INTEREST RATE LINKAGES IN EMU COUNTRIES: A ROLLING THRESHOLD VECTOR ERROR-CORRECTION APPROACH

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Abstract

This paper revisits financial market integration in the European Economic and Monetary Union, using a threshold vector error-correction model (TVECM) for a fixed rolling window. This approach enables us to analyze the dynamics of transaction costs and detect any co-movements with (policy induced) changes in the financial environment. The TVECM methodology is applied on interest rates from different financial markets (government bonds, deposits, loans and mortgages) in Germany, France, Italy, Belgium and the Netherlands for the 1980-2006 period. Our main finding is that only for some country pairs and financial market segments there is evidence in support of financial integration.

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Keywords: interest rate linkages, financial integration, EMU, threshold vector error-correction.

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1 Introduction

The integration of European financial markets has been on the research agenda since the launch of the European Monetary System (henceforth, EMS) in 1979.[1] Financial integration has important economic benefits: it leads to greater opportunities for risk sharing and consumption smoothing (Cochrane 1991; Townsend 1994), improved capital allocation and potential for higher economic growth (Levine 1997) and, last but not least, to a more efficient conduct of a common monetary policy and symmetric transmission of monetary policy shocks across countries in the currency union (Suardi 2001).

According to the definition by Baele et al. (2004), financial markets are considered to be integrated if for a given set of financial instruments all potential market participants with the same relevant characteristics: (a) face a single set of rules in dealing with the financial instruments; (b) have equal access to the mentioned set of financial instruments; and (c) are treated equally when they are active in the market. Baele et al. (2004) discuss various approaches for measuring integration of financial markets. One approach is to use quantity-based indicators, which measure cross-border activity and assume that the more frequently cross-border capital flows take place, the more integrated the markets are. The major limitation of this approach is that the absence of cross-border activity can itself be interpreted as a signal that market integration has already been achieved.

Price-based indicators do not suffer from this problem of interpretability. These indicators are based on the Law of One Price (LOOP) according to which financial instruments with similar risk and cash-flow characteristics should be priced similarly in different countries. However, this approach is not flawless too, since it requires the availability of data on financial instruments with similar characteristics. The presence of non-homogenous financial instruments complicates the interpretation of non-convergence as evidence of absence of financial integration.

Intuitively, one could argue that even if interest rates across markets do not converge, the markets may still be integrated if they respond to common factors in a similar

[1] The literature on the financial integration process in Europe is extensively discussed in recent papers by Adam et al. (2002), Zhou (2003), Baele et al. (2004), and Sander and Kleimeier (2004).

way. This leads to the concept of news-based indicators, which call for application of cointegration analysis to investigate long-run co-movements in interest rates. However, this approach allows for the possibility of integrated financial markets with interest rates drifting apart in the long-run equilibrium, which is difficult to justify from the market integration point of view.

Our approach is to combine the positive characteristics of price-based and news-based indicators into a more tractable measure. In particular, we acknowledge the possibility of thresholds in the behavior of interest rate co-movements across countries. The rationale for the existence of such thresholds is the presence of transaction costs in arbitrage, differences in legal frameworks and tax codes, asymmetric information issues, exchange rate risks etc. On the one hand, the existence of a cointegrating relationship between interest rates in the absence of convergence can be taken as an argument in favor of market integration. On the other hand, the recent introduction of a common monetary policy and the coordination of fiscal policies are likely to have decreased the magnitude of the thresholds hampering interest rate convergence. The most obvious example is the elimination of exchange rate risks following the introduction of the euro in 1999. Our aim is to provide a quantitative assessment of the extent to which financial markets in some EMU countries have become both integrated and converged over time.

This paper contributes to the existing literature in the following respects:

1. We apply the bivariate threshold vector cointegration methodology, which has several appealing features in comparison to the methodologies used before. First, it is free of the assumption of exogeneity imposed in univariate studies and utilizes the full structure of the model. Second, it allows for the possibility of non-linear adjustment towards long-run equilibrium.[2] More specifically, it allows to calculate the size of the "neutral band", within which there is no incentive to arbitrage and therefore no convergence to the long-run equilibrium.

[2]Earlier attempts to apply threshold methodology for studying financial market integration in EMU countries are limited to univariate models, which do not take feedback effects in country-pair relationships into account (Sander and Kleimeier 2004).

2. We apply the rolling threshold cointegration technique that enables us to estimate the dynamics of estimated thresholds and to assess how financial markets converge over time.

3. We apply data from different segments of financial markets, including money market rates and retail banking rates, which enables us to compare interest rate convergence in different financial markets based on the same methodology.

Our main finding is that only for some country pairs and financial market segments there is evidence in support of financial integration.

The paper is organized as follows. Section 2 provides a discussion on methodological approaches for measuring financial market integration. Section 3 presents the data and estimation results. The final section concludes.

2 Review of the methodological approaches

2.1 Decomposition of interest rate differentials

The relationship between interest rates in different countries is grounded on the arbitrage possibilities in international financial markets and the Law of One Price (LOOP). One of the representations of the LOOP in international finance is the covered interest parity condition (CIP):

$$i_t - i_t^* = f_t - s_t \tag{1}$$

where f_t is a log forward exchange rate at time t for delivery at time $t+1$, s_t is the log spot exchange rate, and i_t and i_t^* are domestic and foreign interest rates, respectively. The CIP relationship assumes risk neutral behavior, under which the marginal gain of holding domestic currency (forward discount) must be offset by the opportunity costs of holding funds in domestic currency (interest differential). The presence of exchange rate uncertainty together with the more realistic assumption of risk averse behavior ($f_t = E_t[s_{t+1}] + RP_t$) and rational expectations ($s_{t+1} = E_t[s_{t+1}] + \varepsilon_{t+1}$) brings us to the uncovered interest parity condition:

$$i_t - i_t^* = [s_{t+1} - s_t] - \varepsilon_{t+1} + RP_t \tag{2}$$

where ε_{t+1} is the rational expectations forecast error at time $t+1$, RP_t is a time-varying foreign exchange risk premium, and $E_t(.)$ is mathematical expectation operator conditional on information at time t. The above representation of interest differential suggests that its stochastic properties are related to the stochastic properties of its three components. The first component is the exchange rate change, which was widely documented to be a martingale difference process (Meese and Singleton 1982; Meese and Rogoff 1983; and Baillie and Bollerslev 1989). The second component is the rational expectations error component, which by definition is independent on the information at time t and I(0). The final component is the foreign exchange risk premium, which is the only component which stochastic properties cannot a priori be judged, although there is no asset pricing model that predicts stochastic trending behavior of the currency risk premium.

2.2 Cointegration analysis

Interest parity conditions provide a ground for cointegrating relationship between cross-country interest rates. However, the empirical evidence on the existence of cointegrating relationship is mixed. Karfakis and Moschos (1990), Katsimbris and Miller (1993), and Hassapis et al. (1999), among others, fail to find cointegrating relationship between interest rates in countries participating in the European Exchange Rate System (EMS) and German rates. This finding suggests the presence of non-stationary risk premia in the EMS currencies, which is difficult to justify on theoretical grounds. Later studies resort to structural breaks in the data and misspecification due to omitted deterministic trends to explain the absence of cointegration.

Zhou (2003) argues that rejection of existence of bivariate long-run relationships between interest rates in EMS countries may stem from the misspecification of the model. European countries coordinated their fiscal and monetary policies during several decades, which has introduced trending behavior in the interest rates series. By including a deterministic trend component in the specification of the data generating process of interest rates and focusing on three different sub-samples, Zhou (2003) re-establishes the presence of long-run cointegrating relationships, especially for the period of the late 1990s. He concludes that interest rates in the EMS countries move together more closely over time suggesting increased financial integration. Similarly, looking at the relatively long period from 1985 to 2002, Kleimeier and Sander (2000) and Kleimeier and Sander (2006) identify different phases of cointegration in the euro zone retail banking markets. There is evidence of weak cointegration before 1993, which disappears in the mid 1990s to be re-established in the late 1990s following the launch of the single currency. Interestingly, the authors find that cointegration has strengthened even earlier than the introduction of the euro in 1999, reflecting the anticipation of the launch. In addition, they find different results for different segments of the retail market, with the highest degree of cointegration in the market for corporate lending and the lowest degree of cointegration in the markets for saving and demand deposits.

The problem with standard cointegration techniques is that they fail in interpreting the existence of a cointegrating relationship as evidence of market integration, particularly because during the transformation period the relationships are changing over time. According to Brada et al. (2005), if the countries were in the process of convergence over time, the test of the convergence hypothesis would be biased toward rejecting cointegration, and, thus, convergence. Furthermore, since the convergence takes place gradually, conventional tests for a structural break in the data tend to reject the null of the presence of the break. Applying the cointegration methodology for rolling samples can overcome this problem by explicitly taking into account that series may be more cointegrated in certain subsamples than in others.

2.3 Threshold cointegration analysis

Another critique of the standard cointegration technique is that it does not take into account the impact of possible market frictions (including cross-country barriers, various restrictions, and asymmetric information) and transaction costs on the adjustment of interest rates towards the long-run equilibrium. In the standard cointegration framework, adjustment to the long-run equilibrium is linearly dependent on the magnitude of the deviation. In practice, however, market frictions introduce a non-linear adjustment to the long-run equilibrium (Balke and Fomby 1997). The idea is that market imperfections result in a "neutral band" around the long-run equilibrium path, within which there is no incentive for arbitrage. Therefore, for the adjustment to take place the deviations from the long-run equilibrium should be large enough to cross the transaction costs band and induce arbitrage across markets.

A popular approach designed to account for transaction costs in the adjustment to the long-run equilibrium is the threshold cointegration methodology. This approach was pioneered by Balke and Fomby (1997) and generalized to the multiple equations setting by Hansen and Seo (2002). The appealing feature of the threshold cointegration approach is that it allows to estimate the transaction costs band (which is usually not observable from the data) explicitly and test for its significance.

The invention of the threshold cointegration methodology has spawned a stream of empirical studies on market integration in different fields of economics.[3] Some of these are in the financial markets literature (see Franses and van Dijk 2000). Siklos and Granger (1997) apply regime-sensitive cointegration methodology to the US and Canadian financial markets and find cointegration only beyond some threshold. Balke and Wohar (1998) study the case of the US and UK financial markets integration. They report that the equilibrium relationship between two interest rate series is more persistent within the transaction costs band, while deviations from disequilibrium tend to be smoothed out faster outside the band. Finally, Peel and Taylor (2002) apply the threshold cointegration methodology for US and UK data in the late 1920s. They find strong evidence in favor of transaction costs band in the covered interest parity relationship. Deviations from the long-run equilibrium become significantly mean reverting outside the neutral band, but within the band they exhibit moderately persistent behavior.

Sander and Kleimeier (2004) apply threshold autoregressive models (TAR) for studying market integration in European retail banking. These authors hypothesize that inter-

[3] Lo and Zivot (2001) offer an extensive review of this growing literature.

est rate pass-through across European countries exhibits non-linear adjustment dynamics. To check the validity of their hypothesis, they compare the performance of univariate threshold autoregressive models with their linear counterparts. They find support for the presence of non-linear adjustment in the majority of retail interest rates. However, these authors apply only univariate threshold models and do not extend their analysis to the bivariate setting. As argued by Lo and Zivot (2001), a bivariate extension of the threshold model allows one to uncover potential non-linearities and asymmetries in the adjustment of individual series and provides more information regarding the dynamics of the data. Furthermore, the multivariate procedure for testing threshold cointegration utilizes the full structure of the model and ignores restrictions imposed by the univariate specification. Based on Monte Carlo simulations, Lo and Zivot (2001) show that multivariate models have higher power in detecting threshold effects than their univariate counterparts.

2.4 Multivariate threshold error correction models

As mentioned above, Balke and Fomby (1997) proposed application of threshold error-correction methods in univariate settings. Lo and Zivot (2001) and Bec and Rahbek (2004) extended their approach to a multivariate threshold cointegration model with a known cointegrating vector. Hansen and Seo (2002) proposed a maximum likelihood procedure for estimating multivariate threshold error-correction model when the cointegrating vector is unknown.

Our empirical investigation builds on a two-regime bivariate threshold cointegration specification proposed by Hansen and Seo (2002):

$$\begin{aligned} \Delta Y_t &= (\mu_1 + \sum_{j=1}^{k} \Gamma_{1j}\Delta Y_{t-j} + \Pi_1 ECT_{t-1}) I(|ECT_{t-1}| \leq \gamma) + \\ &\quad (\mu_2 + \sum_{j=1}^{k} \Gamma_{2j}\Delta Y_{t-j} + \Pi_2 ECT_{t-1}) I(|ECT_{t-1}| > \gamma) + \epsilon_t \end{aligned} \tag{3}$$

where $Y_t = (r^i, r^j)'$ is a vector of nominal interest rates for countries i and j, respectively, $I(.)$ is an indicator function depending on the size of the deviation from the long-run equilibrium in the previous period (ECT_{t-1}) relative to the threshold parameter (γ), μ_1 and μ_2 are 2×1 vectors of intercepts, Γ_{1j} and Γ_{2j} are 2×2 matrices of constant parameters representing short-run responses, and Π_1 and Π_2 are 2×2 diagonal matrices representing speed of adjustment to the long-run equilibrium in the first and second regimes, respectively, k is the number of lags and ϵ_t are i.i.d. Gaussian disturbances. This specification assumes that when deviations from the long-run equilibrium are not sufficiently large with respect to the threshold parameter (regime 1), then the price transmission process is defined somewhat differently from the alternative case (regime 2). In particular, the speed of adjustment parameters Π are assumed to have lower values in the non-adjustment regime (regime 1) and potentially could be even insignificant (see Figure 1).

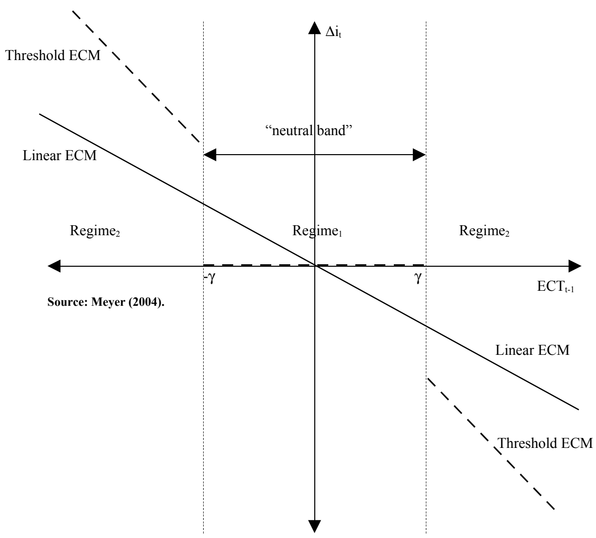

Figure 1: Visual representation of TVECM model

The algorithm for the threshold vector error-correction model (TVECM) estimation procedure contains three steps. The first step consists of testing for stationarity and cointegration using ADF and Johansen (1991) tests, respectively. In the second step, the series that are integrated of order one are used in a standard linear error-correction model. In the final step, the TVECM is estimated for the cointegrated series. For this purpose, the threshold parameter γ is determined using the following selection criteria:[4]

$$\xi(\hat{\gamma}) = min\left(log \left| \frac{1}{n} \sum_{t=1}^{n} \hat{\varepsilon}_t(\gamma)\hat{\varepsilon}_t(\gamma)' \right| \right) \tag{4}$$

Once the value of γ that minimizes (4) is chosen, an additional restriction that each regime should contain at least a pre-specified fraction of the total sample (π_0) is imposed on this grid search procedure:[5]

$$\pi_0 \leq P(|ECT_{t-1}| \leq \gamma) \leq 1 - \pi_0 \tag{5}$$

The statistical significance of the threshold parameter γ (the nuisance parameter) contains elements of non-standard inference. Therefore, the p-values are calculated using SupLM test and the bootstrapping techniques proposed by Hansen and Seo (2002).

Using the TVECM approach for rolling sub-samples enables us to observe the evolution of transaction costs bands over different time intervals. Our argument is that the more integrated the markets are, the smaller the transaction costs band should be, taking other parameters constant. Therefore, diminishing dynamics of transaction costs band over time is considered as evidence in favor of the gradual integration of financial markets in EMU member states.

3 Data and Estimation Results

Interest rate series we are employing in our estimations cover different segments of financial markets in the five largest EMU economies: Germany, France, Italy, Belgium and the Netherlands. The dataset includes series on yields on government bonds, deposits, loans and mortgage contracts (see Table 1). The total sample includes periods before and after the introduction of the single currency. The subsamples used for rolling estimations are fixed to 15 years period (180 months). The data is obtained from the IMF's International Financial Statistics and the ECB's Statistical Data Warehouse databases. The series on

[4]Here we follow Meyer (2004) and assume that the cointegration vector is known, so that the search is performed only with respect to the threshold parameter γ. In the Hansen and Seo (2002) methodology the search is performed also with respect to the cointegration vector.

[5]In our estimations we use $\pi_0 = 10\%$.

retail rates (deposits, loans and mortgages) are harmonized MFI series for the period after 2003. Since these series are not available for the period before 2003, we extrapolated the data for earlier periods by using monthly changes of national retail interest rate series (NRIR) available from the ECB database, using the following formula:

$$i_{m,t} = i_{m,t+1} \frac{i_{NRIR,t}}{i_{NRIR,t+1}} \tag{6}$$

where $i_{m,t}$ is the retail (deposit, loan and mortgage) rate in period t and $i_{NRIR,t}$ is the corresponding rate supplied by the National Banks for the period before 2003.

Figure 2 displays the dynamics of the series. Preliminary examination of the plot suggests different convergence patterns, both over time and across financial markets. The elimination of exchange rate risks following the launch of the euro in 1999 has stimulated convergence in bond rates and deposit rates, but the loan and mortgage market yields have been less affected.

We start our analysis by running Augmented Dickey-Fuller (ADF) tests on the series to test for stationarity.[6] Practically all the series were found to be stationary of the first order (see Table 2). Given that the series are not stationary in levels, we proceed by checking whether they are cointegrated.

As argued by Zhou (2003), empirical tests of cointegration in European financial markets based on the total sample are biased toward rejection of cointegration if a deterministic trend is omitted from the specification of the data generating process of the independent variables. In our error correction specification we therefore allow for a deterministic trend in the data generating process of interest rate series. As economic policies were aimed at integration during our sample period, similar to Brada et al. (2005) we apply rolling cointegration to measure dynamics of convergence in interest rates over time.

Following the conventional stream of the literature, we apply Johansen (1991) cointegration rank test, which is based on the following vector autoregressive (VAR) system:

[6] We use the ADF specification which allows for an intercept and linear trend to be present in the data generating process.

$$\Delta X_t = \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + \Pi X_{t-1} + c_0 + \varepsilon_t \tag{7}$$

where X_t is a vector of n variables, c_0 is a constant term and ε_t is a vector of Gaussian errors with mean zero and variance-covariance matrix Σ. Inclusion of c_0 allows a linear time trend to be present in the data generating process of X_t. The cointegration hypotheses involve properties of the matrix Π. If the rank of Π is r, where $r \leq n-1$, then r is called the cointegration rank and Π can be decomposed into two $n \times r$ matrices, α and β, such that $\Pi = \alpha\beta'$. The economic interpretation of the components of matrix Π is as follows: β consists of r linear cointegrating vectors, while α represents r vector error correction parameters. Cointegration tests are carried out using Johansen (1991)'s maximum eigenvalue (λ_{max}) tests with critical values provided in Osterwald-Lenum (1992). Since our estimations are applied to a set of country pairs, our null hypothesis is $r = 0$ cointegrating relationships (no cointegration) against $r = 1$ relationships (cointegration).

Several conclusions can be drawn from Table 3. First, the hypothesis of no cointegration cannot be rejected for the majority of country pairs for the total sample period estimates. This finding does not come as a surprise since the total sample includes several periods corresponding with different degrees of monetary integration (see Zhou 2003). Second, for most of the country pairs there are quite a few subsamples where cointegration is present. In some of these cases the frequency of subsample cointegration relationships is high. For example, for the bonds market there are three country pairs (GE-FR, BE-FR and FR-NL) for which the number of subsamples with cointegrating relationships clearly exceeds the number of subsamples without cointegration.[7] This suggests that frequent structural changes occurred in the total sample.

Figure 3 provides further insight on the dynamics of the cointegration relationship. Several conclusions follow from this table. First, in many country-pair cases there exists a cointegrating relationship somewhere at the beginning of the sample, and/or closer to the end of the sample. For instance, bond rates in Italy were not cointegrated with the

[7] All the three country pairs include French rates. Similarly, for the case of loans and mortgage markets, this situation applies to the country pairs which include German rates.

rest of EMU countries in the early days of the ERM; cointegration was established in the early 1990s and disappeared afterwards. This type of "yes-no-yes" pattern was also documented by Sander and Kleimeier (2004). Second, in some cases we find persistent cointegration (this applies to mortgage rates in Germany and the Netherlands, deposits in Belgium and France, France and the Netherlands, loans in Germany and the Netherlands, and Belgium and the Netherlands). A comparison with Table 3 shows that in some cases where cointegration is constantly found in subsamples, it is rejected for the total sample (e.g. deposits in Belgium and France), suggesting that structural changes took place.

For the subsamples with cointegration, we investigate whether the convergence to the long-run equilibrium exhibits a non-linear pattern. For this purpose, we estimate the TVECM (3) and test for significance of the threshold parameter γ (using a 10% confidence interval) for the rolling subsamples for which the cointegration hypothesis was not rejected. Unfortunately, for the threshold models usual asymptotic theory can not be applied to test for autocorrelation in residuals (see Lukkonen et al., 1988). In the absence of a methodology for specification testing, we set the number of lags in our estimations to 2 for each of the subsamples.

The estimation results of the rolling threshold vector error-correction models are displayed in Figure 4. For the bond markets, we find evidence of significant thresholds only in four out of ten country pairs. Out of those four country pairs, only for the case of Belgium and France there is a clear evidence of decreasing thresholds, while the other country pairs do not reveal decreasing threshold behavior. In addition, it is worth noting that for Italy cointegration is rejected for the early periods (before 1990). After the beginning of the 1990s, significant thresholds do not exhibit a decreasing pattern, implying slow convergence. In contrast, the estimated thresholds for pairs GE-FR and FR-NL exhibit a clear decreasing pattern, but they are not significant.

For the mortgage market, there is a systematic threshold adjustment present in the case of Germany and the Netherlands. The thresholds slightly decline, suggesting market integration. It is widely documented that mortgage markets are segmented in European countries. However, as mentioned in Kleimeier and Sander (2006), in this case the paradoxical situation appears that the mortgage rates are moving closely together and previous techniques were unable to capture the reality of market segmentation. The threshold cointegration method is more informative in this respect.

Finally, the deposit and loan markets shows completely opposite patterns. First, these markets exhibit contrasting rolling cointegration results: no cointegration in loan markets for subsamples during which deposit markets are cointegrated, and vice versa. Second, the significant thresholds are mostly detected in non-overlapping subsamples across the two markets. The most persistent threshold behavior is detected for loans markets in Belgium and the Netherlands. The threshold does not exhibit a decreasing pattern. There is some evidence of decreasing thresholds for loan markets in Germany and the Netherlands, as well as deposit market in Belgium and the Netherlands, but the number of subsamples where the threshold is detected is not large. It is also important to notice that the threshold parameters are larger in magnitude for the loan and deposit markets relative to the bond and mortgage markets, which suggests higher transaction costs in these European financial markets.

4 Conclusion

In this paper we revisit the issue of interest rate linkages and financial market integration in selected European countries using rolling threshold vector error-correction models. We propose a methodological improvement in measuring interest rate linkages and financial integration, combining price- and news-based indicators into one measure. In addition, our approach allows for time varying transaction costs in arbitrage across spatially separated markets.

Our conclusion is that there is evidence of decreasing thresholds over time for certain markets and certain country pairs. Over time, the number of cases where the hypothesis of cointegration cannot be rejected increases, which indicates strengthening of the cross-country interest rate linkages over time. Estimated threshold parameters are found to be larger for deposit and loan markets relative to the bond and mortgage markets, indicating higher transaction costs.

There are several reasons why our findings should be interpreted with caution. First, in our analysis we use a rolling window of 15 years, so there might still be structural changes present in these subsamples. However, decreasing the size of the subsamples would diminish the power of the threshold models. Second, in most of the cases we do not find significant thresholds towards the end of the total sample, when the euro was introduced. We interpret this finding as evidence of stronger intercountry interest linkages.

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Table 1: Data description

Financial instruments	Countries	Time span	# of obs.
Government bonds	BE, GE, FR, IT, NL	Jan1987-July2006	235
Loans to enterprizes	BE, GE, FR, NL	Apr1984-Sep2006	270
Time deposits	BE, GE, FR, NL	Jan1980-Sep2006	321
Mortgage contracts	BE, GE, NL	Jun1982-Sep2006	292

Source: Statistical Data Warehouse (ECB) and International Financial Statistics (IMF).

Table 2: Augmented Dickey-Fuller test for stationarity

		BE	FR	GE	IT	NL
bonds	levels	-2.7966	-3.0089	-2.7375	-2.4112	-2.7468
	p-value	0.2001	0.1320	0.2226	0.3728	0.2189
	first differences	-13.1816	-11.5988	-11.1298	-11.5308	-11.3258
	p-value	0.0000	0.0000	0.0000	0.0000	0.0000
deposits	levels	-2.4035	-2.4953	-2.4680	–	-2.5883
	p-value	0.3770	0.3303	0.3439	–	0.2860
	first differences	-6.0606	-13.6531	-13.5658	–	-8.1708
	p-value	0.0000	0.0000	0.0000	–	0.0000
loans	levels	-2.1976	-1.8154	-2.0561	–	-1.4720
	p-value	0.4885	0.6948	0.5674	–	0.8369
	first differences	-13.4861	-7.5187	-3.9962	–	-14.6312
	p-value	0.0000	0.0000	0.0016	–	0.0000
mortgage	levels	-2.8164	–	-2.1694	–	-2.3864
	p-value	0.1926	–	0.5044	–	0.3859
	first differences	-6.6531	–	-11.0558	–	-10.1089
	p-value	0.0000	–	0.0000	–	0.0000

Note: The estimations are performed using ADF test specification, which includes an intercept and trend. Lag selection is based on Schwartz-Bayes information criterion.

Table 3: Johansen cointegration test results*

		GE-BE	GE-FR	GE-IT	GE-NL	BE-FR	BE-IT	BE-NL	FR-IT	FR-NL	IT-NL
bonds	# CI	25	46	15	0	48	14	13	11	43	3
	# Not CI	30	9	40	55	7	41	42	44	12	52
	Total sample	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
deposits	# CI	26	35	–	16	141	–	49	–	121	–
	# Not CI	115	106	–	125	0	–	92	–	20	–
	Total sample	NO	YES	–	NO	NO	–	NO	–	YES	–
loans	# CI	61	8	–	86	3	–	74	–	5	–
	# Not CI	29	82	–	4	87	–	16	–	85	–
	Total sample	NO	NO	–	NO	NO	–	YES	–	NO	–
mortgage	# CI	12	–	–	100	–	–	17	–	–	–
	# Not CI	100	–	–	12	–	–	95	–	–	–
	Total sample	NO	–	–	YES	–	–	NO	–	–	–

* CI relationships are tested using Osterwald-Lenum (1992) criterion. Option c in Eviews (linear trend in the data, and an intercept but no trend in the cointegrating equation) was applied. YES and NO indicate that hypothesis of 0 CI relationship can and can not be rejected using Johansen's Max statistic, respectively. The numbers indicate the amount of rolling subsamples for which we either can or can not reject the hypothesis of CI.

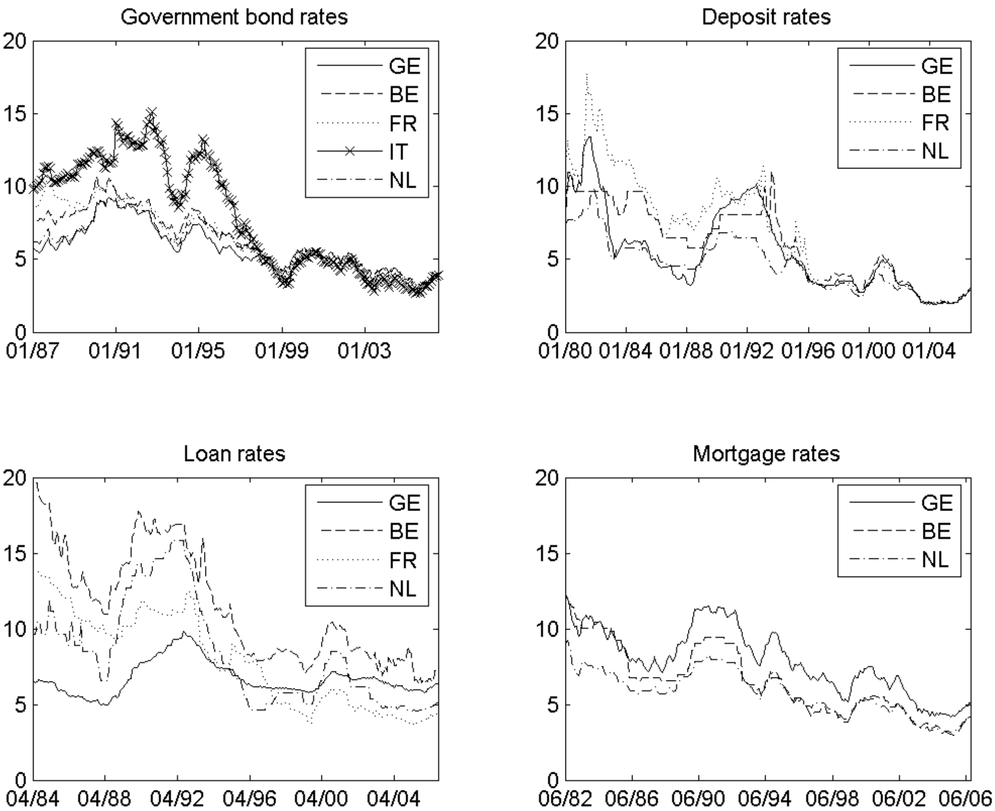
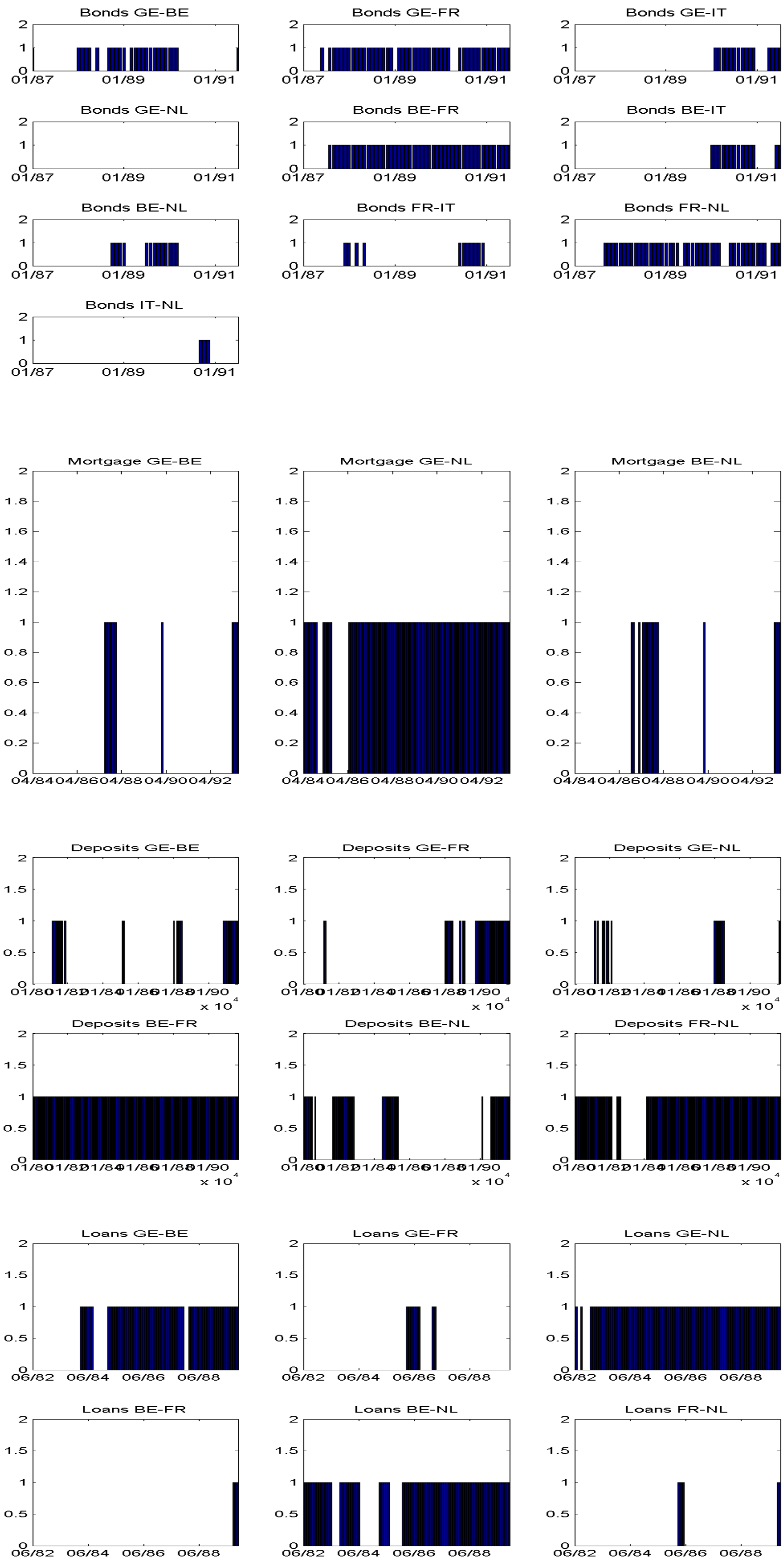
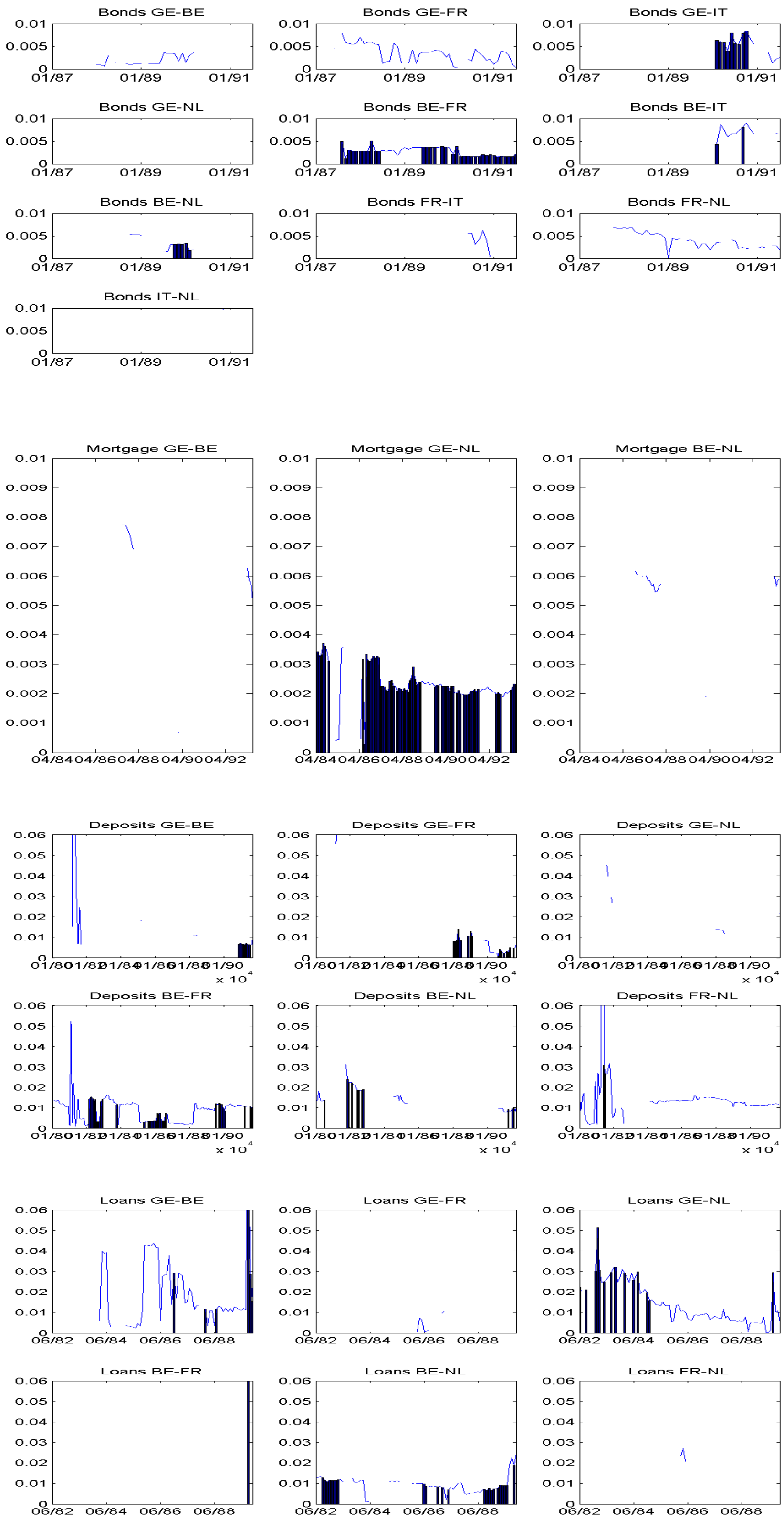


Figure 2: Interest rate series



Note: Bars indicate the beginning of the subsample for which the hypothesis of no cointegration is rejected. The absence of a bar implies that we did not find cointegration in a subsample (see also Table 3).

Figure 3: Rolling cointegration tests for bond, mortgage, deposit and loan markets.



Note: TVECM estimations are performed only for those subsamples where cointegration is found. Solid lines indicate estimated threshold parameter for a given rolling subsample and bars indicate that threshold parameters are significant.

Figure 4: Estimated threshold parameters for bond, mortgage, deposit and loan markets.

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