Testing the Expectations Hypothesis in the Brazilian Term Structure of Interest Rates[*]

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Abstract

We test the Expectations Hypothesis (EH) plus Rational Expectations (RE) in the Brazilian term-structure of interest rates, using maturities ranging from 1 month to 12 months, and daily data from 1995 to 2000. We rely on two methodologies based on single-equation regressions. Our results indicate a rejection of the EH plus RE, specially at the longer maturity. This may have important implications for the rational expectations macro-modeling currently being used to evaluate the conduct of monetary policy in Brazil. We also show the risk premium in the yield curve are positively related to the covered interest rate differential and to the volatility of interest rates.

Key Words: term structure, expectations hypothesis, risk premium .

JEL Code: E43, G14, G15 .

Resumo

Neste trabalho são testadas as hipóteses de expectativas (EH) e as expectativas racionais (RE) na estrutura a termo das taxas de juros, utilizando vencimentos entre 1 e 12 meses e dados diários de 1995 a 2000. Duas metodologias baseadas em regressões de equações simples são empregadas. Os resultados indicam uma rejeição de EH e RE, especialmente nos vencimentos mais longos. Isto pode ter importantes implicações para as modelagens macro de expectativas racionais que têm sido usadas para avaliar a conduta da política monetária no Brasil. É mostrado também que os riscos de prêmio na curva de rendimentos são positivamente relacionados com o diferencial coberto da taxa de juros e com a volatilidade das taxas de juros.

1. Introduction.

Central banks are able to control very short-term interest rates, but aggregate-spending decisions are generally viewed as closely related to long-term interest rates, therefore economic activity should be affected by longer term rates. Thus, changes in short term rates will affect aggregate-spending decisions if long rates are affected which implies that understanding the relationship between long-term and short-term interest rates seems essential to macroeconomic modeling and the conduct of monetary policy.

The best known theory about term structure of interest rates, first articulated by Fisher (1896), is called the Expectations Hypothesis (EH). The EH claims that the long-term interest rate is an average of expected future short-term rates, plus a time-independent risk premium. It also requires that two fixed income investment strategies initiated at the same time for the same horizon have the same expected return, up to a risk premium, which is supposed constant through time but maturity dependent. Therefore, the EH states that the shape of the yield curve is determined solely by expectations of future changes in the short-term interest rate and by time-invariant

risk premium[1].

There is a lot of empirical literature on testing the EH. The vast majority of this literature tests the EH in conjunction with Rational Expectations, i.e., the hypothesis that agents do not make systematic forecast errors[2]. Unfortunately, results have been quite contradictory. They differ widely according to the precise implication of the EH tested, the country, the time period, and the segment of the term structure under study. Shiller (1990) provides a comprehensive survey of the literature up to the eighties. Many important empirical papers have been published since then, including Campbell and Shiller (1991), Evans and Lewis (1994), Tzavalis and Wickens (1997), Jondeau and Ricart (1999) and Longstaff (2000). The econometric techniques used in many of these studies have been subject to criticisms, such as in Stambaugh (1988), Bekaert et al (1997) and Thornton (2000).

The purpose of this paper is to test the Expectation Hypothesis plus Rational Expectations at the short end of the term structure of interest rates in Brazil (maturities up to one year), using two different methodologies based on single equation regressions. We are unaware of previous attempts to evaluate the EH using Brazilian data.

The remainder of the paper is organized as follows. Section 2 describes the methodologies applied in the paper. Section 3 presents the data used, while Section 4 displays and comments the empirical results achieved. Section 5 concludes the paper.

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[1] Refer to chapter 10 of Campbell et al (1996) for an elucidative discussion of the alternative formulations of the EH.

[2] Froot (1989), who uses survey data as a proxy for interest rate expectations, is a well-known exception. Studies based on cointegration techniques (Shea, 1992; Cuthberson, 1996) tests a weaker implication of the EH, but generally do not require the additional hypothesis of rational expectations.

2. Methodology.

We use two different methodologies to test the joint hypothesis of the EH plus Rational Expectations. The next two sub-sections detail each of the procedures used.

2.1 The standard approach.

Consider that R_t^n is the continuously compound of the longer-term n-period rate, i.e, the logarithm of the n-period rate plus one, and that r_t is the continuously compound one-period rate. The roll-over premium λ_n is the expected excess return between the strategy of investing in the n-period rate, and the alternative strategy of rolling over n investments in the one period rate. Note that both strategies are started at the same time, and have the same n-period horizon.

$$\lambda_t^n = R_t^n - (1/n) \sum_{i=0}^{n-1} E_t [r_{t+i}] \qquad (1)$$

Subtracting r_t from both sides of equation 1, and rearranging terms:

$$\sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) (E_t [r_{t+i}] - E_t [r_{t+i-1}]) = (R_t^n - r_t) - \lambda_t^n \qquad (2)$$

The EH states that λ is constant through time for each n, i.e, $\lambda_t^n = \lambda$ for all t. Rational Expectations implies that $E_t[r_{t+i}] = r_{t+i} + v_{t+i}$, where v_t is zero mean iid white noise. Plugging these in (2) and parameterizing:

$$\sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) (r_{t+i} - r_{t+i-1}) = \alpha + \beta (R_t^n - r_t) + \varepsilon_t \qquad (3)$$

where $\alpha = -\lambda^n$, $\beta = 1$, and ε_t is a $MA(j - p - 1)$ process, where j and p stand for the number of days in the long term and short term interest rate, respectively[3].

Then, we can test the EH plus Rational Expectations by regressing a weighted average of changes in the one-period rate on the yield spread and a constant. In the specification given in equation (3), the spread is uncorrelated with future innovations and the OLS procedure is consistent. All that is needed is a correction for the moving average terms, as the residuals have $(j - p - 1)$ common terms. Thus, in this paper we will tests the EH plus Rational Expectations using equation (3).

The yield spread regression method outlined above is a standard approach for testing the EH. It has been used by Mankiw and Miron (1986), Campbell and Shiller (1991), Hardouvelis (1994), Hurn et al (1995), Gerlach and Smets (1997) and Jondeau and Ricart (1999), among many others.

2.2 The "error-orthogonality" approach.

Under the null hypothesis of the EH plus Rational Expectations, the error-term ε_t must be orthogonal to any variable in the information set Ω_t, i.e., there must be no relevant omitted variables in equation (3). This is equivalent as requiring λ_t^n to be unforecastable by any variable on Ω_t.

Therefore, if the joint hypothesis is true, in equation (5) below we should expect to have $\gamma = 0$, in addition to $\beta = 1$:

$$\sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) (r_{t+i} - r_{t+i-1}) = \alpha + \beta \left(R_t^n - r_t\right) + \gamma \Omega_t + \varepsilon_t \quad (5)$$

for any variable on Ω_t.

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[3] $\varepsilon_t = \frac{1}{n} \sum_{i=1}^{n-1} v_{t+i}$

If γ is not equal to zero, then one could say that risk premium are not time-invariant, but are related to the variable used on Ω_t at equation (5). Now which variables could possibly relate to the magnitude of the risk premium?

The risk premium λ_t^n represents the extra return necessary to compensate investors for bearing the extra risk associated with longer-term bonds. Intuitively, the magnitude of this extra return should depend on the "risk conditions" of the economy: the higher the uncertainty about future interest rates, or the higher the probability of a default in public debt[4], the higher should be λ_t^n.

Thus, the natural candidates to represent Ω_t in equation (5) are variables that proxy the notion of "risk" in the Brazilian economy, given the fact that "risk" itself is not directly observable. In this paper we experiment two proxies for "risk" on Ω_t: the one-year covered interest rate differential, and a measure of the volatility of interest rates.

The intuitive reason for including a measure of interest rates volatility is straightforward: the more volatile interest rates are, the riskier a long-term bond is compared to a short-term one. Thus, according to modern portfolio theory, the higher must be the expected return of a longer-term bond relative to a short-term one.

The rationale behind of including the covered interest differential is as follows. The one-year covered interest differential is the remuneration for an arbitrageur who at t_0 borrows dollars for one-year at the fixed risk-free rate, and at the same t_0 transforms those dollars into reais, buys a Brazilian fixed rate government bond maturing in one year, and hedges himself against the depreciation of the real by buying one-year forward the

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[4]For a discussion of the interplay between the basic interest rate of the economy and the rate of government bonds in Brazil please refer to Barbosa (2000).

amount of dollars he needs to pay-back his dollar-denominated debt[5]. Given this ideal situation, risks coming from potential movements in interest and exchange rates would be hedged out:, this arbitrageur would be exposed only to Brazilian "political risk" (the risk of a default of the public debt, the risk of future imposition of controls on dollar outflows, etc.). In this paper we interpret the covered interest differential as the price of this "political risk", following Frankel and McArthur (1988)[6,7].

This "error-orthogonality" approach to test the expectation hypothesis plus rational expectations parallels Friedman (1980), Jones and Roley (1983) and Mankiw (1986).

3. The Data.

We used three sets of data on our analysis. The subsections below provide information about each one of them.

3.1 Interest rates.

The main data are interest rate swaps maturing on 1, 2, 3, 6 and 12 months' time. In these contracts, a party pays a fixed rate over an agreed principal and receives a floating rate over the same principal, the reverse occurring with his or her counterpart. There are no intermediate cash-flows, with

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[5] There are relatively large derivative markets in Brazil, where the dollar-real currency risk can be hedged out. In addition, the Brazilian government also issues exchange-rate linked bonds denominated in reais.

[6,] Accordingly, Garcia and Didier (2001) state that the covered interest rate differential is "[...] *a portrait of the economic and financial situation of a certain country, also showing the political stability and the historic performance in fulfilling its financial obligations*".

[7] The investigation whether this had been a "fair" price is beyond the scope of this paper. Please refer to section 4 of Araújo (2001) for a comment.

the contracts being settled on maturity. The floating rate is the overnight CDI rate (interbank deposits), which tracks very closely the average rate in the market for overnight reserves at the central bank. The fixed rate, negotiated by the parties, is the one used on this paper. These contracts have been traded over-the-counter in Brazil since the early 90's, and have to be registered either on Bolsa de Mercadorias e de Futuros – BM&F (a futures exchange) or on Central de Títulos Privados – CETIP (a custodian).

The data is sampled daily, beginning on January 1995 and ending on April 2001. The full sample has 1540 observations, collected from the Bloomberg system. However, as we have a limited time series for other series our estimation sample will be January 1995 to August 2000. Thus, the sample employed in all our regressions has at most 1380 observations. With the use of equation (3) this number reduces for each equation as we're using the spread to forecast changes in short term rates in the future.

Figure 1 shows the 1 and 12 month interest rates for the period.

Figure 1: 1-month and 12 month interest rates

The peaks in the series reflect the financial crises that took place in the second half of the decade. In March 1995 interest rates went up after Brazil moved from a floating[8] exchange-rate regime to a quasi-fixed one, as a consequence of the Mexican crisis. In September 1997 and August 1998 the peaks resulted from the Asian and the Russian crisis respectively. In February 1999 interest rates were increased once more when the costs of defending the quasi-fixed regime with an over-valued exchange rate turned up unbearable. At that time Brazil was forced to devalue its currency amid a speculative attack, leaving the quasi-fixed exchange-rate regime in favor of a floating rate one.

3.2 Covered interest rate differential[9].

We use daily data for the one-year covered interest rate differential and we covered the period of January 1995 to August 2000. It was obtained from three different instruments: the 12-month interest rate swap mentioned in the previous subsection, the 12-month dollar-real currency swap, and the One-year Treasury Constant Maturity Rate.

In the dollar-real currency swap a party pays a fixed-rate in US dollars over an agreed principal denominated in Reais[10], while the other pays a floating rate in Brazilian reais over that principal. Again, as in the interest rate swap mentioned before, the floating rate is the overnight CDI rate. Similarly to the interest rate swap, there is only one cash-flow at the maturity of the contract.

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[8] Albeit only "upwards floating", since the government had committed itself to defend a floor of 1:1 for the real against the dollar.

[9] The covered interest rate differential data, kindly provided by Marcio Garcia and Tatiana Didier, was used in their study Garcia and Didier (2000).

[10] I.e., this party pays the exchange rate variation plus the fixed rate in US dollars.

Combining the information of these two swaps, one is able to price a dollar-real currency swap, where a party pays a fixed rate in reais over an agreed principal denominated in reais, and receives a fixed rate in US dollars[11].

The One-year Treasury Constant Maturity Rate is a composition of the yields of many US Treasury bonds, adjusted to reflect a constant maturity of one year. It is published by the Federal Reserve Board.

Then, the covered interest rate differential can be calculated from the difference between the fixed rate in reais, the fixed rate in US dollars and the One-year Constant Maturity Treasury Rate.

3.3 Interest rate volatilities.

Daily interest rate volatilities for each maturity were calculated by the "Riskmetrics" methodology, and expressed on an annualized basis. If yt is an interest rate, then the volatility of this rate on day t is:

$$Vol_t = \sqrt{252} \sum_{i=1}^{99} \left(\theta^i \left(\frac{y_{t-i} - y_{t-i-1}}{y_{t-i-1}} \right)^2 \right), \quad \text{where } \theta = 0.94$$

As one could suspect, interest volatilities for different maturities are highly correlated, as displayed on Table 2 below. From now on we will only refer to the volatility of the 12-month rate.

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[11] As Garcia and Didier (2000) point out, there is also a third swap contract with this structure in the Brazilian market, but it is far less liquid then the ones used in their calculations.

Table 1: correlation matrix for interest rate volatilities

	1Mvol	2Mvol	3Mvol	6Mvol	12Mvol
1Mvol	1	0.97	0.94	0.81	0.78
2Mvol		1	0.96	0.87	0.85
3Mvol		1	0.93	0.91	
6Mvol			1	0.98	
12Mvol				1	

4. Empirical Results.

4.1 Unit Root Tests.

In order to check whether we are on good grounds to perform the regressions of equations (3) and (5), we first did unit root tests on the relevant variables[12].

Table 2 displays the results of unit root tests of the interest rate spreads, the one-year covered interest differential and the 12-month interest rate volatility[13]. It refers to ADF tests (Dickey and Fuller, 1979), but similar results were obtained with the alternative Phillips-Perron procedure (Phillips and Perron, 1988).

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[12]It wouldn't be appropriate to use a t-distribution to conduct statistical inference if the variables in a regression contain stochastic trends (time series processes with unit roots). See Hamilton (1995).

[13] In Tables 3 and 4 we report results of tests from August 1995 to August 2000, because this is the sub-sample used to derive the main results of the paper in the following subsections. Results including the period January 1995 to July 1995, not reported here, are similar.

Table 2: ADF unit root tests

Variables	With constant	None
R2-R1	-3.4053**	-3.3543*
R3-R1	-3.2071**	-3.0338*
R6-R1	-3.0355**	-2.7813*
R12-R1	-2.8654**	-2.4648**
CID	-2.7077***	-1.7559***
Volatility	-5.1779*	-3.3645*

*, ** and *** stand for rejection of the null at the 1%, 5% and 10% level, respectively.

We conclude that the explanatory variables of equations (3) and (5) are I(0), then we are free of the spurious regression problem.

4.2 Regressions with Equation (3): the standard approach.

In this sub-section we report the results of the regressions of equation (3). The standard errors and test statistics are robust to overlapping observations. We have calculated Newey and West's (1987) correction for a moving average process of order (n-m-1), where the n and m stand for the number of days in the long and short term interest rates. Thus for the tests using 2, 3, 6 and 12 months we use a correction for MA(20), MA(41), MA(104) and MA(230), respectively, as we are using working days.

a) Equation (3) – Sample from January/1995 to August/2000

Table 3 below displays the results for the model of equation (3), using the maximum sample up to August 2000.

Table 3: Equation (3) – January/95 to August/00

n	α	β	$H_0{:}\beta{=}1$	$H_0{:}\alpha{=}0,\beta{=}1$	R^2	$MA(j{-}p{-}1)$
2 months	-0.0007	0.9940*	0.4809	1.6333	21.92%	20
	(0.0023)	(0.2622)	[0.4883]	[0.1957]		
3 months	-0.0028	0.9264*	0.4468	1.0709	13.13%	41
	(0.0042)	(0.2744)	[0.5040]	[0.3430]		
6 months	-0.0131	0.8033*	0.0720	0.2263	10.25%	104
	(0.0090)	(0.2943)	[0.7884]	[0.7975]		
12 months	-0.0303	0.6527	0.0005	0.0712	6.26%	230
	(0.0183)	(0.5011)	[0.9819]	[0.9313]		

Robust standard errors are given in parenthesis (corrected for $MA(j{-}p{-}1)$ innovations), and p-values for the Wald statistics are given in brackets.

*,** and *** stand for rejection of the null at the 1%, 5% and 10% level, respectively.

We could not reject the null hypothesis of the EH plus Rational Expectations for any maturity. However, the explanatory power of the model seems quite disappointing. Note that $\lambda^n = -\alpha$ increases monotonically with maturity, in accordance to its interpretation as risk premium. Also note that risk premium are statistically undistinguishable from zero for all horizons. We cannot reject the joint null of a risk premium different from zero and a beta different than one. It is worth noting that the coefficient of determination of the regressions decrease monotonically with maturity.

b) Equation (3) – Rolling regressions

In this section we search for evidence of parameter instability by running rolling regressions of equation (3) over the sample used in the previous sub-section.

The sample size for each rolling regression is 900 daily observations. Since the total size of the sample used in Table 5 for $n = 2, 3, 6$ and 12 months is 1360, 1339, 1276 and 1149, respectively we run 400 regressions for the first two maturities and, 376 and 249 regressions for the latter maturities.

Figure 2 below displays the results of the rolling regressions. The graphs of the right column show the point estimate of parameter β for each n, along with a one-standard deviation confidence interval. On the left column Figure 2 shows graphs of the point estimate of the risk premium λ^n for each n, along with a one-standard deviation confidence interval. The estimates are already scaled back to basis points, i.e., Figure 2 displays $\exp(-\alpha)$ minus one[14].

The first thing we note by analyzing the pattern of all graphs is that there seems to be a structural break in the behavior of both parameters. This break is located around observation number 120. Before that observation, parameter estimates for all maturities are very unstable. Then, the parameters estimates for $n = 2, 3$ and 6 appear to be quite stable. For $n = 12$, however, there are still signs of parameter instability after the break, suggesting that the results of regressions of equation (3) for this maturity should be looked with particular caution.

Two other results are worth noting. First, after the break, the parameter β (right column) for all maturities is close to unity, indicating that we cannot reject the EH plus Rational Expectations. Second, we note that for all regressions $\lambda^n = -\alpha$ (left column) increases monotonically with maturity.

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[14] In fact, $\exp(-\alpha)$ minus one is better interpreted as the "average" risk premium for the period of 1.000 observations (nearly 4 years).

Figure 2: Rolling Regressions

The fact that the risk premium seem to be stable after the break, for $n = 2, 3$ and 6, allows us to state that those premium are a good first-order approximation of the expected cost associated with the policy of shifting the composition of the public debt away from one-month bonds and to the direction of 2, 3 or 6 months' bonds. Therefore, if instead of issuing 1-month bonds the government issues 2, 3, 6 or 12 month bonds the expected increase in the cost of servicing the debt over the medium-long run would be 7 bps, 28 bps, 132 bps and 308 bps, respectively[15]. Of course, we are implicitly assuming that the change of policy itself does not affect substantially the market pricing of this kind of risk[16].

c) Equation (3) – Sample August/1995 to August/2000

The structural break we were able to identify using the rolling regressions of the previous section indicate that we should not mix data prior to the break, marked by strong instability of parameters, with data after the break. We decided to cut the sample at observation number 149 (in August 1995). Therefore, in this and in the following sub-sections as well, we are not considering the initial period January/95 to July/95. Our sample from now on begins on August/1995. The regression of the equation (3) with the new sample is on Table 4 below.

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[15] These numbers should be looked with caution.

[16] We will elaborate a bit more on this topic on section 5.

Table 4: Equation (3) – August/95 to August/00

N	α	β	$H_0:\beta=1$	$H_0:\alpha=0,\beta=1$	R^2	$MA(j-p-1)$
2 months	-0.0005	0.9764*	0.0171	0.0513	16.78%	20
	(0.0023)	(0.2041)	[0.8959]	[0.9500]		
3 months	-0.002	0.9739*	0.0071	0.1867	14.89%	41
	(0.0034)	(0.3105)	[0.9329]	[0.8297]		
6 months	-0.073	1.1312*	0.1733	0.7783	25.28%	104
	(0.0068)	(0.3152)	[0.6772]	[0.4595]		
12 months	-0.0015	0.3501*	1.2810	2.4819***	34.75%	230
	(0.0011)	(0.3093)	[0.2580]	[0.0841]		

Robust standard errors are given in parenthesis, and p-values for the Wald statistics are given in brackets.

*,** and *** stand for rejection of the null at the 1%, 5% and 10% level, respectively.

Comparing to the results displayed on Table 3, we see that the regressions of equation (3) using the new sample are much better: the coefficient of determination for all maturities, except $n = 2$, increased. For $n = 2$, there was a slight decrease of explanatory power.

We do not reject the hypothesis that the risk premium $\lambda^n = -\alpha$ is zero for all maturities. The joint hypothesis of the EH plus Rational Expectations cannot be rejected for any maturity. Again, we stress the fact that results for $n = 12$ should be interpreted with caution, since the rolling regressions of the previous sub-section revealed signs of parameter instability all over the sample.

The results of Table 4 are similar to the results achieved by Gerlach and Smets (1997) for many countries.

4.3 Regressions with Equation (5): The error-orthogonality approach with the covered interest rate differential.

In this sub-section we estimated equation (5) using the one-year covered interest rate differential as the variable on Ω_t. Results are on Table 5 below.

Table 5: Equation (5) with Ω as the one year
covered interest rate differential

n	α	β	γ	$H_0:\beta=1$	$H_0:\alpha=0,\beta=1$	R^2	$MA(j-p-1)$
2	0.0058	0.8462*	-0.0838*	0.6337	3.8358**	20.91%	20
months	(0.0030)	(0.1932)	(0.0308)	[0.4261]	[0.0218]		
3	0.0138	0.7217*	-0.2072*	0.8720	5.7664*	25.74%	41
months	(0.0062)	(0.2980)	(0.0620)	[0.3506]	[0.0032]		
6	0.0316*	0.7367*	-0.4843*	0.7573	8.3707*	47.66%	104
months	(0.0127)	(0.3025)	(0.1189)	[0.3844]	[0.0002]		
12	0.056	0.8599*	-0.829*	0.2353	22.2927*	71.53%	230
months	(0.095)	(0.2887)	(0.1242)	[0.6277]	[0.0000]		

Robust standard errors are given in parenthesis, and p-values for the Wald statistics are given in brackets.

*,** and *** stand for rejection of the null at the 1%, 5% and 10% level, respectively.

The R^2-statistics in Table 5 appear to indicate that the covered interest rate differential contain a highly significant amount of predictive power, specially for the 6 and 12 months regressions. For n equal to 6 and 12 months the predictive power almost doubles as can be seen from the R^2, raising from 25.28% to 47.66% and 34.75% to 71.53%, respectively.

We also note that γ has the expected negative sign for all maturities, i.e., an increase in the covered interest differential increases risk premium. The joint null of $\gamma = 0$ and $\beta = 1$ is rejected for all maturities.

For each maturity we can comfortably reject the null-hypothesis that γ is zero. Then, risk premium are indeed time-varying, and positively related to the one-year covered interest rate differential. Thus, the EH plus Rational Expectations is strongly rejected.

4.4 Regressions with Equation (5): The error-orthogonality approach with the interest rate volatility.

Now, we estimated equation (5) using the volatility of the 12-month interest rate as the variable on Ω_t. Results are on Table 6 below.

Table 6: Equation (5) with Ω as the one year
interest rate volatility

N	α	β	γ	$H_0{:}\beta{=}1$	$H_0{:}\alpha{=}0,\beta{=}1$	R^2	$MA(j{-}p{-}1)$
2	0.0036	0.9222*	-0.1897	0.1484	1.4798	21.84%	20
months	(0.0028)	(0.2018)	(0.1103)	[0.7001]	[0.2281]		
3	0.0079	0.8544*	-0.4552**	0.2007	2.4652***	22.01%	41
months	(0.0052)	(0.3250)	(0.2066)	[0.6542]	[0.0854]		
6	0.0146	0.9529*	-0.9643*	0.0189	2.6110***	31.19%	104
months	(0.0105)	(0.3422)	(0.4280)	[0.8907]	[0.0739]		
12	0.0284	1.1167*	-1.8012*	0.1197	18.6077*	61.58%	230
months	(0.0127)	(0.3373)	(0.4074)	[0.7294]	[0.0000]		

Robust standard errors are given in parenthesis, and p-values for the Wald statistics are given in brackets.

*,** and *** stand for rejection of the null at the 1%, 5% and 10% level, respectively.

Results in Table 6 are very similar to the ones in Table 5[17]. The model of equation (5) using the interest rate volatility as Ω

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[17]When we try the "encompassing regression" approach of Fair and Shiller (1990) and include both the covered interest rate differential and the interest rate volatility as explanatory variables, we verify that the interest rate volatility offers little if any incremental

also offer a much better fit for all maturities than the model of equation (3) used on Table 4. However, the explanatory power is marginally smaller than when we used the covered interest rate differential as Ω (Table 5).

The coefficient of the interest rate volatility, γ, is significant for all maturities, and again has the expected negative sign. Thus, Table 6 also offers evidence in favor of the rejection of the EH plus Rational Expectations, because risk-premium are time-varying, and positively related to the level of interest rate volatility.

Restricting the coefficients on the spread to be one and running these regressions yield the same results. This approach, suggested by Mankiw (1986), reveals that there is information content in both the covered interest rate differential and the interest rate volatility in addition to the information that is already contained in the PFS.

5. Conclusions.

Results using the standard approach tend to lead to the acceptance of the EH plus Rational Expectations for the 2, 3 and 6 months interest rates. For the 12-month rate there are stronger signs of parameter instability, so we look at the results for this maturity with greater caution.

However, regressions using the "error-orthogonality" approach provided a decisive rejection of the EH plus Rational Expectations for all maturities, including the shorter ones. Results strongly indicate that risk premium in the yield curve are indeed time-varying, and positively related to the one-year covered interest rate differential and to the volatility of the 12-month interest rate.

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information to the covered interest rate differential. In fact, they are highly correlated (70%).

This may have important implications for the rational expectations macro-modeling currently being developed to evaluate the conduct of monetary policy in Brazil. Current models (Freitas and Muinhos, 2001; Bonomo and Brito, 2001) are calibrated with short-term rates (overnight rates for the former and 3-month rates for the latter), and so far haven't introduced the behavior of the term structure of interest rates[18]. If the Expectation Hypothesis plus Rational Expectations were true, a simple equation would "close" the extended model: changes in the long-term rate are determined solely by changes in rational expectations of future short-term rates. But our results suggest that this is not the case, because a change in risk premium may originate a change in the long-term rate.

Of course, the extension of the current macro-models to incorporate the behavior of the term structure of interest rates is necessary only if economic activity in Brazil really depends more on the long-term rate than on shorter term ones, which is itself a question to be resolved empirically.

If that is the case, and if the macro-modeling is to gain in richness and complexity, there must be some investment in understanding the dynamic behavior of risk premium in the yield curve.

When investigating the behavior of risk premium in the yield curve in Brazil, an important question to be addressed is the impact of public debt management in risk premium. There is international evidence that shifts in the relative supplies of short and long-term public bonds (Agell et al, 1992), or inflation-indexed and non-indexed bonds (Taylor, 1992), have important effects on their yields and returns. Probably this effect is greater in Brazil than in developed economies, given that capital markets for private borrowers are much thinner

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[18]Bonomo and Brito (2001) indicate that this will be a natural extension to their model.

and under-developed, and the public sector borrowing requirements have been more accentuated. Therefore, we believe that the composition of public debt possibly is also a relevant omitted variable in equation (3), just as the proxies for "risk" in the economy.

Finally, when the size of the data sample permits, it will be interesting to check whether there is any significant change in our tests after the introduction of the inflation targeting framework in July 1999.

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