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Abstract

In this paper we analyze the convergence of interest rates in the European Monetary System (EMS) in a framework of changing persistence. This allows us to estimate the exact date of full convergence from the data. A change in persistence means that a time series switches from stationarity to non-stationarity, or vice versa. It is often argued that due to the specific historical situation in the EMS the interest rate differential was non-stationary before the full convergence of interest rates was achieved and stationary afterwards. Our empirical results suggest that the convergence date has been very different for Belgium, France, the Netherlands and Italy and are in line with the conclusions one would draw from a narrative approach. We compare three different estimators for the convergence date and find that the results are quite robust. Our results therefore stress the importance of credibility for monetary policy.

Key Words: Interest rates, convergence, changing persistence, EMS, EMU
JEL-Classification: C22, F33, F36

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1 Introduction

European monetary integration has gained much attention during the last decades. The European Monetary System (EMS) has been the centrepiece of integration prior to the launch of Economic and Monetary Union (EMU). Since its successor, the European Exchange Rate Mechanism 2 (ERM2), is still in service and a membership here is a prerequisite for joining EMU, the experiences gained from the original EMS are of great relevance. The evolution of the interest rate differential is of particular interest, due to several factors.

First, it serves as a measure for the degree of monetary integration. Second, when analyzing the time series properties of the interest rate differential, a puzzle occurs. Whereas one would expect the interest rate differential to be stationary, empirical results show that the interest rates of the participants in the Exchange Rate Mechanism of the EMS were not cointegrated with the German one. At the time of its discovery, this fact challenged the German dominance hypothesis. The odd results can be explained by the specific historical situation of the EMS that has led to an ongoing process of financial and monetary integration, leading to the conclusion that these interest rate differentials are non-stationary.

Third, as it is known that the process of integration came to an end with the launch of EMU, there must have been a switch from a non-stationary to a stationary process. The question arises of when this switch occurred, i.e., when full interest rate convergence has been achieved. This event did not necessarily coincide with the inauguration of EMU: one may also imagine that convergence was achieved before a country was announced to become a member of EMU. This is particularly the case if policy coordination was tight prior to the concrete preparations of EMU. Following the German dominance hypothesis, this basically means that a member state maintains a credible peg to the Deutsche mark. As a result we then observe a convergence

date prior to concrete steps towards EMU. On the other hand, there may still be a lack of convergence even if a country has been announced as a future member of EMU. This can be the case if there are doubts about the validity of the announcement. In this case one should find a convergence date between the official announcement of the country's entry and the actual entry. Our results will show that both cases occurred in the run-up to EMU.

As the achieved convergence of interest rates implies stationary interest rate differentials, a switch must have occurred from non-stationarity to stationarity over time. Caporale et al. (1996) stress the importance of distinguishing between the *process of convergence*, during which we usually do not observe stationarity of interest rate differentials and "*convergence as a state*" (Caporale et al. 1996, p696), i.e. a situation when convergence has been achieved. The interest rate differential will only be stationary in the latter state. Following their line of arguments we seek to find the date when the process of convergence has ended and the state of convergence has been entered. The exact timing of the break may then further illustrate how monetary convergence has been achieved.

This breakpoint can be estimated and identified by means of suitable estimators that have been proposed in the literature on changing persistence. A change in persistence is defined as a change in the (integer) degree of integration of a time series process, see Leybourne et al. (2007). For example, if a time series is non-stationary, i.e., $I(1)$, on the first subsample and stationary, i.e., $I(0)$, during the second, then a change in persistence is said to have occurred. As the time series we investigate are interest rate differentials, changing persistence is clearly defined in our application: The point in time when a change from $I(1)$ to $I(0)$ occurs is the date when interest rate convergence is fully achieved.

We complement the literature by revisiting the puzzle of interest rate differentials of EMS member countries vis-à-vis the German interest rate, but extend previous work in three directions:

First and most important, while most previous studies test for cointegration relations over isolated subperiods using exogenously determined breakpoints (see for instance Kirchgässner and Wolters 1995, Hassapis et al. 1999, Zhou 2003, Baum and Barkoulas 2006), we allow the breakpoint to be endogenously determined as we use appropriate breakpoint estimators. Thus, we do not only focus on the existence of a convergence process, but also on the point in time where the switch occurs. This means that not only the stationarity of interest rate differentials over particular subperiods is important, but also the timing of switch. It turns out that the breakpoints can be explained by the history of European integration. Furthermore, in comparison to sub-sample analysis the methodology applied in this paper allows us to consider the entire sample. It is a well known fact that the statistical tests and estimators become more reliable with an increasing sample length.

Second, we apply a recently proposed test (Leybourne et al. 2007), that explicitly allows to test the null hypothesis that the process has constant persistence against the alternative of a change from a unit root to a stationary process over time. This test has appealing statistical properties which are not shared by others. Among these are the ones proposed by Banerjee et al. (1992), Kim (2000), Kim et al. (2002), Leybourne et al. (2003) and Busetti and Taylor (2004). Whereas these tests suffer from potential spurious rejections the test proposed by Leybourne et al. (2007) is immune. A common characteristic of all aforementioned tests is an abrupt change in persistence under the alternative. A notable exception to this is the approach selected by Newbold et al. (2001): They suggest a simple autoregressive model where persistence is allowed to change smoothly over time. However, the statistical properties are not

fully explored yet and it is not clear whether the unit root test suggested by Newbold et al. (2001) may suffer from spurious rejections as well or not. Third, while the samples in earlier studies usually end in 1999, we include the first years EMU was in service. This enables us to include potential breakpoints up to the launch of EMU.

The paper proceeds as follows: Section 2 describes the components of the interest rate differential between EMS member countries. Section 3 briefly reviews the process of European monetary integration, while section 4 describes the data and introduces the methodology. Section 5 presents the empirical results and section 6 sums up our findings and concludes.

2 Interest rate linkages

Interest rate linkages are based on interest rate parity: If capital mobility is high, which was increasingly the case in the process of European monetary integration, domestic and foreign financial assets with maturity k are - besides differences in the countries' default risk – substitutes for each other. This implies that the domestic interest rate equals the foreign interest rate, plus the forward premium on the foreign currency and a default risk premium (see for example Knot and De Haan 1995), i.e. covered interest parity:

$$i_t - i_t^* = f_t - s_t + \mathrm{CR}_t \ , \tag{1}$$

where i_t and i_t^* are the domestic and foreign interest rates, $f_t - s_t$ is the forward premium on the foreign exchange market with the spot rate s_t and the forward rate f_t over the horizon k. CR_t is a risk premium subject to differences in the countries' default risk. In equilibrium, deviations from the parity are eliminated by arbitrage.

The forward premium can be split up into several components affected by the ex-

change rate (Zhou 2003). In the case of the EMS there are two potential components (Svensson 1991): First, expected fluctuations of the exchange rate, i.e., $E_t(\Delta s_{t+k})$ with $\Delta s_{t+k} = s_{t+k} - s_t$. As the EMS was a system of currencies that were pegged to each other, these fluctuations took place within the band. However, after widening the bands to ±15 per cent in 1993, these intramarginal fluctuations could be of substantial magnitude. Second, there may be a component that is mainly due to the risk of realignment (Knot 1998), to which we refer as the realignment risk RR_t. RR_t is a function of the probability of a change in the central parity and the expected magnitude of the change. The realignment risk also includes the possibility that the EMS fails which means that the respective country can no longer participate in the ERM. As we do not aim to quantify the risk components we treat this as a special case in the second component. By substituting the forward premium for its components equation (1) evolves to uncovered interest parity:

$$i_t - i_t^* = \mathrm{CR}_t + E_t(\Delta s_{t+k}) + \mathrm{RR}_t \ . \tag{2}$$

Interest rate linkages in the EMS have been subject of numerous empirical studies. As empirical results in the case of flexible exchange rates suggest that the risk premium $\mathrm{CR}_t + E_t(\Delta s_{t+k}) + \mathrm{RR}_t$ is time-varying but stationary (see inter alia Fama 1984, Wolff 1987, recently Shively 2000) one would expect the interest rate differential to be stationary, too. Otherwise (2) would be an unbalanced equation in the sense that the left hand side of the equation is $I(1)$, while the right hand side is $I(0)$. Therefore, most studies on countries' with flexible exchange rates apply the cointegration methodology and test for cointegration between domestic and foreign interest rates.

However, using this approach most early studies for EMS member countries came to the conclusion that the interest rate differential has not been stationary (see e.g. Karfakis and Moschos 1990, Katsimbris and Miller 1993, Caporale et al. 1996, Hassapis, Pittis and Prodromidis 1999). This result was puzzling as one would expect an even stronger interest rate linkage in a system like the EMS (Baum and Barkoulas 2006).

One factor which aided this expectation was that at least since the emergence of the 'new' EMS in the early eighties policy coordination was strong compared to that of other countries outside the EMS. Another one was an increasing degree of capital mobility. Thus, the results might suggest an absence of convergence of monetary policies in Europe. Another explanation is that non-linearities in the risk premium caused the odd results.

As the first explanation is counterintuitive the latter explanation has been in the focus of research. Although there is a lack of both, theoretical justifications and empirical evidence for a non-stationary risk premium in flexible exchange rates, it may be non-stationary due to the specific historic situation in the EMS (for a discussion see Caporale and Pittis 1993). There are basically two lines of arguments. First, the EMS has lead to a higher degree of financial and monetary integration, but not necessarily to the whole extent since its launch. This point is stressed by Frömmel and Menkhoff (2001, p. 302), who state that monetary integration "not only causes a once-for-all reduction in [exchange rate] volatility but can also create ongoing progress". This ongoing reduction in exchange rate volatility then directly transfers to the risk premium, as $E_t(\Delta s_{t+k})$ is affected. Furthermore, the probability of realignments will decrease with the increasing coordination in monetary policy and also induce "a monotonic convergence of the member states' rates" (Hassapis et al. 1999, pp.48). This view is supported by Caporale and Pittis (1995). Knot et al. (1998) identify inflation differences, divergent fiscal policies and unemployment figures as sources for a lack of credibility.

There are several arguments to assume the convergence process follow a stochastic rather than a deterministic trend: First, since the efficiency of financial markets is comparatively high, one would expect them to incorporate all deterministic components of the future convergence process into present prices. Therefore the (unex-

pected) news about the convergence process drive the interest rate differentials. Second, and related to the first argument, approaches from social and political sciences, such as historical institutionalism, which stress the importance of path-dependence and irreversibility in political and economic processes (Castaldi and Dosi 2006) point at stochastic processes. Third, the empirical literature is in favor of stochastic rather than deterministic trends in interest rate differentials (see particularly for the EMS Caporale and Pittis 1993). However, as a robustness check we also estimated the breakpoints assuming a deterministic trend. The results do not substantially differ and are available from the authors on request.

Besides the argument of a trend-like convergence process in the EMS a second set of studies argues that the non-stationarity of the risk premium is due to structural breaks in the deterministic part of the time series process, which stem from the particular history of the EMS. This argument was introduced by Katsimbris and Miller (1993) and picked up by Fountas and Wu (1998) who come to the conclusion that taking breaks into account provides evidence for stationary interest rate differentials. It should be noted, however, that it is, given a finite sample, very difficult to distinguish between a non-stationary process and stationary one which is affected by structural breaks in the deterministic components. Another related work is the one by Zhou (2003). She investigates the interest rates of five EMS member states (Belgium, France, Germany, Italy and the Netherlands) between 1979 and 1999. By splitting the whole sample into three subsamples and testing for cointegration for each of the subperiods separately, she concludes that the European interest rates are cointegrated within each sample period.

3 Steps of European monetary integration

We start our analysis in August 1983, although there have been steps of European financial integration in the 1970's, most prominently the launch of the EMS, respectively its Exchange Rate Mechanism (ERM) in 1979. However, it is known that during the first years policy coordination was weak, leading to frequent devaluations of most currencies versus the Deutsche mark. There have been 26 devaluations on seven occasions, the last ones on March 21, 1983. The French franc as the most important currency besides the Deutsche mark experienced a 30 per cent devaluation versus the Deutsche mark during a period of not more than 18 months. The years 1982/83 are commonly accepted as the effective begin of the "new and hard EMS" (Artis and Taylor 1994; Frömmel and Menkhoff 2001) in terms of an improved coordination of monetary and fiscal policy. The further monetary integration has then led to a stepwise, discontinuous, rather than a continuous, trend-like convergence. Further steps towards an increased monetary integration have been the Basle-Nyborg agreement 1987 and the Maastricht treaty 1992, whereas the convergence process may have been distorted by events such as the EMS crises 1992/1993.

The history of the EMS ended on January 1, 1999. The former members of the EMS have either formed the at that time established European Monetary Union (EMU), or have become member of the EMS II. However, whilst the launch of EMU was already under preparation, there still had been no decision regarding the future members. At the informal ECOFIN meeting in Mondorf-Le-Bains (Luxembourg) on September 13 and 14, 1997, it was only agreed to appoint the members of EMU and to fix the parities for the entry in May 1998.

Whereas the degree of uncertainty about the parities was low, there was no consensus about the member countries. Austria, Belgium, France, Germany, Luxembourg and the Netherlands were assumed to be the most likely members of EMU. It was also

known that Denmark, Greece, Sweden and the United Kingdom would not (initially) join EMU. The remaining countries (Finland, Ireland, Italy, Portugal and Spain) have continually given rise to speculations about their entry. The final decision about the members has been taken at the council of the EU on May, 2 and 3, 1998 in Brussels and followed the advice given by the European Monetary Institute (EMI) in their convergence report dated from March 25, 1998. The EMI recommended Austria, Belgium, Germany, Finland, France, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Hence, ten currencies ceased to exist and were transformed to the Euro.

As mentioned above expectations of market participants regarding the member countries were heterogeneous. Therefore one should expect this heterogeneity to be reflected in the interest rate differential. As Germany was assumed to be surely a member of the future EMU, it is straightforward and common to use it as a reference country and focus on the differentials to the German interest rate.

The history of European monetary integration should then be reflected in equation (2): From the comparatively high level of heterogeneity and thus disintegration in 1983, when the national authorities had just started to effectively improve their policy coordination, the risk premia should be expected to get smaller and smaller. Therefore a decline in interest rate differentials is observable, as with the degree of integration the risk of realignments (RR_t) as well as the risk of exchange rate movements $E_t(\Delta s_{t+k})$ decreases. One might further argue, that particularly with the higher fiscal discipline induced by the stability and growth pact even the differences in the default or country risk CR_t can be expected to have become smaller. Finally, with the entry to EMU two of the three components, namely the risks of realignments and exchange rate movements have completely disappeared, whereas the differences in default risk have become comparatively small, although there might be still slight

differences. Thus, the interest rate differential should have become stationary. The question is, however, when this exactly happened. It must have been latest when markets accepted particular countries as members of EMU. This happened most likely between the ECOFIN meeting in Mondorf-Le-Bains in September 1997, and the summit in Brussels in May 1998, when the set of initial member countries was officially announced. However, one may imagine situations where convergence was already reached earlier, if a country fully credibly pegged its currency to the deutsche mark, or later, if there were discussions in the course of 1998 about potential member countries even after the official announcement. We will later see that both cases occurred.

4 Data and methodology

4.1 Data

We focus on those countries that have been members of the EMS from the beginning of the sample period, i.e., Germany as the reference country, Belgium, France, Italy, and the Netherlands.[1] Other countries that either joined the EMS later (Austria, Finland, Greece, Portugal, Spain) or that have not entered EMU (Denmark, Sweden and Great Britain) are not included. The same applies to the new member states. In line with, inter alia, Baum and Barkoulas (2006) and Zhou (2003), we use treasury bill rates with a maturity of 3 months on a monthly basis. The data are taken from the international financial statistics database by the IMF, series ccc60C..ZF, where ccc is the respective country code. These data are available over the whole sample period for four out of the five countries we include in our study (Belgium/Luxembourg, France, Italy and Germany). For the Netherlands we rely on data from the Dutch

[1] Due to lack of data availability, we do not include Ireland, although it was an initial member of the EMS and EMU. Luxembourg is not included as it formed a currency association with Belgium until 1999. In the following we therefore only refer to Belgium.

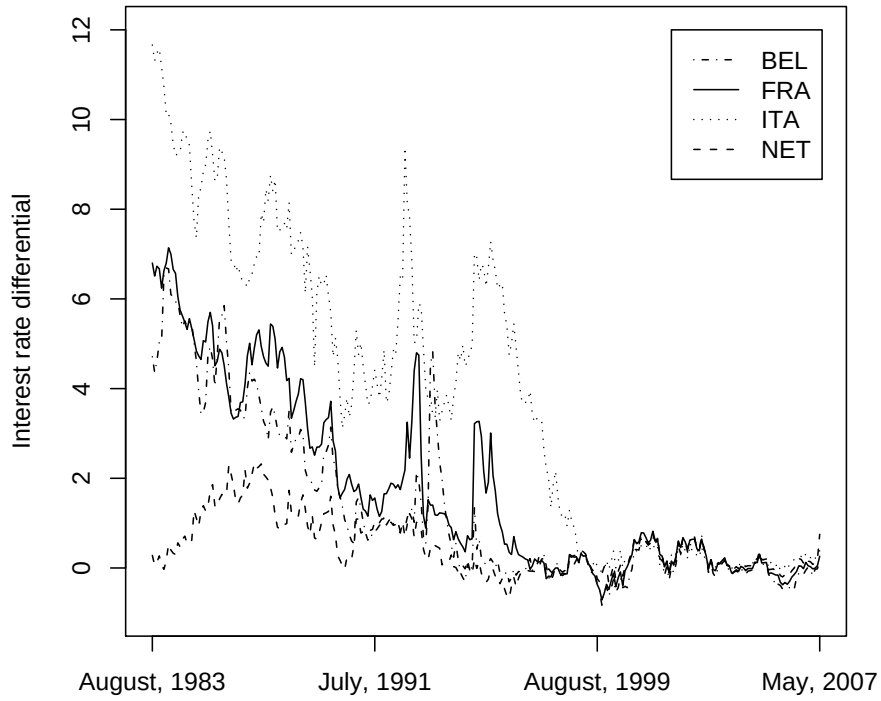

Figure 1: Interest rate differentials from August, 1983 to May, 2007.

central bank (3 months loans to local government). Thus, our analysis covers the interest rate differentials of four countries versus Germany.

The choice of short term interest rates has the advantage that the default risk over short horizons is comparatively small in the case of EMS member countries and it does not play a dominant role in equation (2). Following the observations of several former studies, which state that the convergence process which led to a 'new and hard EMS' did not start before the early 1980's (inter alia Artis and Taylor 1994, Frömmel and Menkhoff 2001), we begin our analysis with the data of August 1983. In order to make sure that there is a sufficiently long period of EMU membership included in the

sample, the end of the sample period is extended to August 2007. Hence, our sample consists of $T = 289$ observations and covers a period of on-going monetary integration in Europe. Indeed, Figure 1 reveals that the evolution of interest differentials for the countries under consideration shows a decline from the start of our sample period. This decline seems to have ended prior to the launch of EMU, with the Dutch one being comparatively small from the beginning, whereas the other ones, particularly the Italian one, start from a high level.

4.2 Econometric methodology

We consider an autoregressive integrated moving average time series process of order p, d, q (ARIMA(p, d, q)) with a deterministic constant a,

$$\Phi(L)(1 - L)^d y_t = a + \Theta(L)\varepsilon_t,$$

where L is the lag operator and ε_t is assumed to be a white noise process with mean zero and variance σ^2. The autoregressive (AR) and the moving average (MA) lag polynomials, $\Phi(L)$ and $\Theta(L)$, are assumed to have all roots outside the unit circle. This process is said to be integrated of order d. Typical values for economic time series are $d \in [0, 1]$. In our subsequent analysis we consider integer degrees of integration, i.e., zero and one, for simplicity. The applied test against a change in persistence, however, has been generalized to fractional orders of integration by Sibbertsen and Kruse (2009).

A change in persistence means a change in the degree of integration, d, over time $t = 1, 2, \ldots, T$. Leybourne et al. (2007) propose a test for the unit root hypotheses against a change in persistence. They consider the following pair of hypotheses,

$$H_{11} \quad : \quad d = d_0 = 1 \quad \text{for all } t$$

$$H_{10} \quad : \quad \begin{cases} d = d_1 = 1 & \text{for } \; t = 1, \ldots, [\tau T] \\ d = d_2 = 0 & \text{for } \; t = [\tau T] + 1, \ldots, T \end{cases}$$

where $[x]$ denotes the biggest integer smaller than x and $\tau \in (0,1)$. Note that H_{10} can be replaced by H_{01}, which is given by

$$H_{01} \quad : \quad \begin{cases} d = d_1 = 0 & \text{for } \ t = 1, \ldots, [\tau T] \\ d = d_2 = 1 & \text{for } \ t = [\tau T] + 1, \ldots, T \end{cases}$$

The interpretation of H_{11} and H_{10}, H_{01} is as follows: the null hypothesis (H_{11}) states the time series y_t is integrated of order one throughout the sample, i.e., y_t is a unit root process throughout the entire sample period. On the contrary, the alternative hypothesis (H_{10}, H_{01}) states that there is a change in the persistence of y_t at some unknown breakpoint $t = [\tau T]$. It is worthwhile noting that a change in persistence from $I(1)$ to $I(d)$ with $0 \leq d < 1$, can be interpreted in the same way as a change from $d = 1$ to $d = 0$. The reason is that an $I(d)$ process with $0 \leq d < 1$ is mean-reverting and that mean-reversion is a sufficient for convergence. The results in Sibbertsen and Kruse (2009) allow the conclusion that the applied unit root test has an asymptotic power of one if such changes occur.

In the context of unit roots and changing persistence, a fourth possibility plays an important role, namely H_{00}, which is given by

$$H_{00} \quad : \quad d = d_0 = 0 \qquad \text{for all } t.$$

Under the validity of H_{00}, y_t follows an $I(0)$ process for all t and, trivially, neither H_{11} nor H_{10}, H_{01} can be true. The tests proposed by Banerjee et al. (1992), Kim (2000), Kim et al. (2002), Leybourne et al. (2003) and Busetti and Taylor (2004) have the major drawback that they reject the null hypothesis asymptotically with probability. This is even the case if there is no change in persistence but the degree of integration is different from the one assumed under the null hypothesis. Therefore, we concentrate on the recently proposed test by Leybourne et al. (2007) which overcomes this problem by suggesting a CUSUM of squares-based test statistic. As discussed in Leybourne et al. (2007), the test statistic R behaves conservatively under

the validity of H_{00}. This means that the asymptotic size of R equals zero and that no spurious rejections may occur. The test statistic R is given by

$$R = \frac{\inf_{\tau\in\Lambda} K^f(\tau)}{\inf_{\tau\in\Lambda} K^r(\tau)},$$

where $K^f(\tau)$ and $K^r(\tau)$ are CUSUM of squares-based statistics. They are based on the forward and reversed residuals of the data generating process as given below. The relative breakpoint $\tau \in \Lambda = [\underline{\tau}, \overline{\tau}]$ is assumed to be unknown so an estimator for τ is given below. In more detail, $K^f(\tau)$ and $K^r(\tau)$ are given by

$$K^f(\tau) = \frac{1}{[\tau T]^2 \hat{\gamma}_0^f(\tau)} \sum_{t=1}^{[\tau T]} \hat{v}_{t,\tau}^2$$

and

$$K^r(\tau) = \frac{1}{(T-[\tau T])^2 \hat{\gamma}_0^r(\tau)} \sum_{t=1}^{T-[\tau T]} \tilde{v}_{t,\tau}^2.$$

Here, $\hat{v}_{t,\tau}$ are the residuals from the OLS regression of y_t on a constant based on the observations up to $[\tau T]$. This is

$$\hat{v}_{t,\tau} = y_t - \bar{y}(\tau)$$

with $\bar{y}(\tau) = [\tau T]^{-1} \sum_{t=1}^{[\tau T]} y_t$. Similarly $\tilde{v}_{t,\tau}$ is defined for the reversed series $z_t \equiv y_{T-t+1}$. In addition, $\hat{\gamma}_0^f(\tau)$ and $\hat{\gamma}_0^r(\tau)$ are OLS variance estimators for $\Delta\hat{v}_{t,\tau}$ and $\Delta\tilde{v}_{t,\tau}$, respectively. Analogous expressions for the case of de-trending can be found in Leybourne et al. (2007). The null hypothesis of a constant unit root process which translates to 'no convergence' in our application is rejected for large values of R in favor of the alternative which means 'convergence' at time $[\tau T] + 1$. Regarding the unknown breakpoint, Leybourne et al. (2007) prove the consistency of a breakpoint estimator under H_{10} which is given by

$$\hat{\tau}^r = \arg\inf_{\tau\in\Lambda} \frac{1}{(T-[\tau T])^2} \sum_{t=1}^{T-[\tau T]} \tilde{v}_{t,\tau}^2.$$

Note, that $\frac{1}{(T-[\tau T])^2} \sum_{t=1}^{T-[\tau T]} \tilde{v}_{t,\tau}^2$ is equal to the unstandardized backward statistic $K^r(\tau)$ (without the long-run variance estimator). A similar consistent breakpoint

estimator can be constructed under H_{01}, see Leybourne et al. (2007). The simulation results in Leybourne et al. (2007) suggest that this estimator works well in small and moderate samples, see their Table VII.

For reasons of comparison and in order to check the robustness of the results we additionally consider breakpoint estimators proposed by Kim et al. (2002) and Busetti and Taylor (2004). Both estimators are applicable in our situation, although the related tests are not applicable because their null hypothesis is that y_t follows an $I(0)$ process for all t. This contradicts the existence of a non-stationary risk premia before the formation of EMU. For details regarding the breakpoint estimators, we refer the interested reader to Kim et al. (2002) and Busetti and Taylor (2004).

It is worthwhile to note that standard unit root test are ill-behaved when changes in persistence occur. As a change in persistence implies that there is a fraction of the sample where the process is stationary, the behavior of standard unit root tests depend entirely on the breakpoint. If the fraction of observations that belong to the stationary regime is small, rejections are not likely and vice versa. Hence, standard tests are not able to discriminate between H_{11} and H_{10}, H_{01}.

5 Results

This section presents our empirical results. Table 1 shows the computed statistics for the CUSUM of squares-based unit root test proposed by Leybourne et al. (2007) and the corresponding critical values for de-meaned data which are taken from their Table I with $T = 250$. In a first step we apply the unit root test to the individual interest rates. In none of the five cases does the null hypothesis have to be rejected. From a statistical viewpoint it is premature to conclude that individual interest rates are $I(1)$ as the test behaves conservatively under H_{00}. This means that a non-rejection might

Table 1: CUSUM of squares-based unit root test results (R)

Time series	BEL	FRA	GER	ITA	NET
i_t	0.691	0.881	1.405	0.281	0.266
$i_t - i_t^{\text{GER}}$	6.217	3.376	—	6.706	2.555

Notes: Reported values are the CUSUM of squares-based unit root test statistics (R) applied to individual interest rates and the differentials. Critical values are given by $(cv_{10\%}, cv_{5\%}, cv_{1\%}) = (2.97, 4.16, 7.61)$ see Leybourne et al. (2007), Table I.

be caused by an $I(0)$ or an $I(1)$ process without any change in persistence over time. Therefore, we apply the DF-GLS unit root test suggested by Elliott et al. (1996) in order to test for $I(1)$ versus $I(0)$. This test is applicable to the individual interest rates because the results for the CUSUM of squares-based test clearly show that no change in persistence occurred. However, the unit root hypothesis is confirmed as the DF-GLS test does not reject the null hypothesis for all considered interest rates.[2]

In a second step we apply the CUSUM of squares-based test to interest rate differentials in order to test for constant against changing persistence. The results reveal that the hypothesis of constant persistence is rejected for three out of four countries at a nominal significance level of ten percent. For Belgium and Italy, the null hypothesis can be rejected in favor of the alternative even for the five percent level. Only for the Netherlands do we not find evidence against the constant persistence hypothesis. This might be caused by the fact that the time series is stationary during the whole sample period since the test is conservative under H_{00}. If the interest rate differential between the Netherlands and Germany can be characterized as a $I(0)$ process for all considered time periods, then full interest rate convergence was already achieved before our sample starts. This possibility is further explored in the following.

Next, we consider the results for the convergence date estimates which are reported

[2]Detailed results are available from the authors upon request.

Table 2: Convergence date estimates ($\hat{\tau}^r$)

De-meaning	LTK	KBA	BT
BEL	May 1995	May 1995	May 1995
FRA	March 1996	September 1996	May 1996
ITA	November 1998	December 1998	December 1998
NET	April 1993	October 1996	November 1987

Notes: LTK, KBA, BT refer to different breakpoint estimators proposed by Leybourne et al. (2007), Kim et al. (2002) and Busetti and Taylor (2004). Please note that the interest rate differential between the Netherlands and Germany is treated as stationary during the whole sample period.

in Table 2. We compare the outcomes of three different breakpoint estimators, see section 4.2. This is done in order to analyze the robustness of the results obtained by the LTK breakpoint estimator. Again, we use de-meaned data. In addition, we specify the interval of potential breakpoints as $[1987:09, 1998:12]$. This means that the earliest and the latest possible convergence dates in our analysis are September 1987 and December 1998, respectively. The earliest potential convergence date is therefore represented by the Basle-Nyborg agreement, aiming at strengthening the exchange rate mechanism of the EMS by providing credit facilities for intramarginal interventions and proposing a better policy coordination. The latest potential convergence date is the launch date of EMU, as by irrevocably fixing the exchange rate convergence in the spirit of section 2 was achieved per definition. Even though we do not find evidence for changing persistence in the case of the Netherlands, we estimate the breakpoint for this time series as well for illustration purposes. However, these results should be taken with a pinch of salt. Furthermore, we apply the DF-GLS unit root test for the full sample, the country-specific prebreak and the postbreak periods. Please note, that the DF-GLS unit root test results for the full sample should be taken with special care for countries except the Netherlands, since this test is not able to account for changes in persistence. The DF-GLS test is applied in order to verify the results obtained by the CUSUM of squares-based test and the outcomes

Table 3: DF-GLS unit root test results

Full sample: August 1983 – August 2007					
Country	DF-GLS	Level	Decision	Lags	Obs
BEL	-0.282	–	$I(1)$	4	1–289
FRA	0.134	–	$I(1)$	4	1–289
ITA	0.272	–	$I(1)$	0	1–289
NET	-2.546	0.05	$I(0)$	0	1–289
Country-specific prebreak periods					
BEL	-0.731	–	$I(1)$	3	1–142
FRA	-0.211	–	$I(1)$	3	1–152
ITA	0.331	–	$I(1)$	0	1–184
NET	-1.687	0.10	$I(0)$	0	1–117
Country-specific postbreak periods					
BEL	-2.961	0.01	$I(0)$	0	143–289
FRA	-2.067	0.05	$I(0)$	3	153–289
ITA	-2.462	0.05	$I(0)$	3	185–289
NET	-2.173	0.05	$I(0)$	1	118–289

Notes: Country-specific pre- and postbreak periods are determined according to LTK breakpoint estimation results, see Table 2. DF-GLS is the Elliott et al. (1996) unit root test statistic, optimal lag length is chosen via AIC. Please note that the full sample analysis is only valid in the case of the Netherlands since this time series is the only one for which constant persistence is evident, see Table 1.

of the breakpoint estimators. Individual pre- and postbreak periods are constructed according to the LTK breakpoint estimates, see Table 2. As the different breakpoint estimators deliver very similar results, this choice is not crucial. We restrict the maximum lag length to 12 and choose the optimal number of lags via Akaike's Information Criterion. We include a constant as deterministic component in the DF-GLS test regression. These results are reported in Table 3.

The outcomes of the breakpoint estimation exercise suggest that the convergence dates have been very different for the respective countries. In the case of the Netherlands it seems that there has been no change in persistence: We find the interest rate differential to be stationary through the whole sample period. Thus there is no statistical evidence for a switch from an $I(1)$ to an $I(0)$ process. This result is supported by the fact that the Dutch central bank followed the Bundesbank's monetary policy for a long time and kept the Dutch guilder/Deutsche mark rate stable. There have only been two realignments of the guilder in the beginning of the EMS (1979-1983) before the Dutch central bank managed to keep the exchange rate stable and inflation differences to Germany low (Klaster and Knot 2002). As a result of its policy the Netherlands continued to peg the guilder to the mark in the narrow ± 2.25 per cent band, whereas the band was widened to ± 15 per cent for all other currencies after the severe EMS crises in 1992 and 1993. Accordingly the credibility of the peg was comparatively high, and there has been no realignment of the Dutch guilder since 1983, i.e., prior to our earliest potential break date 1987.[3] The Netherlands formed a de facto currency union with Germany long before the official launch of EMU. The unit root test results reported in Table 3 also suggest that the interest rate differential between the Netherlands and Germany has been stationary during the whole sample period. The DF-GLS test statistic is significant at conventional levels for the three considered samples. This outcome is in line with the results obtained by the CUSUM of squares-based unit root test, see Table 1. Moreover, this result is clearly in line with the history of Dutch monetary policy. Hence, we conclude that the short-term interest rates in the Netherlands and Germany have converged before our sample starts.

Although Belgium has some characteristics in common with the Netherlands as a small economy with a remarkable degree of openness, its monetary policy has been less credible and there have been seven realignments between 1979 and 1987. In 1990

[3]We also did the calculations with a sample period starting in April 1979. The results of which are available from the authors upon request. These, however, do not change significantly.

Belgium gave up its two-tier exchange rate system and has since then adhered to the "franc-fort" policy, pegging the franc closely to the central parity and enhancing the convergence process. Our analysis indicates that this convergence process has come to an end in May 1995, see Table 2. This breakpoint estimate is remarkably stable across different estimators. Back then, a stable exchange rate had been the target of Belgium's policy for some years and the government had made some successful efforts to bring down Belgium's budget deficit by various measures between 1992 and 1994 (for details see von Hagen et al. 2001). The DF-GLS unit root test results for the pre- and postbreak periods confirm the change in persistence from non-stationarity to stationarity at the estimated breakpoint.

Convergence was achieved slightly later in the case of France: The breakpoint estimators indicate a transition from an $I(1)$ to an $I(0)$ process between March and September 1996. The decline in persistence is supported by the results from our subsample analysis, see Table 3. Again, the later convergence date is in line with the history of the EMS: While the Netherlands and later Belgium as small open economies followed a strict exchange rate target, such a strategy is less sustainable and thus less credible for a large country as France. This became obvious in 1993, when interest rate cuts in France rose suspicion that the stability-oriented policy might be in danger, a fact that was one of the reasons for the 1993 EMS crisis (Gros and Thygesen 1998). Furthermore the French policy sent some conflicting signals regarding budget consolidation (von Hagen et al. 2001). Accordingly the achievement of credibility took comparatively long in the case of France, although it was obvious that a European Monetary Union without France would not be possible. Thus, for the three countries (Netherlands, Belgium and France) membership in EMU was already accepted by markets when the EMI published its convergence report in May 1998.

In contrast, the convergence date for Italy is the last one set: The switch to a stationary interest rate differential occurred as late as November or December 1998, just before EMU was launched. It is worth noting that all breakpoint estimates are very close to each other. Results in Table 3 support this type of change in persistence at this date of convergence. This image of Italy as a late riser which most observers agree upon, is in line with the discussions about Italy's membership in EMU. Italy had huge problems meeting the convergence criteria and had to implement "emergency measures" (von Hagen et al. 2001) such as a temporary Euro tax on income, limited until 1997 (EMI 1998). These problems led to an ongoing debate on Italy's participation in EMU. Back in April 1998, a few weeks prior to the publication of the EMI's convergence report, the Dutch government regarded the Italian membership as critical (Deutsche Bundesbank 1998a), a view that was shared by the influential Deutsche Bundesbank as well (Deutsche Bundesbank 1998b). And even the EMI's convergence report itself left some room for doubts.[4] The summing up of our approach provides results that are in line with the conclusions one would draw from a narrative approach.

6 Conclusions

In this paper the convergence of interest rates in the EMS is investigated by applying a recently proposed framework for changing persistence. A change in persistence means that a time series process switches at a particular date from stationarity to non-stationarity, or vice versa. The analyzed data set contains short-term interest rate differentials for countries that have been member of the EMS from the beginning

[4]"Notwithstanding the efforts and the substantial progress made towards improving the current fiscal situation,there must be an ongoing concern as to whether the ratio of government debt to GDP will be 'sufficiently diminishing and approaching the reference value at a satisfactory pace' and whether sustainability of the fiscal position has been achieved." EMI 1998, p.158.

of the sample period, i.e., Germany as the reference country, Belgium, France, Italy, and the Netherlands. The framework is well suited for analyzing this data set due to the specific historical situation in the EMS. However, it is also suited for analyzing the convergence process of other countries, such as the new member countries of the European Union that experience a similar integration process.

The interest rate differential appears to have been non-stationary before full convergence of interest rates was achieved and it became stationary afterwards. However, the exact timing of convergence is unknown, but our approach allows us to estimate it from the data. We compare three different estimators for the convergence date and find that the results are quite robust. They suggest that the convergence dates have been very different for the analyzed countries. It seems that the main factors driving interest rate convergence between the respective countries and Germany were the coordination of budgetary and monetary policy leading to stable exchange rates in the run-up to EMU. Besides these insights into the process of European integration our results therefore stress the general importance of credibility for monetary policy.

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