Are "New" and "Old" EU Members Becoming More Financially Integrated? A Threshold Cointegration Analysis*

Tigran Poghosyan†
University of Groningen and CERGE-EI

February 22, 2008

Abstract

We assess the degree of financial integration for a selected number of "new" EU member states with Germany. The analysis is performed using a threshold vector error-correction (TVECM) model with fixed rolling window. By employing this methodology we are able to evaluate the degree and dynamics of transaction costs resulting from various market imperfections. TVECM model is applied on interest rate data from different segments of financial markets covering the 1994-2006 period. The hypothesis we test is to what extent European integration tendencies resulted in a more efficient and integrated financial markets. Our findings support the gradual integration hypothesis.

KEYWORDS: financial integration, threshold vector error-correction, "new" EU member states

JEL CLASSIFICATION: F36, P33

---

*This research was supported by a grant from the CERGE-EI Foundation under a program of the Global Development Network. All opinions expressed are those of the author and have not been endorsed by CERGE-EI or the GDN. Helpful comments from Jakob de Haan, Jan Jacobs, Evžen Kočenda, Anders Rahbek and participants of the Tinbergen Institute conference "20 Years of Cointegration", March 23-24, 2007 and Global Development Network RRC VII conference, August 19-20, 2007 are acknowledged. The estimations are performed using a modified version of the GAUSS code kindly provided by Stephan Brosig and Enno-Burghard Weitzel from IAMO (Halle, Germany). The usual disclaimer applies.

†*Correspondence address*: University of Groningen, Faculty of Economics and Business, PO Box 800, 9700 AV, Groningen, The Netherlands. Email: t.poghosyan@rug.nl

1 Introduction

Measuring financial integration between the "new" EU member states and Eurozone is of great interest for policymakers and researchers. To begin, both theory and empirical findings suggest that financial integration contributes to a more efficient capital allocation, which, in turn, fosters economic growth (see Levine et al., 2000; Demirgüç-Kunt and Levine, 2001; Levine, 2004). Several studies find that financial integration in the "old" EU member countries resulting from the introduction of the euro is beneficial for economic development and growth (see Giannetti et al., 2002; LondonEconomics, 2002; Guiso et al., 2004). In addition, the extent to which financial markets in the "new" EU member states are integrated with the Eurozone countries is an important factor in the recent debate on the appropriate time to adopt euro in these countries (Brada et al., 2005; Kočenda et al., 2006; Kutan and Yigit, 2005). Although the benefits from giving up monetary autonomy and adopting a single currency are considered to be proportional to the degree of financial integration already achieved, the financial integration itself can be promoted by the elimination of currency risks following the expansion of the Eurozone. Finally, financial integration has important implication for international investors and portfolio managers. More integrated financial markets offer greater opportunities for agents to diversify portfolios and share idiosyncratic risks across countries (Cochrane, 1991). However, the more integrated financial markets can also lead to spill-overs of negative systematic shocks originating in the "old" EU countries to the "new" EU member states.

Despite the importance of financial integration for monetary convergence and economic development in the "new" EU member states, only few studies provide a quantitative account of the degree and development of financial integration in these countries. Most of the existing studies focus on various aspects of financial integration in the most developed "new" EU member states, including the Czech Republic, Hungary and Poland, for which the information on various financial indicators is more readily available, although some recent studies cover more countries and financial markets. A popular approach for studying financial integration is based on the so–called β–convergence and σ–convergence measures borrowed from the economic growth literature (see Adam et al., 2002; Baele et al., 2004 for application of this methodology to "old" EU members and Babetskii et al., 2007 for a recent application to the "new" EU member states). The β–convergence detects catching-up tendencies across countries, while σ–convergence identifies the state of the convergence for a particular period in time. Both measures are based on the law of one price, which disregards the presence of market frictions and transaction costs.

Another widely used technique employed in the financial integration literature is based on the co-movement of interest rates across countries. The workhorse methodology in this type of empirical works is cointegration analysis (see MacDonald, 2001 and Voronkova, 2004 for a recent application of this methodology to “new” EU member states). However, similarly to the previous measures, a simple linear cointegration methodology is too restrictive since it does not take into account the impact of transaction costs and market frictions, that restrict the adjustment of interest rates towards long run equilibrium (Balke and Fomby, 1997). In addition, a direct application of cointegration methods in the context of “new” EU member countries, most of which evolved through the transformation process from planned to market economy during the 1990s, is problematic as during the transformation period relationships are changing (Brada et al., 2005).

Given the wide variety of empirical strategies employed for studying financial integration in the “new” EU member states, it is not surprising that the evidence coming from these studies is controversial (a more extensive discussion is provided in the next section). In this paper we address the issue of financial market integration in the “new” EU member states using the threshold cointegration methodology. This methodology has been developed recently to take the possibility of discontinuous adjustment to the long-run equilibrium due to market frictions into account and thereby overcome some of the disadvantages of the standard cointegration approach (Balke and Fomby, 1997; Lo and Zivot, 2001; Hansen and Seo, 2002). Threshold vector error-correction models (TVECM) have not been integrated into standard software packages thus far, which explains why their application is limited. The only study we are aware of that applies the TVECM methodology for studying financial integration in the “old” EU member countries is Poghosyan and De Haan (2007). To our best knowledge, the present paper is the first attempt to apply the threshold cointegration methodology for studying financial integration in the “new” EU member countries.

Our conjecture is that various market frictions, including different types of legal and economic barriers and situations of asymmetric information, result in transaction costs that hamper arbitrage across financial markets in different countries. The pre-accession reforms in the “new” EU countries should provide greater opportunities for arbitrage and eventually result in diminishing role of market frictions and establishing more integrated financial markets (ECB, 2004).

In order to test our hypothesis, we evaluate the transaction costs related to the mentioned frictions explicitly from the data. For this reason, we employ threshold cointegration analysis on interest rate data for the "new" EU members and corresponding Eurozone rate. The TVECM model is applied to fixed seven year samples, using a moving window approach, enabling us to take into account structural changes that took place in these countries during their economic transformation from a planned to market-based economic system. For each window, a transaction costs parameter (labeled as "transaction costs band") is estimated and its significance evaluated. By plotting the transaction costs parameter over time and taking into account its significance we provide a measure of the financial integration dynamics for each country under research.

Our estimation results suggest that financial markets in "new" EU members gradually became more financially integrated with "old" EU members. However, the degree of integration differs across financial segments: money markets appear to be the most integrated ones due to lower transaction costs, while loan markets display the lowest degree of integration. In addition, there exist significant differences across financial segments within "new" member states.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literature on the topic. Section 3 describes our methodological approach. Data and estimation results are presented in Section 4. The last section concludes.

2 Measuring Financial Integration

2.1 Background and literature review

There is no single measure which would capture all aspects of financial integration. Baele et al. (2004) consider financial markets to be integrated if all potential market participants with the same relevant characteristics face similar rules in dealing with financial instruments, have equal access to the mentioned financial instruments and are treated equally when active in the market. The authors divide existing measures of financial integration into three broad categories: (a) price-based, (b) news-based, and (c) quantity-based measures. The first set of measures is based on the interest parity relationship, which is a representation of the no-arbitrage condition (law of one price) in financial markets. The second set of measures makes use of the asset pricing theory and distinguishes between common (systematic) and local (idiosyncratic) risks. The markets are considered to be fully integrated when only the common risk factors (often proxied by yields in the benchmark country) determine the equilibrium returns. Finally, the third group of measures accounts for quantitative characteristics of cross-border investment activities in the form of capital flows, listings, M&A and other relevant indicators.

Most of the existing studies on EU financial integration have focused exclusively on financial integration in the "old" EU member states (see among others Fratzscher, 2001; Adam et al., 2002; Adjaoute and Danthine, 2003; Baele et al., 2004; Hartmann et al., 2003; Hardouvelis et al., 2006; Poghosyan and De Haan, 2007). This literature documents that European countries have become more financially integrated over time and that the degree of integration has accelerated following the launch of the single currency in 1999. However, the current level of financial integration differs across different financial segments. In particular, some financial markets still exhibit various frictions preventing full integration.

The evidence on financial integration in the "new" EU member states is far less exhaustive. The existing studies on financial integration in the "new" EU members can be subdivided into descriptive studies and quantitative empirical applications. The descriptive studies focus on various aspects of legal and institutional adjustments, which took place in the "new" EU member countries to adjust their financial markets to the European standards (Schroder, 2001 and Thimann, 2002 contain a collection of such studies). A common finding in this literature is that increasing harmonization of the regulatory framework and integration of underlying financial infrastructures has bolstered the general convergence tendencies in the "new" member states.

The quantitative studies make a use of standard measures of financial integration and apply them to different financial market segments in the "new" EU member states, usually using Germany as a benchmark country. Among those studies, Crespo-Cuaresma and Wojcik (2004) and Herrmann and Jochem (2003) analyze integration of money markets. Crespo-Cuaresma and Wojcik (2004) examine the validity of the monetary independence hypothesis using money market interest rate data for a group of advanced "new" EU member states with different degrees of flexibility in exchange rate regimes: the Czech Republic, Hungary and Poland. They find that neither of the countries could enjoy full monetary independence. The correlation between Czech and foreign interest rates tended to decrease with the increase of the exchange rate flexibility, but for Poland the degree of sensitivity of domestic interest rates to the foreign benchmark has increased with the introduction of more flexible exchange rate regime.

Herrmann and Jochem (2003) study the covered interest parity in “new” members with respect to the Euro area countries and provide a quantitative assessment of the factors driving systematic deviations from parity. They find that money markets in the “new” member countries show an increasing degree of integration with the Euro area. However, discrepancies are not completely eliminated yet due to transaction costs caused by the low level of liquidity and underdeveloped financial markets, which diminish the possibilities of arbitrage.[1]

Pungulescu (2003) and Dvorak and Geiregat (2004) provide evidence for a broader range of financial segments in “new” members, covering money, government and corporate bond, loan and deposit markets. They analyze the dynamics of interest rate spreads between eight CEE “new” EU member countries[2] and the Euro area and report continuing decrease of the margins over time. Dvorak and Geiregat (2004) also study the impact of local (country) and common (industry) factors as determinants of equity returns in “new” members and find that the role of the common factors has increased over time, suggesting deeper integration. In the meantime, the authors argue that the integration process is not irreversible. For example, the deterioration of the fiscal situation in Poland and Hungary has led to widening of interest rate spreads in mid 2003.

Reininger and Walko (2005) study government bond market integration in three “new” members: the Czech Republic, Hungary and Poland, using news-based measures. They provide an analogy between these countries and Greece, Italy, Portugal and Spain (Club-Med countries) in the run-up to membership to the currency union. Similar to Crespo-Cuaresma and Wojcik (2004), they find that Czech yields exhibit the stronger level of integration, comparable to the Club-Med countries. In addition, they show that integration between the “new” EU members and the Euro area has evolved through different phases: the bull period 2000-2003 characterized by a sharp spread contraction, the bear period 2003-2004 of spread widening, and the second bull period 2004-2005. This cyclical

[1] Among the factors contributing to the segmentation of the national financial markets they also mention restrictions on short-term capital movements, which were abolished in 2001.

[2] Pungulescu (2003) also analyzes Bulgaria and Romania.

pattern has also been documented by Dvorak and Geiregat (2004).

Kim et al. (2006) apply a set of complementary techniques (dynamic cointegration and time-varying conditional correlation) to assess time-varying properties of government bond market integration between three major "new" member countries (the Czech Republic, Hungary and Poland) and a subset of "old" EU member states. Contrary to Reininger and Walko (2005), they find only weak linkages between bond markets in the "new" and "old" EU member states. In addition, they report that those linkages are not strengthening over time, which suggests that there is no evidence of growing integration. In addition, their estimations suggest that the Czech Republic is the least integrated of the three major economies due to high currency risks, which is in contrast with the findings by Cappiello et al. (2006).

A number of recent papers studies integration of equity markets in the "new" member states using different methodologies. MacDonald (2001), Gilmore and McManus (2002), Voronkova (2004), Syriopoulos (2006) and Syriopoulos (2007) apply linear cointegration methods, Kahler (2001), Syriopoulos (2006) and Moroe and Wang (2007) employ a GARCH methodology, Babetskii et al. (2007) make a use of the β– and σ–convergence indicators, and Cappiello et al. (2006) use a "comovement box" methodology based on the conditional correlations of different time-varying quantiles of the returns.[3] The common conclusion coming from these studies is that equity markets are becoming more integrated over time, which is reflected in statistically significant long-run relationships between stock indices (cointegration) and decreasing time varying volatility of stock returns in more recent periods.[4] However, the speed and degree of integration greatly varies across countries and the studies provide contradictory conclusions in this regard. For example, Voronkova (2004) argues that there was a break in the cointegrating relationship between countries in the late 1990s, while Syriopoulos (2007) concludes that long-run relationships between "new" member countries estimated for two subsamples, separated by the introduction of the euro, did not change. Furthermore, while Syriopoulos (2006) finds persistent volatility effects in equity markets of the "new" member states, Moroe and Wang (2007) conclude that volatility effects have diminished over time. The conflicting results coming from dif-

[3] Cappiello et al. (2006) apply this methodology also for studying integration in bond markets.

[4] With the exception of Gilmore and McManus (2002), who find no long-term linkages between the three major CEE countries (Poland, Czech Republic and Hungary) and the US. This finding is in contrast with Syriopoulos (2007), who reports cointegration of in the above mentioned equity markets with the US, as well as with Germany.

ferent studies can be explained by different sample periods and different methodologies applied in those studies.

2.2 Interest parity condition and financial integration: Why may transaction costs play an important role?

The theoretical background for analyzing financial integration employed in most of the previous studies is the no-arbitrage condition in international financial markets (law of one price). Analytically, the no-arbitrage condition can be expressed in the form of the covered interest parity (CIP) condition (see Sarno and Taylor, 2002 for a textbook exposition):

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

where f_t is the logarithm of the forward exchange rate at time t for delivery at time $t+1$, s_t is the logarithm of the spot exchange rate, and i_t and i_t^* are domestic and foreign interest rates, respectively. The CIP states that when the domestic interest rate is higher than the foreign interest rate, the domestic currency is expected to depreciate by an amount approximately equal to the interest rate differential. However, the CIP relationship assumes that investors are risk neutral and do not require risk premium for conducting operations under exchange rate uncertainty. In a more realistic setup of risk averse behavior, investors require a risk premium for operations in the foreign exchange market, which is reflected in the forward exchange rate: $f_t = E_t[s_{t+1}] + RP_t$. The presence of the risk premium combined with the assumption of rational expectations ($s_{t+1} = E_t[s_{t+1}] + \varepsilon_{t+1}$) leads 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. Expression (2) suggests that the stochastic properties of the interest rate differential are related to the stochastic properties of its linear components on the right hand side of the equation: the exchange rate change, the rational expectations error and the risk premium. A number of empirical studies documents that the exchange rate follows a martingale process, which implies stationarity of exchange rate changes (Meese and Singleton, 1982, Meese and Rogoff, 1983, and Baillie and Bollerslev, 1989). The rational expectations error term is also stationary by definition. Finally, there is no theoretical justification to predict stochastic trending behavior of the currency risk premium. Empirically, there is substantial support for the stationarity of the time-varying risk premium (see Fama, 1984, Hansen and Hodrick, 1980, Hodrick and Srivastava, 1984 and Shively, 2000 among others). In sum, there is a good reason to expect that the interest differential is a stationary process and cross country interest rates in levels are cointegrated. Many studies on financial integration in the "new" EU member countries have adopted this relationship as background for their empirical investigations (see MacDonald, 2001 and Voronkova, 2004 among others).

However, the major assumption behind the interest parity condition is the absence of market frictions and instantaneous arbitrage across countries when the parity is violated. In the presence of transaction costs and market frictions, which is a more realistic assumption, the adjustment to the parity condition will depend on the relative size of the deviation with respect to the degree of transaction costs.[5] The size of the transaction costs and market frictions depends on the level of financial integration across countries. For example, transaction costs related to the uncertainty about future exchange rate have vanished following the introduction of the euro, resulting in greater convergence in yields across countries. Therefore, evaluating the degree of transaction costs from the data and analyzing their dynamics over time should provide information on the extent to which financial markets have become more integrated in the "new" EU member countries.

2.3 Financial integration and discontinuous adjustment

In the standard cointegration framework, adjustment to the long-run equilibrium is linearly dependent on the magnitude of the deviation. However, in practice we observe different types of market frictions related to barriers to trade, asymmetric information and transaction costs necessary for making arbitrage across spatially differentiated financial markets. These frictions introduce non-linear adjustment to the long-run equilibrium (Balke and Fomby, 1997). The idea is that market imperfections result in a "transaction costs band" around the long-run equilibrium path, within which there is no incentive for

[5]Although we label those frictions in general terms as "transaction costs", they can be interpreted in a broader sense as all possible impediments preventing arbitrage across countries, including capital regulations, differences in legal and institutional structures, exchange rate risks, and other impediments.

arbitraging. Therefore, deviations from the long-run equilibrium should be large enough to move outside of the transaction costs band and induce arbitrage across markets.

A popular approach, which is 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 explicitly estimate the unobservable transaction costs band and test for its significance.

The invention of the threshold cointegration methodology has inspired a stream of empirical studies on market integration in different fields of economics, as reviewed by Lo and Zivot (2001). Some applications can be found in the finance literature, because such markets are believed to clear quickly. Siklos and Granger (1997) apply regime-sensitive cointegration methodology to U.S. and Canadian financial markets and report presence of cointegration only beyond some threshold. Balke and Wohar (1998) study integration of U.S. and UK financial markets. They find that the equilibrium relationship between two interest rate series is more persistent within the transaction costs band, while outside the band deviations from disequilibrium tend to be smoothed out faster. Similarly, Peel and Taylor (2002) apply the threshold cointegration methodology for the U.S. and UK data in the late 1920s, reporting strong evidence in favor of a 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. More recently, Holmes and Maghrebi (2006) test for asymmetries in the adjustment mechanism towards real interest parity relationship in major industrialized countries. The authors find that the speed of adjustment tends to be higher with respect to increasing rather than decreasing deviations from the long-run equilibrium. They attribute this discontinuous adjustment to asymmetric monetary policy responses documented in some of the industrialized countries. Finally, Poghosyan and De Haan (2007) apply the TVECM methodology for analyzing the degree and dynamics of financial integration in "old" EU member countries. They report evidence in support of discontinuous adjustment due to market frictions. For some country pairs and financial market segments these frictions show declining dynamics, suggesting increased financial integration over time.

3 Methodology

Similar to Poghosyan and De Haan (2007), we use a multivariate extension of the threshold cointegration methodology developed in Balke and Fomby (1997) to study financial integration in the "new" EU members.

In our empirical investigation we adopt a threshold cointegration specification suggested by Hansen and Seo (2002):

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

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 regime, respectively, k is the number of lags and ϵ_t are i.i.d. Gaussian disturbances. This specification assumes that adjustment towards equilibrium is regime-dependent and is conditioned upon the relative size of the disequilibrium and the threshold parameter. 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.

Figure 1 provides visual illustration of the discontinuous adjustment mechanism. Horizontal axis plots deviations from the long-run equilibrium between interest rates in the "new" and "old" EU member countries (the error-correction term, ECT), and vertical axis plots interest rate adjustment in the "new" EU member country. The linear error-correction model predicts that the size of the interest rate adjustment in the "new" EU member country is a linear function of the error-correction term (continuous adjustment). Unlike the linear model, the threshold error-correction model predicts that the linear adjustment takes place only in the second regime, in which the deviation from the long-run equilibrium exceeds the threshold γ in absolute terms. If the deviations from the long-run equilibrium are relatively low (the first regime), then interest rates in the "new" EU

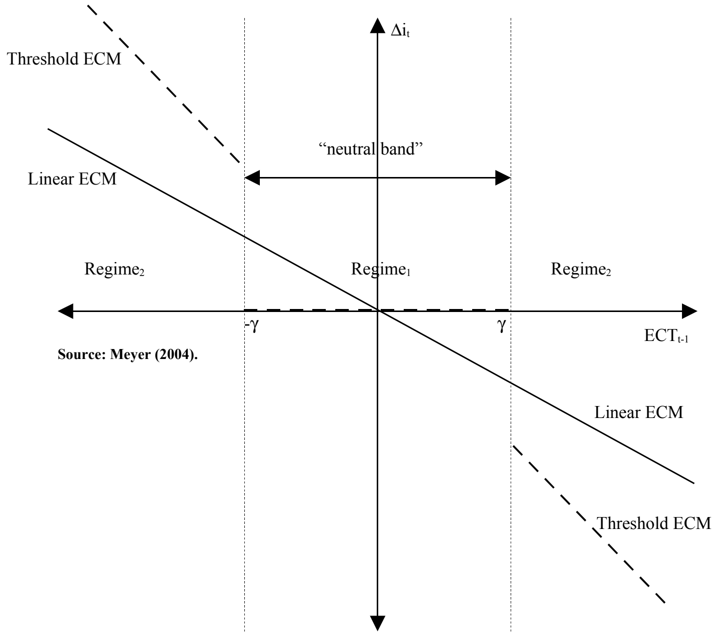


Figure 1: Visual representation of TVECM model

member country do not adjust, implying persistent disequilibrium. The larger is the size of the threshold γ, the greater is the extent to which the persistent disequilibrium can exist, implying lower degree of financial integration. Therefore, we interpret the size of the threshold parameter γ as a measure of financial integration.

The algorithm for the threshold vector error-correction model (TVECM) estimation involves procedure in 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 using the maximum likelihood procedure described in Hansen and Seo (2002). For this purpose, the threshold parameter γ is determined using the following selection criterion:[6]

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

[6]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.

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:[7]

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

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).

Applying a rolling window approach enables us to observe the evolution of the transaction costs bands over time. Intuitively, the more integrated the markets are, the smaller the transaction costs band should be, taking other parameters constant. Therefore, we interpret the decreasing dynamics of transaction costs band as evidence in favor of the gradual integration of financial markets in the "new" EU member states.

4 Data and Estimation Results

We employ interest rate series from different segments of financial markets in Germany (benchmark country) and eight "new" EU members: the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovenia and Slovakia.[8] Our dataset runs from 1994 to 2006 and includes monthly series on TBill, interbank, deposit and loan rates (see Table 1). The interest rate series are comparable across countries and obtained from the IMF's International Financial Statistics and Eurostat databases.[9]

The dynamics of interest rates is present in Figure (2). Over our sample period interest rates in the "new" EU member countries have converged to the German rates in all financial segments. To investigate whether the adjustment contains elements of regime-dependence, we undertake the following steps.

To begin, we test the interest rate series for stationarity using Augmented Dickey-Fuller (ADF) test.[10] The stationarity test results displayed in Table (2) suggest that

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

[8]Malta and Cyprus also joined EU in a recent accession wave, but we exclude those from our sample to focus only on former command economies, which share similar post-transition characteristics.

[9]For Estonia, Latvia, Slovenia and Slovakia we were not able to obtain comparable interest rate series for all four financial segments, which limits the sample for these countries.

[10]In our ADF specification we allow for the intercept and trend to be present in the data generating process.

practically all series are I(1). Therefore, in the next step we proceed by testing whether the series are cointegrated.

We perform Johansen (1988, 1991) cointegration rank tests on a pair of corresponding interest rate series in the "new" EU member states and Germany. In our error correction specification we allow for a deterministic trend in the data generating process of interest rate series, since omission of the deterministic trend may produce test statistics that are biased toward rejection of the cointegration relationship (Zhou, 2003). In addition, following Brada et al. (2005) we test for cointegration using fixed rolling samples with 84 observations (seven years). The rolling window approach is more robust to the possibility of structural breaks in the data (especially in the early transition period) than total sample estimation approach. In addition, it allows to measure the dynamics of convergence in interest rates over time.

Johansen's test is based on the following vector autoregressive (VAR) system:

$$\Delta X_t = \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + \Pi X_{t-1} + c_0 + \varepsilon_t \tag{6}$$

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 $r = 1$ relationship (cointegration).

The results of cointegration tests are presented in Table (3). It is remarkable that when the total sample is used in the Johansen test, the hypothesis of no cointegration in each financial segment cannot be rejected for most of the countries. The exceptions are Slovenia and some Baltic states. In addition, in some cases when the hypothesis of no cointegration is rejected for the whole sample, it cannot be rejected for quite a large number of subsamples (e.g. TBill rates in the Czech Republic). This finding reflects structural changes in the "new" EU members' financial markets during their transformation from a centrally-planned to a market-oriented economy.

For the subsamples where cointegration was established, we investigate whether the adjustment towards the long-run equilibrium is regime-dependent and is affected by the relative size of the deviation with respect to the threshold. For this purpose, we estimate the TVECM (3) and test for the significance of the threshold parameter γ (using a 10% confidence interval) for each of the subsamples with cointegration. Unfortunately, for the threshold models we cannot test for the autocorrelation in residuals using standard asymptotic theory (Lukkonen et al., 1988). Given the low number of observations available in each rolling subsample, in our estimations we uniformly set the number of lags to 1.[11]

Table (4) contains a summary of the threshold cointegration estimations for each of the countries and financial subsamples. The estimation results suggest that the interbank market appears to be the most integrated as the average number of subsamples for which cointegration was established (51) is the highest for this segment. In addition, the average share of significant thresholds in the total number of estimated thresholds (25%) is the second lowest for the interbank market, followed by the TBills market (21%). This finding suggests that there is less support for discontinuous adjustment in money markets, which can be attributed to relatively low transaction costs in this particular market segment. By the same reasoning, the loan market is the least integrated segment – it is described by the lowest number of subsamples for which cointegration was established (18) and the highest share of subsamples for which significant thresholds were obtained (41%). This ranking of financial segments in terms of degree of integration obtained with thresholds cointegration methodology echoes the results by Baele et al. (2004) for the "old" EU member states.

Cross-country comparison reveals significant differences in the degree of financial integration across "new" members. Latvia is leading in terms of the number of subsamples for which cointegration was established: it has the highest scores in all market segments, except for the loans market, in which the highest score is recorded for Slovenia. However, in terms of the share of the significant thresholds the results are mixed. Slovenia shows the lowest degree of discontinuous adjustment in the deposit markets, Latvia in the interbank market, Slovakia in the loans market and Hungary in the TBills market. Such a diverse

[11] Hansen and Seo (2002) and Meyer (2004) also use two lags in their empirical exercises. Hansen and Seo (2002) also report estimation results with number of lags set to one and argue that results do not differ much. As a robustness check, we also reestimated the model with 2 lags and obtained similar results (available upon request).

outcome suggests that there exist substantial differences with respect to the transaction costs and market frictions across financial segments within a particular country.

To obtain a dynamic picture of transaction costs, we present the rolling window estimation results in Figures (3-10). The interpretation of the figures is as follows: solid lines indicate estimated threshold parameter for a given rolling subsample and bars indicate that the thresholds are significant. On the horizontal axis we report the end of the subsample for which the estimations were performed. The Figures reveal a decreasing magnitude of the thresholds in most of the countries and financial segments, which implies that, on average, financial markets have become more integrated over time. In addition, we can see that for many of the countries we were able to establish cointegrating relationship for most recent subsamples. This suggests that stochastic properties of financial returns became more similar other time, implying strengthening of financial linkages with Germany. Thus, based on a conceptually new measure, we find support for the increasing degree of financial integration between "new" and "old" EU member states.

5 Conclusion

In this paper we study dynamics of financial integration in the "new" EU member states using a new measure accounting for the possibility of transaction costs and other market frictions. We apply a threshold vector error correction model with a fixed rolling windows on a set of interest rate series from different financial segments. This methodology is more general than those applied in previous studies as it is based on a more realistic assumption of the existence of transaction costs. Furthermore, it allows to test for the presence of regime-dependent adjustment to the long run equilibrium.

Our main finding is that financial linkages between "new" and "old" EU member states (benchmarked by Germany) have strengthened over time. This finding is valid for each of the four financial segments (TBill, interbank, deposit and loan rates) under consideration, although findings vary across countries and segments. Probably the most important factors driving the acceleration of financial integration are related to the policy measures undertaken by the "new" member states in order to meet European financial standards, including liberalization of capital accounts, legal and institutional reforms. All these measures resulted in a reduction of market frictions and transaction costs.

The degree of financial integration exhibits variation across financial segments. Our estimation results suggest that money markets are the most integrated ones, followed by TBill and deposit markets. Loan markets exhibit the lowest degree of integration. These differences are related to the transaction costs necessary to make arbitrage across countries, which differ from market to market.

The increasing degree of financial integration has important practical implications for the "new" member states. Increased financial integration implies that the benefits from adopting the euro will increase over time. Financial linkages are anticipated to strengthen even further with the introduction of euro due to elimination of transaction costs necessary for hedging against risks related with unexpected currency fluctuations.

References

Adam, K., T. Japelli, A. Menichini, M. Padula, and M. Pagano: 2002, 'Analyze, Compare, and Apply Alternative Indicators and Monitoring Methodologies to Measure the Evolution of Capital Market Integration in the European Union'. Report to the European Commission.

Adjaoute, K. and J. Danthine: 2003, 'European Financial Integration and Equity Returns: A Theory-Based Assessment'. In Gaspar, V. et al. (eds.) "The Transformation of the European Financial System", ECB, Frankfurt.

Babetskii, I., L. Komarek, and Z. Komarkova: 2007, 'Financial Integration of Stock Markets among New EU Member States and Euro Area'. Forthcoming in CNB Working Paper Series.

Baele, L., A. Fernando, P. Hordahl, E. Krylova, and C. Monnet: 2004, 'Measuring European Financial Integration'. *Oxford Review of Economic Policy* **20**, 509–530.

Baillie, R. and T. Bollerslev: 1989, 'Common Stochastic Trends in a System of Exchange Rates'. *Journal of Finance* **44**, 167–181.

Balke, N. and T. Fomby: 1997, 'Threshold Cointegration'. *International Economic Review* **38**, 627–645.

Balke, N. and M. Wohar: 1998, 'Nonlinear Dynamics and Covered Interest Parity'. *Empirical Economics* **23**, 535–559.

Brada, J., A. Kutan, and S. Zhou: 2005, 'Real and Monetary Convergence between the European Union's Core and Recent Member Countries: A Rolling Cointegration Approach'. *Journal of Banking and Finance* **29**, 249–270.

Cappiello, L., B. Gerard, A. Kadareja, and S. Manganelli: 2006, 'Financial Integration of New EU Member States'. ECB Working Paper Series, No. 683, Frankfurt.

Cochrane, J.: 1991, 'A Simple Test of Consumption Insurance'. *Journal of Political Economy* **99**, 957–976.

Crespo-Cuaresma, J. and C. Wojcik: 2004, 'The Monetary Independence Hypothesis: Evidence from the Czech Republic, Hungary and Poland'. National Bank of Poland Research Paper, Bank and Credit No. 1/2004.

Demirgüç-Kunt, A. and R. Levine: 2001, *Financial Structure and Economic Growth: A Cross-Country Comparison of Banks, Markets, and Development.* MIT Press, Cambridge, Massachusetts.

Dvorak, T. and C. Geiregat: 2004, 'Are the New and Old EU Countries Financialy Integrated?'. mimeo, Union College, Schenectady, NY.

ECB: 2004, 'Bond Markets and Long-Term Interest Rates in Non-Euro Area Member States of the European Union and in Accession Countries'. November.

Fama, E.: 1984, 'Forward and Spot Exchange Rates'. *Journal of Monetary Economics* **14**, 319–328.

Fratzscher, M.: 2001, 'Financial Market Integration in Europe: On the Effects of EMU on Stock Markets'. ECB Working Paper No. 48, Frankfurt.

Giannetti, M., L. Guiso, T. Jappelli, M. Padula, and M. Pagano: 2002, 'Financial Market Integration, Corporate Financing and Economic Growth'. European Commission, Economic Papers No. 179.

Gilmore, C. and G. McManus: 2002, 'International Portfolio Diversification: US and Central European Equity Markets'. *Emerging Markets Review* **3**, 69–83.

Guiso, L., T. Jappelli, M. Padula, and M. Pagano: 2004, 'Financial Market Integration and Economic Growth in EU'. CEPR Discussion Paper No. 4295.

Hansen, B. and B. Seo: 2002, 'Testing for Two-regime Threshold Cointegration in Vector Error-correction Models'. *Journal of Econometrics* **110**, 293–318.

Hansen, L. and R. Hodrick: 1980, 'Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis'. *Journal of Political Economy* **88**, 829–853.

Hardouvelis, G., D. Malliaropulos, and R. Priestley: 2006, 'EMU and European Stock Market Integration'. *Journal of Business* **79**, 365–392.

Hartmann, P., A. Maddaloni, and S. Manganelli: 2003, 'The Euro-Area Financial System: Structure, Integration, and Policy Initiatives'. *Oxford Review of Economic Policy* **19**, 180–213.

Herrmann, S. and A. Jochem: 2003, 'The International Integration of Money Markets in the Central and East European Accession Countries: Deviations from Covered Interest Parity, Capital Controls and Inefficiencies in the Financial Sector'. Deutsche Bundesbank Discussion Paper 07/03.

Hodrick, R. and S. Srivastava: 1984, 'An Investigation of Risk and Return in Forward Foreign Exchange'. *Journal of International Money and Finance* **3**, 5–29.

Holmes, M. and N. Maghrebi: 2006, 'Are International Real Interest Rate Linkages Characterized by Asymmetric Adjustments?'. *Journal of International Financial Markets, Institutions and Money* **16**, 384–396.

Johansen, S.: 1988, 'Stochastic Analysis of Cointegration Vectors'. *Journal of Economic Dynamics and Control* **12**, 231–254.

Johansen, S.: 1991, 'Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models'. *Econometrica* **59**, 1551–1580.

Kahler, J.: 2001, 'The Information Efficiency of Stock Markets in Central and Eastern Europe'. In Schroder, M. (ed.), The New Capital Markets in Central and Eastern Europe, Springer, Berlin: pp. 234 – 267.

Kim, S.-J., B. Lucey, and E. Wu: 2006, 'Dynamics of Bond Market Integration between Established and Accession European Union Countries'. *Journal of International Financial Markets, Institutions and Money* **16**, 41–56.

Kočenda, E., A. Kutan, and T. Yigit: 2006, 'Pilgrims to the Eurozone: How Far, How Fast?'. *Economic Systems* **30**, 311–327.

Kutan, A. and T. Yigit: 2005, 'Nominal and Real Stochastic Convergence: Are the New EU Members Ready to Join the Euro Zone?'. *Journal of Comparative Economics* **33**, 387–400.

Levine, R.: 2004, 'Finance and Growth'. In Aghion, P. and Durlauf, S. (eds.) "Handbook of Economic Growth".

Levine, R., N. Loayza, and T. Beck: 2000, 'Financial Intermediation and Growth: Causality and Causes'. *Journal of Monetary Economics* **46**, 31–77.

Lo, M. and E. Zivot: 2001, 'Threshold Cointegration and Nonlinear Adjustment to the Law of One Price'. *Macroeconomic Dynamics* **5**, 533–576.

LondonEconomics: 2002, 'Quantification of the Macro-Economic Impact of Integration of EU Financial Markets'. London.

Lukkonen, R., P. Saikkonen, and T. Teräsvirta: 1988, 'Testing Linearity Against Smooth Transition Autoregressive Models'. *Biometrika* **75**, 491–499.

MacDonald, R.: 2001, 'Transformation of External Shocks and Capital Market Integration'. In Schroder, M. (ed.), The New Capital Markets in Central and Eastern Europe, Springer, Berlin: pp. 268–285.

Meese, R. and K. Rogoff: 1983, 'Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?'. *Journal of International Economics* **14**, 3–24.

Meese, R. and K. Singleton: 1982, 'On Unit Roots and the Empirical Modeling of Exchange Rates'. *Journal of Finance* **37**, 1029–1035.

Meyer, J.: 2004, 'Measuring Market Integration in the Presence of Transaction Costs - A Threshold Vector Error Correction Approach'. *Journal of Agricultural Economics* **31**, 327–334.

Moroe, T. and P. Wang: 2007, 'Volatility in Stock Returns for New EU Member States: Markov Regime Switching Model'. *International Review of Financial Analysis* **16**, 282–292.

Osterwald-Lenum, M.: 1992, 'A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics'. *Oxford Bulletin of Economics and Statistics* **54**, 461–472.

Peel, D. and M. Taylor: 2002, 'Covered Interest Arbitrage in the Inter-war Period and the Keynes-Einzig Conjecture'. *Journal of Money, Credit and Banking* **34**, 51–75.

Poghosyan, T. and J. De Haan: 2007, 'Interest Rate Linkages in EMU Countries: A Rolling Threshold Vector Error-Correction Approach'. CESifo Working Paper No. 2060.

Pungulescu, C.: 2003, 'Measuring Financial Integration in the European Monetary Union: An Application for the East European Accession Countries'. Working Paper, Spring Meeting of Young Economists, Warsaw.

Reininger, T. and Z. Walko: 2005, 'The Integration of the Czech, Hungarian and Polish Bond Markets with the Euro Area Bond Market'. paper presented at the "Conference on European Financial Integration", November 2005, Vienna.

Sarno, L. and M. Taylor: 2002, *The Economics of Exchange Rates*. Cambridge University Press, Cambridge.

Schroder, M.: 2001, *The New Capital Markets in Central and Eastern Europe*. Springer, Berlin.

Shively, P.: 2000, 'Stationary Time-Varying Risk Premia in Forward Foreign Exchange Rates'. *Journal of International Money and Finance* **19**, 273–288.

Siklos, P. and C. Granger: 1997, 'Regime-Sensitive Cointegration with an Application to Interest-Rate Parity'. *Macroeconomic Dynamics* **1**, 640–657.

Syriopoulos, T.: 2006, 'Risk and Return Implications from Investing in Emerging European Stock Markets'. *Journal of International Financial Markets, Institutions and Money* **16**, 283–299.

Syriopoulos, T.: 2007, 'Dynamic Linkages Between Emerging European and Developed Stock Markets: Has the EMU Any Impact?'. *International Review of Financial Analysis* **16**, 41–60.

Thimann, C. e.: 2002, 'Financial Sectors in EU Accession Countries'. European Central Bank.

Voronkova, S.: 2004, 'Equity Market Integration in Central European Emerging Markets: A Cointegration Analysis with Shifting Regimes'. *International Review of Financial Analysis* **13**, 633–647.

Zhou, S.: 2003, 'Interest Rate Linkages within the European Monetary System: New Evidence Incorporating Long-Run Trends'. *Journal of International Money and Finance* **22**, 571–590.

Appendix

Table 1: Data description

Financial instruments	Countries	Time span	# of obs.
TBills	GE, CZ, LT, LV, HU, PL	Jan1994-Dec2006	156
Interbank rates	GE, CZ, LT, EE, LV, HU, PL, SI	Jan1994-Dec2006	156
Time deposits	GE, CZ, SK, EE, LV, HU, PL, SI	Jan1994-Dec2006	156
Loans to enterprizes	GE, CZ, SK, EE, LV, HU, PL, SI	Jan1994-Dec2006	156

Source: International Financial Statistics (IMF) and Eurostat.

Table 2: Augmented Dickey-Fuller test for stationarity

		GE	CZ	EE	HU	LT	LV	PL	SI	SK
Tbills	levels	-2.6277	-1.9853	–	-1.9114	-1.6967	-1.4402	-2.2037	–	–
	p-value	0.2688	0.6044	–	0.6438	0.7483	0.8453	0.4838	–	–
	first differences	-8.7258	-7.1780	–	-8.8436	-14.8837	-12.4293	-11.4438	–	–
	p-value	0.0000	0.0000	–	0.0000	0.0000	0.0000	0.0000	–	–
Interbank rates	levels	-2.4113	-2.6466	-2.1979	-2.0674	-1.3416	-2.6425	-2.1095	-2.9862	–
	p-value	0.3722	0.2606	0.4870	0.5594	0.8736	0.2623	0.5360	0.1396	–
	first differences	-3.4758	-4.8877	-12.1540	-8.5625	-15.8321	-16.0025	-17.8741	-5.7361	–
	p-value	0.0457	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	–
Time deposits	levels	-2.1632	-2.4992	-1.7084	-1.9820	–	-1.3881	-1.9084	-2.3696	-1.8915
	p-value	0.5062	0.3282	0.7431	0.6061	–	0.8609	0.6453	0.3940	0.6540
	first differences	-7.2553	-3.6252	-16.8096	-7.7690	–	-13.7484	-10.7260	-20.5624	-4.1165
	p-value	0.0000	0.0309	0.0000	0.0000	–	0.0000	0.0000	0.0000	0.0074
Loans to enterprizes	levels	-2.1838	-1.9747	-2.6249	-1.7391	–	-0.8982	-1.7042	-3.1803	-1.5733
	p-value	0.4948	0.6100	0.2700	0.7291	–	0.9527	0.7449	0.0923	0.7992
	first differences	-15.7934	-7.5606	-16.8463	-5.4808	–	-18.0230	-9.8978	-7.9930	-12.9938
	p-value	0.0000	0.0000	0.0000	0.0000	–	0.0000	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.

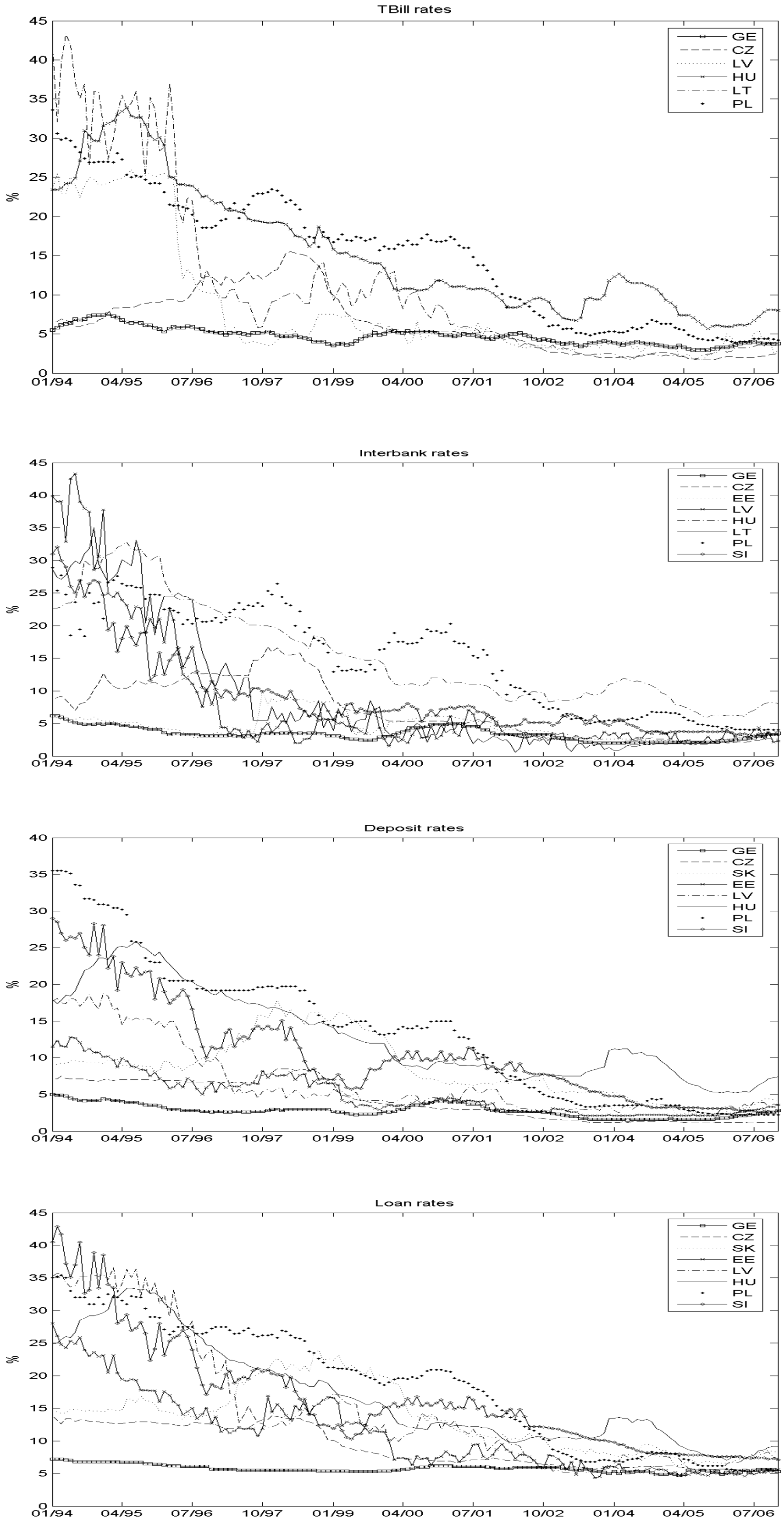
Table 3: Johansen Cointegration Test Results

		CZ-GE	EE-GE	HU-GE	LT-GE	LV-GE	PL-GE	SI-GE	SK-GE
Tbills	# CI	26	–	14	30	57	10	–	–
	# Not CI	46	–	58	42	15	62	–	–
	Total Sample	NO	–	NO	YES	YES	NO	–	–
Interbank rates	# CI	51	43	40	53	72	30	68	–
	# Not CI	21	29	32	19	0	42	4	–
	Total Sample	NO	YES	NO	YES	YES	NO	YES	–
Time deposits	# CI	27	27	25	–	51	18	39	22
	# Not CI	45	45	47	–	21	54	33	50
	Total Sample	NO	NO	NO	–	YES	NO	YES	NO
Loans to enterprizes	# CI	20	20	19	–	13	18	25	14
	# Not CI	52	52	53	–	59	54	47	58
	Total Sample	NO	NO	NO	–	YES	NO	YES	NO

Note: 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.

Table 4: Summary of Threshold Estimation Results

	Deposits							Interbank rates							Average	
	CZ	EE	HU	LV	PL	SI	SK	CZ	EE	HU	LT	LV	PL	SI	Deposits	Interbank Rates
Number of subsamples	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
Number of subsamples for which cointegration was established	27	27	25	51	18	39	22	51	43	40	53	72	30	68	30	51
Number of subsamples for which significant thresholds were obtained	9	4	6	34	1	0	6	3	26	9	1	24	7	20	9	13
Number of significant thresholds as a % of estimated thresholds	33%	15%	24%	67%	6%	0%	27%	6%	60%	23%	2%	33%	23%	29%	29%	25%
	Loans							TBills							Average	
	CZ	EE	HU	LV	PL	SI	SK	CZ	EE	HU	LT	LV	PL	SI	Loans	TBills
Number of subsamples	72	72	72	72	72	72	72	72	–	72	72	72	72	–	72	72
Number of subsamples for which cointegration was established	20	20	19	13	18	25	14	26	–	14	30	57	10	–	18	27
Number of subsamples for which significant thresholds were obtained	16	5	6	7	8	9	2	9	–	0	3	15	2	–	8	6
Number of significant thresholds as a % of estimated thresholds	80%	25%	32%	54%	44%	36%	14%	35%	–	0%	10%	26%	20%	–	41%	21%



Source: International Financial Statistics (IMF) and Eurostat.

Figure 2: Interest rates.

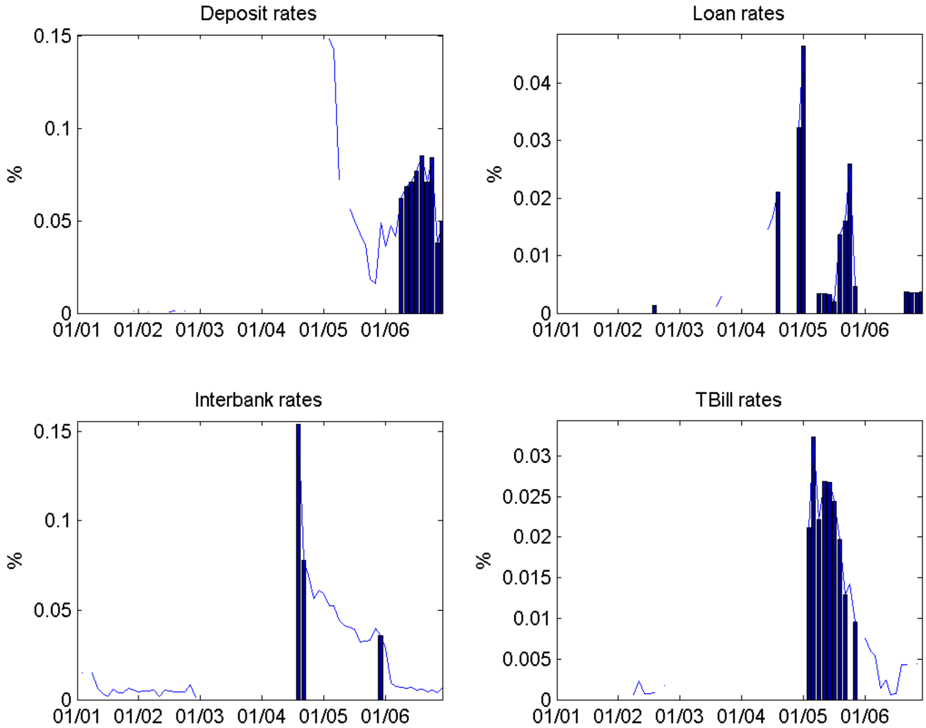


Figure 3: Czech Republic

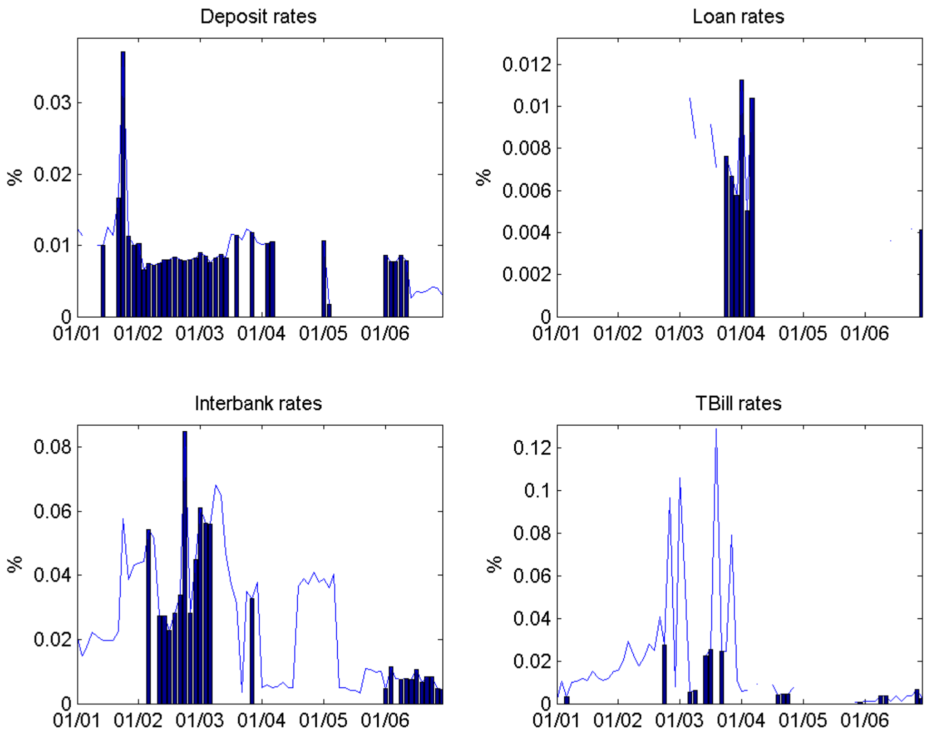


Figure 4: Latvia

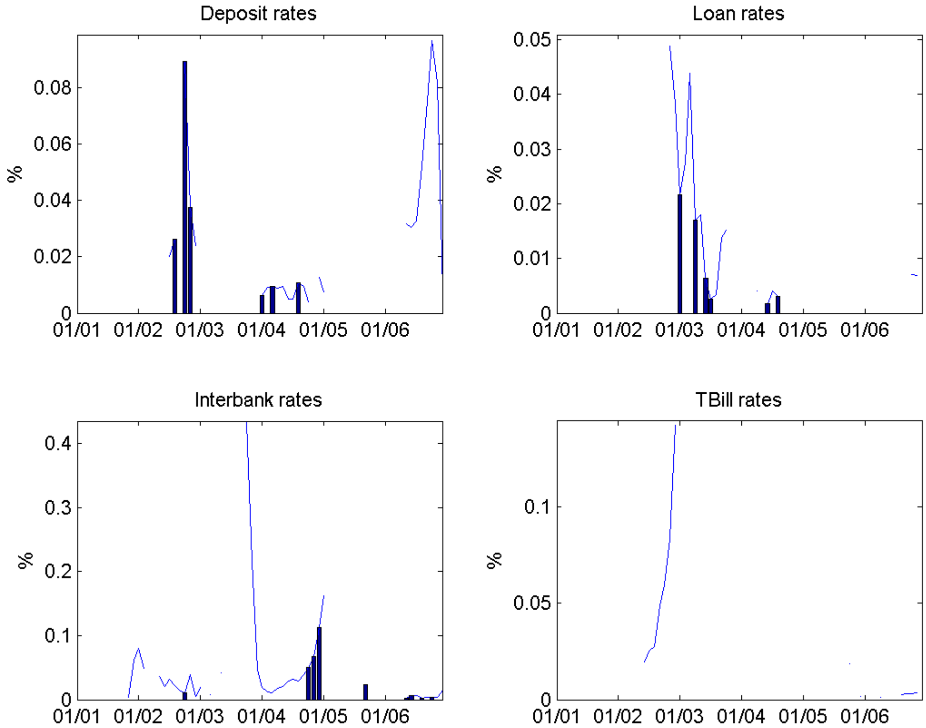


Figure 5: Hungary

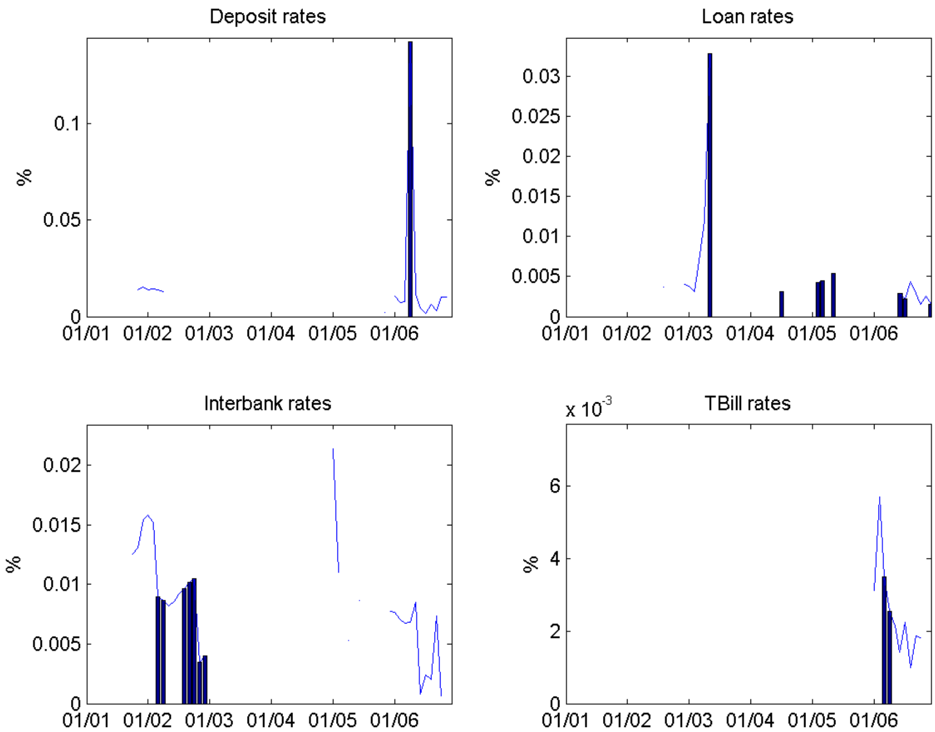


Figure 6: Poland

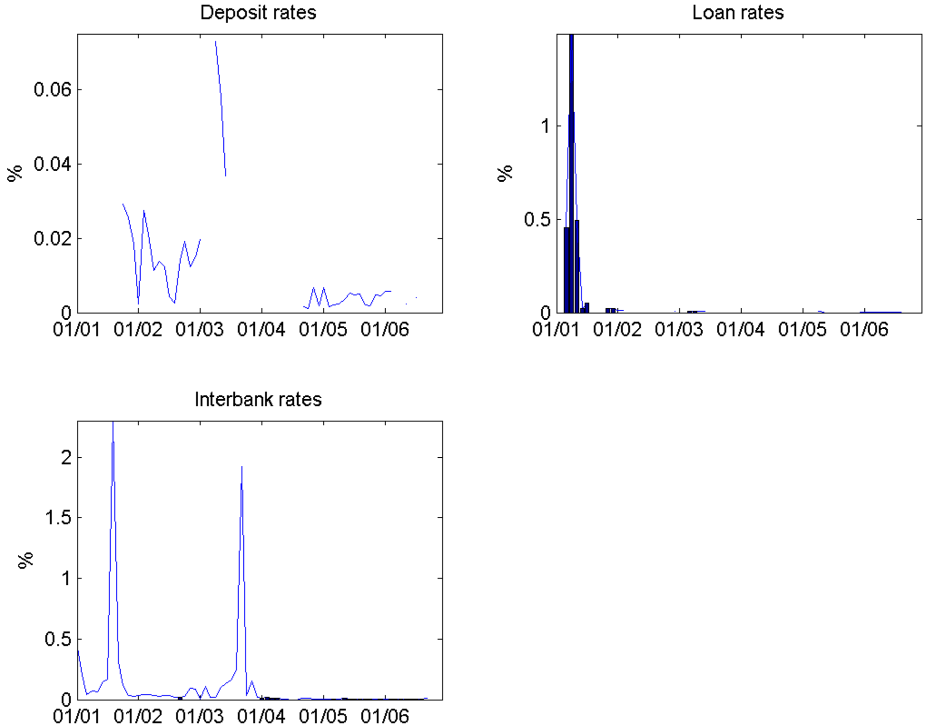


Figure 7: Slovenia

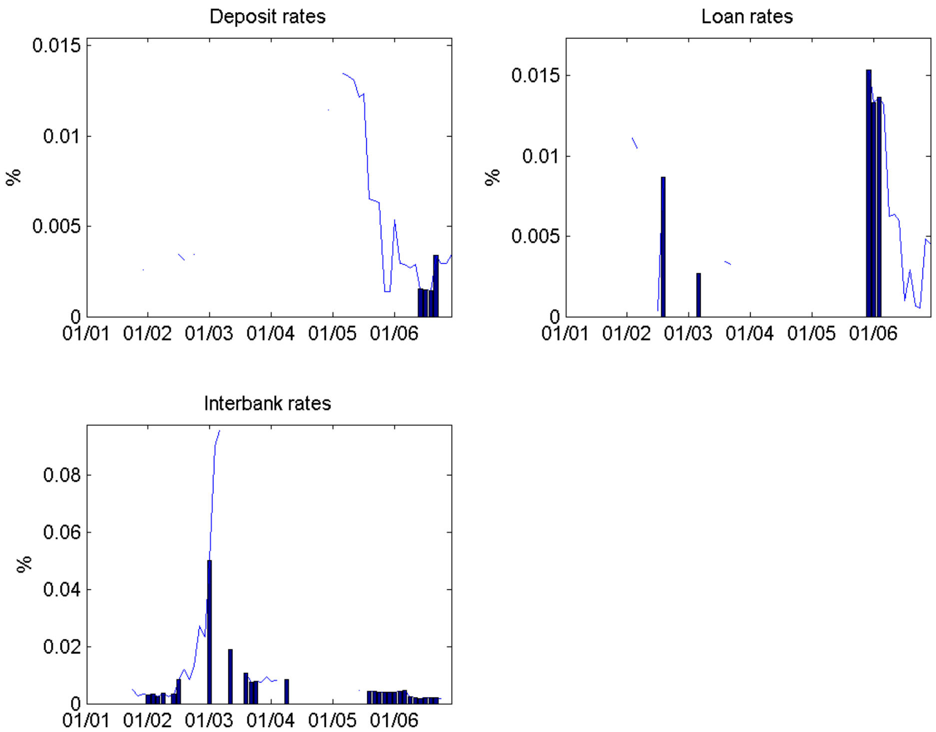


Figure 8: Estonia

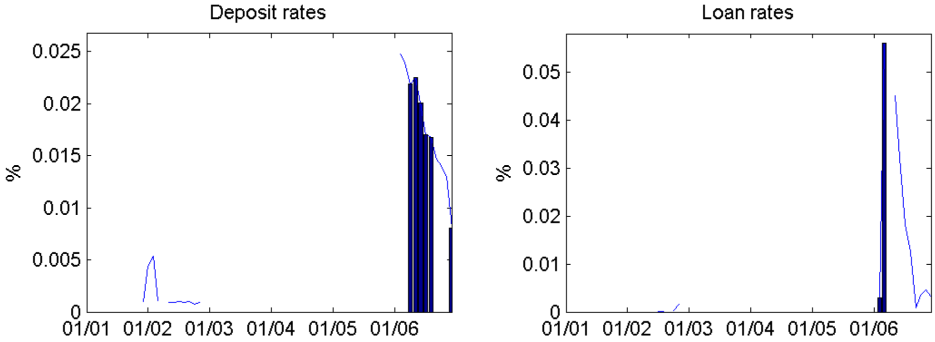


Figure 9: Slovakia

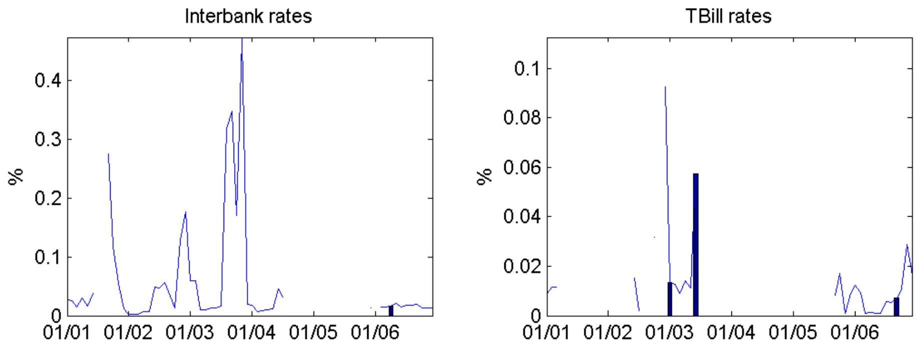


Figure 10: Lithuania