E C O N O M I C S   B U L L E T I N

The expectations hypothesis of the term structure in the Euro area:

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Abstract

This paper tries to ascertain whether the expectations hypothesis of the term structure of interest rates was fulfilled for the EMU countries in the period previous to its launching. To this end, we employ individual country data for the Euro area. Using pooled and panel cointegration techniques we conclude that there is an equilibrium relationship linking the long and the short-run interest rates for both the individual countries and the panel as a whole. Due to the homogeneity found in the short-long term interest rates relationship across countries, the fears raised about the use of area-wide aggregates by the ECB if not discarded need to be, at least, qualified.

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1 Introduction

The role of the term structure, either as an intermediate target or as indicator of policy stance has been already analyzed in the European case using mainly aggregate variables[1]. Berk and Bergeijk (2000), for example, discuss the role of the yield curve as an information variable for the Eurosystem, whereas Estrella and Mishkin (1997) conclude that the spread is a useful piece of information for inflation and output forecasting in Europe and that the term structure has a role in the European monetary policy. However, empirical evidence using individual country data for the Euro area is more scarce. Angeloni et al. (2002) suggest that the area-wide evidence should be complemented with an assessment build up from the country level. This point has also been recently stressed by De Grauwe and Sénégas (2006).

In this paper we use individual country data for the Euro area to gain insight on the feasibility of using effectively the term structure either as a transmission channel of monetary policy or as an information variable of monetary conditions.

More specifically, we contribute to previous empirical literature in various respects: first, we specify and test a relationship linking long and short-run interest rates using national pre-EMU country data in a panel including all the Euro area members[2]; second, using this specification we can analyze the long-run relationship pooling country-specific data (Pool Mean Group Estimators) and using individual country data (cointegration panel techniques); third, the econometric techniques allow us to test for homogeneity restrictions on the long-run parameters.

The remainder of the paper is organized as follows. We first present, in section 2, the testing framework based on the expectations hypothesis (EH hereafter) of the term structure of interest rates. In section 3 we study the relationship between long and short-run interest rates in the Euro-area countries for the period spanning from approximately the creation of the European Monetary System (EMS henceforth) up to the launching of the EMU, that is, 1980:1-1998:4. Conclusions are reported in a final section.

2 Theoretical background and testing framework

The term structure reflects market expectations about future economic conditions. According to Estrella and Miskin (1997), the term structure spread is also an indicator of the stance of monetary policy. In particular, a low spread reflects relatively restricted monetary policy because the spread is low when short-term interest rates are high relative to long term interest rates. At the same time, the term structure spread can play an important role as a leading indicator of real activity and inflation.

The most commonly accepted explanation for the link between interest rates with different maturities is given by the expectations hypothesis of the term structure. According to this hypothesis, long rates are mainly determined by expectations about future short-term rates and, therefore, the slope of the term structure contains information about future short-term interest rates.

As Kozicki and Tinsley (1998) point out, this characterization of the term structure lies on three assumptions. First, there exists a short-run interest rate, such as the EONIA in the Euro-area, which correctly reflects the monetary policy impulses coming from the central bank. This implies in turn that the short-term interest rate is under the central bank control. Second, according to the expectations hypothesis of the term structure, current and expected movements in the policy-controlled short-run interest rates are the main determinants of the term structure of bond rates. Finally, monetary policy affects the real economy since the long-run interest rates reflect the opportunity cost of investment and consumption.

Although modern monetary instruments tend to assure that monetary policy can readily influence short-term rates, long-term rates are generally market-driven and do not react hastily to everyday policy actions. Therefore the transmission mechanism from monetary policy actions to real economic activity will depend on the relation between short and long-term interest rates. This crucial link seems not at all as close as the expectations theory predicts. Therefore, in this paper, we are interested in the fulfillment of this condition implied by the EH. Our main contribution consists of testing for this relationship in a cointegration framework for a panel of the EMU countries. This allows us to compare the behavior of the individual countries and to test for homogeneity conditions.

The EH relates the yield on longer-term financial instruments to expected future yields on short term instruments. Following Campbell and Shiller (1987), we can write the present value model in the case of pure discount bonds as:

$$R_t = (1-\delta)\sum_{i=0}^{\infty}\delta^i E_t r_{t+i} + c \tag{1}$$

where δ is the discount factor, R_t and r_t are the long-term and short-term interest rates respectively, $E_t r_{t+i}$ is the expected value of the short-term interest rate i periods ahead and c is a term premium. Expression (1) equates long-term yields to an average of expected future short-term yields plus a risk premium. This means that market participants expect short-term rates to average in the future and, as time elapses (for i sufficiently large), this may smooth cyclical variations. According to this theory, as long-term rates reflect average short rates over a relatively long time interval, long-term interest rates may act as a benchmark for short-term yields comparison.

A review of the empirical evidence on the expectations hypothesis will show immediately that it is far from being conclusive. For the United States Mankiw and Summers (1984), among others[3] rejected the EH. In contrast, Hall, Anderson and Granger (1992) got favorable evidence on the EH. For the European countries the empirical evidence is also mixed and somewhat country-specific[4].

In sum, the empirical evidence points mainly to the rejection of the EH when using single equation methodologies. However, those authors that have formulated a bi-variate VAR system have frequently obtained more encouraging results.

In this paper, our starting point is the seminal work by Campbell and Shiller (1987) and adopt the linearized expectations model of Shiller (1979) in a panel context. In our case, the information set is also expanded through the cross-section dimension. Accounting for the cross-section dimension is especially important for a group of countries that are members of a regionally integrated area and have finally taken part in a monetary union.

Equation (1) can be formulated in terms of the spread as:

$$S_t = R_t - r_t \tag{2}$$

Substracting r_t from both sides of (1) and rearranging we obtain:

$$S_t = E_t S_t^* + c \tag{3}$$

where:

$$S_t^* = \sum_{i=1}^{\infty} \delta^i \Delta r_{t+i} \tag{4}$$

Equation (4) shows that a necessary condition for the EH to hold puts constrains on the long-run dynamics of the spread. If interest rates in levels are $I(1)$ variables, it is shown in equation (2) that the spread is a linear combination of non-stationary variables. In addition, according to equation (4) the spread is a weighted sum of stationarity variables and, therefore, stationary. Obviously, stationarity of the spread implies that, if yields are non-stationary, they should be cointegrated with a cointegrating vector $[1, -1]$. Although we will analyze both the panel and the country results, in this paper we focus on the specific group of countries rather than on the individual fulfillment of the EH. Thus, our main interest is the long-run relationship between short and long rates, due to its implications for monetary integration.

Therefore, using cointegration tests and estimation techniques applied to panel data, we assess the long-run relationship between short and long-term interest rates, that is, whether the EH holds for the EMU countries[5]. We also test for the stationarity of the spread and, finally, we explicitly test for cross country homogeneity in the long-run relationship linking the two variables.

3 Cointegration analysis of the term structure of interest rates in the Euro area. Pooled and panel analysis

In this section we analyze the existence of a cointegration relationship between short and long-run interest rates. Two complementary econometric approaches are applied. First, the Pooled Mean Group Estimators technique by Pesaran et al. (1999) and, secondly, the cointegration tests derived for panels. We study whether the spread holds for each individual country, and compare the results obtained both for homogeneous and heterogenous[6]panel estimators.

The data are quarterly observations covering the period 1980:1 to 1998:4, that is, from the beginning of the EMS up to the launching of the EMU. The source is the *International Financial Statistics* of the International Monetary Fund, and the variables are the call money rate (r_t) and the ten-year bond rate (R_t), as in Estrella and Mishkin (1997).

The analysis is carried out using a panel approach that is compatible with the hypothesis of cointegration. We first test the specification of the panel using the Pooled Mean Group Estimators by Pesaran et al. (1999), that is, whether the hypothesis of homogeneous slope parameters can be accepted for all the countries.

If the homogeneity hypothesis is accepted, the PMG estimator provides an efficiency gain compared with alternative techniques. As a complement, both homogeneous and heterogeneous panels are estimated to test whether the interest rate spread is a valid stationary relationship for both individual countries and the area as a whole. The comparison of the slope coefficients will allow us to gain further insight on the existence of similarities among the Euro area countries in the interest rate channel as a transmission mechanism of monetary policy.

In what follows, we first study the order of integration of the panel variables and then the long-run links between the two interest rates. Next, once we have found evidence in favor of cointegration, we assess the stationarity of the spread.

3.1 Order of integration of the variables

In this subsection, and previous to the analysis of long-run relationships, we present the results obtained from the analysis of the order of integration of the variables using panel unit root tests. We have applied the LM test for the null of stationarity proposed by Hadri (2000) with heterogeneous and serially correlated errors.

We present the unit root test results for the null of stationarity in table 1. We use the two statistics proposed by Hadri (2000), that are the panel equivalents to the Kwiatkowski et al. (1992) statistics for the time series case: the statistic Z_μ tests for the null of level stationarity, whereas Z_τ tests the null of trend stationarity against nonstationary alternatives. The two statistics proposed by Hadri (2000) are distributed as $N(0,1)$[7].

In table 1 the statistics computed for R_t and r_t are very significant for both model specifications, so that the null hypothesis of stationarity can be easily rejected.

As a conclusion, the panel unit root tests support the non-stationarity of the variables analyzed.

3.2 Pooled Mean Group estimation of dynamic panels.

The Pooled Mean Group (PMG hereafter) estimator proposed by Pesaran et al. (1999) combines two procedures that are commonly used in panels: pooling and averaging. This technique especially suited for panels involving groups of countries, such as the Euro-area. Using the PMG estimator we obtain panel error correction models where the intercepts, short-run coefficients and error variances are allowed to differ freely across cross-section elements, while the long-run coefficients are, in general, constrained to be the same. An interesting feature of this methodology is that the homogeneity of the long-run parameters can be tested using LR-type tests. If homogeneity is rejected, the estimation methods allows for them to differ.

In this case, we estimate the relationship linking long and short interest rates. The implied long-run relationship is the following:

$$R_{it} = \alpha_i + \beta_{1i} r_{it} + \varepsilon_{it} \tag{5}$$

The results obtained from the estimation of the above specification are presented in table 2. In order to apply this methodology, the first step consists of estimating the error correction form of the panel that includes the ten countries analyzed ($N = 10$). To do this, the lags of the variables (that are set equal to two) have been selected using the AIC criterion. Next, the homogeneity of the long-run coefficients is accepted using the LR-test (the p-value is 0.25), as it is shown in the second row of table 2. Therefore, the coefficient of the short-run interest rate is accepted to be equal for all the elements of the panel. Finally, the individual equation residuals pass the specification tests [8].

The estimated coefficients are also shown in table 2 together with their Student's t. Both are very significant: the short-run interest rate estimate is 0.654, whereas the error correction parameter has a reasonable magnitude, with a t-value of -4.98. The error correction term can be used as a cointegration test. In a panel context, according to Pesaran et al. (1999), the cointegration test based on the error correction parameter, as described by Banerjee et al. (1998) follows the normal distribution. However, as the panel dimension in our case is not very large ($N = 10$), we can use the critical values tabulated in Ericsson and MacKinnon (2002) that were computed for the time series test. According to these critical values (-3.43 and -2.86 at 1% and 5% significance levels, respectively) , we can reject the null hypothesis of non-cointegration for the PMG estimates.

In order to complement these results, we are going to analyze the hypothesis of cointegration in a panel setting.

3.3 Panel cointegration test results: homogeneous panel.

In this section we will first apply the panel cointegration tests and estimation procedures for homogeneous panels to the relationship linking long and short-run interest rates. In this framework, that means that we allow for fixed specific effects for each country but restrict the slope coefficients to be equal for all the members of the panel. Kao (1999) proposed DF-type panel non-cointegration tests based on the OLS residuals from the homogeneous panel regression.

The DF test from Kao (1999) follows the model:

$$R_{it} = \alpha_i + \beta r_{it} + e_{it}, \qquad i = 1, ..., N, \quad t = 1, ..., T \tag{6}$$

where both R_{it} and r_{it} are random walks. Thus, under the null hypothesis of non cointegration, the residual series e_{it} should be non-stationary. The limiting distributions are asymptotically normal at mean zero. Kao proposes four Dickey-Fuller (DF) tests[9], as well as the augmented version (ADF) of the test.

We present in table 3 the results of the different tests[10]. According to them, we can reject the null hypothesis of no cointegration with the five tests, as the statistics are normally distributed.

The parameters obtained from the bias-adjusted OLS and $DOLS$ estimation are also shown in table 3. In the two cases, the coefficient for the short-term interest rate is highly significant and of the correct sign. However, there are some differences in the magnitude of the parameters, being the one corresponding to the $DOLS$ procedure 0.75 versus 0.67 from the adjusted OLS. We should note that the PMG

estimate of the parameter was also very close to these values (as the estimated coefficient was 0.65), although the Dynamic *OLS* estimation resulted in a better fit.

3.4 Panel cointegration tests: heterogeneous panel.

In this section, the parameters are allowed to differ across the cross-sections, so that we will analyze the so-called heterogeneous panel. Two types of tests are presented, with different null hypotheses. First, we compute the *ADF* test proposed by Kao (1999) for both the individual members of the panel and the whole panel. The second is a *LM* test that has cointegration as the null hypothesis.

Kao (1999) *ADF* test for varying slopes and intercepts, is based on the following model:

$$R_{it} = \alpha_i + r_{it}^{'}\beta_i + e_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T \tag{7}$$

Here, each cross-section is estimated individually and the pooling from the panel is done in the final step where the panel test statistic is based on the average of the individual cross-section statistics. Thus, each cross-section is allowed its individual cointegrating vector. The cross-sections are then assumed independent of each other although heteroskedasticity across the cross-sections is allowed. The null hypothesis, based on the DF test applied to the error term, is written as $H_0 : \rho_i = 0$ and the t-statistic for each i is called t_{iADF}. In addition, McCoskey and Kao (1998) propose a residual-based panel test of the null hypothesis of cointegration, also called *panel LM* test.

Table 4 shows the results of the panel cointegration tests for heterogeneous panels, as well as the individual and panel *LM* and *ADF* tests results based on the *DOLS* estimates for heterogeneous panels with two leads and lags, as in the PMG estimator. According to the *individual LM* tests, the null hypothesis of cointegration cannot be rejected for the majority of the countries (the exceptions being Finland and France at 10% levels). Moreover, the *LM panel test* (-0.50) does not allow us to reject the null of cointegration at 5% (the critical value being 1.6449).

The *ADF individual tests* for the null hypothesis of non-cointegration are presented in the third column of table 4. In this case, the null is rejected for all the countries in the sample, in the majority of the cases at 1% level of significance. Concerning the *ADF panel test*, the null can be also rejected at 1% level, finding, according to this test, strong evidence of cointegration.

Therefore, once the existence of cointegration has been assessed, both for the individual countries and the panel, we concentrate on the parameter estimates. The *DOLS* parameter estimates for a model with two leads and two lags are shown in table 4, together with the $t-values$ in parentheses. It should be emphasized that this estimation method corrects for endogeneity and autocorrelation using parametric methods[11]. In table 4, the significant coefficients appear in bold. From the results, it should be stressed, first, that both the intercept and the slope parameter are significant in all the equations. In addition, the magnitude of these coefficients differs only slightly among the countries in the sample: the constant terms are included in the interval (1.513, 2.607), whereas the largest value of the short-term interest rate parameter is 0.874 (in the case of Belgium) and the smallest is 0.761

(Ireland).

The cross-country similarity of the coefficients confirm the results obtained in the homogeneous panel case, where the *DOLS* parameter was 0.75, showing that the restriction of common slopes does not seem to be too binding. Moreover, this evidence is also compatible with the results obtained in subsection 3.2 above using Pool Mean Group estimators. As an additional formal test for homogeneity, a Wald-test of the homogeneity restriction can be applied to the panel. This test is distributed as a $\chi^2(10)$, where N=10 is the dimension of the panel (that is, the number of cross-section elements). In this case, its value is 16.89, so that the null can be accepted (with a critical value of 16.92 at 5%)[12]

Accordingly, this supports the similarity of the slope of the term structure for each individual country to the one obtained for the whole area, which we identified as the restriction of common slope. As an additional test, we can apply the Hadri (2000) Z_μ test (level stationarity) to the variable $spread_t$, that is the difference between the long and the short run interest rates for every country in the panel. Thus, we are imposing that the two rates are cointegrated with a $[1, -1]$ vector. The result is presented in the lower row of table 1, where the null hypothesis of stationarity cannot be rejected at 5%.

4 Conclusions

In this paper we add some new evidence to the debate on the adequacy of using country-specific instead of area-wide information in the formulation of the Euro area monetary policy. More specifically, we use country pre-EMU data for the Euro area to gain insight on the fulfillment of the expectations hypothesis of the term structure. The econometric methodology is based on two panel estimation techniques to analyze the existence of long-run relationships: the Pool Mean Group Estimators, and the homogeneous and heterogeneous Dynamic OLS (DOLS) panel cointegration tests and estimates.

We contribute to previous empirical literature in various respects: first, we specify and test a relationship linking long and short-run interest rates using national pre-EMU country data in a panel including all the Euro area members; second, using this specification we can analyze the long-run relationship pooling country-specific data and using individual country data in a panel; third, the econometric techniques allow us to test for homogeneity restrictions on the long-run parameters.

Several conclusions can be drawn from the empirical results. First, the EH of the term structure seems to be a valid relationship both for each country individually considered and for the system as a whole. Second, the slope of the term structure for each individual country is fairly similar across countries. The cross-country homogeneity of the long-run relationships between short and long-term interest rates is of special importance, as many other alternative macroeconomic indicators that could be used by the ECB to monitor monetary policy are unlikely to be as homogeneous. In addition, due to the homogeneity found in the short-long term interest rates relationship, the fears raised about the use of area-wide aggregates by the ECB if not discarded need to be, at least, qualified.

Notes

[1]See Angeloni et al. (2002) for an overview of the recent empirical literature for the euro area, either based on aggregate data or on individual country data.

[2]With the exception of Greece (due to data unavailability) and Luxembourg, whose data is included in those of Belgium.

[3]See Shiller (1979), Shiller, Campbell and Schoenholtz (1983) and Campbell and Shiller (1991).

[4]See Camarero and Tamarit (2002).

[5]We are aware of the fact that the necessary and sufficient conditions for the validity of the EH also impose restrictions on the short-run dynamics. The latter can be tested individually for each country in the sample in a bi-variate stationary VAR in first differences, that is well beyond the scope of this paper.

[6]Different slope parameters across the members of the panel.

[7]It should be stressed that these tests are, according to Hadri (2000), very adequate for series highly dependent over time with large T (the time dimension) and moderate N (the number of cross-sections).

[8]This information has been omitted from the table but is available upon request

[9]Kao constructs statistics whose limiting distributions are $N(0,1)$ and do not depend on the nuisance parameters, that are called DF_{ρ}^{*} and DF_{t}^{*}. Alternatively, he defines a bias-corrected serial correlation coefficient estimate and, consequently, the bias-corrected test statistics and calls them DF_{ρ} and DF_{t}. According to Baltagi and Kao (2000), the main difference between the two groups of tests is that whereas the DF_{ρ} and DF_{t} tests are based on the strong exogeneity of the regressors and errors, the DF_{ρ}^{*} and DF_{t}^{*} are more adequate for cointegration with endogenous relationships between regressors and errors.

[10]The program NPT 1.3. by Chiang and Kao (2002) has been used to compute both the homogeneous tests and estimates, whereas the codes to compute the heterogeneous tests and estimates have been kindly provided by McCoskey and Kao.

[11]According to McCoskey and Kao (1998), the dynamic OLS estimators have better asymptotic properties than the fully modified and OLS estimators.

[12]See (2000) for a description of hypothesis testing in panel data cointegration regressions.

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Table 1: Hadri (2000) stationary panel tests

Variables	Z_μ	Z_τ
R_{it}	8.92*	172.70*
r_{it}	8.36*	169.26*
$spread_{it}$	1.83	—

Note: The statistic Z_μ does not include a time trend, whereas Z_τ does, and are normally distributed. An asterisk denotes rejection of the null hypothesis of stationarity. The number of lags selected is $l = 8$.

Table 2: Pesaran, Shin and Smith (1999) PMG estimation (N=10).

Specified model:		
Model: $R_{it} = \alpha_i + \beta_{1t} r_{it} + \varepsilon_{it}$		
Homogeneity test: LR test		
$r_t(=\forall)$	$\chi^2(9) = 11.31\,[0.25]^{**}$	
AIC	-1421.05	
SBC	-1447.02	
PMG estimation results		
Variables	$short_t$	0.654
		(6.58)
	ecm_{t-1}	-0.088
		(-4.98)

Note:
(a) The model has been specified with two lags
(b)p-values in brackets and t-Students in parentheses.
(c) $= \forall$ stands for homogeneity of the long-run parameters

Table 3: Homogeneous panel cointegration tests.

Kao (1999) DF and ADF tests

	Test	p-value
DF_ρ	-16.81^{**}	0.000
DF_t	2.17^{**}	0.015
DF_ρ^*	-30.76^{**}	0.000
DF_t^*	-5.67^{**}	0.000
$ADF(1)$	-5.29^{**}	0.000

Adjusted OLS and DOLS estimates.

Variable	Adjusted OLS	DOLS (2,2)
r_{it}	0.6767	0.7512
	(33.08)	(34.54)
R^2	0.69	0.86
$\bar{R}^2$	0.69	0.70

(a) The two asterisks denote rejection of the null hypothesis of non-cointegration at 5%. The tests statistics are distributed as $N(0,1)$.
(b) For the OLS and DOLS estimates, t-statistic in parentheses. The DOLS estimate corresponds to a model with two leads and two lags. Dependent variable: R_{it}.

Table 4: Heterogeneous panel cointegration tests.

MODEL: $R_{it} = \alpha_i + \beta_{1t} r_{it} + \varepsilon_{it}$

LM and ADF cointegration tests.

Countries	**LM test**	**ADF test**
Germany	0.04043	-5.22^{**}
Austria	0.03246	-6.495^{***}
Spain	0.04904	-6.34^{***}
Finland	0.30504^{*}	-5.12^{**}
France	0.25776^{*}	-5.05^{**}
Netherlands	0.03293	-5.58^{***}
Italy	0.08688	-6.27^{***}
Belgium	0.04395	-5.16^{**}
Portugal	0.05164	-5.42^{***}
Ireland	0.05164	-7.19^{***}
Panel Tests	-0.50	-13.12^{***}

DOLS cointegration estimates.

Countries	**intercept**	r_i
Germany	**2.525**	**0.769**
	(3.92)	(12.26)
Austria	**2.342**	**0.784**
	(3.73)	(12.83)
Spain	**2.43**	**0.774**
	(4.05)	(3.84)
Finland	**2.066**	**0.802**
	(2.51)	(10.02)
France	**2.236**	**0.780**
	(2.63)	(9.47)
Netherlands	**2.083**	**0.829**
	(3.31)	(13.15)
Italy	**2.221**	**0.816**
	(3.16)	(11.45)
Belgium	**1.513**	**0.874**
	(2.13)	(12.33)
Portugal	**1.999**	**0.834**
	(3.46)	(14.46)
Ireland	**2.607**	**0.761**
	(4.17)	(12.43)

Note:
(a) The lags orders of the ADF tests are 1, whereas the DOLS estimates are obtained form a model with two leads and two lags.
(b) The tests and the models have been estimated using COINT 2.0. in GAUSS 3.0.
(c) The critical values at 1% (***), 5% (**) and 10% (*) for the LM test are 0.5497, 0.3202 and 0.2335 respectively for the case of one regressor (Harris and Inder, 1994).
(d) The critical values at 1% (***), 5% (**) and 10% (*) for the ADF test are -5.3587, -4.7423 and -4.4625 respectively from Phillips and Ouliaris (1990).
(e) For the DOLS estimates t-Students are reported in parentheses. Significant coefficients in bold.