UNIVERSITY OF THE WITWATERSRAND

Can forward interest rates predict future spot rates in South Africa?

A test of the pure expectations hypothesis and market efficiency in the South African government bond market.

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Abstract

The pure expectations hypothesis says that forward rates, implied off a yield curve, are unbiased predictors of future spot rates. Which implies forward rates, according to the pure expectations hypothesis, should provide reliable forecasts of future spot rates.

This study set out to see if the theory behind the pure expectations hypothesis holds in a South African context. If it does hold, it can have an impact on real world applications such as bond trading strategies and the setting of monetary policy.

To test the theory behind the pure expectations hypothesis, South African government bond data for the short end of the yield curve was used. Various regression tests were run. These regressions tested mainly for forward rate forecast accuracy, the relationship between forecast errors and changes in the spot rate, for the presence of liquidity premiums and to test for market efficiency.

The results indicated that forecast accuracy and the relationship between forecast errors and changes in the spot rate were contrary to the theory behind the pure expectations hypothesis. A liquidity premium was found to exist and there appeared to be weak form market efficiency.

These results led to a conclusion that there is very little evidence to support the theory behind the pure expectations hypothesis. This was mainly due to the presence of a liquidity premium. The pure expectations hypothesis does not seem to be of any significant use within real world applications.

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1. Introduction

Financial market participants have always been, and will always be, seeking a model that allows them to gain a competitive advantage. Regardless of whether the model is used to forecast a price, an interest rate or an exchange rate, the ability to forecast the future would have a large impact on everything from investment decisions to monetary policy. This search for a competitive advantage has made market participants and academics alike try to build models that forecast the future using current and historical data, as well as current and historical events. This is the basic tenet of all the theories that have been proposed to explain the yield curve.

There have been four main theories developed to try to explain the shape of the yield curve. These four theories are: the liquidity preference theory, the preferred habitat theory (also known as the market segmentation theory), the pure expectations theory and the expectations theory.

The pure expectations hypothesis has been tested in past research on exchange rate data as well as bond data. The past research does not follow a particular direction, but the methodologies are quite similar. The general findings are that forward rates do not provide reliable forecasts of the future spot rates and that a liquidity premium does exist. Most of the past literature on the pure expectations hypothesis and expectations hypothesis was based on tests done on either American or British data. Building onto past research, this paper aims to test if the pure expectations theory holds when data from a developing country is used. This paper's main concern is to test the validity of the pure expectations hypothesis in the short end of the South African government bond market. A secondary concern of this paper is to test for market efficiency in the South African government bond market.

The rationale for undertaking this paper was that relatively little research has been done on the pure expectations hypothesis and expectations hypothesis in a South African context. The methodology that was used for this paper has been taken from the seminal work done by Hamburger and Platt (1975). The datasets used have been put together so as to replicate the Hamburger and Platt (1975) dataset as closely as possible. The deviations from the Hamburger and Platt (1975) methodology and dataset construction, where they occur, have been highlighted in the relevant sections. This paper extends Hamburger and Platt's (1975) work by applying their methodology to two sets of data. The one set was taken from a yield curve that was constructed using a “perfect fit” technique and the other set of data was taken from a yield curve that was constructed using a “best decency” technique. The reason for using data from different constructions of the yield curve is to see if differing constructions can give differing results.

The rest of this paper will be broken down into the following chapters: Literature review; Methodology and Data; Results; and finally, the Conclusion.

The literature review looks at the various components that contribute to the theoretical underpinnings of the pure expectations theory. The first few subsections of the literature review deal with the foundations of the expectations theories. The pure expectations theory and expectations theory are then dealt with. The findings of this paper’s base paper, Hamburger and Platt (1975), are the final subsection of the literature review. The methodology and data section describes how, and from where, the dataset for this paper was constructed and the methods used to test both the pure expectations hypothesis and to test for market efficiency. The results section discusses the results obtained from the tests of the pure expectations hypothesis and the tests for market efficiency. Finally, the conclusion discusses the contribution made by this research, makes recommendations for future research and provides some concluding remarks.

2. Literature review

2.1 Introduction

The purpose of the pure expectations theory and the expectations theory is to explain the shape of the yield curve. In explaining the shape of the yield curve, a theory would merely be describing the relationship between shorter term and longer term securities. This relationship is obviously of great concern to all market participants such as investors and monetary policy committees. The reasons for concern are quite clear. Any investor would ideally want to be able to have accurate and reliable forecasts of future interest rate movements. Monetary policy tries to affect the short term rate so as to have a desired outcome on the long term rate. The affect is not always as desired, but if there was a theory to accurately describe the relationship between short term and long term interest rates, monetary policy could be used with greater precision to achieve desired outcomes. The four main theories are the liquidity preference theory, the preferred habitat theory, the pure expectations theory and the expectations theory.

The liquidity preference theory is a good example of a risk return trade-off. It describes the relationship between short term and longer term rates with regard to the preferences of lenders and borrowers. On the one hand there are lenders of money who prefer to lend short term so as to minimise the repayment risk. On the other hand there are borrowers who prefer to borrow long term so as to ensure the availability of money. For lenders and borrows to arrive at an agreement, borrowers would have to compensate the lenders for the additional risk that they take on by lending for longer terms. This compensation is known as a liquidity premium and is the basis of the liquidity preference hypothesis (Hicks, 1939). The premium increases at a decreasing rate with term to maturity due to two reasons (International Financial Risk Institute, 2002). The first reason is that bond duration, which measures price sensitivity to changes in the interest rate, increases at a decreasing rate with term to maturity. Secondly, the longer the term to maturity the less volatile the interest rates tend to be. However the liquidity preference theory is not without its critics. One of the criticisms levelled at it is that it seems to only be able to describe an upward sloping yield curve; where in reality yield curves can slope downwards and can even have a hump in them. Another problem with the liquidity preference theory is that it cannot explain why lenders like pension funds, life insurers and trust funds prefer to lend long term.

Modigliani and Sutch first proposed the preferred habitat theory in their 1966 paper "Innovations in interest rate policy". The basis of the preferred habitat theory is that different market participants prefer different terms to maturities, thus segmenting the yield curve. The preferences could be based on anything from investment horizons to regulatory requirements. Under the preferred habitat theory the supply of and demand for loan-able funds is the main determinant of the yield curve's shape. For an investor to move out of their preferred "habitat" they would require a premium. This theory does a better job of explaining downward sloping and humped yield curves than the liquidity preference theory. However it cannot explain why interest rates for different maturities tend to move together. This co-movement is contrary to the idea that interest rates are solely determined by the supply of and demand for loan-able funds.

The basis of the pure expectations theory is that forward rates are unbiased predictors of future spot rates. Which implies that a forward rate implied off a yield curve can accurately forecast the future spot rate. Thus forward rates can be viewed as the market's expectations for the future within the pure expectations theory. This theory can explain all shapes of the yield curve since it is based on market expectations. For this theory to hold the market from which the yield curve is constructed would have to utilise available information efficiently. Although the pure expectations theory is a strong model, in the sense that it only uses forward rates to forecast future spot rates, it has not found a lot of support in academic literature. The main problem that causes this non-support is the presence of a liquidity premium. Due to the presence of a liquidity premium the pure expectations theory was adapted so as to cater for it. The model then became known simply as the expectations theory. The expectations theory says that a forward rate adjusted for a liquidity premium provides a better, more accurate forecast of the future spot rate. This theory is, in a way, a combination of the liquidity preference theory (since it includes the liquidity premium), the pure expectations theory (since it includes the forward rate) and the preferred habitat theory (since the forward rates are implied off a yield curve that has been constructed from a market that has participants with different maturity preferences). The expectations theory has found more academic support than the pure expectations theory. It, however, also has its critics. There have been findings of the model being sufficient in sub-sample periods but not in entire sample periods. There have also been questions raised for both the pure expectations theory and the expectations theory as to the correct way to model expectations; no overwhelming consensus has been reached on this question.

Early literature on interest rates assumed that all interest rates increased and decreased together, and that if there was a difference in interest rates there would be a tendency for these interest rates to converge (Lutz, 1940). The work of Keynes (1930), Hicks (1939) and Lutz (1940) found this relationship between all interest rates to be incorrect. Their findings showed that there was a difference between shorter term and longer term rates, and that shorter term rates have an influence on longer term rates. Lutz (1940) found that shorter term rates and longer term rates were consistent with each other, but not equal. The relationship that best described how shorter term rates and longer term rates were connected was that longer term rates were merely averages of shorter term rates (Hicks, 1939). This relationship helped to explain Keynes (1930) and Hicks's (1939) findings that short term rates moved over a wider range than long term rates. It also explained why Keynes (1930) found that long term rates reflected fluctuations in short term rates. This hypothesis that long term rates are averages of short rates implies that it does not matter if you invest in the short term or long term market. This average relationship between long term and short term rates is the tenet of the pure expectations hypothesis. When Lutz (1940) considered this relationship between long term and short term rates with regard to differing investor expectations, he said that the differing expectations of market participants implies that one cannot call the long rate an average of short rates in a precise sense. By this Lutz (1940) implies that there is not an exact average relationship between short term rates and long term rates, implying that forward rates are not the unbiased predictors of future spot rates that the pure expectations theory claims they are. This implies that to be able to forecast future spot rates, forward rates in conjunction with at least one other variable would have to be considered. The variable that is mostly used in conjunction with the pure expectations hypothesis is one that accounts for liquidity differences between identical securities with differing maturities. This variable is known as the liquidity premium. When the pure expectations hypothesis is combined with this liquidity premium it results in a weaker form model known simply as the expectations hypothesis.

The findings by Hamburger and Platt (1975), McCulloch (1975), Nurick (1982), Mishkin (1988) and Fama (1990) (to name but a few) confirmed the presence of a liquidity premium. The presence of a liquidity premium immediately shows that the pure expectations hypothesis cannot be supported. The fact that the pure expectations hypothesis cannot be supported does not mean that forward rates contain no information regarding future spot rates. It just implies that forward rates contain less information regarding future spot rates than implied by the pure expectations hypothesis. This implies that if forward rates are adjusted for a liquidity premium they should be able to better forecast the future spot rate.

The expectations hypothesis, which says that the forward rate plus a liquidity premium can predict future spot rates, has found more support than the pure expectations hypothesis. The support for the expectations hypothesis is however mixed. Malkiel (1966), Fisher (1966), Fama (1976, 1984a, 1984b), Nurick (1982), Hardouvelis (1988), Mishkin (1988) Froot (1989), Buser *et al.* (1996) and Christiansen (2003) all find support or partial support for the expectations hypothesis. Partial support implies that the author found support for the expectations theory over certain time periods in their sample, but also found no support in other time periods of their sample. In contrast, Culbertson (1957), Holland (1965), Hamburger and Platt (1975), Shiller (1979), Mankiw and Miron (1986) and Campbell and Shiller (1991) found no support for the expectations hypothesis.

Since both the expectations and pure expectations hypotheses rely on forward rates to contain information regarding the future, it makes sense that market efficiency should be considered. Market efficiency looks at how well the market incorporates available information. If the market is inefficient[1] then the yield curves, from which the forward rates are implied, should contain enough information to have a certain amount of forecasting power when it comes to forecasting future spot rates. One of the first authors to incorporate market efficiency into the analysis of the expectations hypothesis was Fama in his 1976 paper titled: "Forward rates as predictors of future spot rates". He found support for weak form market efficiency. His finding was based on the fact that in setting short term rates, the market correctly uses at least the information in past spot rates. This implies that the information in past spot rates could not be used to forecast future spot rates since all of this information is already included in the spot rate.

The literature review will be broken down into subsections to provide a more detailed look at the various facets of the pure expectations and expectations hypotheses. The following subsections will be looked at: the yield curve, forward rates, liquidity premiums, market efficiency, pure expectations theory, the expectations theory and finally the Hamburger and Platt (1975) methodology and interpretations.

[1] There are three forms of market efficiency: weak, semi-strong and strong. The difference between the three forms is the amount of information contained in the security prices. These three forms of market efficiency are discussed in more detail in section 2.5.

2.2 The yield curve

A yield curve illustrates the relationship between the term to maturity and the yield to maturity for a sample of bonds that usually have the same credit quality. Each yield curve graphically represents what the yields of various maturity bonds are now. This implies that no matter what an investor's investment horizon is, they can look at a yield curve and see what interest rate they can get now for the length of time that they want to invest. Yield curves are created for debt instruments that have the same risk characteristics but mature at different times. They can be created for every grade or quality of debt. Government securities are generally viewed as higher grade with lower risk. This paper will use zero curves. A zero curve is a yield curve representing zero coupon government bond yields.

The yield curve is important to the expectations hypothesis since it is needed to imply forward rates. In most cases securities that are the same except for their term to maturity will not mature in a consecutive sequence. This implies that there will not necessarily be a security that matures in one year, one that matures in two years and one that matures in three years. If there are securities maturing in one year, one and a half years, two and a half years and three years, the yield curve will use a curve fitting process to link these non-sequential maturities so as to create a smoothed line from today to any point in the future. It is obvious that the more securities that are available at various maturities the more representative the yield curve will be of the expected course of interest rates. The yield curve is also seen to embody the market's expectations of future events (Cox, Ingersol and Ross, 1985). This embodiment of expectations in the yield curve is one of the reasons why the pure expectations theory hypothesises that implied forward rates are unbiased predictors of future spot rates.

2.3 Forward and spot rates

Forward rates and spot rates are the foundations of the expectations hypothesis. They form the basis of the pure expectations hypothesis since, according to this hypothesis, implied forward rates provide accurate forecasts of future spot rates. A forward rate and spot rate are quoted at the same point in time, but they apply to different time periods. A forward rate is quoted now and represents a short term rate for a future time period. Forward rates can be implied for any future time period by using two securities with different terms to maturity that are available now. If, for example, the forward rate from year two to year three is required, it can be implied from two securities where the one security matures in year two and the other in year three. The spot rate is the rate available now for whichever security the investor is interested in. This implies that if an investor is interested in a one-year, two-year or any other term security, the investor can enter into the transaction now for that term to maturity.

2.4 Liquidity premiums

Liquidity premiums were first rationalised by Hicks (1939) and formed the basis of his liquidity preference theory which was the first theory that was contrary to the pure expectations hypothesis. In the liquidity preference theory Hicks (1939) says that borrowers prefer to borrow long term to ensure the availability of funds and lenders prefer to lend short to minimise the risk of changes in the interest rate and default risk. Therefore lenders need an incentive to lend long term and this incentive is the liquidity premium. Due to the presence of this liquidity premium Hicks (1939) asserts that long term rates should be higher than short term rates. Meiselman (1962) (who was one of the few authors to find support for the pure expectations hypothesis) said, in response to the liquidity preference theory, that many lending institutions like pension funds, life insurance firms and trust funds would prefer to lend long term. These institutions would then not require a liquidity premium as claimed by Hicks (1939). This is a valid point made by Meiselman (1962), however, the liquidity premium was still found to exist by many authors[2] , even if Hicks's (1939) rationale for a liquidity premium is not entirely correct.

The general acknowledgement of the presence of a liquidity premium turned the debate onto whether or not the liquidity premium is constant or if it varies. The liquidity premium can either be constant with regard to time or constant with regard to the level of interest rates. Constant with regard to time implies that each maturity has a fixed liquidity premium. Constant with regard to the level of interest rates implies that for every level of the interest rate there is an associated fixed liquidity premium. If the premium varies it implies that there is no fixed value for the premium for each time period or interest rate level.

[2] Holland (1965), Fisher (1966), Sargent (1972), Hamburger and Platt (1975), McCulloch (1975), Fama (1976, 1984a, 1984b, 1986, 1990), Fama and Bliss (1987), Mishkin (1988), Hardouvelis (1988), Campbell and Shiller (1991), Huang and Lin (1996), Buser, Karolyi and Saunders (1996) and Christiansen (2003). This list is by no implies exhaustive, but provides convincing proof of the existence of liquidity premiums.

There is no consensus on whether or not the liquidity premium varies or if it is constant. Sargent (1972), McCulloch (1975)[3] and Campbell (1986)[4] for instance find evidence of constant liquidity premiums, whereas Fama (1984)[5], Kessel (1965)[6] and Startz (1982) find evidence of varying liquidity premiums. Other authors acknowledge the existence of the liquidity premium but do not comment on the nature of the liquidity premium. However once the liquidity premium has been adjusted for, most of the authors (who re-ran their regressions) found that the adjustment for the liquidity premium added to the power of forward rates as predictors of future spot rates.

2.5 Efficient markets

The inclusion of market efficiency into the expectations theory debate occurred soon after Fama (1970) published his paper on efficient capital markets. After testing the dual hypotheses[7], that forward rates are unbiased estimators of future spot rates, and that expectations were rational[8] in the sense of Muth (1961)[9], Sargent (1972) said that a market that satisfies both of these hypotheses is an efficient market. Considering Muth's (1961) contribution, Hamburger and Platt (1975) say that the rational expectations hypothesis can be described as meaning that expectations tend to be distributed, for the same set of information, about the prediction of the theory. This implies that expectations are generated by the same process through which the actual variable is determined (Hamburger and Platt, 1975).

Fama (1970) says that there are three kinds of market efficiency. The first kind is weak form market efficiency which says that prices include only historical data. The second kind is semi-strong form market efficiency which says that prices adjust to incorporate historical data and other information that is obviously publicly available. The third kind is strong form market efficiency which says that all and any information is included in prices. Sargent (1972) and Fama (1976) tested weak form market efficiency in the US Treasury bill market and

[3] McCulloch (1975) dedicates an entire paper to the existence and nature of the liquidity premium. He found that the liquidity premium is constant both as a function of time and as a function of the level of interest rates.
[4] Campbell (1986) found that the liquidity premium is constant through time and depends only on maturity.
[5] Fama found that liquidity premiums exist and vary in his papers dated 1976, 1984a, 1984b and 1986. An interesting finding of his 1986 paper is that liquidity premiums vary in conjunction with the business cycle.
[6] Kessel (1965) found that the liquidity premium varies with the level of interest rates rather than the term to maturity.
[7] Sargent (1972) says that the two hypotheses follow a martingale sequence which implies that forward rates applicable at one point in time are not expected to change. Hamburger & Platt (1975) as well as Fama (1976) use a martingale model in their tests for market efficiency.
[8] The reason for adding the hypothesis that expectations are rational is to make the tests of the expectations hypothesis sharper (Sargent, 1972).
[9] Muth (1961) says that information is scarce and the market does not waste it, and the way expectations are formed depends on the structure of the relevant system describing the economy.

found evidence in support of it. Hamburger and Platt (1975) tested for semi-strong form market efficiency and found evidence in support of it. All three of these findings were made in the United States of America. Park (1982) tested for market efficiency in the Canadian Treasury bill market. He found support for weak form market efficiency and added that forward rates seemed to contain more information than just past spot rate information, possibly indicating that the market was close to being semi-strong form efficient. Another study conducted outside of the United States of America was done on the New Zealand market by Yip (1991), where he found a lack of support for market efficiency. He attributed this finding to market participants in New Zealand paying too much attention to differences in borrowing costs between the United States of America and New Zealand in forming their expectations of future rates.

Past literature that combines tests of market efficiency and expectations theories is relatively limited; it makes sense that for forward rates to be able to predict future spot rates they have to contain as much available information as possible. This would mean that tests of market efficiency and forward rate predictive power would have to be tested concurrently.

2.6 The pure expectations theory

There are two ways of stating the pure expectations hypothesis. One way can be found in Culbertson (1957), who stated that the interest rate on long term debt tends to equal the average of short term interest rates expected to prevail over the duration of the long term debt. This method of stating the pure expectations hypothesis implies that an investor is indifferent to investing in five one-year bonds or one five-year bond. It could also imply that the short term and long term markets are efficient since they are always in equilibrium. The second way is well articulated by Malkiel (1966). He stated that forward rates implied from the yield curve are unbiased estimators of future short term rates. This implies that the spot rate that prevails in a future time period can be forecast by the forward rate implied off the yield curve in an earlier time period.

Both the Culbertson (1957) and the Malkiel (1966) versions of the pure expectations hypothesis are based on the notion that an investor cannot earn a better return by investing in different maturities. If longer term rates are merely averages of shorter term rates, as per Culbertson (1957), then surely longer term rates used to imply shorter term rates that occur within the longer term, as per Malkiel (1966), should have substantial power to forecast the future short term rate.

Hamburger and Platt (1975) give an intuitively pleasing theoretical representation of the pure expectations hypothesis. Their representation illustrates the relationship between implied forward rates, spot rates, expectations and the efficient market model. The following is the description of the pure expectations theory as per Hamburger and Platt (1975). The pure expectations hypothesis can be described as

$$ {}_{t+j}F_{k,t} = E_t\,({}_{t+j}R_k) \qquad (1) $$

Where ${}_{t+j}F_{k,t}$ is the forward rate that is applicable to the period $t+j$ on a k-period security that is implied by the yield curve at time t.

$E_t\,({}_{t+j}R_k)$ is the market's expectation in period t of the yield in $t+j$ on a bond of maturity k.

On the assumptions of the efficient market model, namely that investors utilise all available information in forming their expectations, it follows that

$$ E_{t+I}\,({}_{t+j}R_k) - E_t\,({}_{t+j}R_k) = \mu_{t+i} \qquad (2) $$

where μ_{t+i} is a random number that represents the information regarding the future spot rate ${}_{t+j}R_k$ available in $t+i$ that was not available at time t. For $i = j$ the above equation reduces to

$$ {}_{t+j}R_k - E_t({}_{t+j}R_k) = \mu_{t,j} \qquad (3) $$

If *(1)* is substituted into *(3)* the result is

$$ {}_{t+j}R_k - {}_{t+j}F_{k,t} = \mu_{t,j} \qquad (4) $$

Therefore the pure expectations hypothesis in conjunction with the efficient market model implies that the difference between the forward rate in period t and the spot rate that prevails is a random number, representing the arrival of new information to the market.

Equation *(4)* can be empirically evaluated in two ways. In the first way a regression can be run with ${}_{t+j}R_k$ as the dependent variable and ${}_{t+j}F_{k,t}$ as the independent variable. This regression will determine the ability of the forward rate to forecast the future spot rate. If this regression finds that forward rates are not good predictors of future spot rates then the second approach can be followed. The second approach is based on Meiselman's (1962) findings concerning whether or not all the available information at the time was incorporated into the implied forward rate. This second approach is less concerned about forecast accuracy than with the relationship between forecast errors and the change in the spot rate. This relationship is tested by running a regression with the difference between the future spot rate and the forward rate as the independent variable and the difference between the current and future spot rate as the dependent variable.

Implied forward rates are the main component of the pure expectations hypothesis, since the pure expectations hypothesis sees the implied forward rates as the expectations of the future rate that will actually prevail. If the implied forward rates can forecast future spot rates then they should be central to any discussion concerning the shape of the yield curve. Being able to predict the future course of interest rates would be of great interest to investors and policy makers alike.

The pure expectations theory has found very little support in academic literature. Most of the research has come out of the United States of America, and likewise most of the non-support has also come from there. Non-support of the pure expectations theory is generally due to there being evidence of a liquidity premium.

The methods used to test the pure expectations hypothesis are almost always regressions of implied forward rates on future spot rates, or implied forward rates on changes in spot rates. The data used in the tests of the pure expectations hypothesis is mostly from government bonds. This is because government bonds have almost no default risk in their yields which, if present, could affect the results. However some of the tests of the pure expectations hypothesis do not use government bond data and seem to come to different conclusions regarding the validity of the pure expectations hypothesis. This potentially implies that the differences in default risk between government non-government bonds could obscure the results of tests on the pure expectations hypothesis.

Meiselman (1962), who created the first testable model of the pure expectations hypothesis, also found support for the pure expectations hypothesis within his model. What made the Meiselman (1962) model unique was that it did not rely on forward rate forecast accuracy. It is an error learning model which shows how expectations of market participants can change when new information becomes available[10]. Meiselman's (1962) contribution was significant in terms of developing a testable model of the pure expectations hypothesis. However subsequent authors, like Kessel (1965) and Holland (1965), re-tested the Meiselman (1962) model and found evidence of liquidity premiums within their results.

Support for the pure expectations hypothesis was found outside of the United States of America by Tease (1988), Al-Loughani (1991) and Dahlquist and Jonsson (1995) who looked at the Australian, Kuwaiti and Swedish markets respectively. Longstaff (2000) found support for the pure expectations theory in the United States of America. It is interesting to note that Tease (1988), Al-Loughani (1991) and Longstaff (2000) did not use treasury bills to reach their conclusions.[11] It appears that the pure expectations hypothesis performs better when treasury bills are not used. Longstaff (2000) says that the support for the pure expectations hypothesis is directly attributable to the use of repo-rates instead of treasury bills, because repo-rates may be a better measure of the riskless rate. The use or non-use of treasury bills is the most obvious difference between papers that find support and papers that find no support for the pure expectations hypothesis. The literature with regard to the pure expectations hypothesis in a South African context is limited. Studies that are relevant were done by Nurick (1982), Barr and Kantor (1986) and Fedderke and Pillay (2007). They all find no support for the pure expectations hypothesis due to the presence of a time varying risk premium.

The majority of past research found no support for the pure expectations hypothesis, especially when treasury bills were used to test the theory. This finding was due to forward rates having no or limited forecast power and evidence of a liquidity premium being present.

2.7 The expectations theory

The evidence in support of the presence of a liquidity premium was greater than the support found for the pure expectations theory. The focus thus shifted from the belief that only expectations determine the shape of the yield curve, to an acknowledgment and incorporation

[10] Buse (1962) and Malkiel (1966) provide good descriptions, interpretations and discussions on the Meiselman (1962) model.
[11] Tease (1988) used 90 to 180 day bank accepted bills. Al-Loughani (1991) used 3, 6 and 12 month Kuwaiti interbank offered rates. Longstaff (2000) used overnight, 1 week, 2 week, 3 week, 1 month, 2 month and 3 month repo-rates.

of the liquidity premium. This led to a weaker model[12] of the pure expectations hypothesis which is known simply as the expectations hypothesis. The expectations hypothesis states that expectations and a liquidity premium can explain the shape of the yield curve.

The findings on the expectations theory in past research are mixed. Authors such as Fisher (1966), Fama and Bliss (1987), Hardouvelis (1988), Mishkin (1988), Buser *et al.* (1996) and Christiansen (2003) all found support for the expectations theory in either their entire sample period or a sub-sample period. The non-support came from authors such as Holland (1965), Hamburger and Platt (1975), Shiller (1979) and Mankiw and Miron (1986).

2.8 The Hamburger and Platt (1975) study

This paper's methodology is based on the methodology used by Hamburger and Platt (1975). Due to this, a summarised version will be given of the tests they used, their interpretations of the tests and the conclusions they drew. This section has been included purely to give the reader a background on the methodology and reasoning behind the findings of this paper.

The data they used were 44 first day of the month observations of three month spot and forward rates from United States Treasury bills, and their sample period was from March 1961 to December 1971. The results from the Hamburger and Platt (1975) study are not directly comparable to the results of this paper for a few reasons. The sample period and sample size are not the same and are drawn from different countries with vastly different economic positions. The United States has a highly liquid treasury bill market, whereas this paper uses a proxy for the South African Treasury bills due to the illiquid nature of this market.

2.8.1 The accuracy of forward rate forecasts

To test the accuracy or validity of the pure expectations hypothesis two aspects need to be considered. The first deals with how well the forward rate can forecast the future spot rate and the second deals with the relationship between forecast errors and the change in the spot rate. The first test conducted by Hamburger and Platt (1975) deals with the forecast accuracy of the forward rate. It is a regression test of the three month forward rate on the future spot

[12] A weaker model is a model that requires more explanatory variables. In this case the pure expectations theory only needed one (expectations), whereas the expectations theory needs two (expectations and a liquidity premium).

rate in three months time. This test is given by equation (5). The results were as follows (figures in brackets are the t-statistics):

Table 1. Testing the forecast accuracy of the forward rate.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t}$ (5)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 = 0.3 + 0.87\ _{t+3}F_{3,t}$ (1.05) (14.80)	0.84	0.57	1.39

Hamburger and Platt (1975) say that the coefficient for the forward rate ($_{t+3}F_{3,t}$) is significant well beyond the 1% confidence level due to its high t-statistic. The adjusted r-squared value is high. These results were suspect to Hamburger and Platt (1975) since their Durbin Watson test statistics were relatively low.[13]

The Savin and White (1977) tables confirm Hamburger and Platt's (1975) finding of serial correlation. This implies that according to Hamburger and Platt (1975) the predictive power of the forward rate, as indicated by the high adjusted r-squared and forward rates significance, could simply be a reflection of the serial correlation that is present. To ascertain if this is the case a regression with both the forward rate and the current spot rate as independent variables was run. This test is represented by equation (6).

Table 2. Testing if the apparent forecast power of the forward rate is due to serial correlation.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t} + c\ _tR_3$ (6)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 = 0.34 + 0.33\ _{t+3}F_{3,t} + 0.57\ _tR_3$ (1.2) (1.2) (2.0)	0.85	0.55	1.59

Due to the substantial decrease in the forward rate's ($_{t+3}F_{3,t}$) t-statistic and the higher adjusted r-squared value it shows that once the effect of the current spot rate is held constant, the three month forward rate bears no significant relationship to the future spot rate. Their t-statistic fell from 14.8 to 1.2 and the adjusted r-squared value increased from 0.84 to 0.85. This illustrated to Hamburger and Platt (1975) that the predictive power of the forward rate is due largely to the present serial correlation.

[13] A low Durbin Watson test is an indication of positive serial correlation.

It seemed strange to Hamburger and Platt (1975) that expectations[14] were of very little value in forecasting three month spot rates. To investigate this strange finding, Hamburger and Platt (1975) looked at the relationship between the errors made in forecasting and the actual changes in the spot rate that took place. The errors made in forecasting are merely the difference between the forward rate and the future spot rate and the actual change in rates is obviously the difference between the future spot rate and the current spot rate. Hamburger and Platt (1975) did this to determine the extent to which there is a systematic element in the errors. This test is represented by equation (7).

The serial correlation found in the results was cause for concern so Hamburger and Platt (1975) used the Cochrane-Orcutt procedure to correct for it. The Cochrane-Orcutt procedure was developed in the 1940s and has been improved in more recent times. It is now viewed as a more primitive version of the Yule-Walker procedure. The main difference between these two methods is how the first observation is treated. The Cochrane-Orcutt procedure drops the first observation, whereas the Yule-Walker method retains information from the first observation (SAS, 2010). The Yule-Walker procedure is also referred to as the two step full transformation method; the estimated generalized least squares and its estimates are often referred to as Prais-Winsten estimates (SAS, 2010).

Table 3. Testing for a relationship between forecast errors and changes in spot rates before correcting for serial correlation.

${}_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_tR_3)$ (7) *[before correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.34 - 0.91\,({}_{t+3}R_3 - {}_tR_3)$ (7.3) (11.0)	0.74	0.31	1.25

Table 4. Testing for a relationship exists between forecast errors and changes in spot rates after correcting for serial correlation. This test also includes a test for the presence of a liquidity premium.

${}_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_tR_3)$ (7) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.33 - 0.88\,({}_{t+3}R_3 - {}_tR_3)$ (4.7) (11.7)	0.77	0.29	1.92

[14] Forward rates are deemed to be the market's expectations of the future spot rate according to the pure expectations theory.

Hamburger and Platt (1975) found their models to be robust due to the small changes in the coefficients after they had been transformed in order to remove the serial correlation. Due to this they came to the conclusion that the error made in forecasting over a three month horizon is equal to the change in the rates that occurred over the three month horizon plus a constant. This constant could be viewed as an estimate of the liquidity premium. In confirmation of the presence of a liquidity premium the coefficient of $({}_{t+3}R_3 - {}_tR_3)$ was found to be insignificantly different from minus one. This suggested to Hamburger and Platt (1975) that if the future spot rate ${}_{t+3}R_3$ was added to both sides of equation (7), then the forward rate could be said to be insignificantly different from the current spot rate plus a constant.

Hamburger and Platt (1975) said that two limitations of the analysis need to be considered before looking at the implications of the results from equation (7). Firstly Hamburger and Platt (1975) were concerned that a single regression equation to fit an entire sample period may just be describing an average relationship for the entire sample period. This would fail to find if forecast accuracy existed in sub-periods. To check for this they broke their sample down into five subsets containing 12 observations in the first and then 8 observations in the next four subsets. The results Hamburger and Platt (1975) obtained from the sub-sample tests were quite similar to the results from their entire sample. The coefficients for $({}_{t+3}R_3 - {}_tR_3)$ were not found to be significantly different from minus one in any of their sub-sample tests. This confirmed that the results from the whole sample were not merely describing an average relationship.

The second limitation that Hamburger and Platt (1975) were concerned about was the presence of a varying liquidity premium. To test for a variable liquidity premium they added the current spot rate as an extra independent variable to equation (7). This test for a variable liquidity premium is shown by equation (8).

Table 5. Testing if the liquidity premium is variable or not, before correcting for serial correlation.

$_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_tR_3) + c\,{}_tR_3$ (8) *[before correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.21 - 0.90\,({}_{t+3}R_3 - {}_tR_3) + 0.03\,{}_tR_3$ (1.36) (10.5) (0.83)	0.74	0.31	1.24

Table 6. The test to see if the liquidity premium is variable or not, after correcting for serial correlation.

$_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\ ({}_{t+3}R_3 - {}_tR_3) + c\ {}_tR_3$ (8) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.11 - 0.85\ ({}_{t+3}R_3 - {}_tR_3) + 0.05\ {}_tR_3$ (0.45) (10.6) (0.97)	0.77	0.29	1.94

The results indicated to Hamburger and Platt (1975) that it was difficult to differentiate between a variable and constant liquidity premium. This is because both the constant and the coefficient of $_tR_3$ are insignificant, and the coefficient of $({}_{t+3}R_3 - {}_tR_3)$ is still insignificantly different from minus one.

These results from equations (5) to (8) enabled Hamburger and Platt (1975) to come to three conclusions. Firstly they found that forward rates have little forecast power. Secondly there are liquidity premiums present. Thirdly forecast errors are virtually equal to the changes in spot rates even after adjusting for liquidity premiums, which implies that market participants miss all changes in the treasury bill rates.

2.8.2 Testing for market efficiency

To test for market efficiency Hamburger and Platt (1975) tested to see how consistent a static model of interest rate expectations is with Muth's (1961) concept of rational expectations. Muth's (1961) rational expectations hypothesis is that expectations tend to be distributed, for the same information set, according to what the theory predicted. Hamburger and Platt (1975) say that this implies that expectations are generated by the same process through which the actual variable is determined. Muth (1961) has two main contentions. The first contention is that information is scarce and therefore the economic system does not waste it. The second contention is that the way expectations are formed depends specifically on the structure of the relevant system describing the economy. The reason for this approach to testing market efficiency is that the efficient market model has very similar assumptions to Muth's (1961) concept of rational expectations.

To see how consistent the static model of expectations is with Muth's (1961) concept three tests need to be run. The first two tests test weak form conditions of market efficiency and the third test tests a semi-strong form condition of market efficiency.

Before these tests can be run, it first needs to be established if a static model of interest rate expectations adequately describes the data. To test for this Hamburger and Platt (1975) use equation (9) which has the current spot rate as the independent variable and the forward rate as the dependent variable.

Table 7. Does a static model of interest rate expectations adequately describe the data.

$_{t+3}F_{3,t} = a + b\ _tR_3$ (9) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}F_{3,t} = 0.26 + 1.02\ _tR_3$ (1.17) (22.0)	0.96	0.29	1.87

These results indicated to Hamburger and Platt (1975) that it is difficult at high levels of confidence to reject the hypothesis that $_{t+3}F_{3,t}$ = $_tR_3$ since the results indicate that their constant term is insignificantly different from zero and the coefficient of $_tR_3$ is basically 1. A coefficient of 1 indicates that for a 1 unit change in $_tR_3$ the forward rate will change by the same amount in the same direction. On the basis of these results they found that a simple static model of the formation of interest rate expectations seems to fit their data well.

Since it was established that a static model of interest rate expectations was adequate they then went on to test for market efficiency. The first weak form condition that needs to be met is that changes in the three month treasury bill rate need to be serially uncorrelated so that investors cannot observe a pattern in the interest rate changes and form their expectations accordingly. To test for this, firstly the change in the spot rate from three months back to t_0 is regressed on the change in the spot rate from t_0 to the spot rate three months ahead, as shown by equation (10). Then another regression is run on the three month differences from 3 to 6 months back, 6 to 9 months back, 9 to 12 all the way back to 24 months are regressed on the difference between the current spot rate and the spot rate three months forward, as shown by equation (11).

Table 8. Testing if the first weak form condition of market efficiency has been fulfilled. This test is the first of two. The second test is shown in Table 9.

$_{t+3}R_3 - {}_tR_3 = a + b({}_tR_3 - {}_{t-3}R_3)$ (10)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 - {}_tR_3 = 0.1 + 0.11({}_tR_3 - {}_{t-3}R_3)$ (0.17) (0.69)	-0.01	0.57	1.90

Table 9. Part two of the test to see if weak form condition of market efficiency has been fulfilled.

$_{t+3}R_3 - {}_tR_3 = a + b\ ({}_tR_3 - {}_{t-3}R_3) + c({}_{t-3}R_3 - {}_{t-6}R_3) + \ldots + j({}_{t-21}R_3 - {}_{t-24}R_3)$ (11)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 - {}_tR_3 = 0.22 + 0.13\ ({}_tR_3 - {}_{t-3}R_3)$ (0.22) (0.74) $-0.07({}_{t-3}R_3 - {}_{t-6}R_3) - 0.02\ ({}_{t-6}R_3 - {}_{t-9}R_3)$ (0.4) (0.14) $+0.1({}_{t-9}R_3 - {}_{t-12}R_3) - 0.17\ ({}_{t-12}R_3 - {}_{t-15}R_3)$ (0.56) (0.79) $+0.17({}_{t-15}R_3 - {}_{t-18}R_3) - 0.19\ ({}_{t-18}R_3 - {}_{t-21}R_3)$ (0.8) (0.88) $+0.08({}_{t-21}R_3 - {}_{t-24}R_3)$ (0.36)	-0.16	0.61	1.93

From the results of equations (10) and (11) Hamburger and Platt (1975) found no systematic relationship between the current and the past movements in the 3 month rates. Their conclusion was drawn from three results. Firstly the Durbin-Watson statistics indicate that there is virtually no serial correlation present, since they are so close to the range of 1.189 and 1.895. Secondly none of their t-statistics are greater than 1, indicating that the coefficients are insignificant. Finally both of their adjusted r-squared values are very close to zero, which implies that the lagged rates weaken the model to such an extent that there is virtually no explanatory power with regard to the dependent variable. This indicated to Hamburger and Platt (1975) that a static expectations scheme is rational and the first weak form condition of market efficiency was fulfilled.

Hamburger and Platt (1975) say that because three month changes in rates cannot be forecast from the history of past rate movements, their findings lead them to argue that it is appropriate for the market to force the forward rate and current spot rate into equality. They go on to say that since no necessary conditions are imposed on the spot rate within the expectations hypothesis, the finding that changes in the rates are uncorrelated is not necessarily a condition for either the pure expectations hypothesis or the efficient market model. Hamburger and Platt (1975) say that the pure expectations hypothesis and the efficient markets model necessitate only that forward rates follow a martingale sequence. This merely implies that even though the conditions for the first test of weak form conditions have been fulfilled, it is not yet possible to come to a conclusion about market efficiency.

The second weak form test is a test of whether or not the static expectations model provides an accurate description of market participant behaviour. The reasoning behind this test for Hamburger and Platt (1975) was to see if investors attribute as little importance to past rates as their analysis suggested was rational, since there was a wide acceptance of distributed lag theories of interest rate expectations. The distributed lag theories of interest rate expectations say that investors pay more attention to lagged rates than they should, whereas according to Hamburger and Platt (1975), other authors had found that the market correctly used the information in past spot rates which implies the weak form market efficiency exists. This test, as represented by equation (12), regresses the lagged spot rates on the difference between the future spot rate and forward rate.

Table 10. The test of the distributed lag theories of the interest rate.

$_{t+3}R_3 - {}_{t+3}F_{3,t} = a + b_tR_3 + c\ _{t-3}R_3 + d\ _{t-6}R_3 + \ldots + j\ _{t-24}R_3$ (12)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 - {}_{t+3}F_{3,t} = 0.51 - 0.05_tR_3 - 0.07\ _{t-3}R_3$ (1.56) (0.32) (0.29) $+ 0.22\ _{t-6}R_3 - 0.06\ _{t-9}R_3 - 0.15\ _{t-12}R_3$ (0.86) (0.24) (0.47) $+ 0.28\ _{t-15}R_3 - 0.39\ _{t-18}R_3 + 0.06\ _{t-21}R_3$ (0.85) (1.21) (0.2) $-0.02\ _{t-24}R_3$ (0.11)	0.06	0.58	1.64

Since all of the coefficients are insignificant in equation (12) it implies that the variables in equation (12) do not have differing effects on the forward rate and on the future spot rate. However Hamburger and Platt (1975) were concerned that equation (12) did not allow for a variable liquidity premium and that the difference between the future spot rate and the forward rate might be related to the lagged spot rates because the forward rate helps to determine the liquidity premium. To avoid this problem Hamburger and Platt (1975) moved the forward rate to the right hand side of the equation making it an independent variable. This resulted in equation (13).

Table 11. The test of the distributed lag theories of the interest rate controlling for the effect of the liquidity premium.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t} + c_tR_3 + d\ _{t-3}R_3 + e\ _{t-6}R_3 + \ldots + j\ _{t-24}R_3$ (13)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975)	$_{t+3}R_3 = 0.54 + 0.6\ _{t+3}F_{3,t} + 0.4\ _tR_3 - 0.12\ _{t-3}R_3$ (1.64) (1.62) (0.89) (0.49) $+ 0.15\ _{t-6}R_3 + 0.01\ _{t-9}R_3 - 0.19\ _{t-12}R_3$ (0.59) (0.03) (0.58) $+ 0.3\ _{t-15}R_3 - 0.38\ _{t-18}R_3 + 0.15\ _{t-21}R_3$ (0.93) (1.20) (0.46) $-0.08\ _{t-24}R_3$ (0.36)	0.83	0.58	1.78

The results of this test indicate that none of the coefficients for the lagged rates in equation (13) were found to be significant. If they were found to be significant they said it would raise serious questions regarding market efficiency. They also compared the unadjusted r-squared values from equation (6) to equation (13), because they say that a small difference would indicate that the result in equation (13) is due to a lack of association between the dependent and independent variables, rather than the result being due to co-linearity among the independent variables. Due to these findings of equation (12) and (13) Hamburger and Platt (1975) came to the conclusion that investors correctly use past interest rate data. This implies that the distributed lag theories do not seem to be adequate. It also implies that the second condition of weak form market efficiency has been fulfilled.

The third test carried out by Hamburger and Platt (1975), the semi-strong form condition of market efficiency, seeks to determine if other economic variables can better forecast the future spot rate than the forward rate can. They point out that the variables that are most likely to be able to forecast the future spot rate are monetary variables and the level of income available at the time. Hamburger and Platt (1975) say that if these variables are known prior to the realisation of the future spot rate, it would be inefficient not to employ these variables in forecasting the future spot rate.

For this third test the variables were measured as monthly averages due to the nature of the income variables being monthly averages. The variables used by Hamburger and Platt (1975) are M1 (the narrow definition of money supply), MB (monetary base), NBB[15] (non-borrowed monetary base) and Y (personal income). This test is broken down into five sub-tests. The first sub-test tests the ability of the forward rate to forecast the future spot rate when the variables are constructed as monthly averages. This test is shown by equation (14).

Table 12. Testing the forecast accuracy of the forward rate. This test uses monthly average data as opposed to the single day of the month observations used previously.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t}$ (14)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975) *(before correction for serial correlation)*	$_{t+3}R_3 = 0.39 + 0.83\ _{t+3}F_{3,t}$ (1.33) (14.75)	0.83	0.58	1.82
Hamburger and Platt (1975) *(after correction for serial correlation)*	$_{t+3}R_3 = 0.56 + 0.8\ _{t+3}F_{3,t}$ *(1.64) (12.39)*	0.85	0.58	2.00

The results were similar to those found in equation (5), in particular the standard error and adjusted r-squared values are virtually identical. Hamburger and Platt (1975) suggest that these results from equation (14) could be improved by using other economic variables. The other four sub-tests are shown by equations (15) to (18) and test to see if other economic variables can better forecast the future spot rate.

[15] The non-borrowed monetary base was used by Hamburger and Platt (1975) in addition to monetary base to test the hypothesis that changes in the bank reserves have an important short run impact on interest rates.

Table 13. The test to see if other economic variables can better forecast the future spot rate.

$_{t+3}R_3 = a + b\,M1_{t+3} + c\,Y_{t+3}$ (15) $_{t+3}R_3 = a + b\,MB_{t+3} + c\,MB_t + d\,Y_{t+3} + e\,Y_t$ (16) $_{t+3}R_3 = a + b\,NBB_{t+3} + c\,NBB_t + d\,Y_{t+3} + e\,Y_t$ (17) $_{t+3}R_3 = a + b\,NBB_{t-1} + c\,Y_{t-1}$ (18)		$Adj\ R^2$	S.E	Durbin Watson
Hamburger and Platt (1975) *equation (15)*	$_{t+3}R_3 = 14 - 30 \log M1_{t+3} + 23 \log Y_{t+3}$ (0.90) (-2.31) (2.62)	0.84	0.55	1.84
Hamburger and Platt (1975) *equation (16)*	$_{t+3}R_3 = -20 - 34 \log MB_{t+3} - 35 \log MB_t$ (-3.33) (-2.36) (-2.14) $+ 26 \log Y_{t+3} + 23 \log Y_t$ (2.46) (2.29)	0.88	0.49	1.82
Hamburger and Platt (1975) *equation (17)*	$_{t+3}R_3 = -19 - 39 \log NBB_{t+3} - 23 \log NBB_t$ (-4.80) (-2.90) (-1.51) $+ 23 \log Y_{t+3} + 21 \log Y_t$ (2.41) (2.29)	0.90	0.44	1.96
Hamburger and Platt (1975) *equation (18)*	$_{t+3}R_3 = -16 - 29 \log NBB_{t-1} + 22 \log Y_{t-1}$ (-1.75) (-2.38) (2.71)	0.84	0.56	1.77

Equations (15) to (18) illustrated to Hamburger and Platt (1975) that economic variables had a closer relationship to the future spot rate than the forward rate did. In particular they found the NBB to be the most appropriate variable from the results of equations (15), (16) and (17). Where lagged variables were used they were chosen to reflect the availability of the information at the time when the forward rate was implied. Hamburger and Platt (1975) say that their best results were obtained from equation (18). Since the standard error of equation (18) was smaller than that of equation (14), they said this suggested that there were market inefficiencies. However they say that since the relationship represented in equation (18) could not have been known with certainty during their sample period, the results did not yield a direct test of whether better forecasts were available to the market than those contained within the implied forward rates.

Hamburger and Platt (1975) say that an appropriate test would involve a comparison of the sample forecasts given by equation (18) and equation (14). To do this they split the sample period in half and equations (18) and (14) were estimated over the earlier half of the sample period. These estimations of equations (18) and (14) were then used to extrapolate the values for R_3 over the latter half of the sample period. Hamburger and Platt (1975) then compared the extrapolated values for R_3 to the actual values of R_3. They found the root mean squared error from the comparisons of the extrapolated R_3 and the actual R_3 to be 101 basis points for equation (14) and 191 basis points for equation (18). This suggested to them that either regressions fitted to the entire sample period may provide misleading information regarding market efficiency or the treasury bill market appears to be highly efficient.

3. Methodology and Data

The literature on joint tests of the pure expectations hypothesis and market efficiency on South African data is relatively limited. Three[16] papers were found that dealt either directly or indirectly with this topic in a South African context. The most relevant was the work of Nurick (1982) since he replicated the Hamburger and Platt (1975) methodology using South African Negotiable Certificate of Deposit (NCD) data. This paper will also use the Hamburger and Platt (1975) methodology and apply it to South African government bond data. This paper has three aims. The first aim is to see if the pure expectations hypothesis can adequately describe the South African government bond yield curve. The second aim is to see if there is market efficiency within the South African government bond market. The third aim is to see if the curve fitting process used to construct the yield curve can influence the findings of the first and second aims.

The data used in this study was provided by the Interest Rate Division of the Johannesburg Stock Exchange (JSE) and the South African Reserve Bank (SARB). Monthly zero curves provided by the JSE were used to obtain the spot rates and imply the forward rates. The data on monetary base, money supply and disposable income was provided by the SARB. The SARB data are only used in the semi-strong test for market efficiency. The rest of the data used was obtained from JSE monthly zero curves.

Data was extracted from two different constructions of the yield curve. This was done so as to be able to test the third aim of this paper. This implies that one set of implied forward and spot rates was drawn from both constructions of the yield curves over the sample period. The two kinds of yield curve constructions are "perfect fit" and "best decency". Both the perfect fit and best decency yield curves were constructed[17] from the same data, which were the most liquid government bonds available at the time.[18]

Liquidity is vital because the more liquid a security is, the greater the amount of market information that can be reflected in its price. Although there are many government bonds not all of them have zero coupons or have a great deal of liquidity. For this reason the Interest Rate division of the JSE can only use the most liquid government bonds on the market

[16] These papers were: "Interest and exchange rate behaviour in South Africa: Theory and evidence" by Nurick (1982), "The gold price and the forward rate of interest" by Barr and Kantor (1986) and "A theoretically defensible measure of risk: Using financial data from a middle income context" by Fedderke and Pillay (2007).

[17] The Interest rate division of the JSE constructs these curves and they are available directly from the JSE.

[18] See appendix for the list of government bonds used by the JSE to construct each yield curve.

(regardless of their coupon rate) to construct the respective yield curves. These liquid bonds generally contain differing coupons which are stripped[19] out to create both the perfect fit and best decency zero curves. Due to a liquidity problem South African Treasury bills could not be used in this study. The nature of the South African Treasury bill market is such that there is no secondary market for them. When they are auctioned off, major financial institutions buy them all and hold them until they mature. Liquidity is the reason why Nurick (1982) and Barr and Kantor (1986) used NCD data instead of treasury bill data.

The main differences between the perfect fit and best decency yield curves, is the goodness of fit to the data points and the smoothness of the curve. The perfect fit yield curve goes through all of the available points and thus forfeits smoothness in the process. The best decency construction gives a curve that offers the best combination of goodness of fit and smoothing. This implies that the best decency curve will not necessarily go through all of the available data points. Both the perfect fit and best decency yield curves are spot curves. This implies that they give estimations of the yield for any maturity from today out to thirty years and that implied forward rates for future periods can be calculated off of them.

Since forward rates are not formally quoted they need to be implied off a yield curve. The formula that Hicks (1939) used is the most widely used method for calculating implied forward rates. This method was used by Fisher (1966), Hamburger and Platt (1975), Fama (1976), Startz (1982), Barr and Kantor (1986) and Buser *et al*. (1996). The formula is as follows:

Table 14. Equation (20) depicts the notion of the pure expectations hypothesis that a long term rate is the average of short term rates.

$R_{nt} = \frac{1}{n}\sum_{j=0}^{n-1} r_{1\,(t+j)}$ (20)	
$(1+R_3)^3 = (1+r_1)(1+r_2)(1+r_3)$	This is a simplified version of the above equation (20). The three year rate (R_3) is equal to three one year rates (r_1, r_2 and r_3)

Here 'R' is the longer term rate and 'r' is the shorter term rate. According to the expectations hypothesis, longer term rates are merely averages of the short rates that prevail over the maturity of the longer term rate (as shown by table 14). This is illustrated by figure 1. An

[19] When a coupon is stripped out of a coupon bond, the yield of the coupon bond is merely transformed to represent its equivalent zero coupon yield.

example of the calculation for the short rate or implied forward rate that should prevail in three years time is as follows:

$R_3 = 4.65\%$; $r_1 = 4\%$; $r_2 = 4.5\%$.

$$r_3 = \frac{(1 + 0.0465)^3}{(1 + 0.04)(1 + 0.045)} - 1$$

$$r_3 = 0.0545 \text{ or } 5.45\%$$

Table 15. Examples of interest rates that could be taken off a yield curve and the implied forward rates that can be derived from the interest rates.

Maturity	Interest rate	Implied forward rates
Year 1	4%	4%
Year 2	4.25%	4.5%
Year 3	4.65%	5.45%
Year 4	4.89%	5.61%
Year 5	4.99%	5.39%

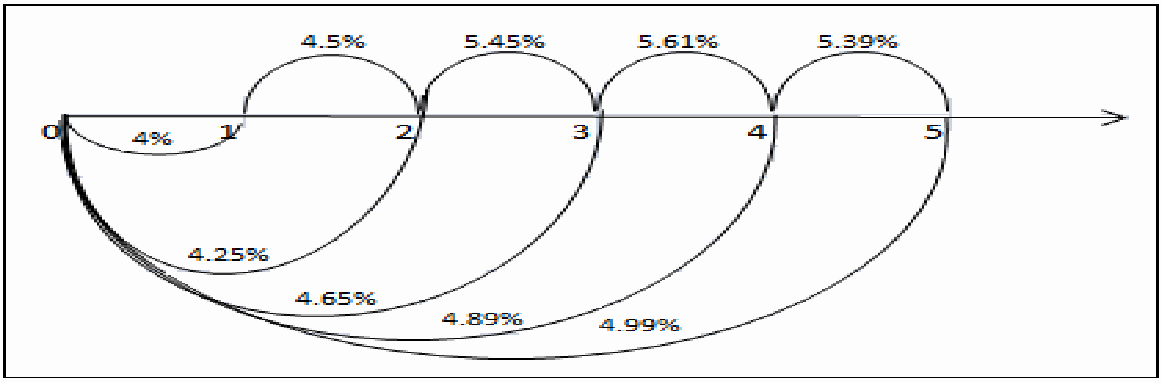

Figure 1. A graphical representation of the relationship between interest rates and implied forward rates. The interest rates are shown below the timeline and the implied forward rates are shown above the timeline.

The same calculation can be used to calculate any interest rate that should prevail over a future time period. In the hypothetical situation in table 15, the actual interest rates from years 1 to 5 are taken off a yield curve. These actual rates are shown in figure 1 below the time line. From these actual rates the short term rates that should make up the longer term rates can be calculated using Hick's (1939) methodology. These short term rates that make up the longer term rates are also known as implied forward rates and are illustrated in figure 1 above the time line.

The datasets collected were limited by the availability of reliable zero curves. The sample period runs from June 2003 to January 2011. Three month spot rates and three month forward rates implied three months prior were used to build the dataset. The three month period was chosen to aid comparability with the similar and numerous studies done in other countries whose governments issue three month treasury bills. A total of 30 observations of spot and forward rates were obtained. Two potential problems were encountered in the data collection process. The first was the illiquid nature of the South African Treasury bill market and zero coupon bond market. This problem was overcome by using the zero curves published by the JSE. The second problem was an issue of overlapping data that would introduce unnecessary serial correlation into the dataset. This problem was solved by using only every third observation since three month rates were being used. Using only every third observation dropped the number of observations from 90 to 30. This did help reduce the serial correlation because when the forward rate regressions were run on the entire data set (90 observations) the Durbin Watson test statistic was 0.641 for the perfect fit data and 0.559 for the best decency data, which indicates strong positive serial correlation. However when observations spaced three months apart were used, the Durbin Watson test statistic increased to 1.48 for the perfect fit data and 1.39 for the best decency data, which indicates substantially less serial correlation.

The tests for the semi-strong condition of market efficiency require the use of other variables. The variables used were chosen to replicate the variables used by Hamburger and Platt (1975). The monetary base (MB) and money supply (M1) variables are quoted by the SARB. However the non-borrowed monetary base (NBB) and personal income (Y) are not quoted by the SARB. The reason why NBB is not quoted is due to the differences in how the United States Federal Reserve (FED) operates compared with the SARB. The main difference is the differing state laws with regard to banking. These differing state laws mean that the FED has member and non-member banks. Member banks are required to purchase stock in the FED. Non-member banks do not have to purchase FED stock and are subject to less regulation than member banks. In South Africa there are no member and non-member banks of the SARB, which implies that the non-borrowed monetary base (NBB) does not exist. NBB is equal to MB less member bank borrowing. For this reason only MB will be used. A proxy will be used for personal income (Y) since it is also not quoted by the SARB. Hamburger and Platt

(1975) do not discuss how personal income is calculated- disposable income[20] was the closest proxy for a measure of personal income.

The core methodologies used to test the pure expectations hypothesis and the expectations hypothesis (since the expectations hypothesis is merely an extension of the pure expectations hypothesis) have not changed substantially. Melino (1988) came to a similar conclusion where he said: “Although much ink has been spilled on the subject, many of the main ideas and positions have changed remarkably little from the original discussion and debate” (Melino, 1988, p. 358).

Regressions with the forward rate as the independent variable and the future spot rate as the dependent variable are the basis of most tests of the pure expectations hypothesis. These regressions are known as forward rate regressions and merely test the forward rates’ forecast accuracy. Since forecast accuracy is not entirely required for the pure expectations hypothesis to hold, regressions that test the relationship between forecast errors and the actual change in the spot rates are normally also tested. The results of the forward rate regression and the forecast error regressions both have to be considered when drawing a conclusion with regard to the validity of the pure expectations theory. Some of the authors that have used these regression tests are Hamburger and Platt (1975), Fama (1976), Nurick (1982), Fama (1984), Fama and Bliss (1987), Mishkin (1988), Dahlquist and Jonsson (1995), Buser *et al.* (1996), Longstaff (2000) and Christiansen (2003).

As the expectations theories go hand in hand with market efficiency, tests of market efficiency within the ambit of the expectations theories would test how well market participants use information that is available in their forecasts of the future spot rate (forward rates are the market’s forecast of future spot rates). These tests would have to look for relationships amongst past data and whether the market considers all available information. If there is any relationship observable in past data it would indicate market inefficiencies because market participants would be able to predict future spot rates by observing past patterns. Regressions looking at lagged spot rates are used to test for this. If other information, apart from forward rates, is included in the forecast of future spot rates and it improves the forecast then it would be an indication that this additional information is incorporated in the forecasts. Forward rate regressions with other forecasting factors included as independent

[20] Disposable income is made up of personal income less taxes on wealth, current transfers to government and transfers to the rest of the world. The code for it is KBP6246K on the SARB website (www.resbank.co.za).

variables are used to test for this. There are not many tests of market efficiency and the pure expectations in the same paper. However Hamburger and Platt (1975) do offer this dual test in their paper. Examples of authors who test for market efficiency are Sargent (1972), Fama (1976), Park (1982) and Yip (1991).

Hamburger and Platt's (1975) methodology is appropriate for this paper for a couple of reasons and will be replicated. The first reason is that the tests of the pure expectations hypothesis have not changed significantly, so the tests done by Hamburger and Platt (1975) are still relevant. The second reason is that their tests encapsulate extensions of the pure expectations hypothesis (by looking at other forecasting variables) and tests of market efficiency which provide better, more robust tests.

3.1 The test of the pure expectations hypothesis

There are two tests of the pure expectations hypothesis that need to be examined. The first is the forecast accuracy of forward rates and the second is the relationship between forecast errors and the actual change in the spot rate.

The pure expectations hypothesis claims that a forward rate implied off a yield curve can forecast the future spot rate. Regressions are used to establish the power of the forward rate to forecast the future spot rate. The test run to determine the accuracy of forward rate forecasts is a regression with the forward rate as an independent variable and the future spot rate as the dependent variable. This is the standard forward rate regression. This test is represented by equation (5).

$$ {}_{t+3}R_3 = a + b\ {}_{t+3}F_{3,t} \qquad (5)$$

Even though an attempt was made to remove the serial correlation from the dataset by only using every third observation, there is a chance that serial correlation could still be present in the results of equation (5). The presence of serial correlation will in all likelihood affect the results and lead to spurious relationships being found. To correct for this the Yule-Walker method could be used. Alternatively, to check if the serial correlation did actually affect the results, equation (5) could be re-run with the current spot rate included as an independent variable; doing this will control for the effect of the current spot rate on the future spot rate. This is shown by equation (6).

$$ {}_{t+3}R_3 = a + b\ {}_{t+3}F_{3,t} + c\ {}_{t}R_3 \qquad (6) $$

Equations (5) and (6) encapsulate the first test of the pure expectations hypothesis which looks at the forecast accuracy of forward rates with regard to the future spot rate. The second test of the pure expectations hypothesis deals with the relationship between the forecast errors (the difference between the forward rate and the future spot rate) and the actual change in the spot rate (the difference between the current spot rate and the future spot rate). This test is done to determine if there is a systematic element to forecasting errors. If a systematic element to forecasting errors is found it would mean that a relationship exists between the forecast errors and the actual change in the spot rates. This test is represented by equation (7).

$$ {}_{t+3}F_{3,t} - {}_{t+3}R_3 = a - b\ ({}_{t+3}R_3 - {}_{t}R_3) \qquad (7) $$

Since the biggest critique of the pure expectations hypothesis is the presence of a liquidity premium, it is vital to test if a liquidity premium is in fact present. The presence of a liquidity premium is in direct contrast to the pure expectations hypothesis, but is in accordance with the expectations theory. The tests for a liquidity premium are twofold. Firstly the existence of a liquidity premium needs to be tested for. If a liquidity premium is found to exist then a test needs to be run to determine if it is variable or constant. For a liquidity premium to exist the coefficient of the independent variable in equation (7) needs to be insignificantly different from minus one. If this is the case, then adding the future spot rate to both sides of equation (7) would result in the forward rate being insignificantly different from the current spot rate plus a constant term which is an estimate of the liquidity premium. There is a possibility that these results are merely describing an average relationship of the entire sample period and could be missing instances that could possibly yield different results. To see if this is the case equation (7) needs to be run on sub-samples. If the coefficients of the independent variables from these sub-sample tests are mostly insignificantly different from minus one, then the presence of a liquidity premium can be confirmed.

To determine if the liquidity premium is variable or constant the current spot rate needs to be added as an independent variable in equation (7). This addition is represented in equation (8).

$$ {}_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\ ({}_{t+3}R_3 - {}_{t}R_3) + c\ {}_{t}R_3 \qquad (8) $$

The significance of the coefficient of the current spot rate and the constant term are of main concern in this test. If the coefficient of the current spot rate and the constant term are found to both be insignificant this would mean that it is difficult to differentiate between a variable and constant liquidity premium.

3.2 Testing for market efficiency

The tests for market efficiency will look at how consistent a static model of interest rate expectations is with Muth's (1961) concept of rational expectations. The reason for this approach is that the efficient market model has very similar assumptions to Muth's (1961) concept of rational expectations. These tests for market efficiency are broken down into three parts. The first two parts test weak form conditions of market efficiency and the third part tests for semi-strong form conditions of market efficiency. Each part contains a test.

For the first weak form condition of market efficiency to be fulfilled, changes in the three month spot rates need to be unrelated. To test for this the differences or changes in the three month lagged rates need to be regressed on the difference between the current spot rate and the future spot rate. This is represented in equation (11).

$$ {}_{t+3}R_3 - {}_tR_3 = a + b\,({}_tR_3 - {}_{t-3}R_3) + c({}_{t-3}R_3 - {}_{t-6}R_3) + \ldots + j({}_{t-21}R_3 - {}_{t-24}R_3) \qquad (11) $$

The second weak form condition of market efficiency looks at the rationality of investor behaviour. Meaning, are market participants wasting their time looking at past spot rates to forecast the future spot rate? The aim of this test is to disprove distributed lag theories of interest rate expectations (which say that market participants pay more attention to past spot rates than they should). To determine if too much attention is paid to past spot rates, a regression needs to be run that contains the future spot rate as the dependent variable and the lagged spot rates as the independent variables. This test is represented by equation (12).

$$ {}_{t+3}R_3 = a + b\,{}_{t+3}F_{3,t} + c\,{}_tR_3 + d\,{}_{t-3}R_3 + e\,{}_{t-6}R_3 + f\,{}_{t-9}R_3 + \ldots + j\,{}_{t-24}R_3 \qquad (12) $$

The forward rate has been included as an independent variable so as to compensate for variable liquidity premiums.

The semi-strong form condition of market efficiency looks at whether other economic variables can forecast the future spot rate better than the forward rate. This test would merely replace the forward rate with the economic variable being tested. For instance if money supply (M1) is being tested the equation would look as follows:

$$ {}_{t+3}R_3 = a + b\,M1_{t+3} $$

4. Results

The following figures give a comparison between the forward rate and the future spot rate. Both the forward rate and the future spot rate are realized at the same point in time. These respective points in time are shown on the x-axis of Figure 2 and Figure 3. The difference between the forward rate and the future spot rate is that the forward rate is implied 3 months[21] prior to the future spot rate in Figure 2 and Figure 3. Wherever the two lines touch indicates good forecast accuracy, meaning the forward rate and the future spot rate were very similar at that point in time. Figure 2 illustrates the perfect fit dataset and Figure 3 illustrates the best decency dataset.

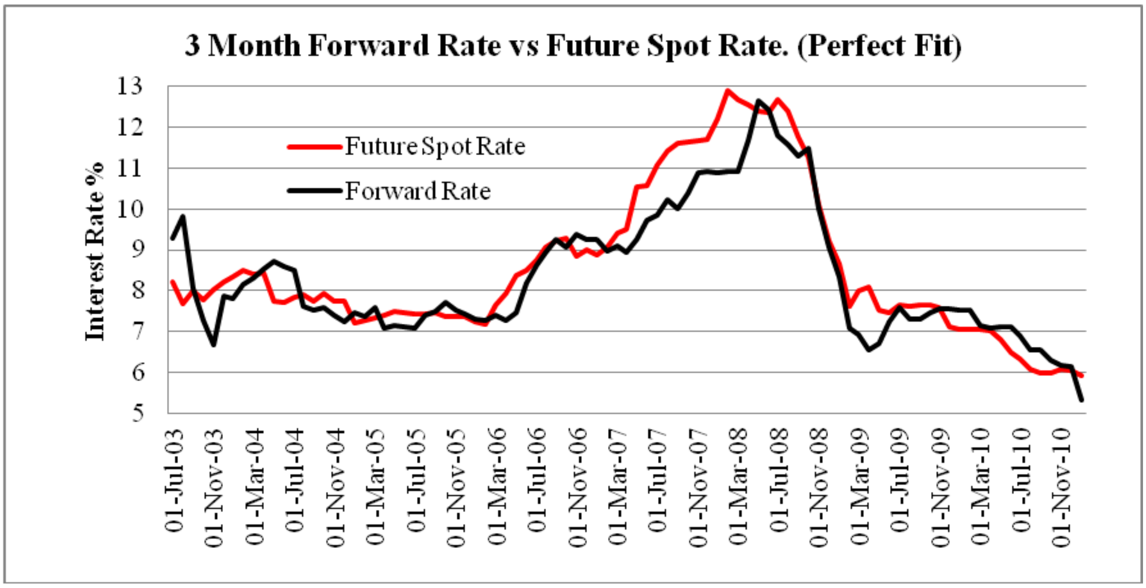

Figure 2. A comparison between the 3 month forward rate and the future spot rate from the perfect fit dataset.

[21] See appendix for the 1, 2, 4, 5, 6 and 24 month graphs.

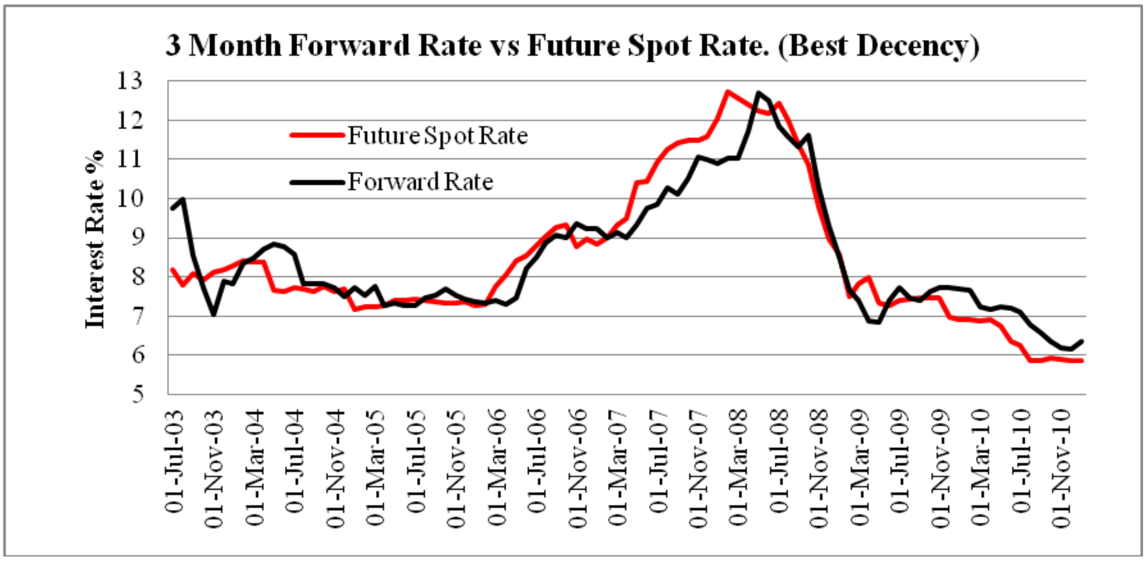

Figure 3. A comparison between the 3 month forward rate and the future spot rate from the best decency dataset.

Without doing any formal tests on the data a couple of things are obviously visible from comparing Figure 2, Figure 3 and the figures in the appendix[22]. Firstly, the two lines touch at relatively few points in all of the figures and the forecast power of the forward rates decreases as one looks further and further into the future. This is evident by comparing Figures 4, 5, 6 and 7 which show the increasing divergence of the forward rates from the future spot rate rates, as the forward rate is implied further into the future.

[22] The figures in the appendix merely show the Forward versus Spot rates further into the future i.e.: further than 3 months into the future.

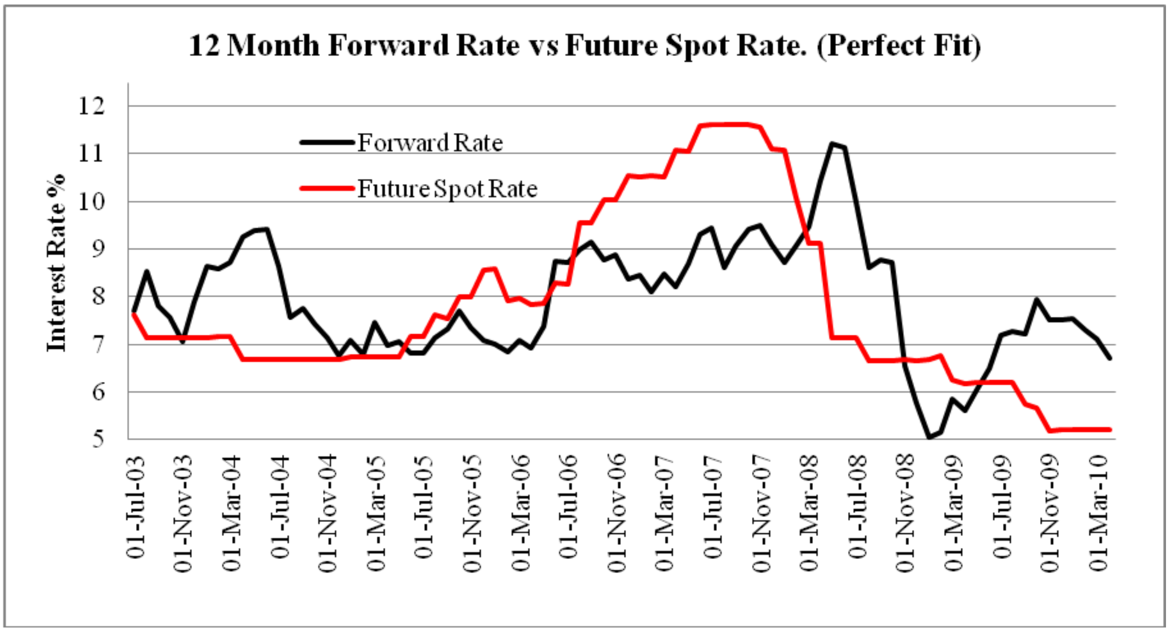

Figure 4. A comparison between the 12 month forward rate and future spot rate from the perfect fit dataset.

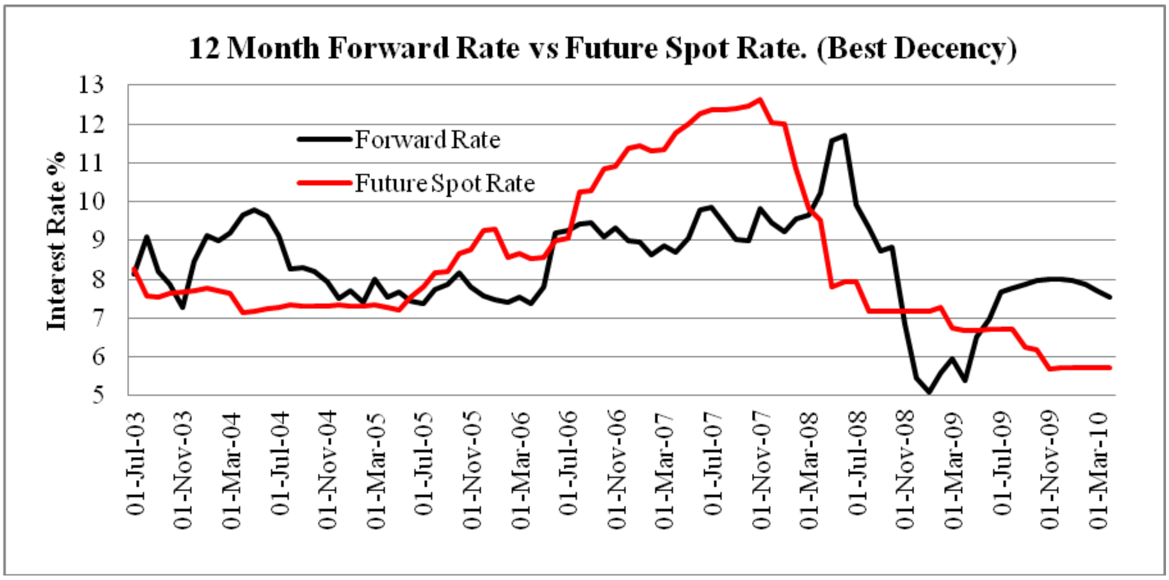

Figure 5. A comparison between the 12 month forward rate and future spot rate from the best decency dataset.

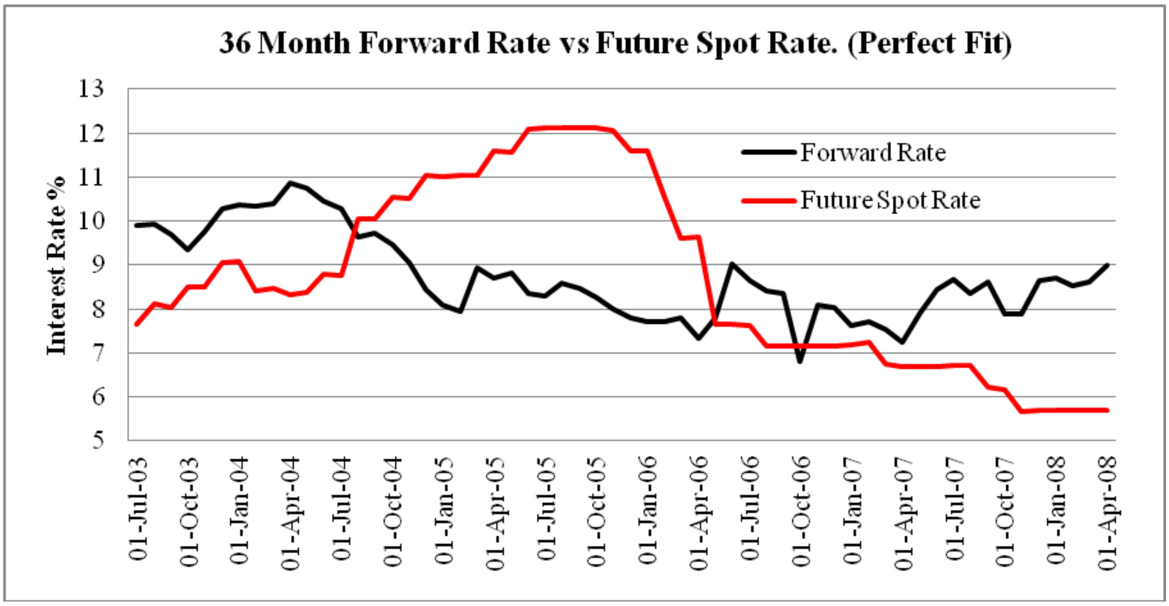

Figure 6. A comparison between the 36 month forward rate and future spot rate from the perfect fit dataset.

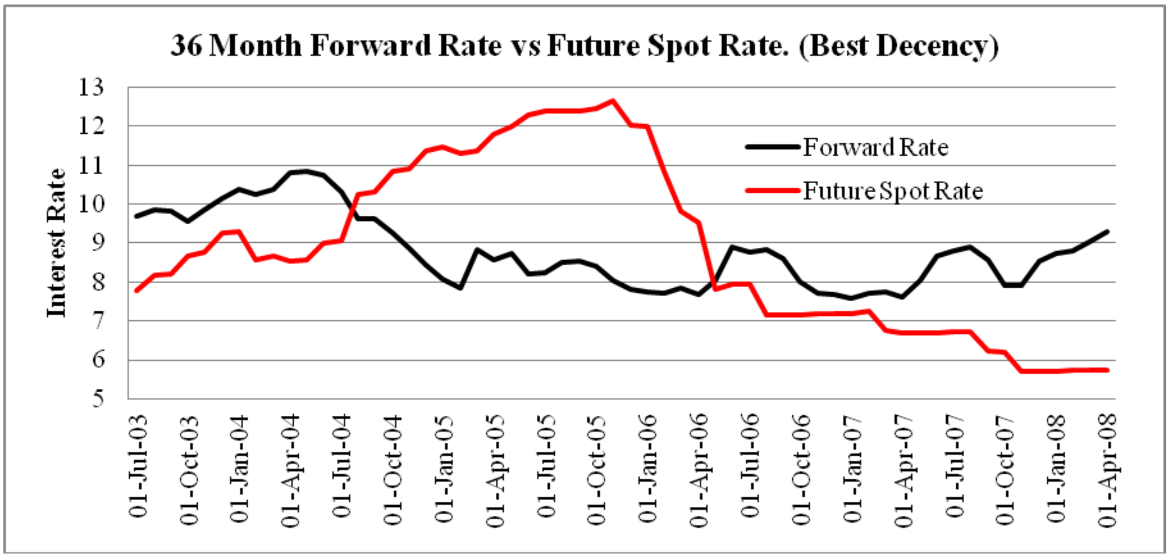

Figure 7. A comparison between the 36 month forward rate and future spot rate from the best decency dataset.

Secondly the financial crisis is evident in Figures 2, 3, 4 and 5 from the spike in interest rates around mid 2007 and into 2008. By looking at Figures 4, 5, 6 and 7 it is clear that the market did not properly anticipate the financial crisis. This is evident from the completely different shapes of the forward rate and future spot rate curves which is especially evident in Figures 6 and 7. Figures 4 and 5 anticipate a spike but only for a period of a few months.

The graphs also illustrate the difference between the data taken off of the perfect fit yield curves and the data taken off of the best decency yield curves, although nothing can really be said at this point regarding their comparative predictive power in their respective forward rates. It is evident, however, that the data graphed from the best decency yield curves is smoother than the data graphed off the perfect fit yield curves. The differences in predictive ability are tested formally in the next section.

4.1 The accuracy of forward rate forecasts

The first test done to determine the accuracy of forward rate forecasts was a regression test of the three month forward rate on the future spot rate in three months time. This test is represented symbolically by equation (5) in Table 16. The results were as follows (figures in brackets are the t-statistics):

Table 16. The forecast accuracy of the forward rate.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t}$	(5)	$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}R_3 = -0.46 + 1.09\ _{t+3}F_{3,t}$ *(-0.82) (15.68)*	0.89	0.62	1.48
Best Decency Data	$_{t+3}R_3 = -0.9 + 1.11\ _{t+3}F_{3,t}$ *(-1.44) (14.45)*	0.87	0.65	1.39

The coefficient for $_{t+3}F_{3,t}$ was found to be significant, for both the perfect fit and best decency datasets, well beyond the 1% confidence level (as indicated by the t-statistic). The adjusted r-squared values are quite high which indicates potentially strong forecast power. The Durbin Watson test statistics were both above the upper bound[23] considering the sample size of 30 and that there was only one independent variable. This is an indication of negative serial correlation being present. This apparent forecast power of the forward rate could simply be a reflection of the serial correlation that exists. To ascertain whether this is the case a regression with both the forward rate and the current spot rate as independent variables is run. This test is symbolically stated by equation (6) in Table 17.

[23] At the 5% level of confidence, with a sample size of 30 and one independent variable, the lower bound for the Durbin Watson test statistic is 1.352 and the upper bound is 1.489 (Savin & White, 1977). If the Durbin Watson value is below the lower bound it indicates that positive serial correlation is present, if it is above the upper bound it indicates the presence of negative serial correlation.

Table 17. The extent to which serial correlation is affecting the results.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t} + c\ _tR_3$ (6)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}R_3 = -0.46 + 0.97\ _{t+3}F_{3,t} + 0.11\ _tR_3$ (-0.83) (5.68) (0.77)	0.89	0.62	1.58
Best Decency Data	$_{t+3}R_3 = -0.87 + 1.06\ _{t+3}F_{3,t} + 0.04\ _tR_3$ (-1.33) (4.6) (0.22)	0.87	0.66	1.47

These findings illustrate that the apparent predictive power of the forward rate was due largely to the present serial correlation. This is due to the substantial decrease in the forward rate's ($_{t+3}F_{3,t}$) t-statistic and the high adjusted r-squared value. The t-statistics fell from 15.68 to 5.68 for the perfect fit data set, and for the best decency data set they fell from 14.45 to 4.6. The adjusted r-squared values decreased slightly from 0.8909 to 0.8893 for the perfect fit data set, and for the best decency data set from 0.8739 to 0.8696. However both adjusted r-squared values were still high indicating that once the effect of the current spot rate is held constant, the three month forward rate bears a less significant relationship to the future spot rate than the pure expectations theory claims it does. This is due to the fact that although the t-statistics fell, for both the perfect fit and best decency datasets, they were still significant. The findings from equation (6), for both the perfect fit and best decency datasets, appear to indicate that there does seem to be a weak relationship between the three month forward rate and the future spot rate.

According to the pure expectations theory it seems strange that expectations[24] are of limited value in forecasting three month spot rates. To investigate this finding further, the relationship between the errors made in forecasting and the actual changes in the spot rate needs to be looked at. Meiselman (1962) based his support for the pure expectations hypothesis on the basis that strong forecast accuracy was not required, and that the relationship between forecast errors and changes in spot rates was a better test of the pure expectations hypothesis. The errors[25] made in forecasting are calculated by taking the difference between the forward rate and the future spot rate. The actual change in rates is

[24] Forward rates are deemed to be the market's expectations of the future spot rate according to the pure expectations theory.

[25] Startz (1982) found that there are two contributing factors to the forecast error. The first was due to the market's error in forecasting and the second was due to variation in the liquidity premium. He says that the variation in the liquidity premium had a bigger effect than the market's error in forecasting.

obviously the difference between the future spot rate and the current spot rate. This test was done to determine the extent to which there is a systematic element in the errors. The test and results are represented by equation (7) in Table 18 and Table 19.

The serial correlation found in the results of Table 18 is cause for concern so the Yule Walker procedure was used to correct for it in Table 19.

Table 18. Determining if there is a systematic element in forecast errors. These results are before the correction for serial correlation.

$_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_tR_3)$ (7) *[before correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}F_{3,t} - {}_{t+3}R_3 = -0.31 - 0.34\,({}_{t+3}R_3 - {}_tR_3)$ (-3.14) (-2.59)	0.20	0.28	0.99
Best Decency Data	$_{t+3}F_{3,t} - {}_{t+3}R_3 = -0.1 - 0.49\,({}_{t+3}R_3 - {}_tR_3)$ (-0.98) (-3.78)	0.34	0.25	0.85

Table 19. Determining if there is a systematic element in forecast errors. For these results serial correlation had been adjusted for.

$_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_tR_3)$ (7) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}F_{3,t} - {}_{t+3}R_3 = -0.34 - 0.48\,({}_{t+3}R_3 - {}_tR_3)$ (-2.12) (-3.78)	0.42	0.21	1.29
Best Decency Data	$_{t+3}F_{3,t} - {}_{t+3}R_3 = -0.09 - 0.62\,({}_{t+3}R_3 - {}_tR_3)$ (-0.55) (-5.01)	0.57	0.17	1.27

The equations in Table 18 and Table 19 can be deemed to be robust if, after correcting for serial correlation, there is only a small change in the coefficients. If this is the case then it can be said that the error made in forecasting over the three month horizon will be equal to the change that occurred in the spot rate plus a constant. In addition, if the coefficient is found to be insignificantly different from minus one, adding the future spot rate to both sides of equation (7) would result in the forward rate being insignificantly different from the current spot rate plus a constant which is an estimate of the liquidity premium.

After correcting for serial correlation the best decency data yielded a smaller change in its coefficient (it changed from -0.49 to -0.62 which is a 26% change) than the perfect fit data (it changed from -0.34 to -0.48 which is a 41% change). Neither of these changes is deemed to be small (Hamburger and Platt (1975) found a change of 3.3% with the coefficient moving from -0.91 to -0.88). This indicates that equation (7) is not robust. So it cannot be said that the error made in forecasting over the three month horizon will be equal to the change that occurred in the spot rate plus a constant. The constant which is an estimate of the liquidity premium appears to be negative. Fama and Bliss (1987) found that the liquidity premium varied with the business cycle: during good times they were positive and during bad times they were negative. This might be why the liquidity premium found here is negative, since a large part of the data used in this paper occurred during the financial crisis. The coefficients were also found to be significantly different to minus one, with the t-statistics from a two tailed test being 6.65 for the perfect fit data and 7.01 for the best decency data. This implies that the forward rate is significantly different from the current spot rate plus a constant.

Even after correcting for serial correlation there was still some positive autocorrelation present (both Durbin Watson values were below 1.35). The adjusted r-squared values were also low indicating that the change in the spot rate did not explain enough of the forecast error. These findings indicate that the relationship between the forecast errors and the change in the spot rate are not what the pure expectations hypothesis would predict. More, or perhaps different, explanatory variables seem to be needed to explain the relationship between forecast errors and the change in spot rates. Barr and Kantor (1986) look at the relationship between forecast errors and the change in gold price, because they say that in South Africa short term interest rates are affected by the movements in the gold price[26]. They found that the relationship between forecast errors and the change in the gold price did not have overbearing explanatory power. The gold price was found to be merely an influence on the short term interest rate, but was not the only influencing variable. However, Barr and Kantor (1986) said that the market's success in forecasting future spot rates is related to the success of the market forecasting the gold price. Contrary to the finding of these results and those of Barr and Kantor (1986), Nurick (1982) found that forecast errors were due solely to the receipt of new information and that forecast errors are approximately equal to the change that occurred in the spot rate. Hamburger and Platt (1975) found that the error made in forecasting was equal to the change in the spot rates plus a constant.

[26] The South African economy is largely a commodity driven economy. However it's important to note that gold is no longer as significant a driver of the economy as it was in the 1980's.

There are two possible limitations to the analysis in Table 19 that need to be considered before looking at the implications of these results. The first limitation is the possibility that using a single regression equation to fit an entire sample period may just be describing an average relationship for the entire sample period. This would fail to detect any forecast accuracy occurring in sub-periods. To check for this the sample is broken down into five subsets, the first sub-sample was made up of ten observations and the other four sub-samples were made up of five observations. The results from the sub-sample tests were quite similar to the results from the entire sample. The coefficients for $({}_{t+3}R_3 - {}_{t}R_3)$ ranged from -0.40 to -0.65 and the t-statistics were all around -4, indicating that there did not appear to be instances of forecast accuracy in the sub-samples.

The second limitation that needs to be considered is the possibility of a varying liquidity premium that could have an impact on the results. To test for a variable liquidity premium the current spot rate is added as an extra independent variable. This test is represented by equation (8) in Table 20 and Table 21.

Table 20. Determining the presence of a variable liquidity premium. These results are before the correction for serial correlation.

${}_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_{t}R_3) + c\,{}_{t}R_3$ (8) *[before correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.9 - 0.38\,({}_{t+3}R_3 - {}_{t}R_3) - 0.15\,{}_{t}R_3$ (2.25) (-3.31) (-2.11)	0.41	0.22	1.59
Best Decency Data	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 1.25 - 0.54\,({}_{t+3}R_3 - {}_{t}R_3) - 0.17\,{}_{t}R_3$ *(2.58) (-5.06) (-2.39)*	0.58	0.17	1.61

Table 21. Determining the presence of a variable liquidity premium. For these results serial correlation had been adjusted for.

${}_{t+3}F_{3,t} - {}_{t+3}R_3 = a + b\,({}_{t+3}R_3 - {}_{t}R_3) + c\,{}_{t}R_3$ (8) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 0.75 - 0.43\,({}_{t+3}R_3 - {}_{t}R_3) - 0.13\,{}_{t}R_3$ (1.6) (-3.5) (-2.33)	0.44	0.21	1.49
Best Decency Data	${}_{t+3}F_{3,t} - {}_{t+3}R_3 = 1.14 - 0.59\,({}_{t+3}R_3 - {}_{t}R_3) - 0.15\,{}_{t}R_3$ *(2.47) (-5.08) (-2.56)*	0.60	0.16	1.50

If the constant as well as the coefficient of the current spot rate are insignificant then it would mean that it is difficult to differentiate between a variable and constant liquidity premium. The results from the perfect fit data indicate that the coefficient of the current spot rate is significant, but the constant is insignificant. The best decency data indicates that the coefficient of the current spot rate and the constant were both significant. The results from the best decency data indicate that it is not difficult to differentiate between a variable and constant liquidity premium since both the constant and ${}_tR_3$ are significant. A similar result was found for the perfect fit data except that the constant was found to be insignificant. This could perhaps imply that in all likelihood the liquidity premium varies, which is the dominant finding in other literature[27] and, in particular, a varying liquidity premium was found by Fedderke and Pillay (2007) in South African data.

From the results of this section there seems to be a marginal amount of information in the forward rate when it comes to forecasting the future spot rate. This result is partially[28] supported by Nurick (1982), who found forward rates to be weak but optimal forecasters of the future spot rate. Nurick's (1982) findings could be due to him not using government bond data, since Tease (1988), Al-Loughani (1991) and Dahlquist and Jonsson (1995) also found forecast power in the forward rates on non-government bond datasets. The presence of a liquidity premium is also a likely cause of the forward rate on its own having weak forecast power. Weak forecast power alone does not necessarily mean the pure expectations hypothesis is not supported since additional information arrives in the market between the time the forward rate is implied and the time the future spot rate is realised. The relationship between the forecast errors and the change in spot rates is limited[29] since the forecast errors were found not to be approximately equal to the change in the spot rate. These two findings could indicate that perhaps other variables could better forecast the future spot rate than the forward rate can, or perhaps one of the other theories of the yield curve are better suited to the South African government bond yield curve. There does seem to be a liquidity premium present and it more than likely varies. From these findings the pure expectations hypothesis does not appear to be able to adequately explain the shape of the South African government

[27] Holland (1965), Fisher (1966), Sargent (1972), Hamburger and Platt (1975) McCulloch (1975), Fama (1976, 1984a, 1984b, 1986, 1990), Startz (1982), Fama and Bliss (1987), Melino (1988), Mishkin (1988), Hardouvelis (1988), Campbell and Shiller (1991), Huang and Lin (1996), Buser, Karolyi and Saunders (1996) and Christiansen (2003).

[28] It is only partially supported since the results of this paper only indicate the forward rates to be weak and not optimal forecasters of the future spot rate.

[29] This could be due to the model used not being able to adequately account for variation in the liquidity premium which Startz (1982) found to be a major influence on the forecast error.

bond yield curve. None of these findings changed when data from different constructions (perfect fit and best decency) of the yield curve were used.

4.2 Testing for market efficiency

To test for market efficiency it first needs to be established if a static model of interest rate expectations fits the data well. If it does then this static model needs to be tested for its consistency to Muth's (1961) concept of rational expectations. From these tests conclusions regarding market efficiency can be drawn since the efficient market model has very similar assumptions to Muth's (1961) concept. To see how well a static model fits the data the relationship between the forward rate and current spot rate needs to be analysed. If there is a close association it would mean a static expectations model is a good fit for the data. This test is represented by equation (9) in Table 22.

Table 22. To what extent can the current spot rate explain the forward rate.

${}_{t+3}F_{3,t} = a + b\,{}_tR_3$ (9) *[after correcting for serial correlation]*		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	${}_{t+3}F_{3,t} = 1.22 + 0.81\,{}_tR_3$ *(1.58) (8.93)*	0.91	0.22	1.25
Best Decency Data	${}_{t+3}F_{3,t} = 1.17 + 0.84\,{}_tR_3$ *(1.29) (11.49)*	0.94	0.21	1.24

Both the perfect fit and best decency results indicate a strong relationship between the current spot rate and the forward rate. The statement is supported by four results. The first result is the insignificant constants for both data sets; the t-statistics were 1.58 and 1.29 for the perfect fit and best decency datasets respectively. The second result is that the coefficients from both the perfect fit and best decency datasets were both significant, with t-statistics of 8.93 and 11.49 respectively, and close to one. The third result is the high adjusted r-squared values, both above 90%. The fourth and last result is that this strong relationship between the forward rate and current spot rate was not due to serial correlation since both the Durbin Watson test statistics were within the required[30] range of 1.134 to 1.264. From these results it can be said that a static model of the formation of interest rates seems to fit the data reasonably well.

[30] The required range for a regression with one independent variable and 30 observations is 1.134 for the lower bound and 1.264 for the upper bound, these bounds are for the 1% significance test (Savin & White, 1977).

To test how consistent this static model is with Muth's (1961) concept for rational expectations, three conditions need to be met. The first two conditions are weak form conditions of market efficiency and the third is a semi-strong form condition of market efficiency. Only weak form and semi-strong form conditions of market efficiency will be tested for, no tests of the strong form market efficiency will be run.

The test for the first weak form condition of market efficiency, tests to see if changes in the three month spot rates are related. To test for this, firstly the change in the spot rate from three months back to t_0 is regressed on the change in the spot rate from t_0 to the spot rate three months ahead. This test is represented by equation (10) in Table 23. Then another regression is run on the three month differences from 3 to 6 months back, 6 to 9 months back, and so on all the way back to 24 months on the difference between the current spot rate and the spot rate three months forward. This test is merely an extension of the test in Table 23 and is represented by equation (11) in

Table 24. Both the tests in Table 23 and

Table 24 are part of the tests for the first weak form condition that needs to be met.

Table 23. Testing for the first weak form condition of market efficiency.

$_{t+3}R_3 - {}_tR_3 = a + b({}_tR_3 - {}_{t-3}R_3)$ (10)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}R_3 - {}_tR_3 = -0.06 + 0.07({}_tR_3 - {}_{t-3}R_3)$ (-0.3) (0.43)	0.16	0.35	1.13
Best Decency Data	$_{t+3}R_3 - {}_tR_3 = -0.08 + 0.03({}_tR_3 - {}_{t-3}R_3)$ (-0.47) (0.23)	0.12	0.37	1.14

Table 24. The second test in testing for the first weak form condition of market efficiency.

$_{t+3}R_3 - {}_tR_3 = a + b\,({}_tR_3 - {}_{t-3}R_3) + c({}_{t-3}R_3 - {}_{t-6}R_3) + \ldots + j({}_{t-21}R_3 - {}_{t-24}R_3)$ (11)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}R_3 - {}_tR_3 = -0.04 + 0.18\,({}_tR_3 - {}_{t-3}R_3)$ (-0.24) (1.04) $+0.05({}_{t-3}R_3 - {}_{t-6}R_3) - 0.19\,({}_{t-6}R_3 - {}_{t-9}R_3)$ (0.32) (-1.12) $+0.29({}_{t-9}R_3 - {}_{t-12}R_3) - 0.19\,({}_{t-12}R_3 - {}_{t-15}R_3)$ (1.76) (-1.15) $-0.13({}_{t-15}R_3 - {}_{t-18}R_3) + 0.08\,({}_{t-18}R_3 - {}_{t-21}R_3)$ (0.77) (0.49) $-0.06({}_{t-21}R_3 - {}_{t-24}R_3)$ (-0.42)	0.11	0.50	1.02
Best Decency Data	$_{t+3}R_3 - {}_tR_3 = -0.04 + 0.21\,({}_tR_3 - {}_{t-3}R_3)$ (-0.24) (1.2) $+0.09({}_{t-3}R_3 - {}_{t-6}R_3) - 0.22\,({}_{t-6}R_3 - {}_{t-9}R_3)$ (0.51) (-1.27) $+0.26({}_{t-9}R_3 - {}_{t-12}R_3) - 0.17\,({}_{t-12}R_3 - {}_{t-15}R_3)$ (1.51) (-1.02) $-0.11({}_{t-15}R_3 - {}_{t-18}R_3) - +0.09\,({}_{t-18}R_3 - {}_{t-21}R_3)$ (-0.67) (0.53) $-0.06({}_{t-21}R_3 - {}_{t-24}R_3)$ (-0.42)	0.09	0.46	1.04

For the changes in the three month spots to be unrelated there needs to be no serial correlation present, the coefficients cannot be significant and the adjusted r-squared values need to be very low.

The results from Table 23 and

Table 24 indicate that the changes in spot rates are unrelated. The Durbin Watson test statistics from Table 23 are within the required range (1.134 to 1.264), as are the Durbin Watson test statistics in

Table 24 (since they are in the range[31] of 0.684 and 1.925). This implies that there is very little serial correlation present. None of the coefficients in either Table 23 or

[31] This range is different since there are eight independent variables. This range is also testing for serial correlation at the 1% level of significance.

Table 24 are significant since the absolute values of their t-statistics are all well below 2. The low adjusted r-squared values indicate that the models in Table 23 explain very little of the change that occurs between the current spot rate and the future spot rate. The adjusted r-squared values in Table 11 are lower, indicating that the model got even weaker when more independent variables were added. These results indicate that the first condition of market efficiency is fulfilled and the static model of the formation of interest rate expectations appears to be rational so far. This implies that the change in the spot rate from the current rate to the future rate cannot be forecast from the history of past rate movements.

Since the tests in Table 23 and

Table 24 are the first of three tests to see if the static expectations model reflects rational behaviour, it is not yet possible to come to a conclusion about the South African government bond market. However, the results from both the perfect fit and best decency datasets indicate that the condition for the first weak form of market efficiency has been fulfilled.

The second weak form test is a test of whether or not the static expectations model provides an accurate description of investor behaviour, meaning: Are market participants wasting their time looking at past spot rates to forecast the future spot rate? The aim of this test is to disprove distributed lag theories of interest rate expectations. To determine if too much attention is paid to past spot rates, a regression needs to be run that contains the future spot rate as the dependent variable and the lagged spot rates as the independent variables. The forward rate has been included as an independent variable so as to compensate for variable liquidity premiums. This test is shown in

Table 25 by equation (13).

Table 25. The test determining the validity of the distributed lag theories of interest rate expectations.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t} + c_tR_3 + d\ _{t-3}R_3 + e\ _{t-6}R_3 + \ldots + j\ _{t-24}R_3$ (13)		Adj R^2	S.E	Durbin Watson
Perfect Fit Data	$_{t+3}R_3 = 2.83 + 0.73\ _{t+3}F_{3,t} + 0.02\ _tR_3 + 0.14\ _{t-3}R_3$ (2.24) (4.46) (0.1) (0.95) $+ 0.03\ _{t-6}R_3 + 0.11\ _{t-9}R_3 - 0.15\ _{t-12}R_3$ (0.19) (0.77) (-1.08) $+ 0.09\ _{t-15}R_3 - 0.01\ _{t-18}R_3 - 0.18\ _{t-21}R_3$ (0.65) (-0.05) (-1.37) $-0.09\ _{t-24}R_3$ (-0.84)	0.81	0.26	1.4
Best Decency Data	$_{t+3}R_3 = 3.04 + 0.74\ _{t+3}F_{3,t} + 0.06_tR_3 + 0.12\ _{t-3}R_3$ (2.44) (3.53) (0.24) (0.74) $- 0.03\ _{t-6}R_3 + 0.09\ _{t-9}R_3 - 0.16\ _{t-12}R_3$ (-0.21) (0.57) (-1.03) $+ 0.12\ _{t-15}R_3 + 0.01\ _{t-18}R_3 - 0.19\ _{t-21}R_3$ (0.79) (0.04) (-1.29) $-0.13\ _{t-24}R_3$ (-1.16)	0.84	0.24	1.38

To disprove the distributed lag theory, the coefficients of the lagged spot rates would have to be insignificant. If the coefficients are insignificant it would indicate that lagged rates play a negligible role when the market forms their expectations of the future spot rate. It is evident from

Table 25 that all of the lagged spot rates' coefficients are insignificant for both the perfect fit and best decency tests. Since none of the lagged rates' coefficients are significant they would not have differing effects on the forward rate as opposed to the spot rate. Another indication of the lack of association between the independent and dependent variables in

Table 25 is the slight change in the unadjusted r-squared values between Table 18's tests and

Table 25's tests. The unadjusted[32] r-squared values for the tests in Table 18 were 0.87 for the perfect fit data and 0.86 for the best decency dataset. This implies that the difference between the unadjusted r-squared values from Table 18 and

[32] The unadjusted r-squared values have not been reported in Table 18 or Table 25.

Table 25 are 0.055 for the perfect fit dataset and 0.029 for the best decency dataset. Both of these are small differences.

These results indicate that the distributed lag theories do not hold which implies the static model of interest rate expectations appears to be rational since the market makes appropriate use of past spot rate data. This implies that the second weak form condition of market efficiency has been fulfilled. This applies to both the perfect fit and best decency data. Hamburger and Platt (1975) and Fama (1976) also found that the market correctly used the information in past spot rates.

The third and final test, tests the semi-strong form condition of market efficiency which looks at whether other economic variables can forecast the future spot rate better than the forward rate can. It seems obvious that if there is information known about economic variables that affect the interest rate, this information should be included in forecasts. The monetary base (MB), money supply (M1), and personal income (Y) variables used are all quarterly nominal data. So the forward rate and spot rate used are three month averages so as to have the same frequency as the rest of the variables. This was done to add power to the tests. The forward rate and future spot rate data in Table 26 are three month average data as opposed to the single day observations that were used in the prior sections and tests. Therefore the test in Table 26 and the test in Table 16 are exactly the same test, except for how the variables were calculated, and the results were similar. These results from Table 26 will be compared with the results from

Table 27 to see if the other economic variables are more suited to forecasting the future spot rate than the forward rate is.

Table 26. The accuracy of forward rate forecasts. Three monthly average data is used for this test as opposed to the single day of the month observations that were used previously.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t}$ (14)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data *(before correction for serial correlation)*	$_{t+3}R_3 = -0.79 + 1.13\ _{t+3}F_{3,t}$ (-1.46) (16.70)	0.90	0.32	1.76
Perfect Fit Data *(after correction for serial correlation)*	$_{t+3}R_3 = -0.73 + 1.12\ _{t+3}F_{3,t}$ (-1.28) (15.78)	0.91	0.33	1.71
Best Decency Data *(before correction for serial correlation)*	$_{t+3}R_3 = -1.05 + 1.13\ _{t+3}F_{3,t}$ (-1.8) (15.77)	0.89	0.34	1.71
Best Decency Data *(after correction for serial correlation)*	$_{t+3}R_3 = -0.92 + 1.11\ _{t+3}F_{3,t}$ (-1.46) (14.40)	0.90	0.35	1.61

Table 27. Can other economic variables can better forecast the future spot rate?

${}_{t+3}R_3\ =\ a + b\ M1_{t+3} + \text{c Y}_{t+3}$ (15) ${}_{t+3}R_3\ = a + b\ MB_{t+3} + c\ MB_t\ + d\ Y_{t+3} + e\ Y_t$ (16) ${}_{t+3}R_3\ = a + b\ MB_{t-1} + c\ Y_{t-1}$ (19)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data *equation (15)*	${}_{t+3}R_3\ =\ -1.97 + 7.03\ \log M1_{t+3} - 5.6\ \log Y_{t+3}$ (-0.09) (1.05) (-0.77)	0.76	0.65	0.90
Best Decency Data *equation (15)*	${}_{t+3}R_3\ = 0.43 + 6.84\ \log M1_{t+3} - 5.85\ \log Y_{t+3}$ (0.02) (1.03) (-0.81)	0.75	0.63	0.84
Perfect Fit Data *equation (16)*	${}_{t+3}R_3\ =\ -9.32 + 11.92\ \log MB_{t+3} - 13.56\ \log MB_t$ *(-0.29) (1.91) (-1.16)* $-1.12\ \log Y_{t+3} + 5.7\ \log Y_t$ *(-0.16) (0.79)*	0.81	0.56	0.92
Best Decency Data *equation (16)*	${}_{t+3}R_3\ =\ -5.67 + 10.25\ \log MB_{t+3} - 12.67\ \log MB_t$ *(-0.18) (1.81) (-1.11)* $-0.68\ \log Y_{t+3} + 5.3\ \log Y_t$ *(-0.1) (0.76)*	0.79	0.52	0.88
Perfect Fit Data *equation (19)*	${}_{t+3}R_3\ = 16.11 - 2.55\ \log MB_{t-1} + 0.74\ \log Y_{t-1}$ (0.56) (-0.37) (0.13)	0.84	0.60	0.85
Best Decency Data *equation (19)*	${}_{t+3}R_3\ = 18.72 - 2.70\ \log MB_{t-1} + 0.39\ \log Y_{t-1}$ (0.67) (-0.40) (0.07)	0.83	0.57	0.78

The results of

Table 27[33] indicate that the economic variables are not as closely related to the future spot rate as the forward rate is. This is due to the fact that they have higher standard errors, lower adjusted r-squared values and none of the coefficients are significant. A test was also run with each economic variable being the sole independent variable and the results[34] were similar to those of

[33] The basis for choosing the variables and running the tests in Table 27 was to include appropriate monetary and income variables likely to explain the spot rate. Hamburger and Platt (1975) say that if such variables are known at t-3, it would be inefficient not to utilise them in forecasting the future spot rate. They indicate that within the frame work of the efficient markets model, the values of the explanatory variables are random at t-3. Hamburger and Platt (1975) go on to say that it is possible for ${}_{t+3}R_3$ to be determined by distributed lags of monetary and income variables, and the fact that these variables change relatively slowly indicates that knowledge of current and lagged values of these variables may be sufficient to provide estimates of the future spot rates that have smaller mean errors than those based on auto regressions.

[34] The t-statistic for M1 was -0.79, for MB it was -0.34 and for Y it was 0.39. These tests regressed the current value (t_o) of the economic variable on the future spot rate (${}_{t+3}R_3$).

Table 27. The most appropriate variable of the economic variables is MB, since equation (16) when compared to equation (15), has a higher adjusted r-squared, lower S.E and the MB coefficient is the most significant out of M1 and Y. This applies to both the perfect fit and best decency datasets. To be able to determine if the South African government bond market fulfils the semi-strong condition of market efficiency, equation (19) was run and the results compared to equation (14). The S.E of equation (19) is larger than that of equation (14) which would suggest market efficiency according to Hamburger and Platt (1975), since the economic variables are not able to better forecast the future spot rate. However the relationship illustrated by equation (19) could not have been known with certainty during the sample period so the results do not yield a direct test of whether or not better forecasts were available to the market than those implicit in forward rates. A more appropriate test is to compare the out of sample forecasts provided by equation (14) and equation (19). To do this the sample period is split in half and equations (14) and (19) re-estimated over the earlier half of the sample period. These equations are then used to extrapolate the values for R_3 over the latter half of the sample period. These extrapolated values are then compared to the actual values. The extrapolation equations are shown by Table 28 and the comparison between the actual and extrapolated values are shown in

Table 29.

Table 28. Equations (14) and (19) after being re-estimated over the earlier half of the sample period.

$_{t+3}R_3 = a + b\ _{t+3}F_{3,t}$ (14) $_{t+3}R_3 = a + b\ MB_{t-1} + c\ Y_{t-1}$ (19)		$Adj\ R^2$	S.E	Durbin Watson
Perfect Fit Data *equation (14)*	$_{t+3}R_3 = 2.57 + 0.66\ _{t+3}F_{3,t}$ (2.39) (4.62)	0.65	0.17	1.68
Best Decency Data *equation (14)*	$_{t+3}R_3 = 3.66 + 0.50\ _{t+3}F_{3,t}$ (2.75) (2.90)	0.60	0.20	1.30
Perfect Fit Data *equation (19)*	$_{t+3}R_3 = -29.66 + 5.3 \log MB_{t-1} + 2.18 \log Y_{t-1}$ (-1.15) (0.71) (0.24)	0.65	0.32	1.04
Best Decency Data *equation (19)*	$_{t+3}R_3 = -29.62 + 5.04 \log MB_{t-1} + 2.21 \log Y_{t-1}$ (-1.14) (0.69) (0.25)	0.66	0.30	1.00

Table 29. The comparison between the actual values of R_3 and the extrapolated values of R_3 for both equations (14) and (19) from Table 28.

Equation (14): *Actual – Extrapolated value*	MSE	Root MSE
Perfect Fit Data	0.017	0.131
Best Decency Data	0.024	0.156
Equation (19): *Actual – Extrapolated value*	MSE	Root MSE
Perfect Fit Data	0.071	0.266
Best Decency Data	0.067	0.260

These results indicate that there are market efficiencies present because a higher root mean squared error was found in

Table 29 for the economic variables compared to that of the forward rate. However regressions fitted to the entire sample period may provide misleading information with regard to market efficiency. The tests for the semi-strong form of market efficiency seem to be inconclusive, so it could not be said with certainty that the semi-strong condition has been fulfilled.

5. Conclusions

The objective of this study was to determine if the pure expectations hypothesis holds in the South African government bond market. It did this by having three aims. The first was to test to see if the pure expectations hypothesis can adequately explain the South African government bond yield curve. The second was to test for market efficiency in the South African government bond market, and the third was to see if the construction of the yield curve affected the findings of the first two aims. This paper has contributed evidence that the pure expectations hypothesis does not hold in the short end of the South African government bond market. These findings in the South African context are similar to the past research that has been done on the pure expectations hypothesis. This paper has added additional evidence, to the relatively little past research on this topic (in a South African context), that very little support can be found for the pure expectations hypothesis.

The tests of the pure expectations hypothesis, specifically the ability of the forward rate to accurately forecast the future spot rate and the relationship between forecast errors and the change in the spot rate, both yielded results contrary to what is predicted by the pure expectations hypothesis and the Meiselman (1962) model respectively. This is due to the finding of only marginal forecast power in the forward rate and virtually no relationship being found between the forecast errors and the change in the spot rate.

The market efficiency tests' results indicate that weak form market efficiency appeared to exist, but the results for the semi-strong form condition of market efficiency were inconclusive.

The construction of the yield curve did not have an impact on the results of the tests of the pure expectations hypothesis or market efficiency tests. The findings for both the perfect fit and best decency datasets were mostly very similar for all of the tests that were run.

In conclusion the pure expectations hypothesis does not seem to be able to adequately explain the shape of the of the South African government bond yield curve. This is mostly due to the presence of liquidity premiums. As soon as a liquidity premium is present, whether it is positive or negative, the theory behind the pure expectations hypothesis says it cannot hold. There is evidence of liquidity premiums in a substantial amount of past research done on this topic.

This research could be extended in the future by examining the nature and characteristics of South African government bond liquidity premiums. This could be done in conjunction with looking to see if the yield curve can be better explained by models that adjust or compensate for liquidity premiums.

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7. Appendix

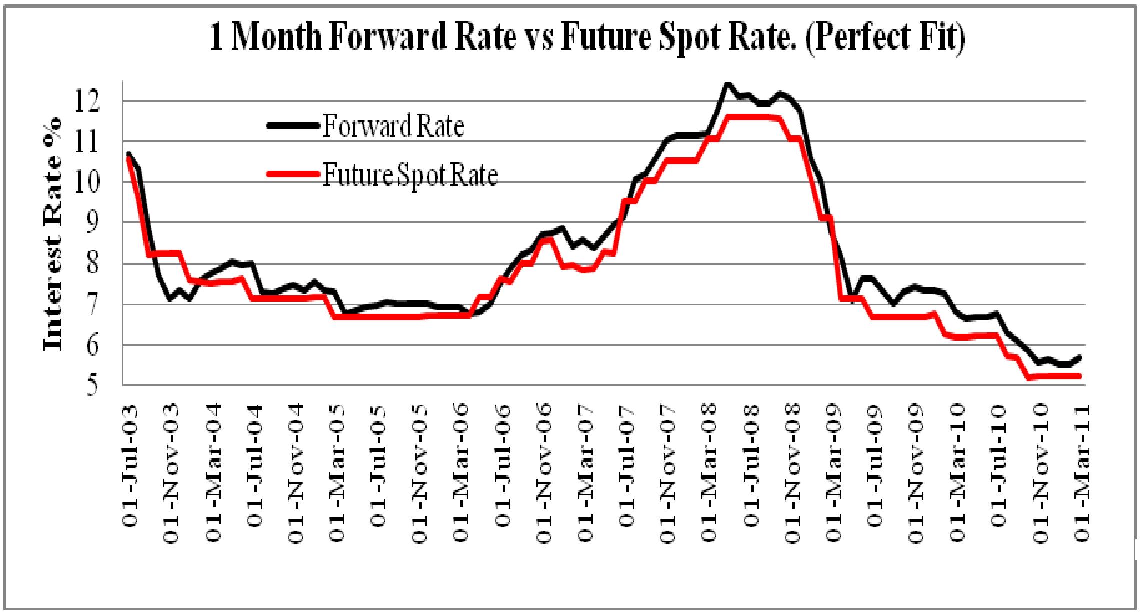

Figure 8. A comparison between the 1 month forward rate and future spot rate from the perfect fit dataset.

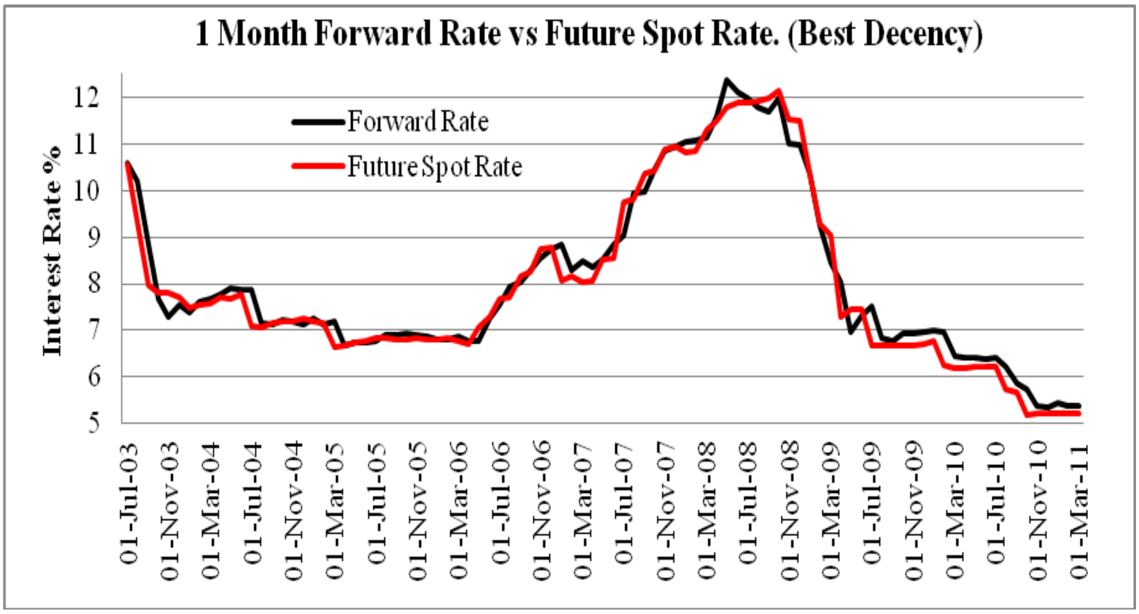

Figure 9. A comparison between the 1 month forward rate and future spot rate from the best decency dataset.

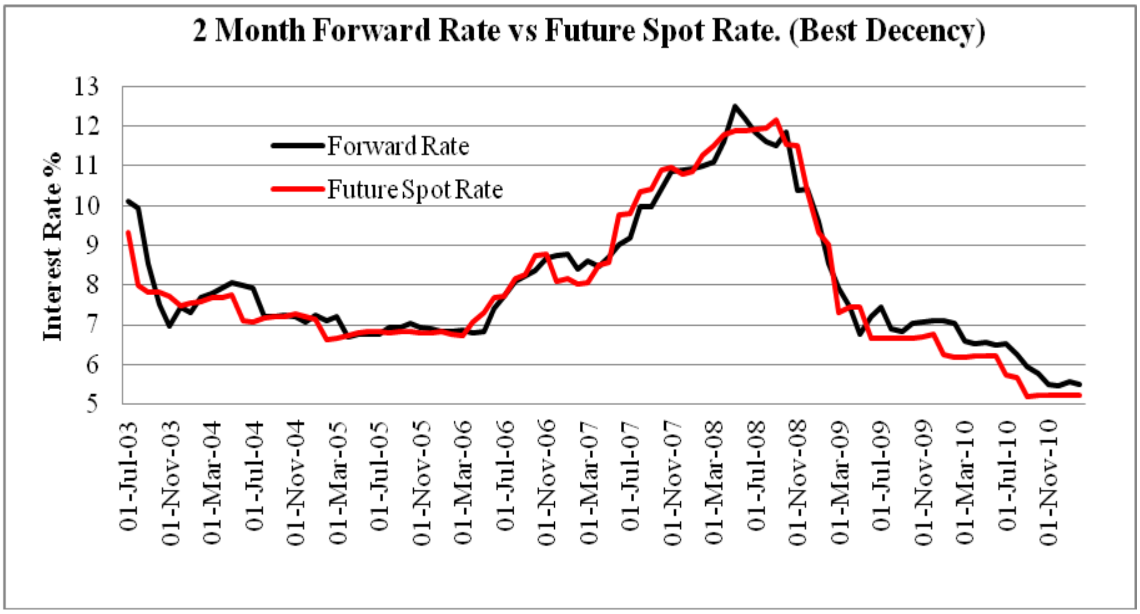

Figure 11. A comparison between the 2 month forward rate and future spot rate from the best decency dataset.

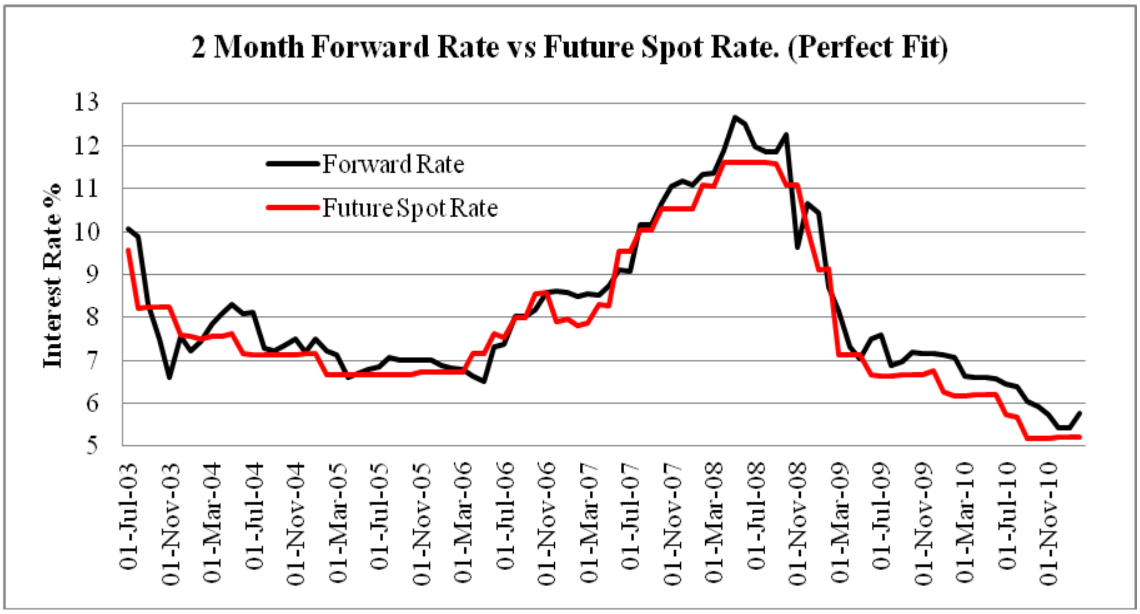

Figure 10. A comparison between the 2 month forward rate and future spot rate from the perfect fit dataset.

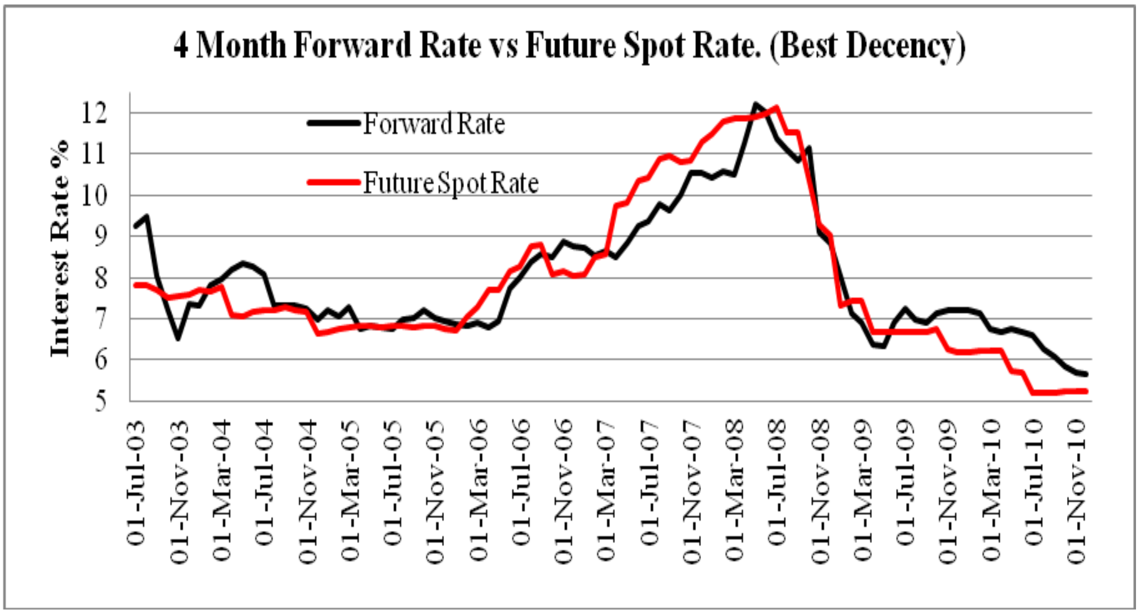

Figure 13. A comparison between the 4 month forward rate and future spot rate from the best decency dataset.

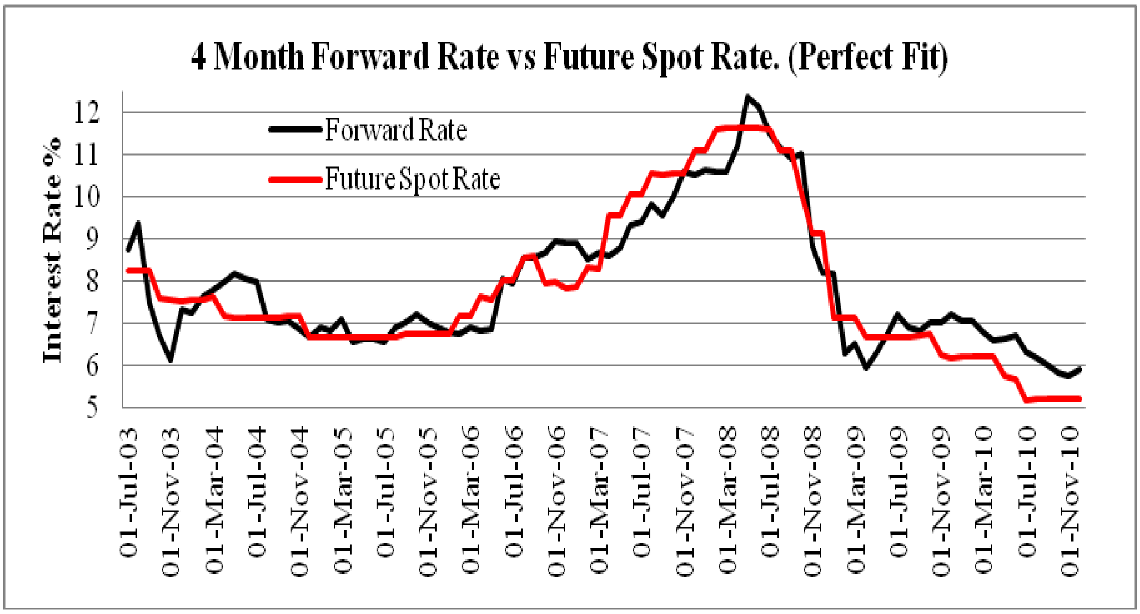

Figure 12. A comparison between the 4 month forward rate and future spot rate from the perfect fit dataset.

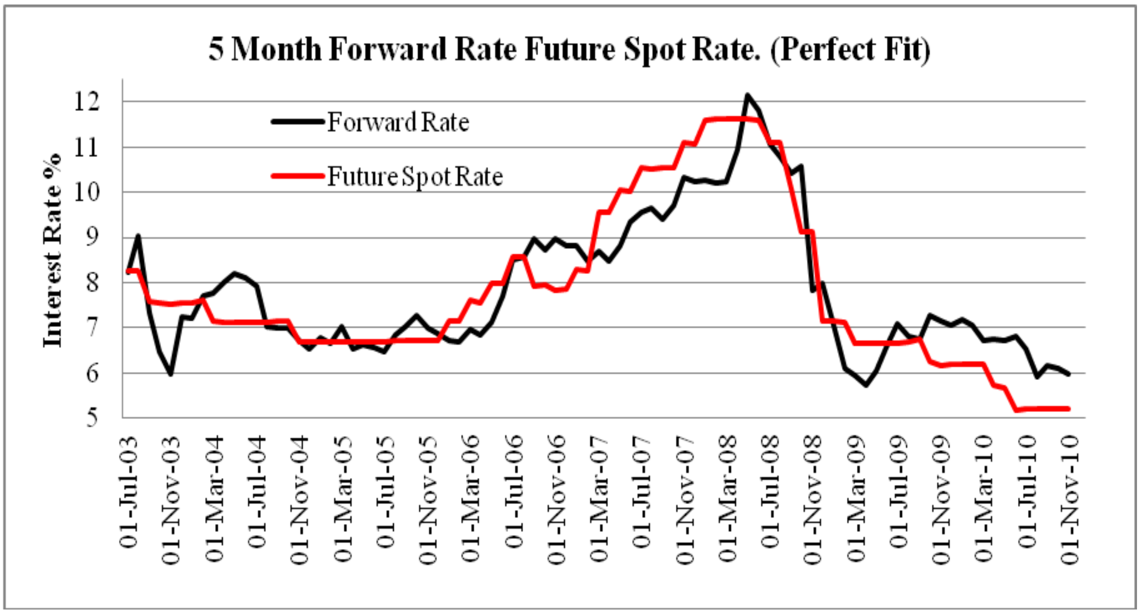

Figure 15. A comparison between the 5 month forward rate and future spot rate from the perfect fit dataset.

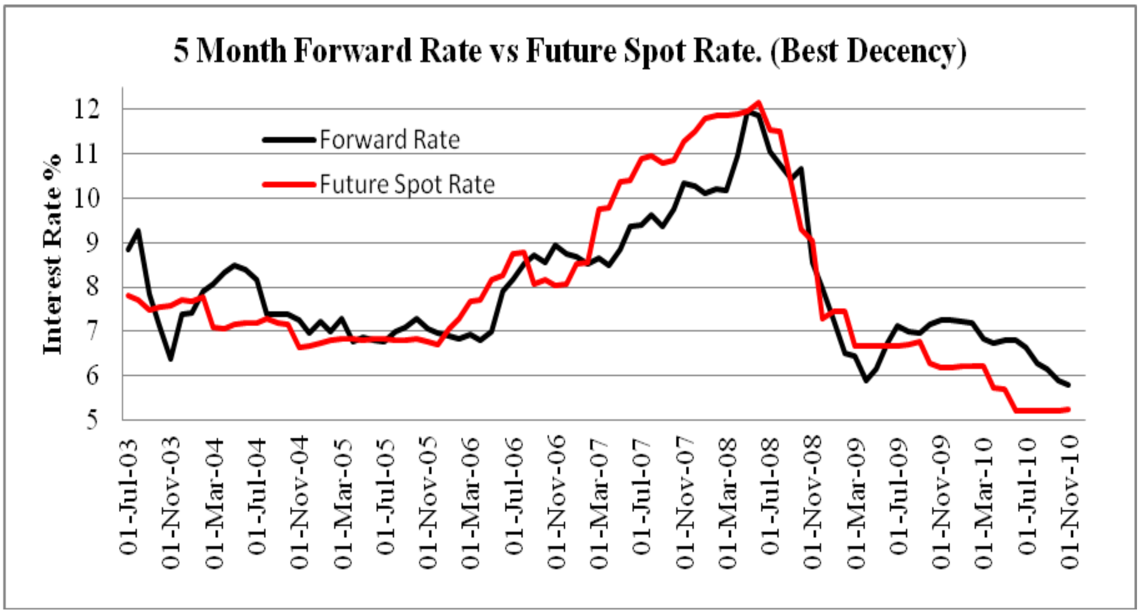

Figure 14. A comparison between the 5 month forward rate and future spot rate from the best decency dataset.

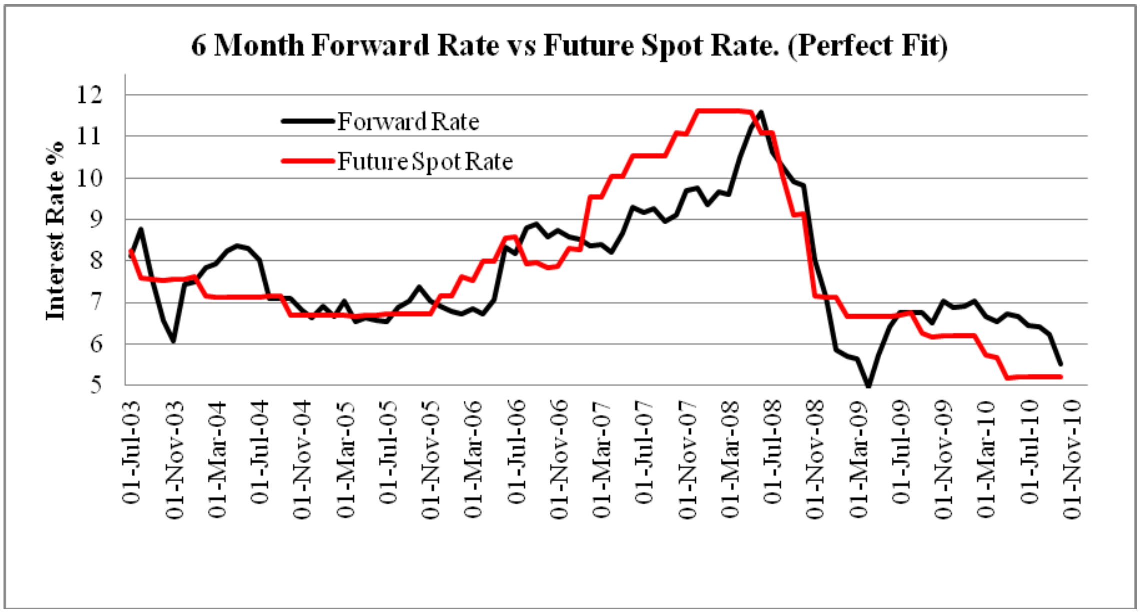

Figure 16. A comparison between the 6 month forward rate and future spot rate from the perfect fit dataset.

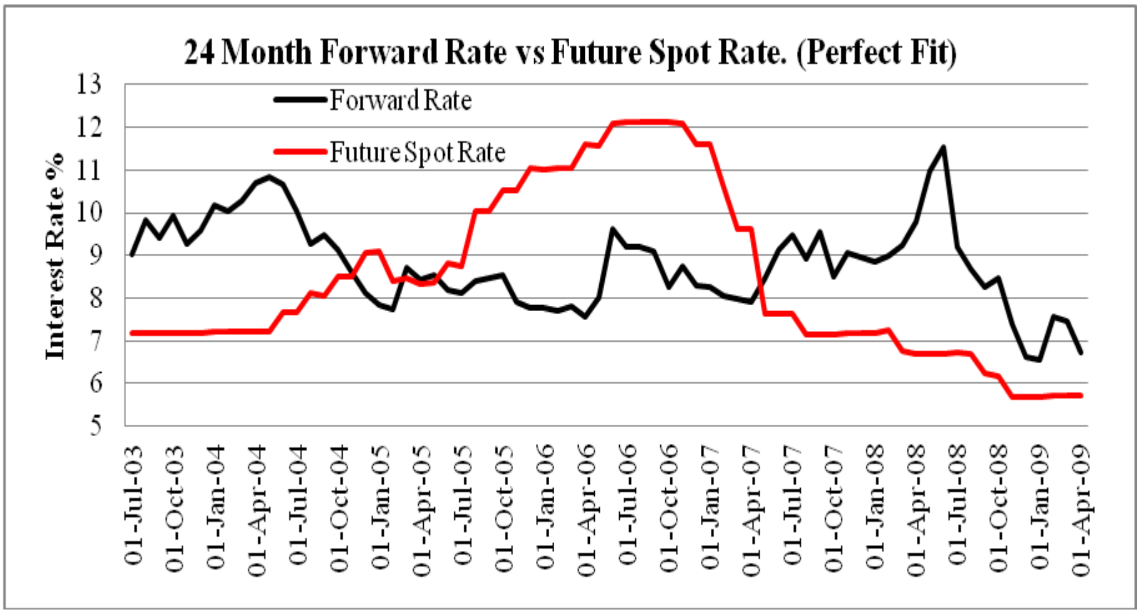

Figure 17. A comparison between the 24 month forward rate and future spot rate from the perfect fit dataset.

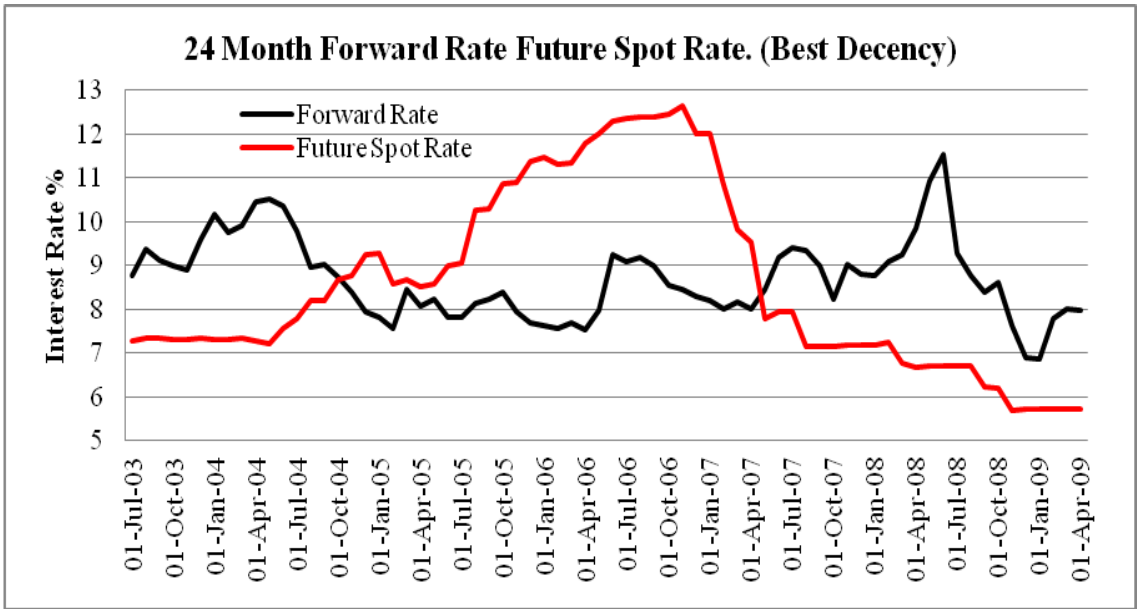

Figure 18. A comparison between the 24 month forward rate and future spot rate from the best decency dataset.

Table 30. The lists of the South African government bonds used to create each of the monthly yield curves

31-Jul-03	29-Aug-03	30-Sep-03	31-Oct-03	28-Nov-03	31-Dec-03
3MC	R15O	R15O	R15O	R15O	R15O
12MC	R184	R184	R184	R184	R184
R15O	R194	R194	R194	R194	R194
R194	R153	R153	R153	R153	R153
R153	R157	R157	R157	R201	R201
R157	R186	R186	R186	R157	R157
R186				R186	R186

30-Jan-04	27-Feb-04	31-Mar-04	30-Apr-04	31-May-04	30-Jun-04	30-Jul-04	31-Aug-04	30-Sep-04	29-Oct-04	30-Nov-04	31-Dec-04
R15O	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152
R184	R184	R184	R184	R184	R184	R184	R184	R184	R184	R203	R203
R194	R194	R194	R194	R194	R194	R194	R194	R194	R194	R194	R194
R153	R153	R153	R153	R153	R153	R153	R153	R153	R153	R153	R153
R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157
R186	R186	R186	R186	R186	R186	R186	R186	R186	R186	R186	R186

31-Jan-05	28-Feb-05	31-Mar-05	29-Apr-05	31-May-05	30-Jun-05	29-Jul-05	30-Aug-05	30-Sep-05	31-Oct-05	30-Nov-05	30-Dec-05
R152	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152
R203	R184	R184	R184	R184	R184	R184	R184	R184	R184	R184	R184
R194	R194	R194	R194	R194	R194	R194	R194	R194	R194	R194	R194
R153	R153	R153	R153	R153	R153	R153	R153	R153	R153	R153	R153
R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157
R186	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
	R186	R186	R186	R204	R204	R204	R204	R204	R204	R204	R204
				R186	R186	R186	R186	R186	R186	R186	R186

31-Jan-06	28-Feb-06	31-Mar-06	28-Apr-06	31-May-06	30-Jun-06	31-Jul-06	31-Aug-06	29-Sep-06	31-Oct-06	30-Nov-06	29-Dec-06
R152	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152	R152
R184	R184	R184	R184	R184	R184	R184	R184	R184	R207	R207	R207
R194	R194	R194	R194.m	R194.m	R194.m	R194.m	R194.m	R194.m	R194.m	R194.m	R194.m
R153	R153	R153	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m
R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R157	R157	R157	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m
R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204
R186	R186	R186	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m

31-Jan-07	28-Feb-07	30-Mar-07	30-Apr-07	31-May-07	29-Jun-07	31-Jul-07	31-Aug-07	28-Sep-07	31-Oct-07	30-Nov-07	31-Dec-07
R152	R196	R196	R196	R196	R196	R196	R196	R196	R196	R196	R196
R207	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m
R194.m	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206
R153.m	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R201	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m
R157.m	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
R203	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204
R204	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207
R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m

Table 31.The continuation of table 30; the lists of the South African government bonds used to create each of the monthly yield curves.

31-Jan-08	29-Feb-08	31-Mar-08	30-Apr-08	30-May-08	30-Jun-08	31-Jul-08	29-Aug-08	30-Sep-08	31-Oct-08	28-Nov-08	31-Dec-08
R196	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m
R153.m	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206
R206	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R201	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m
R157.m	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
R203	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204
R204	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207
R207	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m
R186.m	R209	R209	R209	R209	R209	R209	R209	R209	R209	R209	R209

30-Jan-09	27-Feb-09	31-Mar-09	30-Apr-09	29-May-09	30-Jun-09	31-Jul-09	31-Aug-09	30-Sep-09	31-Oct-09	30-Nov-09	31-Dec-09
R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R153.m	R208	R208	R208	R208	R208
R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206
R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157.m	R157	R157	R157	R157	R157
R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204
R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207
R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186.m	R186	R186	R186	R186	R186
R209	R209	R209	R209	R209	R209	R209	R155	R155	R155	R155	R155
							R209	R209	R209	R209	R209

29-Jan-10	26-Feb-10	31-Mar-10	30-Apr-10	31-May-10	30-Jun-10	30-Jul-10	31-Aug-10	30-Sep-10	29-Oct-10	30-Nov-10	31-Dec-10
R208	R208	R208	R208	R208	R208	R208	R208	R208	R208	R208	R208
R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206	R206
R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201	R201
R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157	R157
R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203	R203
R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204	R204
R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207	R207
R186	R186	R186	R186	R186	R186	R186	R186	R186	R186	R186	R186
R155	R155	R155	R155	R155	R155	R155	R155	R155	R155	R155	R155
R209	R209	R209	R209	R209	R209	R209	R209	R209	R209	R209	R209

31-Jan-11	28-Feb-11	31-Mar-11
R208	R208	R208
R206	R206	R206
R201	R201	R201
R157	R157	R157
R203	R203	R203
R204	R204	R204
R207	R207	R207
R186	R186	R186
R155	R155	R155
R209	R209	R209