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Does the euro dominate Central and Eastern European money markets?

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A B S T R A C T

The so-called German Dominance Hypothesis (GDH) claimed that Bundesbank policies were transmitted into other European Monetary System (EMS) interest rates during the pre-euro era. We reformulate this hypothesis for the Central and Eastern European (CEE) countries that are on the verge of accessing the eurozone. We test this "Euro Dominance Hypothesis (EDH)" in a novel way using a global vector autoregressive (GVAR) approach that combines country-specific error correction models in a global system. We find that euro area monetary policies are transmitted into CEE money market rates, providing evidence for monetary integration between the eurozone and CEE countries. Our framework also allows for introducing global monetary shocks to provide at least tentative empirical evidence regarding the effects of the recent financial crisis on monetary integration in Europe.

1. Introduction

Long before the introduction of a single European currency, the notion of potential asymmetries within the European Monetary System (EMS) startled a debate both between academics and central bankers. The claim was that other members' central banks surrendered their monetary sovereignty to

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the Deutsche Bundesbank by mimicking German monetary policies with an eye towards keeping their domestic currency values stable vis-à-vis the Deutschmark (DM).

This so-called *German Dominance Hypothesis* (henceforth GDH) has received considerable attention in the empirical exchange rate literature. Whilst monetary economic theory provides arguments in favour of an asymmetric monetary system (Barro and Gordon, 1983; Giavazzi and Pagano, 1988), conclusive and robust empirical evidence on the validity of the GDH is rather scant. The econometric approach used to test the GDH was typically based on short-run nominal money market rates and identified asymmetries in the EMS using Granger causality tests. The monetary system was considered asymmetric in the strict sense if there was evidence for unidirectional causality from German money market rates to the other EMS members (Uctum, 1999). Several authors (Katsimbris and Miller, 1993; Hassapis et al., 1999) added an extra-European dimension to test how monetary innovations from the rest of the world (ROW), proxied by the US, were transmitted into the EMS. International asymmetry in this context implied that the ROW only affected the other EMS countries through its impact on German money market rates. German Dominance would then only be fulfilled if both forms of asymmetry could not be rejected simultaneously.

German monetary leadership in the EMS has been investigated empirically by a number of authors. Fratianni and von Hagen (1990), von Hagen and Fratianni (1990) and de Grauwe (1989), for example, find no statistical evidence for the notion of German Dominance – at least not in the strong form of unidirectional causality. Their results rather support the idea of multidirectional linkages within the EMS, attributing the Bundesbank an important, yet not dominant, role. Karfakis and Moschos (1990), on the other hand, fail to reject the GDH.[1] Using a bivariate set-up, they conclude that German interest rates Granger-cause other EMS members' rates.

We believe, however, that previous empirical results on the GDH should be taken with a pinch of salt due to several limitations in the econometric methodology employed at that time. In particular, the notion of cointegration was not well established and often not tested for at all. Commonly used vector autoregressive (VAR) specifications in first differences are hence likely to yield biased estimates. Also, Granger causality tests suffer from a timing problem as they are unable to distinguish between the short run and the long run. These issues are addressed properly by Kirchgässner and Wolters (1993). They formulate and test the GDH in a multivariate cointegration framework and find evidence for German Dominance by imposing appropriate restrictions on the loading coefficients and the cointegrating vector.

The original GDH debate was essentially couched in terms of the loss of monetary independence (a cost). The notion of German Dominance referred to the alleged contradiction between the symmetry of monetary policy adjustments the design of the EMS had intended and the claim that the Bundesbank was dictating its monetary policy to other members' central banks, hereby turning the EMS into a "Greater DM Area". In today's institutional environment of a still enlarging eurozone, however, the alternative notion of monetary integration (arguably a benefit) seems more appropriate.[2]

Indeed, the institutional environment in Europe has changed fundamentally since the earlier tests of the GDH with the creation of the European Economic Monetary Union (EMU). Whilst the empirical evidence on German Dominance in the pre-euro era (and the loss of monetary autonomy of national central banks to the Bundesbank) remains a matter of debate, the European Central Bank (ECB) nowadays acts as the single legal body that is ultimately in charge of monetary policymaking for the whole euro area. The eurozone as monetary system is hence by definition symmetric, if we are willing to abstract from potential governance issues within the ECB. The question of greater cooperation of national central banks as opposed to following a hegemonic player no longer applies in the absence of the "$N-1$ problem".[3] For countries *outside* the EMU, however, the case is not as clear-cut. Whilst potential ECB leadership may be desirable from a convergence perspective, it may equally turn out to

[1] Giavazzi and Giovanni (1987) and MacDonald and Taylor (1991) are amongst others to support the idea of German Dominance as well.

[2] Estonia was the latest country to introduce the euro in 2011.

[3] See Fratianni and von Hagen (1992) for a lucid discussion of the cooperative versus the disciplinary interpretation of the EMS.

be problematic in the face of domestic or global shocks over a shorter horizon. This also raises the question of the transmission of EMU-wide shocks to those countries.

The main contribution of this paper consists in reformulating the GDH in terms of the current eurozone and non-eurozone countries that are on the brink of accession; that is, we introduce the so-called *Euro Dominance Hypothesis* (henceforth EDH). Our monetary convergence analysis focuses on the transitional economies from Central and Eastern Europe (CEE) for several reasons. First, the process of European integration received a fresh impetus with the eastern enlargement of the European Union (EU). This, in turn, revitalised research into issues such as the endogeneity of optimum currency areas, the potentially increasing heterogeneity in monetary policy transmission channels or the impact on movements of goods, capital and labour across borders.[4] Second, unlike countries such as the United Kingdom or Denmark, the Treaty on European Community requires newly-joining EU member states to eventually introduce the euro. Out of the original ten CEE member countries only Slovenia (in 2007), Slovakia (in 2009) and Estonia (in 2011) so far have complied with the Maastricht convergence criteria on a lasting basis which allowed them to introduce the euro. The CEE countries that are yet to join are in alphabetical order: Bulgaria, the Czech Republic, Hungary, Latvia, Lithuania, Poland and Romania.[5] We define European monetary integration in this paper as a gradual convergence process between CEE and euro interest rates that culminates in the introduction of the euro as single currency. This implies that domestic central banks irrevocably fix their national currencies to the euro at some predetermined rate and hand over their monetary autonomy to the ECB. Although national central banks can still influence the decision making within the ECB, implementing monetary policies independently to stabilise the domestic economy will then no longer be possible.

The current situation of CEE countries outside the eurozone trying to bring their domestic monetary policy stance and currency more in line with the ECB policies bears similarities with the EMS situation. In the 80's and 90's, the DM and the Bundesbank were considered the major currency and, respectively, the "leading" central bank within the EMS. The DM was widely used outside Germany – particularly in CEE. About 30–40% of the currency in circulation was held abroad according to a Bundesbank study (Seitz, 1995). A similar degree of currency substitution for the euro can also be identified in some CEE economies (Dvorsky et al., 2008). Both ECB and Bundesbank, moreover, share a similar constitution. The GDH was generally motivated by the credible low-inflation path of the Bundesbank, which the ECB intends to continue. Given these historical and institutional similarities, it seems natural to consider the euro and the ECB as a continuation of the DM and the Bundesbank, respectively, and to upgrade models developed for the analysis of interest rate linkages within EMS to today's environment.

Our testing framework not only offers an upgrade in the institutional dimension but also at the methodological level. While reduced-form specifications such as the vector error correction model (VECM) employed by Kirchgässner and Wolters (1993) may be considered theory-averse, large-scale macroeconometric models are by their very nature computationally intense. We test for monetary convergence between EMU and non-EMU countries using a rather novel global vector-error correcting modelling approach (Global VAR; henceforth GVAR) due to Pesaran et al. (2004) and furthered by Dees et al. (2007).

GVAR modelling may be considered an attempt to unite more data-driven European approaches with the more theory-driven American take on econometrics.[6] In contrast to cointegrated systems as advanced, most notably, by Johansen (1995), some variables are treated as structurally exogenous based on theoretical considerations. This procedure allows for richer dynamic specifications and a more efficient analysis of macroeconomic data, particularly for relatively short time periods (Pesaran et al., 2000).

The GVAR approach seems to be particularly suitable for the case of small open economies, where it is plausible to assume that variables such as foreign prices are exogenous. Loosely speaking, variables are considered weakly exogenous in this context if they only affect domestic variables contemporaneously but are not affected by domestic deviations from the long-run equilibrium. Granger and Lin

[4] See for instance Angeloni et al. (2005) or de Grauwe and Mélitz (2005) for a further discussion.
[5] Given the time span considered, our analysis also includes Estonia as one of the euro entry candidates.
[6] Also see Hoover et al. (2008) and the references therein for a discussion on this controversy.

(1995) refer to weakly exogenous variables as *long-run forcing* in the presence of cointegration and as such this notion is very much different from *Granger causality* which commonly framed the empirical investigation of the GDH.

While the GDH suggested that the Bundesbank dominated monetary policies in the EMS, our version of the EDH implies that the ECB now takes up a similar role in the enlarging E(M)U. The GVAR approach allows for a coherent formulation of the EDH: it fully exploits the information set and at the same time reflects the structural underpinnings of monetary integration in Europe. We also investigate to what extent the EDH testing results are sensitive to the prevailing exchange rate regime in the CEE countries. More specifically, it will be interesting to see whether the EDH not only applies to countries such as Bulgaria, Estonia or Lithuania which have adopted a unilateral currency board arrangement with the euro but also to explicit inflation targeters such as Poland or the Czech Republic.

The paper is structured as follows. Section 2 discusses and compares in more detail alternative ways of formulating the EDH. We present the data and test the EDH in Section 3. Section 4 investigates how the findings on Euro Dominance are affected by global shocks. Section 5 concludes.

2. Formulating the EDH

2.1. The EDH in terms of a VECM

In line with the state of econometric advancement at the time of earlier tests of the GDH, the main approach to testing the GDH was by means of Granger causality tests, typically in bivariate VAR systems in first differences. Kirchgässner and Wolters (1993) were the first to properly account for cointegration by formulating the GDH in terms of a VECM which combines short-run deviations with long-run equilibrium co-movements in a multiple-equation setting. We could follow their approach and write in the presence of cointegration the reduced form **VECM(p)** of order p for the N countries as

$$\Delta \boldsymbol{R_t} = \boldsymbol{\Phi d_t} + \alpha\beta' \boldsymbol{R}_{t-1} + \sum_{k=1}^{p-1} \boldsymbol{\Pi_k} \Delta \boldsymbol{R_{t-k}} + \varepsilon_t, \tag{1}$$

where ε_t is a N-dimensional zero mean white noise process with positive definite covariance matrix and $\boldsymbol{\Phi}$ includes deterministic terms such as dummies and $\boldsymbol{R_t}$ contains the domestic nominal interest rate series. The parameter matrices $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are of dimension $(N \times r)$ with r representing the number of cointegrating relations. It is well-known that the VECM is a restricted VAR in that it adds the cointegration space $\boldsymbol{\Gamma} = \alpha\beta'$ which identifies the long-term integration process: $\boldsymbol{\beta}$ quantifies the cointegrating relations and $\boldsymbol{\alpha}$ contains the loading coefficients which attach weights to the long-run equilibrium relations. The short-run interest rate dynamics are described by $\boldsymbol{\Pi}$. The VECM is thus sometimes referred to as Cointegrated VAR (CVAR) and obviously nests the first-differenced VAR.

Amidst the absence of an opt-out clause, we assume for the remainder that all CEE countries have the intention to join EMU over the long run. A natural way to identify Euro Dominance is therefore to analyse convergence in terms of $\boldsymbol{\Gamma}$. Drawing upon terminology used by Kirchgässner and Wolters (1993), the EDH may be thought of consisting of the following hypotheses: CEE Dependence, Euro Independence, CEE Insularity and Global Insularity – all of which could be tested by imposing appropriate exclusion restrictions on $\boldsymbol{\alpha}$.

The notion of CEE Dependence implies that CEE interest rates and euro rates cointegrate, whereas Euro Independence additionally requires evidence for weak exogeneity of the euro area with respect to the CEE markets. We would be unable to reject the EDH in its strong form if we found evidence for the first two conditions, which would identify euro rates as the common stochastic trend. The notion of CEE Insularity might be considered a way of enriching the argument by allowing for feedback relations in a multivariate context. The other insularity condition lifts the EDH to a global level, thereby accounting for the increasing interlinkages across countries and allowing for feedback with the ROW. Apart from the latter aspect of global linkages, theses hypotheses have been investigated by Kadow (2011) in a multiple-equation cointegration setting. While his emphasis is more on the role of the evolving banking sectors, he finds evidence for multilateral links both across CEE economies and with the eurozone.

Even though the VECM approach allows us to formulate the EDH in a consistent manner, economically meaningful normalisations of the cointegrating vector would crucially hinge on the existence of a common stochastic trend. Indeed, the preceding discussion would be of limited use without having established econometric evidence for this. Cointegration tests for large N but a relatively short time dimension – as is the case for the CEE transition economies – may be prone to size distortions, however. The most natural way of dealing with this "curse of dimensionality" appears to be to first investigate interest rate linkages on a domestic level, before analysing all series in a combined system. This is the essence of GVAR modelling we discuss next.

2.2. The EDH in terms of a GVAR

Our proposed approach in formulating and testing the EDH is mainly empirical in nature but it also has some structural underpinnings. Suppose there are two blocs of countries (*CEE* and *EMU*), both of which have their own independent central banks. *EMU* is a large economy and adopts a common monetary policy stance, whereas *CEE* consists of several somewhat more disjoint small open economies. Monetary policymakers in *CEE* are as a consequence slightly more heterogeneous in their choice of operating procedures, yet they share the common overall objective of ultimately becoming part of *EMU*.

We may conceptualise the situation in *CEE* by means of the following policy rule:

$$\boldsymbol{R_{it}} = \boldsymbol{G}(\boldsymbol{L})\boldsymbol{z_t},$$

where $\boldsymbol{R_{it}}$ represents the vector of policy instruments in any given *CEE* country (typically short-term interest rates or foreign reserves), $\boldsymbol{G}(\boldsymbol{L})$ is a vector polynomial in the lag operator L and $\boldsymbol{z_t}$ contains policy-relevant endogenous and exogenous variables, including short-term interest rates in *EMU*.[7] Specifying some sort of reaction function, however, might not only be limited by data availability and reliability but would also lead us to exclusively centre the analysis around short-run central bank behaviour. Our proposed error-correcting specification is richer: it captures short-run deviations but models interest rate convergence in the context of a long-run equilibrium.

Table 1 gives an overview of the prevailing monetary policy regime as of the end of 2009. As can be seen, CEE central banks have moved towards the extremes of the spectrum of possible exchange rate arrangements over the last decade. The Bank of Latvia, for example, has pegged the lat tightly to the euro, only allowing for much smaller fluctuations than stipulated in the Exchange Rate Mechanism II (ERM II), which essentially replaced the former EMS. Other national central banks announce explicit inflation targets and allow their exchange rates to float more freely. The Maastricht criteria of stable nominal exchange rates with low and stable inflation rates describe the relevant benchmarks for monetary convergence and the stabilising effects on the bilateral exchange rate from inflation targeting, or active exchange rate fixing, are apparent from market data.[8] Table 2 thus provides important institutional background for the remainder as it facilitates comparisons of the transmission of shocks of inflation targeting with exchange rate targeting countries in CEE.

Whilst the GVAR model can easily be generalised, we confine ourselves in line with the structural underpinnings and reported descriptive and anecdotal evidence to short-term nominal interest rates. This allows for a more transparent mapping to the VECM approach for testing the GDH (a crucial methodological contribution of our paper). Nominal interest rates also seem to be the most reliable measure of monetary convergence for the enlarged euro area. Coricelli et al. (2006) study the transmission of monetary policies in CEE and find empirical evidence for a complete passthrough from key domestic monetary policy rates to short-term money market rates. Indeed, the CEE banking industry has undergone substantial reforms towards market-based structures during the 90's. In contrast to bond, equity and derivative markets, the financial sector currently matches EMU standards and can no longer be considered "underdeveloped".[9] Previously state-owned banks were privatised to establish

[7] Obviously, if euro area interest rates would not matter to the policy rule in *CEE* the corresponding parameter value g_i in the parameter vector $\boldsymbol{g}$ was just zero. Other variables which may be part of $\boldsymbol{z_t}$ are output gaps or exchange rate differentials between the two blocs.

[8] See Fig. A.1. A notable exception may be the Hungarian forint which has been subjected to speculative attacks over the recent past.

[9] See Schadler et al. (2005) for more detailed evidence.

Table 1
Overview of monetary policy frameworks in CEE (December 2009).

	Monetary policy framework
Bulgaria	CBA[a]
Czech Rep.	Floating; inflation targeting
Estonia	CBA[a]; ERM II[b]
Hungary	Floating[c]; inflation targeting
Latvia	Hard peg[d]; ERM II[b]
Lithuania	CBA[a]; ERM II[b]
Poland	Floating; inflation targeting
Romania	Floating; inflation targeting

[a] Unilateral currency board arrangement with the euro.
[b] Membership in the ERM II.
[c] Replaced exchange rate intervention band against the euro in 2008.
[d] Replaced peg to SDR basket of currencies in 2005.Sources: Public information by the ECB and national central banks in CEE.

a so-called two-tier banking system, consisting of an independent central bank and several private commercial banks. The process of market liberalisation led to the removal of interest rate ceilings on credits and lowered entry barriers for private domestic and foreign banks. Accounting standards, commercial and bankruptcy law as well as banking supervisory and regulatory procedures were put in place to meet the changed market structures (Dickinson and Mullineux, 2001).

Given the state of development of the financial sector in CEE, convergence of monetary policies may therefore be best identified on the domestic money markets. If national central banks outside the eurozone mimicked the ECB's path, it may be conjectured that this is reflected there, i.e. CEE and EMU interbank rates are expected to be cointegrated. GVAR modelling (Pesaran et al., 2004; Dees et al., 2007) initially tests for cointegration in country-specific systems, before combining all error-correcting terms in a global model. One may thus view the proposed framework as an attempt to consolidate the different approaches used during the EMS period to examine the GDH (i.e. considering both single- and multiple-equation systems). This two-stage approach offers an alternative, more structural, way of investigating the EDH.

A crucial difference between the VECM and the GVAR model related to these structural underpinnings lies in the way weak exogeneity is introduced. Weak exogeneity is tested for in the VECM by imposing exclusion restrictions on the estimated parameters, whereas particular variables in the GVAR specification (typically foreign quantities) are treated as weakly exogenous from the outset. We could, of course, also condition on weakly exogenous variables in the VECM. As we shall see below, however, the GVAR allows for a coherent analysis of impulse responses within a global system and thus accounts for the interlinkages across the partial models.

Each country-specific error-correcting model contains both domestic and foreign variables. The latter ones are treated as long-run forcing in the sense of Granger and Lin (1995) without necessarily ruling out short-run feedback effects from the lagged variables. We conjecture euro rates to be (weakly) exogenous to CEE countries. We also introduce global influences, proxied by US interest rates. We have $N = 10$ countries, where EMU is the reference country. We thus adopt the following notation: euro rates are denoted by R_{0t} and dollar rates by R_t^*, respectively. We index CEE rates by $i = 1, \ldots, n$ with $n = 8$.

We model the EDH in terms of the GVAR as follows. We introduce two sets of $VARX^*(p_i, q_i)$ models for each country bloc, CEE and EMU, where p_i and q_i refer to the lag order of the domestic and the foreign rates, respectively. The CEE-system has the following representation

$$\boldsymbol{\Theta}_i(L, p_i)\boldsymbol{R}_{it} = \boldsymbol{a}_{i0} + \boldsymbol{\Lambda}_i(L, q_i)\boldsymbol{R}_{0t} + \boldsymbol{\varepsilon}_{it} \tag{2}$$

and for EMU we have

$$\Theta_0(L, p_i)R_{0t} = a_0 + \Lambda_0(L, q_i)R_t^* + \varepsilon_{0t}. \tag{3}$$

All idiosyncratic shocks $\boldsymbol{\varepsilon}_t$ are assumed to be i.i.d. Note that equations (2) and (3) are simply reduced-form VAR models augmented by (weakly) exogenous foreign variables which nest standard unrestricted VAR processes, if $\boldsymbol{\Lambda}(L, q_i) = 0$. The CEE model suggests that CEE countries are small open

Table 2
$VARX^*(p_i,q_i)$ order based on AIC.

Country	p_i	q_i
Bulgaria	1	1
Czech Rep.	1	1
Estonia	2	1
Hungary	2	1
Latvia	2	1
Lithuania	2	1
Poland	1	1
Romania	2	1
euro area	2	2

economies which take interest rates in the large economy – EMU – as exogenously given. US interest rates affect under the null CEE markets indirectly via EMU rates and are thus meant to proxy outside influences arising from the ROW.

The EDH can now be stated as a joint hypothesis consisting of three legs:

(I) CEE Dependence:

R_i and R_0 are cointegrated.

(II) Euro Independence:

R_0 is weakly exogenous to R_i.

(III) Global Independence:

R^* is weakly exogenous to R_0.

Loosely speaking, Condition (I) implies that CEE and EMU rates are linked over the long run. Provided these linkages really exist, it may be conjectured that central banks in CEE are influenced by the ECB's course over a longer horizon in their preparations for joining the euro. However, without establishing evidence for the idea of Euro Independence, we would believe in the notion of a linear combination between the series as common stochastic trend. Only if euro rates were weakly exogenous to CEE rates, we would be able to give some empirical justification for identifying the ECB as the dominant player in this long-run process. Clearly, given the institutional environment, this should be expected. It will therefore be interesting to see what role EMU plays in transmitting shocks to CEE markets and how results differ across countries. Next to relating the evidence to the prevailing official policy stance in CEE, we therefore also add Condition (III) which considers the role of US rates. Provided US rates can also be identified as the common stochastic trend in the EMU model, it follows that interest rate movements in our countries of interest, the CEE economies, have no effect on the ROW.

Our definition of the EDH implies several adjustments compared to the original GDH specification. In particular, we no longer conjecture any form of "insularity" (i.e. the absence of spill-over effects) which seems to be an awkward notion, given the size of the CEE countries and the degree of cooperation and coordination within the EU. The way we formulate the EDH rather reflects two developments the EU faces: globalisation and integration. Globalisation particularly refers to linkages outside Europe with the ROW as captured by Condition (III). Integration is more related to intra-EU issues, most notably the eastern enlargement of the E(M)U, which Conditions (I) and (II) examine. In a later step, in Section 4, we shall elaborate on the idea of globalisation and the impacts on the EU and fully exploit the GVAR approach by linking models (2) and (3).

3. Testing for Euro Dominance

3.1. Data

Our study is based on 3-month interbank rates obtained from Eurostat. Since Bernanke and Blinder (1992)'s seminal paper, short-term money market rates have become the commonly accepted proxy for modelling monetary policy behaviour and transmission in many economies. Amid our focus on long-term aspects of monetary convergence and given the noise and jumps present in daily interest rate movements, we opted for a monthly frequency. The dataset ranges from January 2000 to August 2009, roughly one year after Lehman Brothers declared bankruptcy. Accession negotiations with the CEE countries started already in the late 90's such that market expectations and interest rate differentials in line with the idea of uncovered interest rate parity are likely to reflect any signs of convergence early on.[10]

Fig. 1 shows the CEE money market series in levels. Money market rates for the eurozone and the US are added for the sake of comparison. The figure seems to suggest that short-term interest rates are indeed converging.[11] All interbank rates display a sharp increase towards the end of 2008 – a clear indication of the alleged credit crunch on global financial markets. Interestingly, past CEE interest rate fluctuations have often been much more severe than these spikes. Romania or Poland, for example, experienced interbank rates that were up to 10 times higher than their end-of-sample values.

Whilst Fig. 1 is suggestive of a converging pattern, graphs on their own might be misleading and a more formal analysis is called for. Our proposed framework obviously requires variables to be integrated of order 1, $I(1)$, even though the GVAR approach is flexible enough to accommodate stationarity. We employ standard augmented Dickey–Fuller (ADF) regressions to test for the presence of unit roots in the series:

$$\Delta R_t = \mu + \gamma R_{t-1} + \sum_{k=1}^{p} \delta_k \Delta R_{t-1} + \varepsilon_t.$$

On the basis of the graphical analysis we decided not to include deterministic trends in the Dickey–Fuller regressions. As usual, we test the null hypothesis of a unit root, $H_0:\gamma = 0$, against the alternative that the time series is stationary, or $I(0)$, $H_1:\gamma < 0$. We conducted the tests at different levels of augmentation, up to a quarter. The lag length was chosen using the Akaike Information Criterion (AIC). Results are reported in Table B.1 and suggest that all series are $I(1)$ at the 5% significance level. As robustness check, we have moreover computed unit root t-statistics based on weighted symmetric (WS) estimations of ADF-type regressions (see Pantula et al., 1994 for details). Those have according to Leybourne et al. (2005) more power than the standard ADF test. The test statistics of the WS-ADF unit root test are summarised in Table B.2 and provide further evidence for the $I(1)$-ness of the individual series.

3.2. Empirical results

Having established that the cointegrating framework is sensible, we proceed with testing the EDH. We first specify the lag structures of equations (2) and (3). Table 2 reports the lag order of the individual country models. The length selection is performed using the AIC which suggests that a $VARX^*(2,1)$ suffices for most CEE country models.[12] Subject to residual-based specification tests we decided to treat EMU and the US symmetrically, with $p_i = q_i = 2$.

Stacking endogenous and exogenous variables in $\boldsymbol{z}_t$, and after some reparameterisations we obtain the $VECMX^*(p_i - 1, q_i - 1)$:

$$\Delta R_{it} = c_{i0} + \alpha_i \beta_i' z_{i,t-1} + \sum_{k=1}^{p-1} \Psi_k \Delta z_{i,t-k} + \sum_{k=1}^{q-1} \Lambda_k \Delta \tilde{R}_{i,t-k} + \varepsilon_{it}, \tag{4}$$

where $\tilde{R}_i$ refers to euro rates in case of $i = 1, \ldots, 8$ and to dollar rates for $i = 0$.

The EDH can now be tested using equation (4) in two steps. We start by examining the cointegration properties of the individual country models, followed by an assessment of the weak exogeneity

[10] Ideally, one would like to initialise the data in 1999. We refrained from doing so due to a considerable amount of missing values for some countries in that period.

[11] We also report the individual series in Figs. A.2 and (in differenced form) A.3 to account for the substantial initial spread between some CEE interest rates and euro rates.

[12] By conditioning on weakly exogenous variables we obtain a richer dynamic structure than in VAR models of the same order which would first need to be rewritten in univariate autoregressive (integrated) moving average (AR(I)MA) representations for comparability (Pesaran et al., 2004).

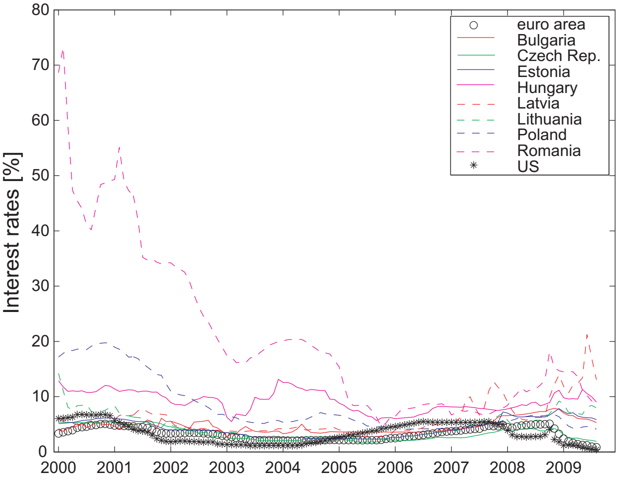

Fig. 1. Monthly observations of 3-month money market rates.

assumption. The country-specific cointegration rank r_i is determined using Johansen's trace statistic. We follow Pesaran et al. (2000)'s testing procedure and restrict the intercept to the cointegrating relations, hereby ruling out linear trends in the data. Critical values are simulated based on 10,000 replications.

Detailed cointegration test results can be found in Table B.3. In sum, euro and dollar rates cointegrate but there is also strong evidence for cointegration between CEE and EMU rates. Evidence for Bulgaria is slightly weaker but still well within the 10% level. We failed to establish cointegration between Hungarian and EMU interbank rates. This finding may well be a result of the financial turmoil in Hungary as the national central bank had to deal with speculative attacks on the forint. While we may find evidence for Euro Dominance in Hungary in a different information set, we concluded that the EDH is not supported by Hungarian money market rates, which as a result are not considered further.

To test for Euro and Global Independence (Conditions (II) and (III)), we assess the pivotal weak exogeneity assumption which in econometric terms may be considered a test for misspecification. We test for the significance of the estimated error-correcting term, $ECT_{i,t-1}$, in the marginal model for $\tilde{R}_{it}$ following Dees et al. (2007). For example, to test for weak exogeneity of EMU interest rates in the Bulgarian country model ($i = 1$) we need to evaluate the null hypothesis that $\gamma_1 = 0$ in the auxiliary regression:

$$\Delta R_{0t} = \mu_1 + \gamma_1 ECT_{1,t-1} + \sum_{k=1}^{s_1} \delta_{1,k} \Delta R_{1,t-k} + \sum_{m=1}^{n_1} \varphi_{0,m} \Delta R_{0,t-m} + \varepsilon_{1,t},$$

where we maintain the lag order of the underlying *VARX** by setting $s_1 = p_1$ and $n_1 = q_1$. Results of this standard t-test are provided in Table B.4 and support the notion of weak exogeneity in all relevant country-specific models.

Table 3 summarises the empirical results. Overall, we seem to have established strong evidence for the notion of Euro Dominance in the enlarging euro area. With the exception of Hungary, domestic CEE money markets are dominated by the euro area over the long run, which follows from Conditions (I) and (II). The EDH seems to hold in the strong form in the sense that euro rates are weakly exogenous. We also find that dollar rates move independently from the eurozone. US interest rates thus affect CEE money markets only via the euro area which confirms the idea of Condition (III) of Global Independence.

3.3. Impulse response analysis

Any investigation of financial linkages is of little meaning without analysing the transmission of shocks. Based on the empirical evidence for Euro Independence and Global Independence, we shock foreign interest rates in the country-specific models and estimate Generalised Impulse Response

Table 3
Summary of EDH testing.

Country	(I) CEE Dependence	(II) Euro Independence	(III) Global Independence
Bulgaria	‡	†	†
Czech Rep.	†	†	†
Estonia	†	†	†
Hungary	–	–	–
Latvia	†	†	†
Lithuania	†	†	†
Poland	†	†	†
Romania	†	†	†

‡ indicates significance at the 10% level.
† indicates significance at the 5% level.

Functions (GIRFs). We distinguish between the impulse responses arising from an EMU shock on CEE interest rates and a ROW shock on EMU interest rates. Both shocks are scaled appropriately to correspond to a rise by one standard deviation of the error variance on impact. Graphical output is summarised in Fig. 2. The panel in the far lower right corner shows the eurozone impulse response function. The solid lines plot the country-specific point estimates; the dashed lines represent the 95% confidence intervals which are based on a sieve bootstrap using 5000 replications.

The Figure illustrates the varying speeds of adjustment of the error-correcting relations over a period of 2 years. The ROW shock on euro rates appears to have quite prolonged effects, with the response only gradually dying out. More interesting for the case at hand is how EMU innovations are transmitted across the CEE countries. Referring back to Table 1, we see that by and large the short-term adjustment of exchange rate targeting countries is faster. This is particularly true for the Baltic countries of Estonia (which indeed joined EMU in 2011) and Lithuania. The inflation-targeters Poland and the Czech Republic show quantitatively a relatively weaker but more sustained response. This feature of a more gradual EMU shock adjustment appears to be in accordance with their prevailing official monetary stance. The case for Romania and Bulgaria is somewhat less clear-cut, however. In line with the result on inflation-targeting regimes, effects on Romanian rates are more prolonged but quantitatively quite strong in comparison to the Polish and Czech impulse function. The Bulgarian impulse function is fairly persistent despite the introduction of the CBA already in the late 90s. These differences in the Bulgarian and Romanian shock profile compared to the other CEE countries may be attributed to their relatively late EU entry but also structural features such as different stages of financial market development and thus differences in transmission mechanisms.

4. Economic and financial globalisation and the EDH

The distinct feature of the GVAR modelling approach is that it permits incorporating aggregated foreign variables to investigate the transmission of shocks both on a regional and global level. This appears particularly relevant given the widespread consensus among academics and policymakers that the ongoing financial and economic globalisation and market integration also require more policy coordination at the supranational level. Indeed, the recent financial and economic crisis constitutes an obvious reminder of that need. Moreover, thus far, we have only exposed the CEE countries to EMU-specific shocks. We therefore analyse in this section to what extent the evidence on Euro Dominance is affected by such global shocks, also in an attempt to provide some preliminary insights into the impact of the Crisis.

Amid our particular interest in the efforts of CEE countries to integrate with EMU we may think of domestic CEE money markets as being driven by a weighted average of foreign rates, i.e. other CEE money markets but also EMU and the US. We refer to this aggregate variable as $\boldsymbol{R}_{it}^{*}$ to indicate the conjectured linkages across markets. Foreign interest rates for each CEE country are constructed using country-specific weights

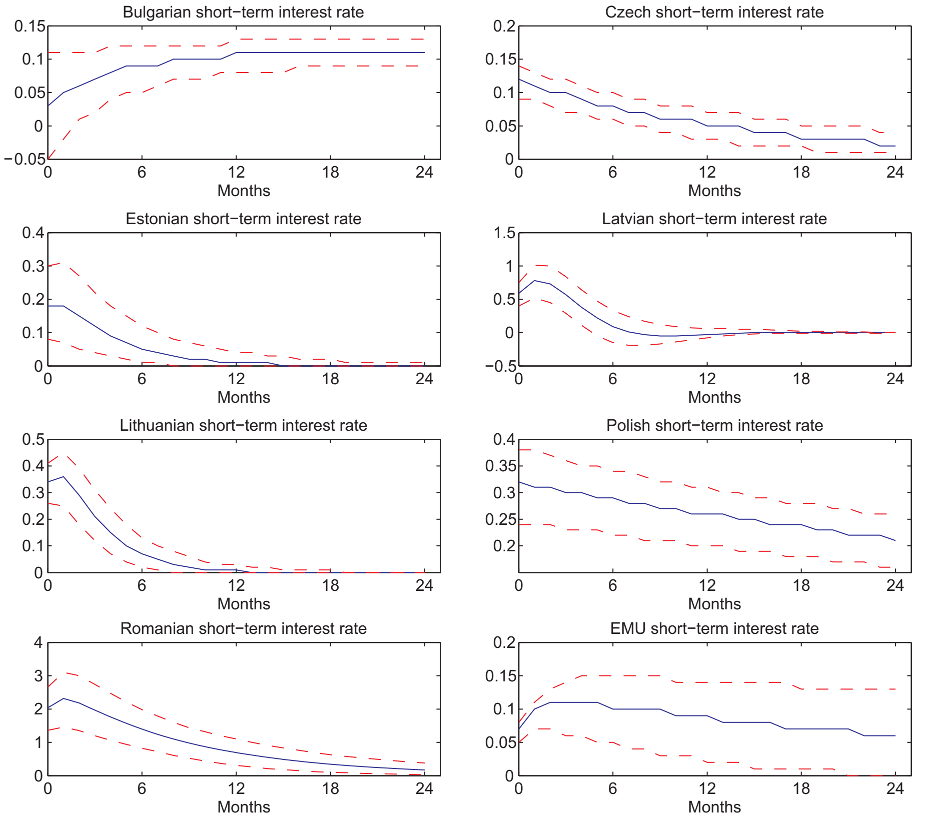

Fig. 2. GIRF to country-specific shock.

$$R_{it}^{*} = \sum_{j=0}^{N} w_{ij} R_{jt},$$

where w_{ij} is the weight for CEE country i with respect to country j and $w_{ii} = 0$. We experimented with different weighting schemes but as the main results were not materially affected by this, we decided to resort to simple equal weighting (to reflect the overall converging pattern) which appeared most natural for the research question at hand. To ensure consistency between country-level and aggregate evidence on the EDH, we exclude the Hungarian series and index the remaining variables from $1, \ldots, n-1$.

We again stack domestic and (now weighted) foreign country-specific variables in the vector z_{it} and introduce the matrix $\boldsymbol{W_i}$ that contains the country-specific weights. This weighting matrix links all domestic models and is needed to solve the GVAR recursively. Note that the empirical outcomes of the analysis are invariant to the ordering of the countries.

Stacking all endogenous variables in $\boldsymbol{R_t}$ we can write

$$\boldsymbol{z_{it}} = \boldsymbol{W_i R_t} \quad i = 1, \ldots, n-1. \tag{5}$$

Using equation (5) allows us to rewrite equation (2)

$$\boldsymbol{A_i}(L,p)\boldsymbol{W_i R_t} = \varphi_{it}, \quad i = 1, \ldots, n-1, \tag{6}$$

where

$$\varphi_{it} = \boldsymbol{a}_{i0} + \boldsymbol{a}_{i1} t + \varepsilon_{it}.$$

We retain the lag structure of the previously specified country models and stack them together to obtain the *GVAR*(p):

$$\boldsymbol{G}(L,p)\boldsymbol{R_t} = \varphi_t, \tag{7}$$

where

$$\boldsymbol{G}(L,p) = \begin{pmatrix} \boldsymbol{A}_1(L,p)\boldsymbol{W}_1 \\ \vdots \\ \boldsymbol{A}_{\boldsymbol{n}-1}(L,p)\boldsymbol{W}_{\boldsymbol{n}-1} \end{pmatrix}$$

and

$$\varphi_t = \begin{pmatrix} \varphi_{1t} \\ \vdots \\ \varphi_{(n-1)t} \end{pmatrix}.$$

We can solve equation (7) for all endogenous CEE interest rates simultaneously which allows us to analyse impulse responses across the entire information set. We may think of the *GVAR*(p) in this context as a regional model of CEE money markets because it links this bloc of countries with both EMU and the ROW, while at the same time allowing for the existence of linkages across CEE economies. Thus, the presence of a solution to this system also provides indirect evidence against the notion of "CEE Insularity" we have referred to above.

The previous impulse response analysis implicitly assumed that shocks are not global, i.e. they originate from a particular country or region. While this holds by definition for intra-EU shocks, the financial crisis has demonstrated that there are also events that cannot so easily be attributed to a particular country or region. This is in particular due to the strong interconnectedness and global character of the financial market place. We therefore construct a "global" shock which is a weighted average of variable-specific shocks (based on PPP-GDP weights) and as such common to all CEE countries in the model.[13]

Fig. 3 summarises the estimated GIRFs to a one standard error global shock in CEE. The effects through time are qualitatively rather similar to the previous impulse responses to EMU shocks, which confirms the predominant role of the euro area in setting CEE monetary policies as well as the strong impact of eurozone events in general on this area. The global analysis thus provides further support for the validity of the EDH. It appears one cannot necessarily claim that the occurrence of global shocks matters for the process of European monetary integration. It rather seems to be the case that predominantly regional E(M)U events drive the adjustment towards a long-run equilibrium or at least that global shocks are largely "absorbed" by the eurozone and from there transmitted further.

4.1. Structural break analysis

As is generally accepted, the possibility of structural breaks in macroeconomic data can never be ruled out a priori. This is particularly true for the case of the emerging CEE economies that are and have been subjected to political and social changes. The presence of structural breaks would be a serious issue in any cointegrating study as structural stability of both long-run and short-run coefficients is implicitly assumed. However, as Dees et al. (2007) point out, the GVAR framework might help in alleviating the structural problem somewhat as it can readily accommodate co-breaking and the underlying *VARX** models might be more robust to possible structural breaks than for instance reduced-form single equation models.

Given the relatively short time span considered, it appears more meaningful to focus in our structural break analysis on the stability of short-run coefficients and error variances that are crucial for the investigation of the transmission of shocks. In particular, we calculate Ploberger and Krämer (1992)'s maximal OLS cumulative sum (CUSUM) statistic, denoted by PK_{sup} and its mean square variant PK_{msq}. We moreover consider the test for parameter constancy by Nyblom (1989) in its

13 See Pesaran et al. (2004) for further technical details and other applications of this procedure.

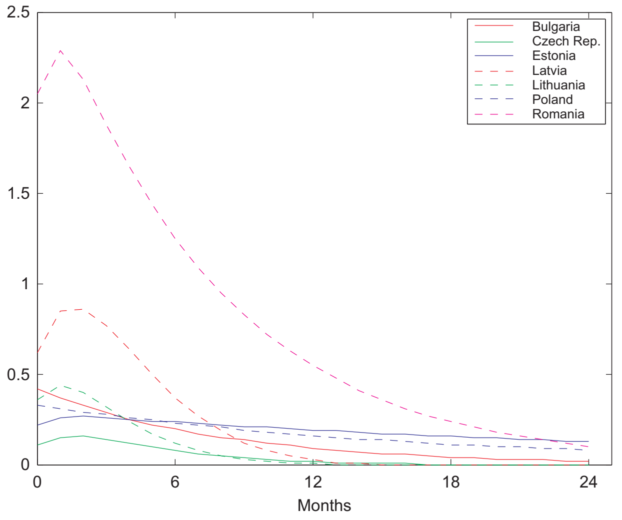

Fig. 3. GIRF to global shock.

heteroskedasticity-robust version. The critical values of the tests under the null of parameter stability are computed using a sieve bootstrap. Results are reported in Table B.5 and cast little statistical doubt on coefficient stability. There is some evidence for the Bulgarian series to reject the null of parameter constancy and to a lesser extent for the US and Latvian series using the Nyblom test. Overall, however, structural instability does not seem to have a strong impact on our results on the EDH.

5. Concluding remarks

In this paper we have upgraded the so-called *German Dominance Hypothesis* (*GDH*) in two dimensions. First, whereas the earlier literature on the GDH modelled interest rate linkages and causality issues within the former EMS, we reformulate the GDH for the CEE countries vis-à-vis the eurozone. We seek to analyse whether EMU events have a considerable impact on CEE markets. Evidence for this *Euro Dominance Hypothesis* (*EDH*) has important implications for the process of European monetary integration as all these countries have committed themselves to eventually introduce the euro and join the monetary union with a single central bank. Second, we employ the relatively novel methodology of GVAR modelling to investigate convergence and the transmission of external shocks.

Unlike the traditional approaches of testing the GDH that are either bivariate in nature or are expressed in terms of high dimensional VECMs, the proposed GVAR model generalises multivariate cointegration analysis to allow for weakly exogenous, structural $I(1)$ variables. This methodology is hence particularly suitable for small open economies. It deals first with error-correcting terms on the country-level which allows for richer dynamics and more efficient estimation. One can stack this information in a second step into a global (multi-country) system that can be used to investigate impulse response functions on a “global” level. The proposed approach may hence be considered a consolidation of previous testing procedures of the GDH.

We tested the EDH as a set of three complementary hypotheses: CEE Dependence, Euro Independence and Global Independence. Our empirical results strongly support the EDH. We find that there is evidence for the notion of Euro Dominance, i.e. CEE Dependence together with Euro Independence, across CEE economies. Domestic CEE policies seem to follow the ECB’s monetary policy stance (proxied by money market rates) quite closely, irrespective of the prevailing exchange rate arrangement. Country-specific impulse response functions suggest that countries with relatively tight monetary regimes adjust faster in response to EMU shocks. We reject the EDH for Hungary which may reflect the notion of domestic policies dominating over EMU ones. The fact that our procedure reveals differences across economies shows that it has power. Our analysis moreover suggests that inner E(M)U events rather than external global shocks appear to be crucial drivers of monetary integration in Europe.

Whilst we have deliberately confined ourselves to a somewhat stylised setting, the GVAR approach can readily be extended to investigate further the transmission of euro area and global shocks. This may be a fruitful exercise which is left for future work as it allowed to understand more clearly the long-term impact of the Crisis on the process of European integration.

Acknowledgements

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Appendix A

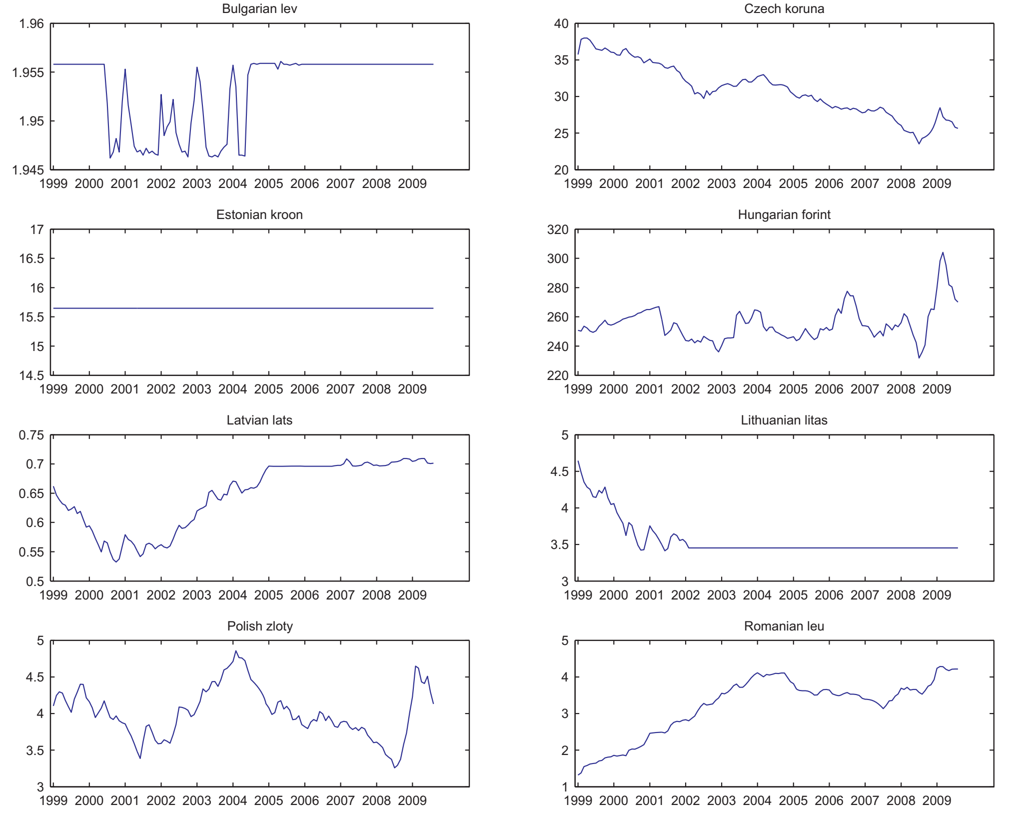

Fig. A.1. Euro exchange rates in terms of domestic CEE currency. Source: ECB. Monthly averages; the old Romanian lei was replaced by the leu on 1 July 2005.

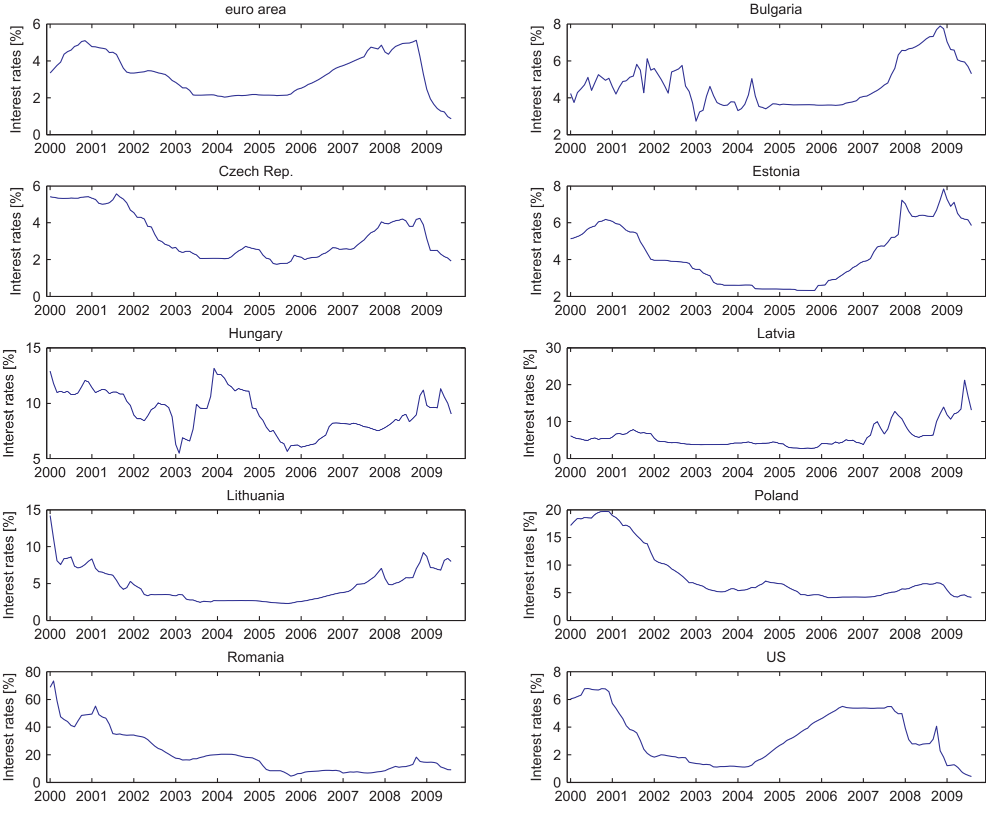

Fig. A.2. Levels of individual series.

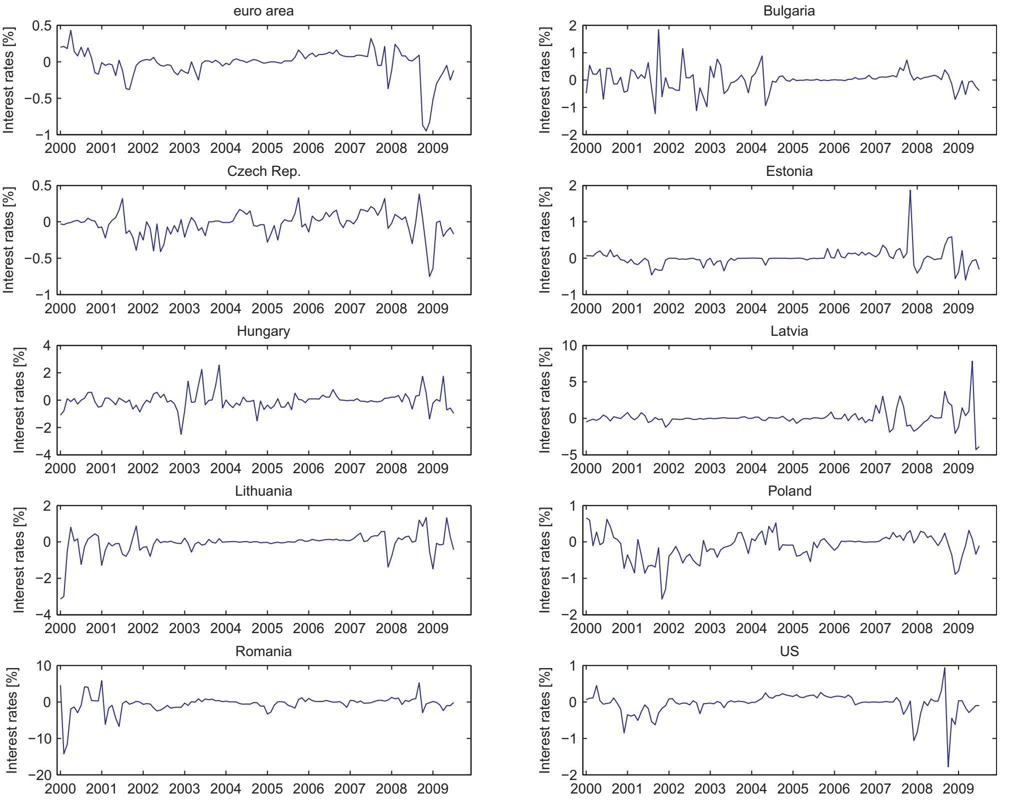

Fig. A.3. First differences of individual series.

Appendix B

Table B.1
ADF test results.

	$p = 0$	$p = 1$	$p = 2$	$p = 3$
Levels				
Euro area	0.27	−1.78[a]	−1.62	−2.05
Bulgaria	−1.81[a]	−1.79	−1.69	−1.79
Czech Rep.	−1.35	−1.59[a]	−1.53	−1.61
Estonia	−0.64	−0.91[a]	−0.83	−1.06
Hungary	−2.41	−2.53[a]	−2.24	−2.32
Latvia	−1.52	−2.11	−0.81[a]	−0.61
Lithuania	−4.56	−2.29	−1.47[a]	−1.46
Poland	−2.08	−2.18	−2.48	−2.27[a]
Romania	−3.89	−4.60[a]	−2.32	−1.48
US	−0.73	−1.15[a]	−1.42	−1.52
First differences				
Euro area	−4.38[a]	−4.35	−3.52	−3.88
Bulgaria	−11.20	−7.76	−5.84	−6.68[a]
Czech Rep.	−5.93[a]	−5.50	−4.44	−3.87
Estonia	−8.59[a]	−7.10	−4.94	−4.15
Hungary	−8.46[a]	−7.35	−5.85	−5.10
Latvia	−8.85	−8.29	−6.87	−6.97[a]

(*continued on next page*)

Table B.1 (*continued*)

	$p = 0$	$p = 1$	$p = 2$	$p = 3$
Lithuania	−8.12	−10.88[a]	−8.09	−6.78
Poland	−5.04[a]	−4.18	−3.07	−3.02
Romania	−7.81[a]	−7.78	−6.77	−5.11
US	−7.46	−5.16[a]	−4.45	−3.58

ADF test statistics for the levels are computed with an intercept. The 5% critical values are −1.94 for the first differences and −2.89 for the levels. Tests are conducted for different lag lengths p with a maximum order of three, where 'a' in superscript denotes the order of augmentation chosen in the Dickey–Fuller regressions according to the AIC.

Table B.2
WS-ADF test results.

Country	Levels	First differences
Euro area	−2.02	−3.65
Bulgaria	−1.99	−6.84
Czech Rep.	−0.83	−5.80
Estonia	−1.26	−7.22
Hungary	−2.12	−7.14
Latvia	−1.20	−8.45
Lithuania	1.13	−6.07
Poland	−1.12	−3.21
Romania	0.60	−4.22
US	−1.01	−5.42

Choice of lag length based on AIC as in ADF test. The 5% critical value is −2.55.

Table B.3
Cointegration rank statistics.

Country	H_0	H_A	Trace statistic	Critical values	
				95%	90%
Bulgaria	$r = 0$	$r = 1$	11.14	12.53	10.69
Czech Rep.	$r = 0$	$r = 1$	20.93	12.53	10.69
Estonia	$r = 0$	$r = 1$	14.86	12.75	10.79
Hungary	$r = 0$	$r = 1$	5.19	12.75	10.79
Latvia	$r = 0$	$r = 1$	16.83	12.75	10.79
Lithuania	$r = 0$	$r = 1$	27.20	12.75	10.79
Poland	$r = 0$	$r = 1$	19.56	12.53	10.69
Romania	$r = 0$	$r = 1$	27.07	12.75	10.79
Euro area	$r = 0$	$r = 1$	16.93	12.80	10.82

Critical values are simulated using 10,000 replications.

Table B.4
Weak exogeneity test results.

Country	t-Statistic	p-Value
Bulgaria	0.44	0.66
Czech Rep.	0.66	0.51
Estonia	0.01	0.99
Hungary	–	–
Latvia	0.04	0.96
Lithuania	−0.03	0.97
Poland	0.50	0.62
Romania	1.54	0.13
Euro area	−0.81	0.42

Hungary not included in the testing procedure due to lack of evidence for cointegration.

Table B.5
Structural break tests

Country	PK_{sup}		PK_{msq}		Robust Nyblom	
	t-statistic	Crit. value	*t*-statistic	Crit. value	*t*-statistic	Crit. value
Euro area	0.85	5.29	0.21	3.14	2.37	6.84
Bulgaria	0.56	2.90	0.05	0.25	1.83	0.74
Czech Rep.	1.00	4.57	0.22	1.98	1.82	3.83
Estonia	0.78	5.00	0.11	2.62	1.97	5.54
Latvia	0.69	4.81	0.07	2.31	1.59	0.97
Lithuania	0.64	5.09	0.08	2.77	0.56	5.59
Poland	1.20	4.01	0.27	1.36	1.14	1.46
Romania	0.80	5.04	0.15	2.68	1.22	5.77
US	0.74	2.93	0.09	0.26	1.28	0.73

95% critical values reported; based on sieve bootstrap with 1000 replications.

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