it raises. With the debt being sold using an auction system, minimizing the cost of debt also means maximizing revenues raised for a given face value. In this part the study looks at the implications on the cost of government borrowing in two parts – first by analyzing the yields from the current auction system and second by looking at the appropriateness of the auction system.

Having a yield curve that has a slope lower than hypothesized might imply existence of systematic arbitrage opportunities. Treasury bills buyers are better off by buying long-term bills and holding them to maturity rather that buying and rolling over short-term bills. However, these opportunities are mitigated by risk considerations and the presence of other assets. To the issuer, that is the government, the position is reversed and, assuming no monetary policy considerations or transaction costs, it pays to issue shorter-term bills and refinance them at maturity. To understand the extent to which the data support this view, the yields on 364-day bills are compared with the annualized compounded average yields for 91- and 182-day bills. In this comparison, only the WAY is used since the discriminatory pricing system used makes WAY the average cost of borrowing to the government. The annualized WAY for the shorter maturing bills are restated to periodic yields over the respective maturity and then compounded over the life of the longer maturing bills. For this purpose, the formula $((1+WAY/100 * D/365)^{364/D} - 1)*100$, where D is the maturity in days, is used. Thus, the periodic (un-annualized) WAY for 91- and 182-day bills are compounded quarterly and semi-annually respectively.

Table 4.10 shows that over the June 1998 through October 2002 period the average WAY on a 364-days bill exceeded that of compounded WAY on 91- and 182-day bills by 0.99 and 1.8 percentage points respectively. Even for the more recent data, over a one-year period, the yield on a 364-days bill exceeds that of compounded WAY on 91-day bills by 1.5 percentage points. This also means that, for a given face value of Treasury bills, issuing four consecutive 91-day bills results into interest cost that is about 25 percent lower than issuing one 364-day bill. Overall, the results in table 4.10 suggest that the government might be able to reduce its interest cost on Treasury bill by issuing short-term bills. In relation to the term structure results this also implies that the further the coefficient of the term structure is below the hypothesized value, the more the savings in interest costs.

In the absence of secondary market, switching from long to short-term bills has negligible implications on the overall aggregate money supply as long as the central bank is credible in its commitment to refinance at maturity. On the other hand one has to consider the implications the change might have on the yield structure, the risk of debt management and issuing costs. First, if the government issues more of the shorter maturing bills the yield structure is likely to be altered with shorter-term yields increasing and longer term yields decreasing. This reduces the excess yield and with it the benefits of issuing shorter term bills. Second, issuing short-term bills is likely to increase the risk of government debt management particularly when short-term yields are highly volatile. By issuing short-term bills and refinancing them at maturity the government is exposing itself to the risk that it may have to refinance them with bills of a higher yield. Based on the data the risk element may not be a serious problem. It was noted earlier that the yields show a general declining trend (Figure A1.1 appendix 1) and the recent data show that the yields are low and less volatile. This, though does not having a yield that is stable, reduces the risk of refinancing short-term bills at a yield that is significantly higher. Finally, with low refinancing risk, the key issue is whether the mix of shorter- and longer-term bills issued achieves an optimum excess yield considering that issuing a series of short-term bills instead of one long-term bill increases the issuing costs. This is an issue that the government may wish to examine further.

As noted earlier the BOT uses a multiple-price, sealed-bid auction system with all bids being competitive and awards being based on individual bids. On its face this system may seem to maximize revenues and minimize the cost of debt as bidders pay their respective prices. However, this is only true if all successful bids represent bidders' true valuation of the securities. A number of studies have shown that bidders' behavior, particularly the one that affects the relation between the values of the bids and the true valuation, is greatly influenced by the price used to award the item(s) being auctioned (Chari and Webber, 1992; Nautz and Wolfstetter, 1997; Laffont, 1997). Though sealed-bid, discriminatory price auctioning system tends to encourage bidders to shed prices, such practice carries the risk that a bidder may not be awarded securities. This has some further effects. First, there is an incentive for bidders to acquire more information on how other bidders are going to bid. Sometimes this information may have no value to the society (Chari and Webber, 1992) especially when the issuer has some mechanisms – that are unknown to bidders – to reduce the effects of bid shading. Second, it may encourage bidders to submit multiple bids and in effect open the auction to manipulation.

Bid shading is not prevalent in a uniform price auction system since most bidders are likely to pay a price that is different from – and in this situation lower than – the one in their bids. As a result bids under this system are closer to the bidders' true valuation and higher than those in the pay-your-price system. The findings that the uniform price system tend to results into more revenues – hence lower cost – to the issuer (Friedman, 1956; Milgrom and Webber, 1982; Ausubel and Crampton, 1998 and others) not only support that the system leads to higher bids but also suggests that the lowest price that clears the securities being auctioned is higher that the weighted average price in the pay-your price system. The fact that the price a bidder pays does not depend on that bidder's bid is probably the reason why uniform price achieves better distribution of auction awards than the discriminatory system ( Pulizzi and Nicholson, 1998; Haller and Lengwiler, 1998; and Heller and Lengwiler, 1998). The literature and observations, therefore, suggest that the auction system can be improved and the cost of government borrowing lowered by switching to uniform price auction system.

Two further factors are likely to be contributing to the weakness in the current auction system in Tanzania – the fact that noncompetitive bids are not allowed and the absence of secondary market. Noncompetitive bids allow bidders to submit bids, usually in limited amounts and subject to low ceilings (Chari and Webber, 1992), without specifying a price. Bidders in this category are awarded securities using the weighted average price from competitive bids. Noncompetitive bids are likely to reduce price shading as they reduce the amount available for competitive bidding. The presence of a secondary market can serve as a correction factor to ensure that bidders do not bid a price that is too much is for the sake of ensuring that they are awarded securities. In this situation bidders' paying a price that is too much will find it difficult to sell the securities in the secondary market. As a result even conservative bidders will be encouraged to ensure that their bids reflect not only what they are willing to pay but also the conditions in the secondary market.

Table 4.10: Annualized compounded average WAY and excess yields

| Sample Period | 98.6-02.10 | 98.6 –00.5 | 00.6-02.10 |
|---|---|---|---|
| 364-days | 9.68 | 13.98 | 6.07 |
| 182-days[a] | 8.69 | 12.92 | 5.21 |
| 91- days[a] | 7.87 | 11.93 | 4.55 |
| Excess yield[b] | 0.99 | 1.06 | 0.86 |
| Excess yield[c] | 0.82 | 0.99 | 0.66 |
| Excess yield[d] | 1.81 | 2.05 | 1.52 |

[a] The periodic (un-annualized) WAY for 91- and 182-day bills are compounded quarterly and semi-annually respectively

[b] Difference between average WAY on a 364-days and average compounded WAY on a 182-day bill

[c] Difference between average compounded WAY on a 182-days and average compounded WAY on a 91-day bill

[d] Difference between average WAY on a 364-days and average compounded WAY on a 91-day bill

# CHAPTER 5

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Summary

This study examines the pricing process of treasury bills in Tanzania and how it is related to the term structure of interest rates and the notion of market efficiency. It uses the biased expectations theory of the term structure of interest rates and the theory of market efficiency to derive a representation of the behavior of the yields to maturity obtained from Treasury bill auctions. The understanding of market efficiency and investors' rationality is also enhanced by an examination of how Treasury bill yields are influenced by inflation expectations. The study covers the period from June 1998 through October 2002 and uses the annualized yields to maturity for three maturities – 91-days, 182-days and 364-days – obtained from weekly Treasury bill auctions and the annualized three- and six-months inflation rates. The sample period is split into two part and both the weighted average yields (WAY) as well as the yields to maturity obtained by the lowest successful price (LSPY) are used. The relationships among the yields and between the yields and inflation rates are examined using equations based on the biased expectations theory of the term structure of interest rates as well as the Fisher hypothesis.

The data were analyzed using SAS statistics software. The residuals from most of the initial estimates were found to be autocorrelated and heteroscedastic. Adjustment to these problems was based on the assumption of an exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model that combines a $j^{th}$ order autoregressive error model with the GARCH(p,q) variance. The order of autocorrelation was determined by using BACKSTEP option in the SAS code while the GARCH specification was restricted to GARCH (1,1) or lower.

When the entire sample is used, mixed results are produced for the equations testing the biased expectations theory as well as those for the relationship between the yields and inflation rates. However when the data are split, a clearer picture emerges. For the June 1998 through May 2000 period the yields do not show the presence of a significant term premium for any of the term structure equations, irrespective of the type of yields used. The term premium is also absent for the June 2000 through October 2002 period when three – and six-month yields are used as short- and long-term yields respectively. When 12-month yields are used as long-term yields both WAY and LSPY have term premia that are significant with LSPY faring better than WAY. The presence of a significant term premium also mean the hypothesis that longer maturing bills are riskier cannot be rejected. In all equations, the coefficients are positive and significantly different from zero. The coefficients are, however, below their theoretically hypothesized values. The significance of the coefficients implies that the current spread between long- and short-term yields contains information that is useful in the prediction of future short-term yields.

The results for the relationship between the yields and inflation rates show the presence of a real yield that is significant and that inflation is used in determining the yields. The Fisher effect holds, though not on one-to-one basis. Overall, LSPY provides more satisfactory results than WAY supporting the notion that bidders quoting the minimum successful price are more informed. LSPY's term premiums are significant at higher levels of confidence, the yield curves have larger coefficients and the equations have higher $R^2$s. The better results for the tests in the split data are attributable to the low level and variability of the yields and inflation rates in the June 2000 through October 2002 period, that make both the yields and inflation rates easier to predict and hence more useful in forecasting nominal yields and future short-term yields. In general, the market seems to be efficient and, assuming the low volatility displayed in the more recent yields and inflation rates continues, this efficiency is improving with time. On the other hand the efficiency could be improved and the cost of government borrowing lowered by switching from discriminatory pricing of awarded securities to uniform pricing system.

## 5.2 Implications, Limitations and Future Research

The findings in the study have a number of implications, two of which were raised in the previous chapter. First, is on the cost of government borrowing and second is the superiority of the result from LSPY over those from WAY has implications on the auction system. In the absence of debt instruments issued by the private sector, the findings in this study are not sufficient to assess the implication of the term structure on monetary policy transmission. That is, whether the yields' effects transfer to the other interest rates particularly the yields on long-term lending instruments issued by private entities. On the other hand a cursory look at the short-term rates by commercial banks (BOT Monthly Economic Review March 2003) shows a narrowing spread between lending and deposit rates in the June 2000 through October 2002 period. Deposit rates are almost flat but lending rates are falling. However, the spread is still high at more that 10 percentage points and the lending rates seem to be declining slower than the Treasury bill yields.

It is a common knowledge that specification of a hypothesis and its underlying assumptions are critical in the interpretation of results from empirical tests on the hypothesis. The specifications and assumptions in this study dictated and in effect limited the extent to which tests were conducted on the data to understand the relationships among the yields and those between the yields and inflation. Thus the empirical results on the biased expectations hypothesis and the Fisher effect models in this study can only be accepted or rejected based on their specifications and assumptions. Changing the specifications and the assumptions can greatly enhance the understanding of the issues examined in this study. Froot (1989), for instance, found that the expectations hypothesis fits the data better if expectations are taken from survey rather than when they are based on rational expectations assumption. Again here it may be assumed that revealing expectations does not affect buyers' and sellers' behavior.

Being a pioneering study in this area in Tanzania, the study adopted a narrow focus but it offers a basis on which a wide range of research can be based on. First is the use of general equilibrium approaches that recognize the presence of other assets and incorporate them in modeling the term structure. In Tanzania, such assets include foreign currencies. It was noted earlier that banks are the major players in both the Treasury bill market and the foreign currency market. Banks use the latter market to hedge against currency depreciation as well as to store liquidity. If, for example, the Tanzanian shilling is expected to depreciate banks may hedge by buying foreign currency rather than treasury bills with the possible result being higher yields in the Treasury bill market. Indeed, the risk of change in the value of the local currency may be as equally important as the default risk in the choice of investments. Considering the foreign currency market is also critical especially since the data shows that the yields do not adequately reflect inflation. In addition to including foreign currency in a generalized term structure model, one may be interested to test the relation between the change in the value of the currency and the yields in the Treasury bill market.

The alternative approach is to derive a model for the expected demand given the amount offered. This is of particular importance in the pay-your-bid system. Theoretically a bidder sets the bid price on assumption that it is the market-clearing price. Given a demand model, it is possible for bidders to bring their bids closer to the expected market-clearing price with an improved level of accuracy. The model may need to take into account factors such as seasonal patterns, the liquidity position of market participants – specifically banks – and the conditions that may make the issuer sell bills of amount different from the offered amount. The latter may include the perceived urgency for the government to secure fund to, say, retire maturing debt or meet a budget shortfall while banks' liquidity position is affected by factors such as aggregate deposits and the central bank's examination cycle. It is important to note that the bid pattern revealed by the data in the current discriminatory pricing system, particularly the unsuccessful bids, might not be a true indicator of the demand pattern due to possibility of bid shading.

A number of interesting observations that are not directly related to the issues examined in this study were made during the data collection process. First, the dispersion in the yields for successful bids is sometimes very high. In the sample period some dispersions were more than 5 percentage points while most were above one percentage point. This implies that for a given auction and maturity, it is not uncommon to find a highest accepted yield that is 20 percent above the lowest yield. This is much higher than the maximum of 6 percent observed by Godbout et al. (2002) in Canada. Since the dispersion is associated with abnormal conditions in the market and has been found to affect the performance of the term structure model (Godbout et al., 2002) a look at the explanation for the high dispersion observed and its possible effects on the integrity of the auctioning system is a worthwhile research issue.

The information released after each auction also reveals that the BOT, on behalf of the treasury, does sell bills of amounts different from the one stated in pre-auction announcements. It is understandable that bills of amount less than that offered can be sold if not enough bids are received or if the seller has target minimum price (as is likely to be the case though such price is not revealed) and the received bids that are above this price fall short of the offered amount. The motives for selling above the offered amount are, however, not so clear and at best they are subject to speculation.

Now that government securities are scheduled for trading in the secondary market, it will be interesting to compare the performance of term structure models results based on the yields from the primary market for the period without secondary market and for the period when the treasury bills are traded in the secondary market once sufficient observations become available. In general answers to some interesting research issues require a comprehensive evaluation of the auction system.

## References


Amihud, Yakov, and Mendelson, Haim, "Liquidity, maturity, and the yields on U.S. Treasury securities," *Journal of Finance* 46 4, (1991), pp. 1411-1425

Ausubel, Lawrence M., and Peter Cramton, "Auctioning Securities," Working Papers, Department of Economics, University of Maryland, March 1998 (www.ausubel.com/auction-papers.htm accessed 6/20/2003 6.44 pm)

Bakshi, Gurdip S., and Zhiwu Chen, "Inflation, Asset Prices, and the Term Structure of Interest Rates in Monetary Economies," *Review of Financial Studies*, Vol. 9, No. 1, (Spring, 1996) pp. 241-275

Bank of Canada, "Revised rules pertaining to auctions of Government of Canada securities and the Bank of Canada's surveillance of the auction process," *Final Report*, 11 August 1998.

Bank of Tanzania, *Monetary Policy Statement* June 2001.

Bank of Tanzania, *Monthly Economic Review*, Dar es Salaam, (various months)

Bank of Tanzania's Internet web site www.bot-tz.org (various sections of the site)

Bierwag, G. O., and M. A. Grove, "A Model of the Term Structure of Interest Rates," *Review of Economics and Statistics*, Vol. 49, No. 1, (Feb., 1967), pp. 50-62.

Bonello, F. J., *The Formulation of Expected Interest Rates* MSU Business Studies, 1966

Brenner, Robin J., Richard H. Harjes, and Kenneth F. Kroner, "Another Look at Models of the Short-Term Interest Rate," *Journal of Financial and Quantitative Analysis*, Vol. 31, No. 1, (March, 1996) pp. 85-107

Browne, Frank and Paolo Manasse, "The Information Content of the Term Structure of Interest Rates: Theory and Practice," *OECD Department of Economics and Statistics Working Papers No 69* September 1989

Campbell, B., and J.W. Galbraith, "Inference in expectations models of the term structure: A non-parametric approach," *Empirical Economics* 18 (1993), pp. 623-638.

————, "Non-parametric regression models of deviations from orthogonality in the expectations theory of the term structure," *Oxford Bulletin of Economics and Statistics* 59 2 (1997), pp. 265-284

Campbell, John Y., "A defense of traditional hypotheses about the term structure of interest rates," *Journal of Finance* 41 1, (1986) pp. 183-193

————, "Some Lessons from the Yield Curve," *Journal of Economic Perspectives*, Vol. 9, No. 3, (Summer, 1995), pp. 129-152.

Campbell, John Y. and Robert J. Shiller, "A simple account of the behavior of long-term interest rates," *American Economic Review Papers and Proceedings,* 74 2, (1984) pp. 44-48

————, "Yield Spreads and tests of present value models: a bird's eye view," *Review of Economic Studies*, 58, (1991) pp 495-514.

Cargill, Thomas F., "The Term Structure of Interest Rates: A Test of the Expectations Hypothesis," *Journal of Finance* Vol. 30 No. 3 (June 1975) pp. 761-771

Carr, J., J.E. Pesando and L.B. Smith, "Tax effects, Price expectations and the Nominal Rate of Interest," *Economic Inquiry* Vol. 14 (1976) pp. 259 – 269

Chari, V. V and Robert J Webber, "How the U.S. Treasury Should Auction its Debt" *Fedral Reserve Bank of Minneapolis Quarterly Review*, Volume 16, No. 4 (Fall 1992)

Cox, John C.; Jonathan E. Ingersoll, Jr. and Stephen A. Ross, "A Re-Examination of Traditional Hypotheses about the Term Structure of Interest Rates," *Journal of Finance*, Vol. 36, No. 4. (September, 1981), pp. 769-799

Culbertson, John M., "The Term Structure of Interest Rates," *Quarterly Journal of Economics*, Vol. 71, No. 4, (November, 1957) pp. 485-517

Dai, Quing and Kenneth J. Singleton, "Expectations Puzzles, Time-varying Risk Premia, and Dynamic Models of the Term Structure," *NBER Working Papers* No.w8167 (March 2001)

Deaves, Richard, "Forecasting Canadian Short-Term Interest Rates," *Canadian Journal of Economics,* Vol. 29, No. 3, (August, 1996) pp. 615-634

Dobson, Steven W., Richard C. Sutch, and David E. Vanderford, "An Evaluation of Alternative Empirical Models of the Term Structure of Interest Rates," *Journal of Finance*, Vol. 31, No. 4, (September, 1976), pp. 1035-1065

Engle, Robert F., Victor K. Ng, "Time-Varying Volatility and the Dynamic Behavior of the Term Structure," *Journal of Money, Credit and Banking*, Vol. 25, No. 3, Part 1, (August, 1993) pp. 336-349

Engsted, Tom and Carsten Tanggaard, "Cointegration and the US term structure," *Journal of Banking and Finance* 18 (1994) pp 167-181

Fama, Eugene F., "Short-term Interest rates as Predictor of Inflation," *American Economic Review* 65, No. 3, (1975) pp 269-282

———, "Inflation Uncertainty and Expected Returns on Treasury Bills," *The Journal of Political Economy*, Vol. 84, No. 3, (June, 1976) pp. 427-448

———, "The information in the term structure," *Journal of Monetary Economics*, 13 (1984), pp. 509-529

Feldstein, Martin, and Otto Eckestein, "The Fundamental Determinants of Interest Rate," *Review of Economics and Statistics,* Vol. 52, (November 1970), pp. 365-375

Frankel, Jeffrey A., and Cara S. Lown, "An Indicator of Future Inflation Extracted from the Steepness of the Interest Rate Yield Curve Along Its Entire Length," *Quarterly Journal of Economics*, Vol. 109, No. 2, (May, 1994), pp. 517-530.

Friedman, Lawrence, "A Competitive-Bidding Strategy" *Operations Research*, Vol. 4, No. 1. (Feb., 1956), pp. 104-112.

Froot, Kenneth A., "New Hope for the Expectations Hypothesis of the Term Structure of Interest Rates," *Journal of Finance*, Vol. 44, No. 2. (June 1989), pp. 283-305.

Gerlach, Stefan and Frank Smets, "The term structure of Euro rates: Some Evidence in support of the expectation hypothesis," *Bank for International Settlement (BIS) Working Paper*, No 28. (1995)

Godbout, Lise, Paul Storer and Christian Zimmermann, "The Canadian Treasury bill auction and the term structure of interest rates," *Journal of Banking and Finance* Volume 26 Issue 6 (June 2002) pp. 1165-1179

Gray, Jean M., "New Evidence on the Term Structure of Interest Rates: 1884-1900," *Journal of Finance*, Vol. 28, No. 3. (June, 1973), pp. 635-646.

Hall, Anthony D., Heather M. Anderson and Clive W.J. Granger, "A Cointegration Analysis of Treasury Bill Yields," *Review of Economics and Statistics*, Vol.74, Issue 1 (February 1992) pp. 116-126

Haller, Hans and Yvan Lengwiler, "A Discrete Model of Discriminatory Price Auctions – An Alternative to Menezes-Monteiro," *Federal Reserve Board Publications* January 1998 (http://www.federalreserve.gov//pubs/feds/1998/199808/199808pap.pdf Accessed April 30 2003)

Hamburger, Michael J and Elliot N. Platt, "The Expectations Hypothesis and the Efficiency of the Treasury Bill Market," *Review of Economic and Statistics* 57 no.2 (May 1975) pp. 190-199

Harris, Lawrence, *Monetary Theory,* McGRaw-Hill, Inc 1981

Hejazi, Walid, Huwein Lai and Xian Yang, "The expectations hypothesis, term premia, and the Canadian term structure of interest rates," *Canadian Journal of Economics,* 33 1 (2000), pp. 133-148

Heller, Daniel and Yvan Lengwiler, "The Auctions of Swiss Government Bonds: Should the Treasury Price Discriminate or Not?" *Federal Reserve Board Publications* January 1998 (http://www.federalreserve.gov/pubs/feds/1998/199811/199811pap.pdf Accessed April 30 2003)

Hicks, John R., *Value and Capital: An Inquiry into some Fundamentals Principles of Economic Theory,* 2nd Edition, Clarendon Press, Oxford 1946

Kugler, Peter, "An Empirical note on the term structure and interest rates stabilization policies," *Quarterly Journal of Economics* Vol. 103, No. 4, (November 1988) pp. 789-792

————, "The expectations hypothesis of the term structure of interest rates, open interest rate parity and central bank policy reaction," *Economics Letters* (66) 2 (2000) pp. 209-214

Laffont, Jean-Jacques, "Game theory and empirical economics: The case of auction data" *European Economic Review* Volume 41 Issue 1 (January 1997) pp. 1-35

Lee, Sang-Sub, "Macroeconomic Sources of Time-Varying Risk Premia in the Term Structure of Interest Rates," *Journal of Money, Credit and Banking*, Vol. 27, No. 2, (May, 1995) pp. 549-569

Longstaff, Francis A. and Eduardo S. Schwartz, "Interest Rate Volatility and the Term Structure: A Two Factor General Equilibrium Model," *Journal of Finance*, Vol. 47, No. 4, (September, 1992) pp. 1259-1282

Luckett, Dudley G., "Multi-Period Expectations and the Term Structure of Interest Rates," *Quarterly Journal of Economics*, Vol. 81, No. 2, (May, 1967), pp. 321-329

Maddala, G.S. and C.R. Rao. *Statistical Methods in Finance,* Elsevier Science B.V. 1996

Mankiw, N. Gregory and Jeffrey A. Miron, "The Changing Behavior of the Term Structure of Interest Rates," *Quarterly Journal of Economics*, Vol. 101, No. 2, (May, 1986), pp. 211-228.

McAfee, R. Preston and John McMillan, "Auctions and Bidding: A Primer" *Journal of Economic Literature* 25 (June 1987) pp. 699-738

Meiselman, David, *The Term Structure of Interest Rates*, Prentice-Hall, Inc. Englewood Cliffs N.J. (1962)

Milgrom, Paul, R. "Auctions and Bidding: A Primer" *Journal of Economic Perspective* Volume 3 No. 3 (Summer 1989) pp. 3-22

————, and Robert J. Webber "A Theory of Auctions and Competitive Bidding" *Econometrica* Volume 50 (September 1982) pp. 1089-1122

Mishkin, Frederic S., "Is the Preferred-Habitat Model of the Term Structure Inconsistent with Financial Market Efficiency?" (in Comments) *Journal of Political Economy,* Vol. 88, No 2, (April, 1980), pp. 406-411

————, "The Information in the Term Structure: Some Further Results," *Journal of Applied Econometrics*, Vol. 3, No. 4, (Oct. - Dec., 1988), pp. 307-314.

————, "The Information in the Longer Maturity Term Structure About Future Inflation," (in Short Papers) *Quarterly Journal of Economics*, Vol. 105, No. 3, (August, 1990), pp. 815-828

Modigliani, Franco and Richard Sutch, "Innovation in Interest Rates Policy," *American Economic Review* 56 No. 1/2 (March 1966) pp. 178-197

Modigliani, Franco and Robert J Shiller, "Inflation, Rational Expectations and the Term Structure of interest rates," *Economica* 40 (February 1973) pp. 12-43

Nautz, D. and Wolfstetter, E., "Bid shading and risk aversion in multi-unit auctions with many bidders" *Economics Letters*, (Oct 1997) pp. 195-200

Nelson, C. R., *The Term Structure of Interest Rates*, Basic Books Inc., New York (1972)

Nyborg, Kjell, G. and Suresh Sundaresan, "Discriminatory versus Uniform Treasury Auctions: Evidence from when issued Transactions" Journal of Financial Economics 42 (1996) pp.63-104

Pesando, James E., "Alternative Models of the Determination of Nominal Interest Rates: The Canadian Evidence," *Journal of Money, Credit and Banking*, Vol. 8, No. 2, (May, 1976) pp. 209-218

————, "On the Efficiency of the Bond Market: Some Canadian Evidence," *Journal of Political Economy* 86 no. 6 (December 1978) pp. 1057-1076

————, "On the Random Walk Characteristics of Short- and long-term interest rates in an efficient market," *Journal of Money Credit and Banking* Vol. 11, No. 4 (November, 1979), pp. 457-466

Phillips, Llad and John Pippenger, "Preferred Habitat vs. Efficient Market: A Test of Alternative Hypotheses," *Federal Reserve Bank St. Louis Rev.* 58 No. 5 (May 1976): pp. 11-19

Pulizzi, Henry J. and Jonathan Nicholson, "Dutch-auction format to be adopted by the treasury in more sales of issues," *Wall Street Journal,* 27 October 1998, pp. A24.

Roll, Richard *The Behavior of Interest Rates: An Application of the Efficient Market Model to U.S. Treasury Bills*, Basic Books, Inc., New York, 1970

Sargent, Thomas P., "Rational Expectations and the Term Structure of Interest Rates," *Journal of Money, Credit and Banking,* Vol. 4, No. 1, (February, 1972) pp. 74-97

Shen, Pu and Ross M. Starr, "Liquidity of the treasury bill market and the term structure of interest rates," *Journal of Economics and Business* Volume 50, Issue 5 (September 1998) pp. 401-417

Shiller, Robert J., "Rational Expectations and the Term Structure of Interest Rates: Comment," (in Comments and Replies) *Journal of Money, Credit and Banking,* Vol. 5, No. 3. (August, 1973), pp. 856-860

————, "The volatility of long-term interest rates and expectations models of the term structure," *Journal of Political Economy* 87 6, (1979), pp. 1190-1219

————, "The Term structure of interest rates," in Friedman, B.M. and Hahn, F.H. (editors), *Handbook of Monetary Economics* Vol. 1 North-Holland, New York, (1990) pp. 627-722.

United Republic of Tanzania, *Bank of Tanzania Act* (1995)

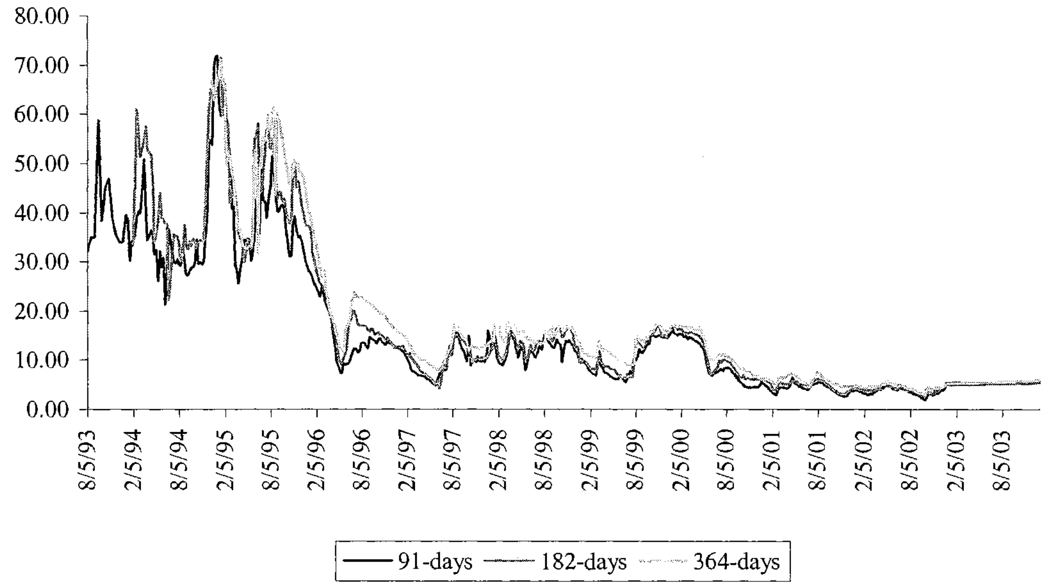
Wallace, Myles S. and John T Warner, "The Fisher Effect and the Term Structure of Interest Rates: Tests of Cointegration," *Review of Economics and statistics* Vol. 75, No. 2, (May, 1993), pp. 320-324

Yohe, William P., and Denis S. Karnosky, "Interest Rates and Price Level Changes, 1952-69," *Federal Reserve Bank St. Louis Rev.* 51, No. 5 (December 1969): pp. 19-36.

## Appendix

## Appendix 1: 1993-2002 Weighted Average Yields and Inflation Rates: Graphs and Summary statistics

Figure A1.1: Weighted Average Yields obtained from Treasury bill auctions




Source: Bank of Tanzania

Table A1.1: 91-days Treasury bill yields (percent)

| Year | 1993/4 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| Low | 21.30 | 25.59 | 7.32 | 5.01 | 7.84 | 5.45 | 4.40 | 2.62 | 2.02 |
| High | 71.63 | 71.83 | 28.08 | 15.91 | 15.56 | 16.52 | 15.36 | 6.38 | 5.30 |
| Average | 36.44 | 40.43 | 15.30 | 9.59 | 12.06 | 10.09 | 9.29 | 4.22 | 3.62 |
| Standard Deviation | 9.94 | 10.31 | 5.66 | 2.92 | 1.79 | 3.48 | 4.02 | 0.87 | 0.72 |
| Coefficient of Variation | 0.27 | 0.26 | 0.37 | 0.30 | 0.15 | 0.34 | 0.43 | 0.21 | 0.20 |

Source: Bank of Tanzania and own computations

Table A1.2: 182-days Treasury bill yields (percent)

| Year | 1993/4 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| Low | 22.14 | 29.87 | 8.98 | 4.20 | 9.22 | 6.32 | 5.99 | 3.07 | 2.54 |
| High | 65.00 | 71.45 | 37.25 | 15.47 | 16.57 | 16.96 | 16.84 | 6.07 | 4.90 |
| Average | 42.33 | 46.31 | 18.15 | 10.06 | 13.44 | 10.90 | 10.53 | 4.81 | 3.94 |
| Standard Deviation | 11.31 | 10.12 | 6.45 | 2.87 | 2.04 | 3.55 | 3.93 | 0.89 | 0.52 |
| Coefficient of Variation | 0.27 | 0.22 | 0.36 | 0.29 | 0.15 | 0.33 | 0.37 | 0.19 | 0.13 |

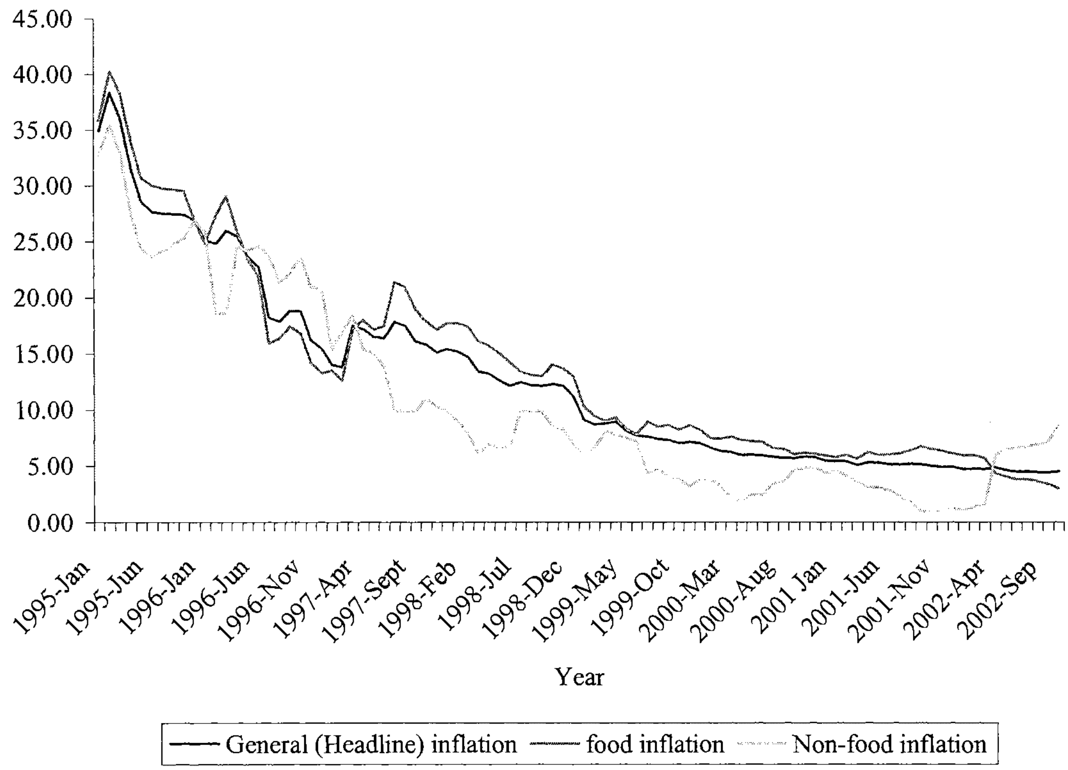
Source: Bank of Tanzania and own computations

Table A1.3: 364-days Treasury bill yields (percent)

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Low | 31.67 | 11.46 | 7.98 | 12.03 | 8.96 | 6.14 | 4.54 | 3.00 |
| High | 71.01 | 40.37 | 17.31 | 17.85 | 17.24 | 17.07 | 7.47 | 5.59 |
| Average | 49.16 | 21.78 | 12.16 | 15.26 | 12.77 | 11.82 | 5.78 | 4.48 |
| Standard Deviation | 10.19 | 6.59 | 2.54 | 1.41 | 2.73 | 3.77 | 0.86 | 0.58 |
| Coefficient of Variation | 0.21 | 0.30 | 0.21 | 0.09 | 0.21 | 0.32 | 0.15 | 0.13 |

Source: Bank of Tanzania and own computations

Figure A1.2: Annual Inflation Rates 1995-2002




Source: Bank of Tanzania

VITA ②

Ellinami J Minja

Candidate of the Degree of

Doctor of Philosophy

Thesis: THE TERM STRUCTURE OF INTEREST RATES AND TREASURY BILL MARKET EFFICIENCY IN TANZANIA

Major Field: Economics

Biography:

Personal Data: Born in Marangu, Moshi Tanzania, the son of Yohane Ngeleuya and Gladness Morio

Education: Completed secondary education at Moshi Secondary School in November 1983; attained Advanced Certificate of Secondary Education Examination from Umbwe High School in May 1986: received Bachelor of Commerce degree in Accounting from University of Dar-es-Salaam, Dar-es-Salaam, Tanzania in November 1991; received Master of Business Administration degree from University of Nairobi, Nairobi, Kenya in December, 1996; successfully completed examinations leading to Certified Public Accountant (CPA (T)) certification, National Board of Accountants and Auditors, Dar-es-Salaam, Tanzania in November, 1996. Completed the requirements for the Doctor of Philosophy degree with major in Economics, at Oklahoma State University in December 2003

Professional Experience: Tutorial Assistant, Department of Finance, University of Dar-es-Salaam, April 1991-October 1993; Volunteer Tutorial Assistant in Management Accounting courses - Faculty of Commerce, University of Nairobi, Nairobi, 1994-1995; Assistant Lecturer, Department of Finance, University of Dar-es-Salaam, Dar-es-Salaam, December 1996-July 1998; Part-time Tutor in Computerized Accounting, Institute of Information Technology, Dar-es-Salaam, 1996-1997; Resource Person in preparing candidates for CPA examinations, APT Consultants, Dar-es-Salaam, Tanzania,1996-1998; Graduate Teaching Associate, Department of Economics and Legal Studies in Business, Oklahoma State University, Oklahoma, 2000-2002.