Faculdade de Economia da Universidade de Coimbra
Grupo de Estudos Monetários e Financeiros (GEMF)
Av. Dias da Silva, 165 – 3004-512 COIMBRA, PORTUGAL
http://www4.fe.uc.pt/gemf/ - gemf@sonata.fe.uc.pt

JOSÉ SOARES DA FONSECA

The Risk Premiums in the Portuguese Treasury Bills Interest Rates

Estimation by a cointegration method

ESTUDOS DO GEMF

N.º 8 **2001**

PUBLICAÇÃO CO-FINANCIADA PELA
FUNDAÇÃO PARA A CIÊNCIA E TECNOLOGIA

The Risk Premiums in the Portuguese Treasury Bills Interest Rates
Estimation by a cointegration method

José Soares da Fonseca
jfonseca@sonata.fe.uc.pt

Universidade de Coimbra
Grupo de Estudos Monetários e Financeiros

July 2001

ABSTRACT

One central subject in the literature on the term structure of interest rates is the empirical evidence about risk premiums and their stochastic processes. The traditional theory of the term structure accepted that risk premiums were zero or monotonically increased with the bonds' maturity.

Cointegration methods provide a useful tool for obtaining estimations of the long-term mean of risk premiums. For this reason, these methods are applied in the present research to the Portuguese Treasury Bills Interest Rates series from 1990 to 1998, in order to show the nature of stable relationship between interest rates of different terms, and to obtain information about the forward premiums.

Introduction

The term structure of interest rates is mainly determined by expectations on the forward interest rates, and by risk premia. The modelisation of the term structure of interest rates can be divided into two main approaches: 1) a *traditional* approach according to which expectations about forward interest rates, together with forward premia, are extracted from observed discount functions; 2) a *modern* approach where the identification of the risk factors is the starting point for the determination of equilibrium relations between the expected return and the risk of bonds. Not withstanding their differences, there is a certain degree of compatibility between the two approaches, since each forward premium considered in the traditional approach, can be represented as a sum of expected risk premia defined according the modern approach.

I. Expectations forward premia and holding return premia

According to expectations theory (and to Hicksian theory of risk premia), any interest rate, at time t, referred to a zero coupon bond with maturity at date t+n, hereafter represented by $R_{t,n}$, is the sum of all the short-term interest rates expected from t till its maturity, plus a *forward* premium:

$$R_{t,n} = \frac{1}{n}\sum_{i=1}^{n} E_t\left(R_{t+i-1,1}\right) + \Pi\left(n\right)_t \qquad (1).$$

It is possible to obtain forecasts of interest rates for the future, using equations of type (1), referring to a succession of adjacent interest rates, provided that the forward premia $\Pi(n)_t$ are constant, as is defended by Evans and Lewis (1994) and Hardouvelis (1994), or at least stable. In equation (1) there is no direct relationship between the forward premium $\Pi\,(n)_t$ and a measure of the interest rate risk of the zero coupon bond, which leads to the implicit identity between the bond's maturity and its risk measure.

The difference between a bond's return and the short-term interest rate corresponds to another definition of risk. Let us represent by $h(n)_{t,t+1}$, the return obtained from holding a zero coupon bond between date t and date t+1. The excess of this return relative to the risk--free interest rate is:

$$h(n)_{t,t+1} - R_{t,1} = f(n)_t \qquad (2).$$

The traditional approaches to the term structure of interest rates, especially those of Fama (1984) and McCulloch (1987) accept that the return premium is proportional to the maturity of the zero coupon bond. The dynamic approach, introduced in the theory by Vasicek (1977) and Cox, Ingersoll and Ross (1985) supposes that the term structure is dependent on a certain number of *state variables*. According to the dynamic models the return premium is the sum of the market prices of risk of the state variables, weighted by the *stochastic durations* of the bond related to those variables.

A direct link can be established between *forward* premia and *return* premia, as can be shown using continuous time compounding discount functions. Using functions of this type, the price of a zero coupon bond with a maturity at dates t and t+1 respectively of n and n-1, can be represented as follows:

$$P_{t,n} = \exp\left(-nR_{t,n}\right) \quad (3)$$

and

$$P_{t+1,n-1} = \exp\left[-\left(n-1\right)R_{t+1,n-1}\right] \quad (4).$$

The return obtained from holding the bond between t and t+1 is:

$$h\left(n\right)_{t,t+1} = \ln\left(\frac{P_{t+1,n-1}}{P_{t,n}}\right) \quad (5),$$

which also can be represented by the following expression:

$$h\left(n\right)_{t,t+1} = nR_{t,n} - \left(n-1\right)R_{t+1,n-1} \quad (6)$$

Replacing h(…) in equation (2) by the expression on the right-hand side of eq. (6) the result is:

$$R_{t+1,n-1} - R_{t,n} = \frac{1}{n-1}\left(R_{t,n} - R_{t,1}\right) - \frac{1}{n-1}f\left(n\right)_t \quad (7).$$

Finally, applying the law of iterated expectation to eq. (7), from t to t+n-1, we get to eq. (1), and we can establish the following relation between the current forward premium of the bond and the expected return premia:

$$\Pi\left(n\right)_t = \frac{1}{n}\sum_{i=1}^{n} E_t\left(\phi\left(n-i+1\right)\right)_{t+i-1} \quad (8).$$

II. The use of cointegration as a tool for term structure analysis

Cointegration is a method for studying the relations between non-stationary variables. A certain number of non-stationary variables of order d of integration, are cointegrated if a linear combination of order d-b (b>0) can be obtained between them. This means that the stochastic process followed by each of those variables can be explained by the cointegration relation. The cointegration method is indicated for the analysis of the term structure, because of the interdependency usually observed between different interest rates.

II.1 Presentation of the cointegration procedure used in this research

Cointegration was proposed by Engle and Granger (1987) in the form of error correction model, which consists of estimating, by ordinary least squares, the long-term relation between two variables, and then using a VAR which includes the error term of the long term regression, to explain the short term changes in the variables.

The cointegration method used in this article was proposed by Johansen (1988,1991), and takes as its point of departure a VAR of the following type:

$$\Delta y_t = \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_k \Delta y_{t-k} + \Pi y_{t-1} + m + \Phi D_t + e_t \qquad t = 1, \ldots, T, \qquad (9).$$

where y_t is a vector of cointegrated variables, $\Delta y_{t-1} \ldots \Delta y_{t-k}$ are the vectors of their changes, m is a constant, D_t is a vector of dummies or weakly exogenous variables, $\Gamma_1, \ldots, \Gamma_K$, are vectors of parameters, and Π is the following matrix product

$$\Pi = \begin{bmatrix} p_{11} & p_{12} & \ldots & \ldots & p_{1p} \\ p_{21} & p_{22} & \ldots & \ldots & p_{2p} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ p_{p1} & p_{p2} & \ldots & \ldots & p_{pp} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1r} \\ a_{21} & a_{22} & \ldots & a_{2r} \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ a_{p1} & a_{p2} & \ldots & a_{pr} \end{bmatrix} \begin{bmatrix} b_{11} & b_{21} & \ldots & \ldots & b_{p1} \\ b_{12} & b_{22} & \ldots & \ldots & b_{p2} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ b_{1r} & b_{2r} & \ldots & \ldots & b_{pr} \end{bmatrix} \qquad (10),$$

Where the matrix with betas represents the long-term relation between the variables, and the matrix with alphas measures the elasticities of reverting to the long-term relation. The rank of the matrix Π is chosen thorough the statistics λtrace and λmax, proposed by Johansen (1988).

II.2. Cointegration and the Term Structure of Interest Rates

The use of cointegration in the analysis of the term structure of interest rates is based on the hypothesis that the spread between the long-term and the short-term interest rates $S_{t,n}=R_{t,n}-R_{t,1}$, contains information about the expected short-term interest rates. In fact, from equation (1) $R_{t,1}$, we can obtain the following relation between the spread, the changes in expected short-term interest rates and the forward premium:

$$R_{t,n}-R_{t,1}=\sum_{i=1}^{n-1}\left(1-\frac{i}{n}\right)\left[E_t\left(R_{t+i,1}\right)-E_t\left(R_{t+i-1,1}\right)\right]+\Pi(n)_t \qquad (11),$$

The empirically testable version of eq. (11) is:

$$\sum_{i=1}^{n-1}\left(1-\frac{i}{n}\right)\left(R_{t+i,1}-R_{t+i-1,1}\right)=a_0+a_1\left(R_{t,n}-R_{t,1}\right) \qquad (12)$$

which can be used to test the expectations theory, provided, according to Campbell and Schiller (1991), that the forward premium is a constant represented by a_0, and that $a_1=1$.

If $R_{t+1,n-1}$ is replaced by $R_{t+1,n}$ in (7), this equation can be used to obtain the following relation between the changes in the long-term interest rate and the spread:

$$\Delta R_{t,n}=\frac{1}{n-1}\left(R_{t,n}-R_{t,1}\right)-\frac{1}{n-1}f(n)_t \qquad (13),$$

which can also be the basis for estimating the changes in the long-term interest rate, if the risk premium is constant.

The relations between the short-term and the long-term interest rates represented in (12) and (13) are the basis for the use of cointegration methods in the estimation of the relations between the two interest rates.

III. The estimation of risk premiums in the Portuguese Treasury Bills Interest Rates using cointegration

The present research is devoted to the analysis of the stochastic processes followed by the Treasury bills interest rates and their risk premiums in Portugal, in the period between January 1990 and April 1998. Treasury bills in Portugal were issued between 1985 and 1998 with a maturity of 91, 182 and 364 days.

Two previous studies (Fonseca (1992) and Fonseca (2000)) were also dedicated to the study of the Portuguese Treasury bills interest rates. The first of these studies consisted of applying Vasicek's model to the series of those interest rates covering the period between 1985 and 1991. The second study, which covered the same period as the present one, consisted of applying ARCH models to analysis of the volatility of ex post excess returns in Treasury Bills.

The present study covers a period where the evolution of the interest rates in Portugal was dominated by the participation of the escudo in the exchange rate mechanism of the EMS (since March 1992) and by the conditions for participation in stage three of European Monetary Union. During the period covered in this study there was also a crisis in currencies (during the spring of 1993). This crisis caused a significant increase in the volatility of interest rates and also a structural break in the series, as our tests show.

The data series used in the present research consist of average monthly rates of the Treasury bills auctions, published by the Banco de Portugal.

III.1. The analysis of the stationarity of the series

Non-stationary series have a long-term memory, meaning that the effect of a shock remains over time. Our test began with the estimation of the Augmented Dickey-Fuller (ADF) Z statistic on the following three types of regression:

$$\Delta R_{t,t} = g_a R_{t-1,t} + \sum_{i=2}^{p} b_i \Delta R_{t-i,t} + e_t \qquad (14),$$

$$\Delta R_{t,t} = a_0 + g R_{t-1,\,t} + \sum_{i=2}^{p} b_i \Delta R_{t-i\,,\,t} + e_t \,(\qquad 15),$$

and

$$\Delta R_{t,t} = a_0 + a_1 t + g R_{t-1,t} + \sum_{i=2}^{p} b_i \Delta R_{t-i\,,t} + e_t \qquad (16).$$

The lagged changes of the dependent variable on the regressions were included to ensure that error terms are white noise. The number of lagged chances in each regression was determined by the Akaike-Schwartz criterion. In equation (15), together with the calculation of the Z statistic, we tested the joint hypothesis of a unit root and no constant, $\alpha_0=\gamma=0$. In the same equation, we did a test to determine the significance of the constant term. In equation (16), together with ADF Z statistic, we tested the joint hypothesis of a unit root, no constant and no trend, $\alpha_0=\alpha_1=\gamma=0$.

The results of these tests are presented in Table I for equation (14), in Table II for equation (15) and in Table III for equation (16). The values of the ADF Z statistic for the critical level 5% are also presented in the tables.

Table I –Augmented Dickey-Fuller tests of the model without constant
(equation (14))

Interest Rate (term)	Nº of lags	Z Statistic	Z at Critical level of 5%
91 days	5	-0.8800	-8.0
182 days	2	-0.9453	-8.0
364 days	5	-1.0760	-8.0

Table II –Augmented Dickey-Fuller tests of the model with constant
(equation (15))

Interest Rate (term)	Nº of lags	Z Statistic	Z at Critical level of 5%	Constant		H. : $a_0 = g = 0$,	
				Coef.	T	Stat.	Crit. level of 5%
91 days	5	0.2068	13.7	-0.00161	-1.0077	2.5558	4.71
182 days	2	0.1649	13.7	-0.00151	-1.1945	4.2745	4.71
364 days	5	-0.3246	13.7	-0.00073	-0.5897	2.1734	4.71

Table III –Augmented Dickey-Fuller tests of the model with constant and trend
(equation (16))

Interest Rate (term)	Nº of lags	Z Statistic	Z at Critical level of 5%	Constant		Trend		H.: $a_0 = a_1 = g = 0$	
				Coef.	T	Coef.	T	Stat.	Crit. level of 5%
91 days	5	-21.693	-20.7	0.03498	3.2030	-0.00029	-3.3834	5.7449	6.49
182 days	2	-10.989	-20.7	0.01944	2.3644	-0.00017	-2.5770	3.3358	6.49
364 days	5	-23.273	-20.7	0.02272	2.7301	-0.00019	-2.8468	4.0890	6.49

The results of the model without constant and without trend (Table I) lead to the non-rejection of the null hypothesis of a unit root in the three maturities of interest rates. The tests on the models with constant (equation (15)), and with constant and trend (equation (16)) have been conducted as a consequence of the result of the tests on the first model. The results of the ADF Z test shown in Table II lead to the exclusion of the constant as the cause of the non-stationarity of the three series. These results are confirmed by the low values of the T-statistic of the constant in the three cases. The results of the joint tests of a unit root and no constant show, additionally, that the restricted regression is not binding, which also confirms that the second model is not sufficient to determine the cause of the non-stationarity.

The results of the Z statistic in the model with trend (Table III, equation (16)), in the cases of the 91- and 364-day interest rates, do not allow the trend to be excluded as the main cause of the non-stationarity. However, these results and the value of the T statistic on the trend's coefficient, are not in accordance with the results of the tests about the joint hypothesis of a unit root and no constant and no trend, which lead to the hypothesis that the restricted regression is not binding. In the case of the 182-day interest rate, neither the Z statistic nor the tests on the joint hypothesis allow the trend to be accepted as an explanation of the non-stationarity.

The contradiction between the results of different tests, in the case of the 91- and 364-day interest rates, and the quite evident non-stationarity of the 182 rate in the three models, lead us to test the hypothesis of a structural break in the series. For that purpose we used a research procedure, proposed by Perron (1997) to determine the moment of the structural break. The first model considered in Perron's procedure allows a change in the intercept, the null hypothesis being the unit root. In the case under analysis in the present research this model is represented by the following equation:

$$R_{t,t} = m + qDU_t + bt + dD\left(T_b\right)_t + aR_{t-1,t} + \sum_{i=1}^{k} c_i \Delta R_{t-i,t} + e_t \qquad (17),$$

where T_b+1 denotes the time at which the break occurs in the trend function, $D(T_b)$ being a dummy with value equal to 1 at Tb+1 and equal to zero at all the other dates. The dummy variable DU_t ($t>T_b$), represents change in the trend intercept, which results from the innovation that begins at T_b.

The second model considered in Perron (1997) allows a change in both the intercept and the slope, at time T_b+1. In the case under analysis this model is represented by the following equation:

$$R_{t,t} = m + qDU_t + bt + gDT_t + dD\left(T_b\right)_t + aR_{t-1,t} + \sum_{i=1}^{k} c_i \Delta R_{t-i,t} + e_t \qquad (18),$$

where DT_t represents the change in the slope. The results of the tests on the first and second models of Perron are presented in Tables IV and V, respectively.

Table IV: Tests of the structural break with the first model of Perron

Interest Rate (term)	Break date	Constant (Stud. T)	DU (Stud. T)	DT_b (Stud. T)	Trend (Stud. T)	$R_{t-1,\tau}$ (Statist. α=1)*
91 days	1993:03	0.08137 (5.4987)	-0.00791 (-4.0340)	0.02079 (4.1833)	-0.000531 (-5.16086)	0.55587 (-5.62854)
182 days	1993:03	0.0589 (5.0452)	-0.00517 (-3.2212)	0.00194 (4.8626)	-0.000391 (-4.72784)	0.68480 (-5.18615)
364 days	1994:02	0.03142 (3.7860)	0.00570 (3.1194)	-0.00926 (-2.4210)	-0.000337 (-4.4749)	0.84078 (-3.75087)

***** critical value at 5%: for 100 obs.: -5.05

Stationary series for the 91-day and the 182-day interest rates resulted from the implementation of the first of these models (Table IV). This means that the structural break (occurred in March 1993) is the result of a change in the intercept of the trend function. The second model (Table V), on the contrary, did not generate a stationary series for any of the maturities. According to these results the hypothesis of a change in the slope of the trend function can be excluded.

Table V: Tests of the structural break with the second model of Perron

Interest Rate (term)	Break date	Constant (Stud. T)	DU (Stud. T)	DT_b (Stud. T)	Trend (Stud. T)	DT (Stud. T)	$R_{t-1,\tau}$ (Statist. α=1)*
91 days	1993:10	0.01577 (1.3248)	-0.00428 (-1.1901)	0.00046 (0.9519)	0.00034 (-3.8199)	0.00022 (2.6376)	0.93798 (-0.9084)
182 days	1994:05	0.03668 (2.9086)	-0.00404 (-1.0901)	0.01305 (3.1421)	-0.000453 (-3.5408)	0.00017 (2.2797)	0.82968 (-2.7129)
364 days	1993:10	0.02436 (2.7981)	-0.00152 (-0.5133)	-0.00230 (-0.5480)	-0.00035 (-3.9043)	0.00014 (2.2560)	0.888 (20.123)

* critical value at 5%: for 100 obs.: -5.05

Since the tests on the series of the interest rates show their non-stationarity, ADF tests on the series of the interest rates first differences were used to identify their degrees of integration. The results of these tests are presented in Table VI.

Table VI –ADF tests on the interest rates first differences

Interest Rate (term)	Nº of lags	Z Statistic	Z at critical level of 5%
91 days	4	-52.8978	-7.9
182 days	1	-159.7049	-7.9
364 days	4	-21.8665	-7.9

The results of the ADF tests on Table VI show that the first differences of interest rates are stationary, which means that the interest rates series are integrated of order 1.

III.2. The cointegration between interest rates of different terms and the estimation of risk premiums

Cointegration can confirm or deny the existence of a stable relation between the interest rates of two different terms and it also gives information on risk premiums, provided that these are stable.

The representation of the cointegration model, adjusted to the variables used on this research is the following:

$$\Delta R_t = \Gamma_1 \Delta R_{t-1} + \ldots + \Gamma_k \Delta R_{t-k} + \Pi R_{t-1} + e_t \qquad (19),$$

where k is the number of lags, ΔR_t and R_{t-1} being vectors, respectively, of the first differences and of the levels of interest rates. The determination of the number of lags included in the model is based on the following group of tests on the residuals: a Ljung-Box test, two Lagrange multiplier tests of orders 1 and 4, and an ARCH test. In one of the models, hereafter designated the *first model,* the cointegration between the 91-day and the 182-day interest rate was estimated. In the other model, hereafter designated the *second model*, the cointegration between the 91-day and the 364-day interest rate was estimated.

The values calculated for the λ-max and λ-trace statistics are presented in Table VII. According to the tables for these statistics presented by Johansen and Julselius (1995) the existence of one cointegration vector can not be rejected at the critical level of 90%, in either case.

Table VII: λ-max and λ-trace statistics

Coint. between the 91-day and the 182-day interest rates			Coint. between the 91 day and the 362-day interest rates		
Eigenval.	λ-max	λ -trace	Eigenval.	λ-max	λ -trace
0.0720	7.10	11.43	0.1364	14.08	18.65
0.0445	4.33	4.33	0.0465	4.57	4.57

After normalizing the first vector in both models, by the coefficient β of the 91-day interest rate, this vector can be represented by the following equations, in the first and in the second model respectively:

$$R_{t,91} - 0.975 R_{t,182} + 0.0003308 = 0, \qquad (20),$$

$$R_{t,91} - 0.962 R_{t,364} + 0.003143 = 0 \qquad (21).$$

The values of the α coefficients corresponding to the parameters of equations (20) and (21), and their respective Student T statistics, are given in Table VIII.

Table VIII: Values of α and respective student T statistics corresponding to the normalization of the vector by the 91-day interest rate

Coint. between the 91day and the 182-day interest rates			Coint. between the 91-day and the 364-day interest rates		
	ALPHA	T-Values		ALPHA	T-Values
ΔR91	-0.481	-2.347	ΔR91	-0.270	-3.891
ΔR182	-0.013	-0.130	ΔR364	-0.027	-0.802

In order to make an economic interpretation of the constant in the models possible, the coefficients of the 182- and 364-day interest rates have been set as equal to –1. This restriction gives the possibility of interpreting the constant as being a stationary sum of changes in expectations, plus a risk premium, according to equation (11).

This restriction has the following effects on the vectors of the first and the second model, respectively:

$$R_{t,182} = R_{t,91} + 0.005, \qquad (22),$$

$$R_{t,364} = R_{t,91} + 0.008 \qquad (23)$$

The standard error of the constant is 0.002 in both of these equations. A likelihood ratio test was used to verify if the restriction imposed on the beta coefficients of the 182- and 364-day interest rates is binding. The values calculated for the χ^2 statistics and their probabilities, were:

a) for the first model: χ^2 (1)= 0.64 with prob. =0.42;

b) for the second model : χ^2 (1)= 0.60 with prob. =0.44.

According to these values of the χ^2 statistics and their probabilities, the restriction imposed is not binding in any of the models. Since for most of the time covered by this research, the interest rates have been diminishing, the negative changes in interest rates have been dominant during that period. Under this hypothesis, it can be accepted that the constant in both models (eq. (22) and (23)) includes a positive risk premium. The fact that the constant is higher in the second model than in the first can be interpreted as meaning that the risk premiums vary positively with the maturity of the interest rates. The values of the α coefficients calculated after the imposition of restriction on the beta coefficients, and their respective Student T statistics, are given in Table IX.

Table IX: Values of α and respective student T statistics corresponding to the normalization of the vector by the 91days interest rate and the imposition of the restriction on betas

Coint. between the 91-day and the 182-day interest rates			Coint. between the 91-day and the 364-day interest rates		
	ALPHA	T-Values		ALPHA	T-Values
ΔR91	-0.306	-2.507	ΔR91	-0.237	-3.791
ΔR182	-0.048	-0.789	ΔR364	-0.019	-0.641

A likelihood ratio test was also used to verify if the alpha coefficients are significantly different from zero. For this test, in each model, the alpha coefficients related to the 91-day interest rate and to the longer-term rate were alternatively set as equal to zero. The values calculated for the χ^2 statistics and their probabilities are presented in Table X.

Table X: Likelihood ratio test on the alpha coefficients

Coint. between the 91-day and the 182-day interest rates	Coint. between the 91-day and the 364-day interest rates
1) Restriction on the 91-days interest rate alphas χ^2 (2)= 3.57 prob. =0.17	1) Restriction on the 91-days interest rate alphas χ^2 (2)= 9.7 prob. =0.01
2) Restriction on the 182-days interest rate alphas χ^2 (2)= 0.94 prob. =0.62	2) Restriction on the 182-day interest rate alphas χ^2 (2)= 0.89 prob. =0.64

According to the results of the LR tests on the alpha coefficients, in the first model both interest rates can considered weakly exogenous. These results mean that the short-term changes are not governed by the reversion to the long-term relation in either of the two variables. In the second model only the 364-day interest rate is weakly exogenous.

Table XI: Residual Analysis

Coint. between the 91-day and the 182-day interest rates	Coint. between the 91-day and the 364-day interest rates
TEST FOR AUTOCORRELATION	TEST FOR AUTOCORRELATION
L-B(23), CHISQ(74) = 92.095, p-val = 0.08	L-B(24), CHISQ(82) = 99.377, p-val = 0.09
LM(1), CHISQ(4) = 2.909, p-val = 0.57	LM(1), CHISQ(4) = 10.240, p-val = 0.04
LM(4), CHISQ(4) = 8.688, p-val = 0.07	LM(4), CHISQ(4) = 8.924, p-val = 0.06
TEST FOR NORMALITY	TEST FOR NORMALITY
CHISQ(4) = 32.034, p-val = 0.00	CHISQ(4) = 54.091, p-val = 0.00
ARCH(5) Normality R-squared	ARCH(4) Normality R-squared
23.700 8.101 0.260	21.733 27.189 0.218
6.005 21.933 0.793	1.001 22.248 0.696

The results of the residual analysis of the models with restrictions on the betas are presented in Table XI.

The results of the residual analysis show that there is no presence of residual autocorrelation in either model of cointegration. However, a certain degree of heterocedasticity for the 91-day interest rate remains in both models.

Conclusion

The traditional theories on the term structure of interest rates accept that risk premiums are stable and monotonically increasing with the maturity of interest rates. In the present research, cointegration methods have helped to show the stable relationship between the Portuguese Treasury Bills interest rates of 91, 182 and 364 days. At the same time, these tests allowed verification of the fact that the forward premiums contained in that term structure and varying positively with maturity, are an important part of that stable relationship.

References

CAMPBELL, J. and SHILLER, R. (1991), “Yield spreads and interest rate movements: *Review of Economic Studies*, Nº 58, pp.495-514.

COX, J., INGERSOLL, J., ROSS, S. (1985), " A Theory of the Term Structure of Interest Rates, *Econometrica*, March, pp. 385-407.

ENGLE, R. and GRANGER, C. (1987), “Cointegration and Error-Correction: Representation, Estimation and Testing”, *Econometrica*, Nº 55, pp251-76.

EVANS, M. and LEWIS, K. (1994) “Do stationary risk premia explain it all? Evidence from the term structure”, *Journal of Monetary Economics*, Nº 33, pp. 285-318.

FAMA, E. (1984), “ The Information in the Term Structure”, *Journal of Financial Economics*, 509-528.

HARDOUVELIS, G. (1994), "The term structure spread and future changes in long and short rates in the G7 countries", *Journal of Monetary Economics*, Nº 33, pp. 255-283.

JOHANSEN, S. (1988), "Statistical Analysis of Cointegrating Vectors", *Journal of Economic Dynamics and Control*, Vol. 12, pp-231-254.

JOHANSEN, S. (1991), "Estimating and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Auregressive Models", *Econometrica*, Nº 59, pp 1551-1580.

JOHANSEN, S. and JUSELIUS, K. (1995), *CATS in RATS: Cointegration Analysis of Time Series*, Ed. Estima, Illinois, USA, 87 pages.

MCCULLOCH, J.H. (1987), " The Monotonicity of Term Premium: a closer look", *Journal of Financial Economics*, Vol. 18, pp. 185-192.

PERRON, P. (1997), "Further Evidence on Breaking Trend Functions in *Journal of Econometrics*, Nº 80, pp. 355-385.

VASICECK, O., (1977) " An Equilibrium Characterization of the Term Structure", *Journal of Financial Economics*, vol. 5., pp. 177-188.

ESTUDOS DO G.E.M.F.

2001

Nº. 8 *The Risk Premiums in the Portuguese Treasury Bills Interest Rates: Estimation by a cointegration method*
– José Soares da Fonseca

Nº. 7 *Principais factores de crescimento da economia portuguesa no espaço europeu*
- Maria Adelaide Duarte e Marta Simões

Nº. 6 *Inflation Targeting and Exchange Rate Co-ordination*
- Fernando Alexandre, John Driffill e Fabio Spagnolo

Nº. 5 *Labour Market Transition in Portugal, Spain, and Poland: A Comparative Perspective*
- Paulino Teixeira

Nº. 4 *Paridade do Poder de Compra e das Taxas de Juro: Um estudo aplicado a três países da UEM*
- António Portugal Duarte

Nº. 3 *Technology, Employment and Wages*
- John T. Addison e Paulino Teixeira

Nº. 2 *Human capital investment through education and economic growth. A panel data analysis based on a group of Latin American countries*
- Maria Adelaide Duarte e Marta Simões

Nº. 1 *Risk Premiums in the Porutguese Treasury Bills Interest Rates from 1990 to 1998. An ARCH-M Approach*
- José Soares da Fonseca

2000

Nº. 8 *Identificação de Vectores de Cointegração: Análise de Alguns Exemplos*
- Pedro Miguel Avelino Bação

Nº. 7 *Imunização e M-quadrado: Que relação?*
- Jorge Cunha

Nº. 6 *Eficiência Informacional nos Futuros Lisbor 3M*
- Nuno M. Silva

Nº. 5 *Estimation of Default Probabilities Using Incomplete Contracts Data*
- J. Santos Silva e J. Murteira

Nº. 4 *Un Essaie d'Application de la Théorie Quantitative de la Monnaie à l'économie portugaise, 1854-1998*
- João Sousa Andrade

Nº. 3 *Le Taux de Chômage Naturel comme un Indicateur de Politique Economique? Une application à l'économie portugaise*
- Adelaide Duarte e João Sousa Andrade

Nº. 2 *La Convergence Réelle Selon la Théorie de la Croissance: Quelles Explications pour l'Union Européenne?*
- Marta Cristina Nunes Simões

Nº. 1 *Política de Estabilização e Independência dos Bancos Centrais*
- João Sousa Andrade

1999

Nº. 9 *Nota sobre a Estimação de Vectores de Cointegração com os Programas CATS in RATS, PCFIML e EVIEWS*
- Pedro Miguel Avelino Bação

Nº. 8 *A Abertura do Mercado de Telecomunicações Celulares ao Terceiro Operador: Uma Decisão Racional?*
- Carlos Carreira

Nº. 7 *Is Portugal Really so Arteriosclerotic? Results from a Cross-Country Analysis of Labour Adjustment*
- John T. Addison e Paulino Teixeira

Nº. 6 *The Effect of Dismissals Protection on Employment: More on a Vexed Theme*
- John T. Addison, Paulino Teixeira e Jean-Luc Grosso

Nº. 5 *A Cobertura Estática e Dinâmica através do Contrato de Futuros PSI-20. Estimação das Rácios e Eficácia Ex Post e Ex Ante*
- Helder Miguel C. V. Sebastião

Nº. 4 *Mobilização de Poupança, Financiamento e Internacionalização de Carteiras*
- João Sousa Andrade

Nº. 3 *Natural Resources and Environment*
- Adelaide Duarte

Nº. 2 *L'Analyse Positive de la Politique Monétaire*
- Chistian Aubin

Nº. 1 *Economias de Escala e de Gama nos Hospitais Públicos Portugueses: Uma Aplicação da Função de Custo Variável Translog*
- Carlos Carreira

1998

Nº. 11 *Equilíbrio Monetário no Longo e Curto Prazos - Uma Aplicação à Economia Portuguesa*
- João Sousa Andrade

Nº. 10 *Algumas Observações Sobre o Método da Economia*
- João Sousa Andrade

Nº. 9 *Mudança Tecnológica na Indústria Transformadora: Que Tipo de Viés Afinal?*
- Paulino Teixeira

Nº. 8 *Portfolio Insurance and Bond Management in a Vasicek's Term Structure of Interest Rates*
- José Alberto Soares da Fonseca

1997

1996

Nº. 7 *Housing Shortage and Housing Investment in Portugal a Preliminary View*
- Vítor Neves

Nº. 6 *Housing, Mortgage Finance and the British Economy*
- Kenneth Gibb e Nile Istephan

Nº. 5 *The Social Policy of The European Community, Reporting Information to Employees, a U.K. perspective: Historical Analysis and Prognosis*
- Ken Shackleton

Nº. 4 *O Teorema da Equivalência Ricardiana: aplicação à economia portuguesa*
- Carlos Fonseca Marinheiro

Nº. 3 *O Teorema da Equivalência Ricardiana: discussão teórica*
- Carlos Fonseca Marinheiro

Nº. 2 *As taxas de juro no MMI e a Restrição das Reservas Obrigatórias dos Bancos*
- Fátima Assunção Sol e José Alberto Soares da Fonseca

Nº. 1 *Uma Análise de Curto Prazo do Consumo, do Produto e dos Salários*
- João Sousa Andrade