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TESTING THE EXPECTATIONS HYPOTHESIS ON CORPORATE BOND YIELDS

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Abstract: This paper has the purpose of testing the expectations hypothesis of the term structure for two corporate bond yields. A new test is developed based on an ARIMA data generation process of the short rate, and on the derivation of a relation between the change in the long rate and revisions of expectations of future short rates. The paper makes the point that adjustment of the change in the long rate to short rate news does not occur instantaneously but is dynamic over time. For this reason a polynomial distributed lag of the short rate news, which provides support to the expectations hypothesis, is estimated. This is quite remarkable because the liquidity, term, and default risk premiums are left out of the analysis.

JEL Code Classifications: E43, G12, C22.

Keywords: term structure, expectations hypothesis, yield curve, corporate bonds, revisions of expectations, ARIMA model, polynomial distributed lag model.

INTRODUCTION

The term structure of interest rates, also known as the yield curve, is the relation between bond yields and maturity or term. This relation is important for many reasons. If, for example, a person has a horizon of 20 years, then she has more than one investment alternative. One of them is to invest in a bond with a maturity of exactly 20 years. Another is to invest in a money market mutual fund, or any other short term asset, and roll over or renew the investment at each maturity. Yet another is to invest in bonds with a term higher than 20 years and sell these bonds after 20 years. Usually such a pre-established horizon is a characteristic of an investor who is planning for retirement. The shape of the yield curve is also crucial for households that are applying for a real estate mortgage. Should they agree to a fixed rate mortgage or a floating interest rate mortgage? The shape of the yield curve will also determine how a government will finance its budget deficit. Since the yield curve is most often upward sloping, borrowing short term may be a worthwhile decision for a government keen on reducing interest rate costs. In addition the yield curve is watched closely by monetary authorities because they have a hold over the short rates while the economy adjusts in reaction to the long rates. See the discussion in Campbell (1995) on the above issues.

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One of the oldest theories of the 'term structure of interest rates' is the expectations hypothesis. If, at time t, the long corporate rate is rl_t and the short monthly government rate of interest is rs_t, and if one assumes no or a constant default, (iI) liquidity, and maturity risk premiums, then the strong form of the expectations theory of the term structure implies the following relation for a maturity k:

$$1 + {}_k rl_t = [(1 + rs_t)\,(1 + E_t(rs_{t+1}))\,(1 + E_t(rs_{t+2}))...(1 + E_t(rs_{t+k-1}))]^{1/k} \tag{1}$$

where E_t is the expectation operator with the current information set Ω_t. Campbell and Shiller (1991) adjust equation (1) in two ways. In order to present their argument, assume that k = 2, meaning that the long bond has a maturity of 2 years (see also Choi and Wohar, 1991). Equation (1) will become:

$$(1 + {}_2 rl_t)^2 = (1 + rs_t)\,(1 + E_t\,(rs_{t+1})) \tag{2}$$

Equation (2) can be approximated by linearizing, and hence it follows that:

$$2_2\, rl_t = rs_t + E_t\,(rs_{t+1}) \tag{3}$$

Bringing rl_t to the right of the equation, and bringing rs_t to the left, one obtains:

$${}_2rl_t - rs_t = E_t\,(rs_{t+1}) - {}_2\,rl_t \tag{4}$$

Campbell and Shiller (1991) estimate expanded versions of equation (4). In addition if both sides of equation (3) are divided by 2, and rs_t is brought to the left of the equation, then one obtains:

$${}_2rl_t - rs_t = \frac{\left(E_t\left(rs_{t+1}\right) - rs_t\right)}{2} = \frac{E_t\Delta\left(rs_{t+1}\right)}{2} \tag{5}$$

Again Campbell and Shiller (1991) estimate expanded versions of equations (5). Both equations (4) and (5) have the same left-hand side value, which is the maturity premium, also known as the excess premium. When they regress this premium on the right-hand side of equations (4) and (5) separately, Campbell and Shiller (1991)[1] find empirically that the slope on the right-hand side of equation (4) is systematically negative, insignificant statistically, and far away from 1, while the slope on the right-hand side of equations (5) is systematically positive, often significant statistically, and close to 1. They conclude that the first empirical fact rejects the expectations hypothesis while the second empirical fact supports this hypothesis. This has been called the Campbell-Shiller paradox. Thornton (2006) criticizes these tests by pointing to the fact that in equation (4) the variable ${}_2\,rl_t$ appears on both sides of the equation with opposite signs, and this will bias the regression slope to be negative. He points also to the fact that rs_t appears on both sides of equation (5) with the same sign, and this will bias the regression slope to be positive and near 1.

On a different level, if rs_t follows a random walk, then equation (1) will collapse to the following after linearization:

$${}_k\,rl_t = rs_t \text{ or } {}_krl_t - rs_t = 0 \tag{6}$$

Equation (6) has prompted many researchers to test whether the maturity premium is stationary, or, whether ${}_k\,rl_t$ and rs_t are cointegrated (Choi and Wohar, 1991; Hall, Anderson, and

Granger, 1992; Sarno and Thornton, 2003; Thornton, 2004; Mills and Markellos, 2008). Maki (2006) has found a non-linear cointegrating relation between ${}_k rl_t$ and rs_t.

Finally and rather recently a Lagrange multiplier test, which applies in case of stationarity and of non-stationarity of the bond rates, was developed to test the expectations hypothesis (Bekaert and Hodrick, 2001). Bekaert and Hodrick (2001), Thornton (2004), and Sarno, Thornton, and Valente (2007) have used this new test to assess the validity of the expectations hypothesis and have found negative results: the expectations hypothesis is deemed too simple to be true, and more complicated versions should be considered. Sarno, Thornton, and Valente (2007) have also tested multivariate VAR models and have included macroeconomic conditioning variables in the test, but all this to no avail: the constraints implied by the expectations hypothesis are rejected.

In practice since short rates are equally likely to go up and down, the expectations hypothesis predicts that the yield curve is horizontal. This is contrary to the finding that the yield curve is frequently upward sloping (Kritzman, 1993, and Mishkin, 2004). However the expectations hypothesis can explain both upward and downward sloping yield curves depending on the behavior of expected short rates (Mishkin, 2004).

THE THEORY

Taking logs on both sides of equation (1), then, one obtains equation (7):

$$\log\left(1+{}_k rl_t\right)=\frac{\log\left(1+rs_t\right)+\log\left(1+E_t\left(rs_{t+1}\right)\right)+\ldots+\log\left(1+E_t\left(rs_{t+k-1}\right)\right)}{k} \tag{7}$$

Equation (7) can be linearized and simplified as follows:

$${}_k rl_t \approx \frac{rs_t+E_t\left(rs_{t+1}\right)+E_t\left(rs_{t+2}\right)+\ldots+E_t\left(rs_{t+k-1}\right)}{k} \tag{8}$$

Leading equation (8) by one period, taking its difference from equation (8), and noting that $rs_{t+1} = E_{t+1}(rs_{t+1})$, then, with the same maturities k of the corporate yield, one obtains:[2]

$${}_k rl_{t+1}-{}_k rl_t=\Delta\left({}_k rl_{t+1}\right)=\frac{-rs_t+\left[\left(E_{t+1}-E_t\right)\sum_{i=t+1}^{t+k-1}\left(rs_i\right)\right]+E_{t+1}\left(rs_{t+k}\right)}{k} \tag{9}$$

Equation (9) states "that changes in the bond [long] rate should be closely linked not to today's change in the funds [short] rate but to revisions in expectations of the future path of the funds [short] rate" (Poole, 2005, p. 590). If, in addition, the short rate follows the following data generation process, an ARIMA (0, 1, 1):

$$\Delta(rs_t) = \alpha + \beta\varepsilon_{t-1} + \varepsilon_t \tag{10}$$

Then it can be shown that:

$${}_k rl_{t+1}-{}_k rl_t=\Delta\left({}_k rl_{t+1}\right)=\frac{k\varepsilon_{t+1}+\left(k-1\right)\beta\varepsilon_{t+1}+\beta\varepsilon_t}{k} \tag{11}$$

Assuming 30 years as a maturity for the long rate then, and with monthly short rates, k becomes equal to 360. Hence, as $k \to \infty$, equation (11) will converge to:[3]

$$\underset{k\to\infty}{\text{Limit}}\left({}_{k}rl_{t+1} - {}_{k}rl_{t}\right) = \underset{k\to\infty}{\text{Limit}}\left(\Delta\left({}_{k}rl_{t+1}\right)\right) = (1+\beta)\varepsilon_{t+1} \tag{12}$$

Equation (12) predicts that the standard deviation of the first-differences of the long rate is $(1 + \beta)$ multiplied by the standard error of the residual ε from the ARIMA (0, 1, 1) model of the first-differences of the short rate, i.e. the residual from equation (10). In other terms one can define a parameter θ, derived from taking standard deviations on both sides of equation (12) as follows:

$$\theta = \frac{\sigma_{\Delta rl}}{\sigma_{\varepsilon}} \text{ and this ratio must be equal to } (1 + \beta) \tag{13}$$

Equation (13) assumes an instantaneous adjustment of $\Delta(rl)$ upon ε. It will be shown in the following empirical section that equation (13) does not hold. The alternative is a dynamic adjustment, whereby the current value and lagged values of ε have an impact on $\Delta(rl)$. Two formulations of a dynamic adjustment are available in the econometric literature: the geometric lag and the polynomial distributed lag (Gujarati, 2003, pp. 665-696). The geometric lag applies in two cases: an adaptive expectations model of the independent variable, or a stock (partial) adjustment model of the dependent variable. Nonetheless, the second lag model, i.e. the polynomial distributed lag model, is considered econometrically to be superior for four reasons: (1) it does not assume that the coefficients on the lags die out geometrically, (2) the size and sign of the coefficients on the lags is left very flexible, (3) it abstracts from the statistical problem of including the stochastic lagged dependent variable, and (4) the number of estimated coefficients is usually lower (Gujarati 2003, p. 691). Because of this the superior polynomial distributed lag model is used in the empirical part that comes next. This lag model produces results that are consistent with the expectations hypothesis. Therefore one can conclude ahead of time that the expectations hypothesis of corporate yields is supported, especially since two corporate long rates with different default premiums will be tested: the Aaa and the Baa corporate bond yields.

THE EMPIRICAL RESULTS

Monthly data for the 3-month US T-bill rate, for the Baa and for the Aaa corporate bond yields, are taken from the web page of the Federal Reserve Bank of Saint Louis and span the period from January 1945 till July 2008. The KPSS (1992) unit root test is applied on the variables. This test has stationarity as the null hypothesis. This null is rejected for the levels of the T-bill rate, and the levels of the Aaa and Baa corporate bond yields at significance levels less than 1%. Moreover the null is rejected for the spreads of these two bond yields over the T-Bill rate at significance levels less than 1%. The null is not rejected for the first-differences of the T-Bill rate, of the Aaa and of the Baa corporate bond yields at significance levels greater than 10%.[4]

Table 1 provides the descriptive statistics on the Δ(T – Bill), Δ(Baa), and Δ(Aaa) variables, where Δ stands for the first-difference operator. What is remarkable in this table is that the means of the last two series are insignificantly different from zero, a fact that is in conformity with equation (12), since the expected value of ε_{t+1} at time t is zero.

Table 1
Descriptive Statistics on the Change of the Three Variables

	Δ(T – Bill)	Δ(Baa)	Δ(Aaa)
Mean	0.00013667	0.00040467	0.00032592
Standard deviation	0.03494	0.01536	0.01675
Standard error	0.0012657	0.0006676	0.0006067
Actual t-statistic for a zero mean	0.108	0.727	0.537
Maximum	0.2175	0.0958	0.1075
Minimum	-0.3850	-0.0850	-0.0983

All figures are in percentage per month, except the t-statistics.

First a general ARIMA (1, 1, 1) model is fitted on the change in the short rate, the T-Bill rate. This change is stationary as evidenced above. Unfortunately the coefficient on the AR variable turns out to be insignificant statistically. Hence an ARIMA (0, 1, 1) model is selected. The results are as follows, with standard errors in parenthesis:

$$\Delta(rs_{t+1}) = 0.001199 + 0.415163\ \varepsilon_t + \varepsilon_{t+1} \tag{14}$$
$$(0.02000)\ (0.033021)$$

The standard error of the model is 0.390283, which stands for σ_ε. The standard deviations of the change in the Baa and the Aaa yields are 0.18441 and 0.20097 respectively, which stand for $\sigma_{\Delta rl}$. The ratio θ (see equation (13)) is 0.4725 and 0.5149 respectively, both far below the value of 1, and therefore of $1 + \beta$, which is 1.4152. Therefore the assumption of an instantaneous adjustment does not stand.

As argued in the previous section, the alternative is a polynomial distributed lag. The transformed independent variables (Z) for a lag of 3 and a second degree of the polynomial are as follows:

$$\begin{aligned} Z_{0t} &= \varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + \varepsilon_{t-3} \\ Z_{1t} &= \varepsilon_{t-1} + 2\varepsilon_{t-2} + 3\varepsilon_{t-3} \\ Z_{2t} &= \varepsilon_{t-1} + 4\varepsilon_{t-2} + 9\varepsilon_{t-3} \end{aligned} \tag{15}$$

If the estimated coefficients on Z_{0t}, Z_{1t} and Z_{2t} are respectively α_1, α_2, and α_3, then the implied total coefficient on is ε_t is α_1. The implied total coefficient on ε_{t-1} is $\alpha_1 + \alpha_2 + \alpha_3$. The implied total coefficient on ε_{t-2} is $\alpha_1 + 2\alpha_2 + 4\alpha_3$. The implied total coefficient on ε_{t-3} is $\alpha_1 + 3\alpha_2 + 9\alpha_3$. The implied total impact of the current value and all lags of ε is $4\alpha_1 + 6\alpha_2 + 14\alpha_3$.

The changes in the long rate, whether Baa or Aaa, are regressed on the ARIMA (0, 1, 1) residual (ε) of equation (14) with a specified lag structure for ε. Tables 2 and 3 provide the results. Three lag structures are selected: 24, 36, and 48. Since the data is monthly, these three lag structures correspond to 2, 3, and 4 years respectively, and this is the reason for their selection. Four equation polynomials are assumed: 3, 4, 5, and 6. The model is estimated with AR (1) errors. The coefficients on all the AR (1) variables (i.e. ρ in Tables 2 & 3) are statistically significant, thereby providing support for the functional forms of these models.

Table 2
Estimates of an AR (1) Regression of the Change in the Corporate Bond Yield on a Distributed Polynomial Lag of the Residual of the Short Rate (ε) Obtained from an ARIMA (0, 1, 1) Model. The Dependent Variable is Δ(Baa). The Model Assumes a Zero Coefficient after the Coefficient on the Maximum Lag

Degree of the polynomial		Current value and 24 lags	Current value and 36 lags	Current value and 48 lags
	ρ	0.3720	0.3775	0.3764
	(standard error)	(0.0343)	(0.0345)	(0.0348)
3	Sum of lag coefficients	0.9623	1.311	1.692
	(standard error)	(0.1248)	(0.1664)	(0.2115)
	Adjusted R^2	0.353	0.3438	0.3384
	Loglikelihood	351.532	334.623	320.362
	t-test	3.508	0.018	-1.293
	ρ	0.3538	0.3657	0.3678
	(standard error)	(0.0346)	(0.0347)	(0.0349)
4	Sum of lag coefficients	0.8647	1.106	1.427
	(standard error)	(0.1219)	(0.1689)	(0.2170)
	Adjusted R^2	0.3692	0.3572	0.3508
	Loglikelihood	361.666	343.134	328.112
	t-test	4.359	1.796	-0.054
	ρ	0.3421	0.3368	0.3511
	(standard error)	(0.0348)	(0.0351)	(0.0352)
5	Sum of lag coefficients	0.8928	1.157	1.492
	(standard error)	(0.1198)	(0.1596)	(0.2094)
	Adjusted R^2	0.3743	0.3776	0.3669
	Loglikelihood	365.272	355.819	337.98
	t-test	4.204	1.584	-0.362
	ρ	0.3416	0.3324	0.3284
	(standard error)	(0.0348)	(0.0352)	(0.0356)
6	Sum of lag coefficients	0.8802	1.156	1.389
	(standard error)	(0.1206)	(0.1584)	(0.2019)
	Adjusted R^2	0.3742	0.3793	0.3801
	Loglikelihood	365.695	357.292	346.339
	t-test	4.278	1.602	0.128

Notes: ρ is the partial autocorrelation coefficient of the AR (1) regression. The sum of lag coefficients is the sum of the coefficients on the current value and all lags of the polynomial distributed lag model. The t-test is a hypothesis test where the null is that the difference between the sum of the lag coefficients and (1 + β) is zero. β is the coefficient on the MA (1) component of the ARIMA (0, 1, 1) model of the short rate.

From Tables 2 and 3 it is inferred that, with 48 lags, the sums of the coefficients on the current value and the 48 polynomial distributed lags are always statistically insignificantly different from the value (1 + β) as required by equation (12).[5] These results stand whatever the degree of the

Table 3
Estimates of an AR (1) Regression of the Change in the Corporate Bond Yield on a Distributed Polynomial Lag of the Residual of the Short Rate (ε) Obtained from an ARIMA (0, 1, 1) model. The Dependent Variable is Δ(Aaa). The Model Assumes a Zero Coefficient after the Coefficient on the Maximum Lag

Degree of the polynomial		Current value and 24 lags	Current value and 36 lags	Current value and 48 lags
	ρ	0.3190	0.3176	0.3196
	(standard error)	(0.0349)	(0.0353)	(0.0355)
3	Sum of lag coefficients	0.8214	1.142	1.509
	(standard error)	(0.1308)	(0.1734)	(0.2227)
	Adjusted R^2	0.3088	0.2924	0.2783
	Loglikelihood	262.047	243.355	226.413
	t-test	4.401	1.548	-0.417
	ρ	0.2997	0.3126	0.3129
	(standard error)	(0.0352)	(0.0353)	(0.0356)
4	Sum of lag coefficients	0.6962	0.9067	1.181
	(standard error)	(0.1269)	(0.1769)	(0.2272)
	Adjusted R^2	0.3336	0.3115	0.2998
	Loglikelihood	276.871	254.248	238.047
	t-test	5.483	2.825	1.02
	ρ	0.2798	0.2842	0.3002
	(standard error)	(0.0355)	(0.0357)	(0.0358)
5	Sum of lag coefficients	0.7606	0.9832	1.272
	(standard error)	(0.1219)	(0.1659)	(0.2197)
	Adjusted R^2	0.3573	0.3478	0.3252
	Loglikelihood	291.358	275.248	252.171
	t-test	5.183	2.554	0.644
	ρ	0.2678	0.2749	0.2834
	(standard error)	(0.0356)	(0.0358)	(0.0360)
6	Sum of lag coefficients	0.7069	0.9786	1.145
	(standard error)	(0.1198)	(0.1624)	(0.2132)
	Adjusted R^2	0.3691	0.3589	0.3443
	Loglikelihood	298.886	282.322	263.577
	t-test	5.700	2.634	1.252

Notes: ρ is the partial autocorrelation coefficient of the AR (1) regression. The sum of lag coefficients is the sum of the coefficients on the current value and all lags of the polynomial distributed lag model. The t-test is a hypothesis test where the null is that the difference between the sum of the lag coefficients and $(1 + \beta)$ is zero. β is the coefficient on the MA (1) component of the ARIMA (0, 1, 1) model of the short rate.

polynomial and for both the Baa and the Aaa corporate bond yields. The test assumes that the estimate of β from equation (14) is independent from the estimates of the sum of the coefficients on the lags from the distributed lag model, an assumption which is reasonable. Hence it can be concluded that the expectations hypothesis is supported because equation (12) is satisfied.

It might be useful to implement log likelihood ratio tests between the three lag models for a given degree of the polynomial. Unfortunately these hypotheses are not nested. If they were nested the log likelihood of the model with more lags should be at least equal to the log likelihood of the one with less lags, because the model with more lags is the unrestricted model. This turns out not to be true (see Tables 2 & 3). The only conclusion that can be drawn is that the expectations hypothesis is supported with a 48-lag model whatever the degree of the polynomial, because the calculated t-statistics are all insignificant statistically. These t-statistics test whether the sum of the coefficients in the polynomial distributed lag regression is equal to 1 plus the value of the estimated from the ARIMA (0, 1, 1) model of the change in the T-Bill rate (equation 14).

Other likelihood ratio tests are conducted to find out the degree of the polynomial functional form that is statistically the best. See Tables 4 and 5. For each corporate yield there are 18 such joint tests. In what concerns the Baa corporate bond yield, the fifth polynomial degree is supported for the 24-lag model. The fifth polynomial degree is supported for the 36-lag model. But the sixth polynomial is supported for the 48-lag model (Table 4).

In what concerns the Aaa corporate bond yield, the sixth polynomial degree is always statistically the best and this is true for all lag models and for all degrees of the polynomial (Table 5).

Table 4
Probabilities of the Likelihood Ratio Tests for Comparing the Degree of the Polynomial. A Low Probability Indicates that the Model with the Higher Polynomial Degree is Statistically more Significant. Regressions are for Δ(Baa)

24-lag model

Polynomial	3	4	5	6
3		< 0.0001	< 0.0001	< 0.0001
4			0.0072	0.0178
5				0.3577
6				

36-lag model

Polynomial	3	4	5	6
3		< 0.0001	< 0.0001	< 0.0001
4			< 0.0001	< 0.0001
5				0.0861
6				

48-lag model

Polynomial	3	4	5	6
3		0.0001	< 0.0001	< 0.0001
4			< 0.0001	< 0.0001
5				< 0.0001
6				

Table 5
Probabilities of the Likelihood Ratio Tests for Comparing the Degree of the Polynomial. A Low Probability Indicates that the Model with the Higher Polynomial Degree is Statistically More Significant. Regressions are for Δ(Aaa)

24-lag model

Polynomial	3	4	5	6
3		< 0.0001	< 0.0001	< 0.0001
4			< 0.0001	< 0.0001
5				0.0001
6				

36-lag model

Polynomial	3	4	5	6
3		< 0.0001	< 0.0001	< 0.0001
4			< 0.0001	< 0.0001
5				0.0002
6				

48-lag model

Polynomial	3	4	5	6
3		< 0.0001	< 0.0001	< 0.0001
4			< 0.0001	< 0.0001
5				< 0.0001
6				

CONCLUSION

This paper tested the expectations hypothesis on two corporate bond yields, the Baa and the Aaa. In the theoretical background a model is developed whereby the change in the corporate bond yield is related to revisions of expectations of the future short rate (the T-bill rate). This short rate is found to follow an ARIMA (0, 1, 1) data generation process. The theoretical impact is found to be 1.415. It is shown that this is inconsistent with instantaneous adjustment of the corporate rate. The alternative is a dynamic adjustment. With such an adjustment the actual impact is found to be insignificantly different from the theoretical impact when a 48-lag model is estimated whatever the degree of the polynomial. The conclusion is that the expectations hypothesis is supported, contrary to the empirical evidence elsewhere in the literature. This is remarkable because the corporate bond yields include not only a term premium, but also (il)liquidity and default premiums, and the latter are not modeled in this paper, or at least are assumed implicitly to be time-invariant.

The implication of the expectations hypothesis is that, for a given time horizon, there is no difference between investing in short term securities and renewing the investment, and investing in long-term securities. Both investments have the same expected return. Individuals planning for retirement ought to be indifferent about choosing short or long term investments. Individuals intending to buy a house ought to be indifferent about choosing fixed or floating rate mortgages. The government ought to be indifferent about borrowing short or long. Monetary authorities need not monitor long-term rates even if they have control over only short rates.

If the long rate is higher than the short rate, this does not mean that long term securities are more appealing, but it means that short rates are expected to rise, and vice versa. Finally since the long rate is a geometric average of the short rates, this implies that the long rate is less variable than the short rate. Table 1 provides evidence about the latter by looking at the standard deviations: the standard deviation of the change in the T-bill rate is more than twice that on either the change in the rate or the change in the rate.

Future work should unravel whether the methodology applied in this note can be generalized to other fixed-income securities.

Notes

1. See also Campbell, Lo, and MacKinlay (1997).
2. See similar computations in the literature on the permanent income hypothesis: Flavin (1981), Campbell and Deaton (1989), and Bagliano and Bertola (2004).
3. Campbell and Shiller (1987) assume also an infinite horizon with their present-value model.
4. The details of the unit root tests are available from the author.
5. The raw data ${}_{k}rl_{t+1} - {}_{k}rl_{t}$, which is the change in the corporate bond yield, looks like a sample that has an average that is statistically insignificantly different from zero (see Table 1 which provides descriptive statistics). This means that the raw data for the two corporate bond yields is consistent with equation (12) where the expectation of the residual is zero. Therefore the change in the two corporate bond yields converges to zero as the theory predicts.

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