ESTIMATING REAL INTEREST RATES USING THE YIELD CURVE: EVIDENCE FROM GHANA

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ABSTRACT: *This empirical study is to find out whether the yield curve for government debt securities with maturities of one year or less contains significant information about future changes in real interest rates. At the various spreads isolated, there is overwhelming evidence that the yield curve wields significant explanatory power in future real interest rate-changes. These results from Ghana show that the yield curve could serve as a powerful forecasting tool in monetary policymaking as well as asset pricing by central bankers and portfolio managers.*

KEYWORDS: Real interest rate, yield curve, Government, Ghana

INTRODUCTION

The high acclaim of the term structure theory among policymakers in both developed and developing economies stems from the increased empirical realization that the slope of the yield curve (the yield spread) is capable of explaining future changes in rates of output, inflation and real interest (Plosser and Rouwenhorst, 1994; Dotsey, 1998; Fama, 1984; Fama and Bliss, 1987; Campbell and Shiller, 1987; Hardouvelis, 1988; Mishkin, 1988). Evidently, knowledge of the nature of future changes in these variables is deemed to, among other things; aid the implementation of monetary policy, the pricing of securities and the testing of term structure theories (Bolder and Streliski, 1999). Given that macroeconomic development in Ghana rests partly on the nature of real interest rates, policymakers have much to gain from the empirical establishment of the yield spread as a tool for explaining future changes in real interest rates. Since future real interest rate changes are unobservable, it has become imperative to find if the yield curve on a class of debt securities can significantly explain future changes in this variable. This finding will form a good basis for comparison with the assertion that 'yield curves provide a concise and accurate reflection regarding the market's expectation of the expected future path of interest rates (Sen, 2001).

The yield curve on short-term Government of Ghana debt securities, with maturities of not more than a year, is particularly well developed in the Ghanaian money market and is worthy of empirical investigation. This market-determined yield curve is associated with financial liberalization and deregulation of the financial system, which substantially purged the short-term debt securities market of many irregularities (Bank of Ghana, 1999). The Wholesale Auction of

Government Short-Term Debt Securities was introduced in March 1996. This provided a market-funding environment for government debt securities thereby deepening the market. From March 1996, the yields on these traded debt securities became more reflective of market expectations.

LITERATURE REVIEW

The Financial Sector Reforms in Ghana

In 1983, the Government of Ghana, after much encouragement from the World Bank, launched a comprehensive Economic Recovery Program (ERP) in an attempt to reverse the several years of socio-economic decline. This involved a shift from a controlled economic policy regime to a market-oriented and private- sector-led economy. The economic reforms included measures to promote fiscal discipline, reform the trade and exchange system and initiate price liberalization and deregulation of many economic activities. The Financial Sector Adjustment Program (FINSAP) was an important component of the ERP. FINSAP sought to develop fully-liberalized money and capital markets (Bank of Ghana, Annual Report 1989/1990). Among others, it also aimed at reforming the institutional structure of the Central Bank and promoting the proliferation of non-bank financial institutions. To an extent, the chronology of actions associated with FINSAP infused activity into the debt securities market.

First, in September 1987 the market mechanism was accorded an increased role in the allocation and monitoring of capital when maximum lending and minimum deposit rates were decontrolled. Also, to make for more market-determined rates on money market instruments, Bank of Ghana introduced the Weekly Treasury Bills Tender in October 1987. The tender was opened to banks, discount houses and the public at large although the public had to submit their applications through the banks (Bank of Ghana, 2002). Further, an active inter-bank market for the trading of debt securities was boosted in September 1988 when the 90-day Bank of Ghana bills for banks were introduced. This activity was carried a pitch higher in December 1989 when non- rediscountable, medium-term Bank of Ghana debt instruments with 182-day, 1- year and 2-year maturities were introduced for banks. In November 1990, these instruments were made available to the non-bank sector.

Also, in line with the overhaul of the institutional structure of the Central Bank, the Provisional National Defense Council (PNDC) approved a new Banking Law on August 8, 1989. This law covered capital adequacy, reserve requirements, loan limits and financial reporting procedures. This was against the background that the Banking Act of 1970 had become outdated in many areas and the supervisory capacity of the Central Bank had become questionable (Antwi-Asare and Addison, 2000). The new law therefore strengthened Bank of Ghana in its supervision of the money market, and infused it with some degree of autonomy (Fosu, 2000). FINSAP also revitalized the long end of the debt securities market, beginning in 1990. Based on detailed diagnostic reports, financially-distressed banks were restructured with each bank recapitalized by offsetting non-performing loans with interest-bearing FINSAP bonds offering between 7 and 9 per cent per annum. To sustain the effect of this string of reforms on the short as well as long-term debt securities markets, there was the need for firming-up supervision and regulation. In this direction, a new Bank of Ghana Law was enacted in October 1992 to give Bank of Ghana a tighter grip on goings-on in the debt securities market under its domain. In furtherance of this same

objective, the Securities Regulation Commission (SRC) was established under PNDC Law 333 of 1993.

The Government Debt Securities Market after the Financial Sector Reforms
Since the onset of the financial sector reform in 1989-1990, a modest representation of a debt securities market has emerged in Ghana. The debt securities market has arisen as a better player in a much more free market environment. The establishment of the Ghana Stock Exchange (GSE) rode on the back of the financial sector reform. The 26 per cent GSE Commemorative Registered Stock, with a total par value of 5 billion cedis, was the first bond to be listed. Bank of Ghana did the issue of this 5-year bond in behalf of the government for the purpose of providing an additional medium of savings for investors and to assist in the repayment of maturing debt. Sadly, this issue was not fully subscribed at closing and it took three years to place it completely. This disappointing performance was attributed to the fact that the stated interest rate of 26 per cent was below the treasury bill rate of 30 per cent at the time. To encourage active trading of this issue, the offered interest rate was subsequently hang to a floating rate, reset every 12th November at 3 per cent above the prevailing Treasury bill discount rate. This made it the highest-yielding fixed-income instrument during its 5-year term. Despite this action, trading in the bond both over–the-counter as well as on the GSE was very limited with only 94.4 million cedis worth of bonds changing hands (Bank of Ghana, 1999). A notable development was the introduction of the Wholesale Auction of Government Debt Securities on March 1, 1996. This was to help in further deepening the government debt securities market as well as to encourage secondary market trading in these debt instruments (Bank of Ghana, 2002). Under this process, even though the monetary policy of the government still exerted a powerful and indirect influence over returns on debt instruments, lenders in response to market conditions basically determined them. This was done through the bidding system as well as the supply and demand conditions of the time.

To add to this, a primary dealership system was introduced in mid-1998 to ensure a pure Wholesale Auction for the government securities market. Thus, the government debt securities market ever since has become appreciably well- deepened to anchor the present proliferation of trading in treasury bills, treasury notes, certificates of deposit, commercial papers and other money market debt instruments. Though to a limited extent, a secondary market for money market debt instruments has also emerged. The secondary trading of Government of Ghana securities, unlisted on the GSE, takes place over-the-counter at the office of primary distributors. As regards longer-term government debt securities, a noteworthy development occurred on 7th September 2001, when the Government of Ghana Index-Linked Bond (GGILB) was launched and secondary market trading of this issue on the GSE commenced on 28th December 2001. Given that Ghana's fiscal deficit stood at 8.5 percent of GDP at the end of 2000 and the domestic debt situation was appalling, the GGILB was a means of restructuring Ghana's debts (Securities Exchange Commission, 2001). This restructuring involved the conversion of existing domestic debt stock from mainly short-term to medium-term debt instruments.

Issued by Bank of Ghana at periodic auctions, the GGILB is a three-year inflation-protected Government of Ghana bond, each GGILB having a principal of 1 million cedis paid semi-annually at a rate determined by competitive bidding at the time of issue. The principal and each interest payment are adjusted in line with changes in the Consumer Price Index (CPI) to take account of

accrued inflation after the GGILBs are issued. At maturity, GGILBs will be redeemed at the greater of their inflation-adjusted principal amount or the original 1 million cedis face value of the GGILB even if inflation is negative. Individuals are not taxed on interest income received on the GGILB. Generally, increased activity in the government debt securities market accompanied the many reforms in this segment of the market. For example, as of January 31, 2002, the total value of Government of Ghana securities outstanding was 7,394.89 billion cedis increasing to 10, 070 billion cedis at end- March 2003 (GSE, 2002; Bank of Ghana, 2003).

METHODOLOGY

Data Source
The empirical analyses make use of monthly data sets on inflation, money supply and Government of Ghana debt securities available in maturities of 91 days, 182 days and 1 year. The inflation data is derived from a CPI series with monthly rates for inflation over three, six and twelve months calculated appropriately. For example, to derive inflation rate over three months starting from June 1997, the March CPI data is subtracted from the CPI data for June. The result is divided by the CPI data for March and the outcome multiplied by 100. The monthly M2 measure of broad money as found in stocks of billions of cedis is used. Following the transformation done to the CPI data, M2 changes over three, six and twelve months are similarly found. Use is also made of primary market interest equivalent rates on the debt securities isolated, given that the capture of market expectations in debt yields is crucial to the forecasting ability of the yield spread, Kanagasabathy and Goyal (2002) hold a divergent view on the use of these primary market yields. They hold that data on primary market yields in developing economies may at times be policy- induced and only secondary market yields are truly reflective of market expectations. This concern notwithstanding, the choice of primary market yields in this study is maintained because of the limited secondary market activity in Ghana. Other sources of data include Institute of Statistical Social and Economic Research and The Ghana Stock Exchange.

Model Specification
The theoretical underpin for the analyses of the relationship between the yield spread and future real interest rates in Ghana consists of a combination of the 'Fisher (1930) equation' and the expectations theory of the yield curve. The 'Fisher (1930) equation' identifies the link between nominal interest rates, real interest rates and expected inflation. According to this equation, expected inflation over m periods is equal to the difference between the m-period nominal interest rate and the m-period real interest rate. The real interest rate described here is the expected real return on a nominally riskless debt security. However, as advanced by Benninga and Protopapadakis (1983), the real interest rate so defined will not be equal to the riskless real interest rate. Nevertheless, for the short-term interest rates that this study focuses on, it seems that the difference between these two explanations of the real interest rate in Fisher's identity is minimal. Fisher's specification was:

$E_t \pi_t^m = i_t^m - rr_t^m$ …………………………………………………………………………………..3.1.1

where

E_t = expectations at time t

π_t^m =inflation rate from time t to $t+m$

i_t^m =m-period nominal interest rate at time t.

rr_t^m =m-period real interest rate at time t (that is the ex-ante real return on an m- period debt security from time t to $t+m$.

M=monthly period

From Fisher's specification in (1), the realized inflation rate over the next m periods can be written as the expected inflation rate plus the forecast error of inflation, as shown in the equation below:

$$\pi_t^m = E_t \pi_t^m + \varepsilon_t^m \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3.1.2$$

Where $\varepsilon_t^m = \pi_t^m - E\pi_t^m$ is the forecast error of inflation.

Substituting equation (1) into equation (2), the following representation is obtained:

$$\pi_t^m = i_t^m - rr_t^m + \varepsilon_t^m \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3.1.3$$

Weaving the expectations hypothesis of the term structure theory into the analyses, Mishkin (1990) made manipulations to equation (3.1.3) and arrived at a specification for the relationship between the yields spread, future real interest rate changes as well as expected inflation changes. These manipulations involved subtracting equation (3.1.3) for the *n*-period inflation rate from equation (3.1.3) for the *m*-period inflation rate. This gave the following:

$$\pi_t^m - \pi_t^n = i_t^m - i_t^n - rr_t^m + rr_t^n + \varepsilon_t^m - \varepsilon_t^n$$

Rearranging, the equation arrived at was:

$$\pi_t^m - \pi_t^n = \left(rr_t^n - rr_t^m \right) + \left(i_t^m - i_t^n \right) + \left(\varepsilon_t^m - \varepsilon_t^n \right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3.1.4$$

where

m and *n* are monthly horizons; m>n

π_t^m is inflation rate from time t to t+m (realized inflation rate over the next m periods)

π_t^n is inflation rate from time t to t+n (realized inflation rate over the next n periods)

rr_t^m is m-period real interest rate at time t.

rr_t^n is n-period real interest rate at time t.

i_t^m is m-period nominal interest rate at time t

i_t^n is n-period nominal interest rate at time t

$i_t^m - i_t^n$ is slope of the yield curve (the yield spread)

ε_t^m and ε_t^n are forecast errors of inflation at the various monthly horizons

Representing the slope of the real term structure of interest rates as $rr_t^m - rr_t^n$, Mishkin (1990) expressed the mean slope of the real term structure of interest rates as $\overline{rr^n} - \overline{rr^m}$. Thus, letting $u_t^m = rr_t^m - \overline{rr^m}$ and $u_t^n = rr_t^n - \overline{rr^n}$, it implies that $rr_t^n = u_t^n + \overline{rr^n}$ and $rr_t^m = u_t^m + \overline{rr^m}$. Substituting for rr_t^n and rr_t^m in equation (5), this gave;

$$\pi_t^m - \pi_t^n = \left[\left(u_t^n + \overline{rr^n} \right) - \left(u_t^m + \overline{rr^m} \right) \right] + \left(i_t^m - i_t^n \right) + \left(\varepsilon_t^m - \varepsilon_t^n \right)$$

This could still be expressed as:

$$\pi_t^m - \pi_t^n = \left(\overline{rr^n} - \overline{rr^m} \right) + \left(i_t^m - i_t^n \right) + \varepsilon_t^m - \varepsilon_t^n - \left(u_t^m - u_t^n \right)$$

This expression therefore gives:

$$\pi_t^m - \pi_t^n = a_{m,n} + \beta_{m,n}\left(i_t^m - i_t^n\right) + \eta_t^{m,n} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3.1.5$$

Where

$a_{m,n} = \left(\overline{rr^n} - \overline{rr^m}\right)$ and is the mean slope of the real term structure

$\beta_{m,n} = 1$ and is the coefficient of the yield spread.

$\eta_t^{m,n} = \varepsilon_t^m - \varepsilon_t^n - \left(u_t^m - u_t^n\right)$

Further, manipulations of (3.1.5) were made in order to specify a theoretical relationship between the yield spread and future changes in real interest rates. To achieve this, $\left(i_t^m - i_t^n\right)$ was subtracted from both sides of (3.1.5), with the resultant expression multiplied through by (-1). This gave:

$$eppr_t^m - eppr_t^n = -a_{m,n} + \left[1 - \beta_{m,n}\right]\left(i_t^m - i_t^n\right) - \eta_t^{m,n} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3.1.6$$

Where;

$eppr_t^m = i_t^m - \pi_t^m$ is the ex post real interest rate on a *m*-period debt security at time *t*.

$eppr_t^n = i_t^n - \pi_t^n$ is the ex post real interest rate on a *n*-period debt security at time *t*.

In line with developments in the literature on the expectations hypothesis, the following assumptions underlay the model specifications in (3.1.6):

i. Expectations are rational implying, in this context, the unpredictability of forecast errors of inflation and real interest rates at the moment that the expectation is formed.

ii. The slope of the real term structure, $rr_t^m - rr_t^n$ remains constant over time

Under these assumptions, OLS estimation of (3.1.6) would produce a consistent estimate of $\beta_{m,n}$ and tests of the statistical significance of this coefficient would reveal to what extent the yield spread explained future changes in real interest rates.

Empirical Framework

The empirical framework for this study draws heavily on the theoretical contributions of Fisher (1930) and Mishkin (1990b) mentioned above. However, some modifications are made to suit the Ghanaian situation. The modifications are informed by the 'missing variable debate'. Thus, due consideration is given to factors that have been known to explain inflation in Ghana and the plausibility of adding these variables to the inflation-change equation (as in 3.1.5) is examined. The modification is then extended to the real interest rate-change equation (as in 3.1.6)

To this end, Sowah (1996) provided a model that captured the monetarist and structuralist explanations of inflation in Ghana and is represented as:

$$P_t = \phi\left(M_t, Y_t, b_t\right) \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \; 3.2.1$$

Where all variables are given in logs and are defined as;

P_t : Price level

M_t : Nominal money

Y_t : Real income

b_t : Parallel exchange rate

Consequently, a modification of equation (3.1.5) is made by incorporating Sowah's (1996) determinants of inflation in Ghana, as captured in equation (3.2.1), into equation (3.1.5). The regression equation is rewritten as:

$$\pi_t^m - \pi_t^n = a_{m,n} + \beta_{m,n}\left(i_t^m - i_t^n\right) + Y_{m,n}\left(M_t^m - M_t^n\right) + \delta_{m,n}\left(Y_t^m - Y_t^n\right) + \lambda_{m,n}\left(b_t^m - b_t^n\right) + \eta_t^{m,n}$$

………3.2.2

Where;

M_t^m is m-period change in nominal money at time t.

M_t^n is n-period change in nominal money at time t.

Y_t^m is m-period change in real income at time t

Y_t^n is n-period change in real income at time t

b_t^m is m-period change in parallel exchange rate at time t

b_t^n is n-period change in parallel exchange rate at time t

However, for expositional ease, the following inflation-change estimable equation is used

$$\pi_t^m - \pi_t^n = a + \beta\left(i_t^m - i_t^n\right) + Y\left(M_t^m - M_t^n\right) + \varepsilon_t \dots\dots\dots\dots\text{3.2.3}$$

Where m and n come in the following combinations: 6-3, 12-6, and 12-3, given that $m>n$.

Further, in line with Mishkin (1990b), an estimable equation is derived from (3.2.3) to highlight the relationship between the yield spread, the money supply- change variable and future real interest rate changes. Hence, $\left(i_t^m - i_t^n\right)$ is subtracted from both sides of (3.2.3) to give:

$$\pi_t^m - \pi_t^n - i_t^m + i_t^n = a + \beta\left(i_t^m - i_t^n\right) - \left(i_t^m - i_t^n\right) + Y\left(M_t^m - M_t^n\right) + \eta_t$$

Multiplying through by (-1), this gives:

$$\left(i_t^m - \pi_t^m\right) - \left(i_t^n - \pi_t^n\right) = -a + [1-\beta]\left(i_t^m - i_t^n\right) - Y\left(M_t^m - M_t^n\right) - \eta_t$$

Simplifying, the following estimable equation for future real interest rate-changes in Ghana is arrived at;

$$rr_t^m - rr_t^n = a + b\left(i_t^m - i_t^n\right) + c\left(M_t^m - M_t^n\right) + e_t \dots\dots\dots\dots\text{3.2.4}$$

Where

$rr_t^m = \left(i_t^m - \pi_t^m\right)$ is the ex poste real interest rate on a *m-period* debt security at time t (that is the realized real return from time t to $t + m$)

$rr_t^n = \left(i_t^n - \pi_t^n\right)$ is the ex poste real interest rate on a *n-period* debt security at time t (that is the realized real return from time t to $t + n$)

$a = -a_{m,n}$ $b = [1 - \beta_{m,n}]$ $c = -Y_{m,n}$ $e_t = -\eta_t^{m,n}$ and m, n come in the following combinations: 6-3, 12-6, and 12-3, given that $m>n$.

To this end, a statistical rejection of the null hypothesis, b=0, in 3.2.4 indicates that the yield spread for the *m-n* horizon significantly explains future changes in real interest rates.

The Data

The empirical analyses make use of monthly data sets on inflation, money supply and Government of Ghana debt securities available in maturities of 91 days, 182 days and 1 year. The inflation data is derived from a CPI series with monthly rates for inflation over three, six and twelve months

calculated appropriately. For example, to derive inflation rate over three months starting from June 1997, the March CPI data is subtracted from the CPI data for June. The result is divided by the CPI data for March and the outcome multiplied by 100. This derivation when done for inflation over twelve months corresponds to what is commonly called in Ghana 'the year-on-year inflation. The monthly M2 measure of broad money as found in stocks of billions of cedis is used. Following the transformation done to the CPI data, M2 changes over three, six and twelve months are similarly found. Stocks of M2+ were not used because this measure of broad money was only introduced in December 1996 and M2+ values for months prior to this were needed in order to calculate changes in this money supply aggregate over twelve, six and three months -beginning from March 1997, the start-date for the sample period. Use is also made of primary market interest equivalent rates on the debt securities isolated. Given that the capture of market expectations in debt yields is crucial to the forecasting ability of the yield spread, Kanagasabathy and Goyal (2002) hold a divergent view on the use of these primary market yields. They hold that data on primary market yields in developing economies may at times be policy- induced and only secondary market yields are truly reflective of market expectations. This concern notwithstanding, the choice of primary market yields in this study is maintained because of the limited secondary market activity in Ghana. Other sources of data include Institute of Statistical Social and Economic Research and The Ghana Stock Exchange.

Exploratory Analyses
Prior to estimation, exploratory analyses on the variables is done to check for stationarity of the series, investigate the correlation and causality properties of the variables as well as specify cointegration relationships and the associated ECMs models where appropriate.

Estimation Technique and Diagnostic Tests
After the exploratory analyses mentioned above, the OLS estimation technique is applied to arrive at the regression results. The estimation output is also subjected to diagnostic tests such as the White Heteroskedasticity, the Histogram Normality, and the RAMSEY tests.

Expected Results
The theoretical rationale linking the yield spread to future changes in real interest rates and inflation specifies a positive relationship between the yield spread on one hand and each of these variables on the other hand. Thus, from the real interest rate-change forecasting equation designated 3.2.4, b is expected to be positive and statistically significant. Concerning the money supply-change variable, the expected sign of its coefficient in the real interest rate change equations stems from the 'tight money paradox' in economic theory. This paradox is a result of a transmission mechanism unleashed immediately after the announcement of a new tight money policy. In this regard, the anticipation of higher inflation by economic agents may provoke a flight from real money balances that drives up inflation immediately after the announcement of a tight money policy. The relationship portrayed here is a negative one and therefore suggests that the c coefficient in (3.2.4) is expected to be positive. The statistical significance of these coefficients is also expected.

RESULTS

Exploratory Data Analyses

A correlation matrix for the real interest rate-change equation reveals significant correlation between the system variables. Pairwise Granger Causality tests conducted at lag six reveal that the interest rate-change variable as well as the money supply-change variable individually Granger-cause inflation (at the one per cent significance level) in the six-three month inflation-change equation (represented in its general form as equation 3.2.3). This result implies that the interest rate-change and money supply-change variables could be included as relevant explanatory variables in this inflation-change equation. By extension, the result shows that the variables could as well be included in the six-three month real interest rate- change equation since the latter is a mathematical modification of the estimable general inflation-change equation designated 3.2.3.

As regards the twelve-six month inflation-change equation, the test at lag six reveals unilateral causality from the interest rate-change variable to the inflation- change variable at the 5 percent significance level as well as a unilateral causality from the money supply change variable to the inflation-change variable at the 1 percent significance level. The result indicates that both the interest rate-change and money supply-change variables could be included as explanatory variables in this inflation-change equation. Hence, their inclusion in the associated twelve-six month real interest rate change equation is justified.

For the twelve- three month inflation-change equation, the causality test at lag six shows unilateral causality from the money supply change variable to the inflation change variable but independence, in the Granger sense, between the inflation-change and interest rate-change variables at significance levels of 1 percent. This trace of independence notwithstanding, this study proceeds with a single-equation estimation of the associated twelve-three month real interest rate change equation.   An examination of the Akaike and Schwartz properties as well as the associated DW statistics of each of the variables under consideration showed that the appropriate lag level for performing the Augmented Dickey-Fuller test is at lag 1 in all cases. The employment of the Dickey and Fuller (1981) F-statistics also showed that for most of the variables under consideration, the intercept and trend terms are not statistically significant. Hence in carrying out the ADF test, the ADF model containing no intercept and trend terms is used. Thus, the ADF test for stationarity using the third ADF model in the Eview program and a lag level of 1 for each of the variables under consideration gave the results shown in Table 4.1 below. From the table, three of the variables (INF1203, INT1206 and INT1203) are non-stationary in levels and attain stationarity after differencing by 1.

Table 4.1: Results for ADF Unit root tests

VARIABLE	τ- statistic of ADF in levels	τ- statistic of ADF in 1st differences	Order of Integration
INF603	-5.344771**		I(0)
INF1206	-4.690842**		I(0)
INF1203	-1.441709	-3.314587**	I(1)
INT603	-2.533985*		I(0)
INT1206	-1.112115	-4.698950**	I(1)
INT1203	-1.193688	-4.769631**	I(1)
MON603	-4.299593**		I(0)
MON1206	-3.773310**		I(0)
MON1203	-2.756200**		I(0)

** τ –statistic significant at one per cent level using McKinnon critical value of –2.5954
* τ - statistic significant at one per cent level using McKinnon critical value of –1.9449

In all, three estimable equations are specified. Out of these, only one (the six- three month real interest rate-change equation) can be estimated in levels since the variables concerned reveal stationarity in levels. The stationarity test was done on variables in the specified inflation-change equation. Since the real interest rate-change equation is only a mathematical modification of the inflation-change equation, the results of the ADF test on the variables contained in the latter by extension hold for the former. For the other two equations (the twelve-six month and twelve-three month real interest rate- change equations), the residuals generated from the spurious long-run relation of their variables are subjected to ADF unit root tests. The results show that in the two estimable equations under discussion, the residuals are stationary since the ADF test is passed at the 1 percent significance level thereby indicating co-integration. For these two sets of co-integrated variables, the appropriate Error correction model could take the following general form:

$$\Delta\left(rr^m - rr^n\right)_t = a + \sum_{i=0}^{u} b_i \Delta\left(i^m - i^n\right)_{t-i} + \sum_{j-0}^{v} c_j \Delta\left(M^m - M^n\right)_{t-j} + pe_{t-1} + u_t \ldots\ldots\ldots\ldots\ldots\ldots..4.1.1$$

where *p* refers to the speed at which the short-run dynamics adjust to restore equilibrium in the long-run relation that is the rate at which the dependent variable adjusts to restore equilibrium in the face of past deviations in its long- run relation. e_{t-1} is the error correction term.

OLS Estimations, Results of Other Diagnostic Tests and Analyses
The six-three month real interest rate-change equation
The initial six-three month real interest rate-change regression output suggests the presence of serial correlation as hinted by the DW- statistic of 0.244506. An attempt to correct for serial correlation by introducing an AR (1) brought about little improvement in the DW statistic, as can be seen in the full report on the estimation of this AR (1) model in Table 4.2 below. The Breusch-Godfrey Serial Correlation LM Test was performed on the AR (1) modified model. This test revealed that the serial correlation still persisted. However, the White Heteroskedasticity test was passed, annulling the presence of heteroskedasticity.

Table 4.2: ECM for six three month real interest rate change
72 included observations after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.097588	1.951578	-3.12444	0.0026
INT6O3	0.971108	0.208374	4.660401	0
MON6O3	0.10884	0.040007	2.720552	0.0083
AR(1)	0.891326	0.054681	16.30042	0
R-squared	0.856278	Mean dependent var		-5.748611
Adjusted R-squared	0.849937	S.D. dependent var		4.514484
S.E. of regression	1.748817	Akaike info criterion		4.009709
Sum squared resid	207.9685	Schwarz criterion		4.13619
Log likelihood	-140.3495	F-statistic		135.0453
Durbin-Watson stat	0.758239	Prob (F-statistic)		
				0
Inverted AR Roots				0.89

The serial correlation, though, does not come as a surprise given the use of overlapping data in which the horizon of the debt yield and the real interest rate is longer than the observation interval. Also, from the results in Table 4.2, the R- squared statistic of 0.856278 shows that the explanatory variables in this equation explain about 86 percent of the total variation in the six-three month real interest rate-expectation ($rr_t^6 - rr_t^3$). The F-statistic of 135.0453 for the AR (1) equation is also statistically significant at the 1 per cent level implying that all the right-hand side variables jointly explain variations in the six-three month real interest rate expectations.

An individual examination of the explanatory variables in Table 4.2 shows that the coefficient of the yield spread maintains the expected positive sign. The t-statistic of the yield spread coefficient, 4.660401, is also statistically significant at the 1 percent level. From these impressive results, it could be inferred that a 100 percent change in the yield spread, significantly explains about 97 percent of future changes in real interest rates -holding the money supply-change variable constant. Further, the Wald test performed on this slope coefficient showed that its value of 0.97 was actually equal to 1.0 thereby affirming the stated strong relationship between the yield spread and future changes in real interest rates at this horizon.

In this regression, the money supply change coefficient also maintains its expected positive sign and its t-value of 2.720552 is statistically significant at the 1 percent level. The indication here is that a 100 percent change in money supply change explains about 11 per cent of future changes in real interest rates, holding yield spread changes constant. Comparatively, the yield spread stands above the money supply-change variable as an explanatory factor behind future real interest rate changes in Ghana.

The twelve-six month real interest rate-change equation
An initial ECM with a DW statistic of 0.689210 revealed positive serial correlation at the 5 percent significance level since it is less than the lower limit for d (which is 1.49 from DW Tables). An

attempt to correct for this condition by introducing an AR (1) -as seen from the regression results in Table 4.3- provided a DW of 1.716028. The latter model passed a Breusch- Godfrey Serial Correlation LM test in at the 5 percent level indicating a correction of serial correlation. Other diagnostic tests lend support to this model (presented in Table 4.3); the Histogram Normality test shows the residuals are normally distributed; the White Heteroskedasticity test reveals no heteroskedasticity and the Ramsey Reset Test shows there is no evidence of misspecification.
The results reported here emphasize the satisfactory performance of the model under consideration. The R-squared statistic of 0.812683 shows that the explanatory variables in this model explain about 81 percent of the total variation in the twelve-six month real interest rate-change expectation. Here too, the F- statistic of 70.50155 is statistically significant at the 1 percent level, implying that all the explanatory variables jointly explain variations in the twelve-six month real interest rate-change expectation.

With regard to the individual explanatory variables, the results in Table 4.3 tend to support the explanatory power of the yield spread in future real interest rate- changes. The yield spread at this twelve-six month horizon enters the regression with the expected positive sign and explains about 87.5 percent of variations in the future real rate of interest with its own 100 percent change, holding all other explanatory variables constant. The statistical significance of the yield-spread coefficient at the 1 per cent level lends support to this analysis.

The coefficient of the money supply-change variable also maintains the expected positive sign and its t-value is statistically significant at the 1 percent level. This result indicates that a 100 per cent change in the money supply change variable, holding other explanatory variables constant, explains about 11 percent of changes in future real interest rates. Here too, it is noteworthy that the slope of the yield curve has more explanatory power over future real interest rate- changes than money supply-changes. Worthy of note too is the error correction term whose coefficient is statistically significant at the 5 percent level, indicating that about 28 percent of previous disequilibrium in the long-run relation is partially corrected in the current period.

Table 4.3: 12-6 month real interest rate- change
Dependent Variable: DRR1206
Included observations: 70 after adjusting endpoints
Convergence achieved after 10 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.25345	0.86015	0.29465	0.76920
DINT12O 6	0.87505	0.09144	9.56936	0.00000
DM O N12O 6	0.11215	0.02817	3.98109	0.00020
RECM 2(-2)	-0.28204	0.11619	-2.42753	0.01800
AR(1)	0.79844	0.13163	6.06560	0.00000
R-squared	0.812683	Mean dependent var		0.055714
Adjusted R^2	0.801156	S.D dependent var		3.181315
S.E. of regression	1.418609	Akaike info criterion		3.605979
Sum squared resid	130.8093	Schwarz criterion		3.766586
Log likelihood	-121.2093	F-statistic		70.50155
Durbin-Watson stat	1.716028	Prob (F-statistic)		0
Inverted AR Roots				0.8

The twelve-three month real interest rate-change equation
The initial ECM is fledged with serial correlation as seen by the DW value of 0.527886. After introducing an AR (1), as presented in Table 4.4 below, the Breusch Godfrey test revealed a correction of the serial correlation anomaly. The other diagnostic tests conducted show that valid inference can be made from the results of the model as the White Heteroskedasticity test suggests upholding of the homoskedastic assumption; the Ramsey Reset test points to no model misspecification and the Histogram Normality test reveals normality properties of the residuals.
From Table 4.4, the R-squared statistic of 0.796615 shows that the explanatory variables in the regression equation under discussion explain about 80 percent of the total variation in the twelve-three month real interest rate change expectation. Further, the F-statistic of 63.64775 is statistically significant at the 1 percent level, implying that all the right hand- side variables jointly explain variations in the twelve-three month real interest rate- change expectation. All these indicate that the model under consideration generally performs well.

Table 4.4: Estimation of ECM for 12-3 month real interest rate-change
Dependent Variable: D (RR1203)
Included observations: 70 after adjusting endpoints
Convergence achieved after 13 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.183791	0.619155	0.296842	0.7675
DINT12O3	1.079999	0.102009	10.58731	0
DMON12O3	0.03599	0.024919	1.444273	0.1535
RECM1(-2)	-0.156402	0.066327	-2.35805	0.0214
AR(1)	0.735263	0.104846	7.012807	0
R-squared	0.796615	Mean dependent var		0.181429
Adjusted R^2	0.784099	S.D. dependent var		2.940388
S.E. of regression	1.366256	Akaike info criterion		3.530774
Sum squared resid	121.3325	Schwarz criterion		3.691381
Log likelihood	-118.5771	F-statistic		63.64775
Durbin-Watson stat	2.040422	Prob (F-statistic)		0
Inverted AR Roots		0.74		

From these results the explanatory power of the yield spread as regards future real interest rate changes in Ghana is reinforced. The yield-spread coefficient enters the regression with the expected positive sign and is also statistically significant at the 1 percent level. More to this, a 100 percent change in this yield spread accounts for more than proportionate change (about 108 per cent) in future real interest rates.

Concerning the money supply-change variable, its coefficient carries the expected positive sign though its t-value reveals insignificance at the 5 percent level. The inability of the money supply-change variable to explain future real interest rate-changes corroborates the results from the twelve-three month inflation-change equation discussed earlier.

In this regression, the error correction coefficient is statistically significant at the 5 percent level indicating that 15.6 percent of past deviation from the long-run equilibrium is partially corrected in the current month.

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

The overview of the debt securities market in Ghana revealed dominance by government securities such as obtains in many developing countries. There is also encouraging activity in the trading of debt securities in Ghana's money market, a development this study agrees would generally strengthen the money market to serve as a backbone to long-term debt market development in Ghana.

As regards future real interest rates, the empirical analyses make an interesting revelation: the yield curve, at all the spreads isolated, adequately explains future changes in this variable -with an outstanding performance emerging at the twelve-three month real interest rate-change horizon where up to 108 per cent of changes in future real interest rates could be explained in Ghana. This finding is also in line with similar studies in other countries where at these maturities the yield curve contains significant explanation for future changes in real interest rates. Here too, the money supply-change variable generally entered the regressions significantly. The error correction coefficients, in all cases where they occur, also proved statistically significant –giving an idea about the speeds of adjustments to equilibrium. Finally, though serial correlation featured strongly in the regressions (given the use of overlapping data), attempts at correcting these by introducing AR (1) and lagged dependent variables proved generally efficient. The study concludes that the yield curve, at the spreads under consideration, wields significant explanation for changes in future real interest rates in Ghana.

Policy Recommendations

Given the impressive forecasting of changes in real interest rates emanating from the debt securities market in Ghana, renewed energies must be invested in long- term debt market development. One way will be for government to bolster its activity in the government debt securities market by the issuance of medium to long-term government debt securities instead of the usual practice of issuing short-term treasury bills. This will carve-out a yield curve with a much longer time-horizon, which most likely will contain significant information about future changes in other important economic variables -helping government to reshape existing policies to meet future occurrences of these phenomena.

Further, the central government should address the reverse yield curve situation in the debt securities market in Ghana. In this direction an effective policy will be one that will seek to attract investment in long-term government debt securities by increasing the yield-to-maturity on them. This will significantly address the reverse yield curve phenomenon by increasing long-term rates relative to short- term ones. Such a policy will also have spill-over benefits for the macro economy as it will make for a reduction in money supply and, ceteris paribus, rates of inflation.

SUGGESTED AREAS FOR FUTURE RESEARCH

Future research could focus on finding the ability of a choice yield curve in explaining future changes in GDP growth and inflation in Ghana. Focus could also be on building a framework to model an entire yield curve for government debt securities over time maintaining consistency with the cross-sectional fit across maturities. A framework built along these lines will establish a mapping between the stylized phases of the business cycle in Ghana and stylized yield curve shapes in those phases to find if the business cycle is a key driver of this yield curve.

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