Academy of Economic Studies
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Disentangling Exchange Rate Volatility for the CEE Countries

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Purpose of the paper

- to separate volatility for exchange rates pertaining to four CEE's into components specific to each country;
- to analyze the currencies in the CEE region independently from the effect of the Euro
- to investigate to which extent country specific factors influence the movements in the currencies of exchange rates in a multivariate stochastic volatility framework

Literature Review

- Mahieu and Schotman (1995) managed to extract the movements in the levels of currencies by describing the logarithm of exchange rates as the difference between currency factors.

- Similar factor models are used by Dungey (2001), Beine ,Bos and Coulombe (2009) and Forbes and Rigobon (2002) who test for contagion in capital markets and assume the equity volatility follows a GARCH model with asymmetries.

- Harvey, Shephard and Ruiz (1994) estimate the multivariate stochastic variance model by using quasi maximum likelihood approach; their model has a more parsimonious parameterization than other ARCH type multivariate models.

- Bos and Shephard (2006) apply the methodology of Mahieu and Schotman (1995) in a multivariate stochastic volatility framework.

- Results are comparable with Pramor and Tamirisa (2006)

Methodology (I)

- Given a system of n+1 currencies we have n(n-1)/2 bilateral exchange rates.

- $s_{io}=u_i-u_o$, where s_{io} the log-differences of the bilateral exchange rate of currency i with respect to the numeraire
  u_i is the news originating from country i

- $u_i=\sum_{k=1}^{M} \beta_{ik}v_k+e_i$ where v_k is the worldwide common factor
  β_{ik} is the sensitivity of u_i with respect to v_k
  e_i is the idiosyncratic news component

- For simplicity the worldwide common factor is assumed to be a latent stochastic process with zero mean and unit variance.

- It is assumed that all factors have zero mean and are mutually uncorrelated.

- The variances of the common factors are normalized to one while he variances of the country specific components $E(e^2) = \lambda_i$.

Methodology (II)

- We can find λ_i so that $Var(s_{ij}) = \lambda_i + \lambda_j$ by solving the following SUR that is at any given time t and for n=4:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} \lambda_0 \\ \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \\ v_7 \\ v_8 \\ v_9 \\ v_{10} \end{bmatrix}$$

- where $y_k(t) = s_{ij}^2(t)$ and, v is a vector of errors with 0 mean

Methodology (III)

- Estimate the vector λ by OLS pooling the time series and the cross section of the six bilateral exchange rates

- To construct the efficient estimator we simply solve the SUR system $\tilde{\lambda}$=$(Z^T D^{-1} Z)^{-1}\,(Z^T D^{-1}\overline{y})$, where D is the weighting covariance matrix

- We then estimate the series of ei with GLS:

$$\widehat{e_i}(t) = \left(\sum_{\substack{j=0 \\ j\neq i}}^{n} \lambda_j^{-1}\, s_{ij}(t)\right) \Bigg| \left(\sum_{j=0}^{n} \lambda_j^{-1}\right)$$

Data Used

- Weekley exchange rates EUR/RON, EUR/HUF, EUR/CZK and EUR/PLN and cross rates over a full sample period from Jan 1999 to April 2013 as well as 3 subperiods.

- The data are weekley Wednesday closing prices.

- In the empirical analysis we take exchange rate changes in deviation from their mean.

Estimates (I)

Variance decomposition of exchange rate news $Var(s_{ij}) = \lambda_i + \lambda_j$

Period	λ_{EUR}	λ_{RON}	λ_{HUF}	λ_{CZK}	λ_{PLN}	Wald
Jan1999-Apr 2013 (Full Sample)	0.2381 (0.0362)	1.4808 (0.1304)	0.8436 (0.0879)	0.4349 (0.0431)	0.9597 (0.0972)	102.53*
Jan 1999-Nov 2004	0.1019 (0.0309)	1.8447 (0.2211)	0.5481 (0.1189)	0.4409 (0.0641)	1.2824 (0.1237)	76.97*
Nov 2004-Sep 2008	0.2684 (0.0515)	1.3808 (0.2233)	0.5210 (0.0975)	0.3496 (0.0722)	0.5455 (0.0721)	26.66*
Sep 2008-April 2013	0.2323 (0.0825)	0.6341 (0.1473)	1.3136 (0.1929)	0.5079 (0.0771)	0.9146 (0.2154)	24.89*

Notes: λ_i denotes the exchange rate variances due to country i; standard errors are in the parentheses.
*The Wald test for equality of all 5 λ's has a distribution of $\chi^2(4)$ and tells us that the model is well fitted

Estimates (II)

Second moment (sample variance and estimated), third and fourth moments

	EUR/RON	EUR/HUF	EUR/CZK	EUR/PLN
Jan 1999-Apr 2013				
Sample Variance	1.2944	1.2673	0.8998	1.4290
Estimated Variance	1.7189	1.0817	0.6730	1.1978
Sample Skewness	0.5470	0.1574	-0.1353	0.3165
Sample Kurtosis	6.0426	6.3573	6.3038	5.6008
Jan 1999-Nov 2004				
Sample Variance	1.5384	0.9035	0.7537	1.3558
Estimated Variance	1.9466	0.6573	0.5509	1.3843
Sample Skewness	0.3895	1.1341	0.0156	0.3983
Sample Kurtosis	4.2098	8.3423	4.1633	3.3457
Nov 2004-Sep 2008				
Sample Variance	1.2353	1.0898	0.7880	1.0872
Estimated Variance	1.4692	0.8794	0.7094	0.8139
Sample Skewness	0.0984	0.4288	-0.1337	0.0217
Sample Kurtosis	6.4765	3.8857	5.3854	3.7824
Sep 2008-Apr 2013				
Sample Variance	0.9113	1.7237	1.1273	1.7371
Estimated Variance	0.8664	1.5459	0.7402	1.1469
Sample Skewness	1.1906	-0.1839	-0.2771	0.2073
Sample Kurtosis	11.7563	4.5323	5.8905	5.8841

Estimates (III)

Diagnosis of idiosyncratic news component vector

	e_{EUR}	e_{RON}	e_{HUF}	e_{CZK}	e_{PLN}
Skewness	-0.23	-0.33	-0.35	-0.15	0.46
Kurtosis	6.62	7.97	8.43	5.62	5.38
Normality (JB)	397.80*	752.69*	896.95*	209.34*	196.01*
1’st order AC	-0.107	-0.115	-0.125	-0.061	-0.176
Ljung Box (30)	55.924*	61.951*	64.318*	33.10	66.98*
ARCH(1)	69.597*	77.28*	85.79*	54.418*	52.53*
ARCH(10)	367.46*	332.76*	290.91*	309.08*	251.49*
Cross ARCH	0.1207	0.2783	0.2834	0.1744	0.089
Causality	20.64*	54.69*	56.10*	29.97*	14.96*

Observations:

- All currencies appear to be non-normal
- There is hardly any autocorrelation in the news series but there is strong evidence of ARCH in all components
- There seem to be strong heteroskedasticity spillovers

Model(I)

The univariate stochastic volatility model (Taylor 1968)

$$\begin{cases} s(t) = \varepsilon(t)\sigma(t) = \varepsilon(t)\exp\left\{\frac{1}{2}h(t)\right\}, \varepsilon(t) \sim IID(0,1) \\ h(t) - \mu = \rho(h(t-1) - \mu) + \eta(t), \quad \eta(t) \sim NID(0, \omega^2) \end{cases}$$

s_t - the asset return at the moment t

h_{it} - the log-volatility of the return

μ- the unconditional mean of h(t)

ρ - the persistence parameter

After squaring and taking the logarithm we get:

$w(t)=\ln\{s(t)^2\}= h(t)+\ln\{\varepsilon(t)^2\}=h(t)+\alpha+\xi(t)$, where $E[\xi(t)]=0$

OBS:

- $\alpha=-1.27$ and $E[\xi(t)^2]=\pi^2/2$ so that ε(t) is Gaussian (see Harvey, Shephard,Ruiz(1994))
- The transformed error term ξ(t) is always uncorrelated with η(t)

The system can further be reparameterized:

$$\begin{cases} w_t = x(t) + \zeta + \xi(t), & \xi(t) \sim N(0, \Phi) \\ x(t) = \rho x(t-1) + \eta(t), & \eta(t) \sim N(0, \Omega) \end{cases}$$

where , $\zeta = \alpha + \mu$ and *x(t)=h(t)-μ*

Model (II)

The Multivariate SV Model

$$\begin{cases} w_t = -1.27\breve{l} + \rho h_t + \mu + \xi_t & \xi_{it} \sim N(0, \Sigma_\xi) \\ h_t = h_{t-1} + \eta_t , & \eta_{it} \sim N(0, \Sigma_\eta) \end{cases}$$

We alter the model to fit the framework described in the first part:

$$\begin{cases} w(t) = \frac{1}{2} Z(x(t) + \zeta) + \xi(t), \ Var[\xi(t)] = \Phi \\ x(t) = Ax(t-1) + \eta(t), \qquad Var[\eta(t)] = \Omega \end{cases}$$

With: $\zeta = \mu + \tilde{1}(\alpha + \ln(2))$

Model (III)

Assumptions and parameter specification:

- According to the methodology specified in the firs part: $\exp\big(h_{ij}(t)\big) = \lambda_i(t) + \lambda_j(t) = \exp(h_i(t)) + \exp\big(h_j(t)\big)$; linearizing around $\overline{h_i}$ and $\overline{h_j}$ and assuming $\overline{h_i}=\overline{h_j}$ we find: $h_{ij}(t) \approx \ln(2) + \frac{1}{2}(h_i(t) + h_j(t))$
- We assume all changes in exchange rates have the same type of distribution and that the estimated variance of ξ(t) is:

$$\Phi = \phi^2 \begin{pmatrix} 1 & r & r & r & r & r & r & r & r & 0 \\ r & 1 & r & r & r & r & r & r & 0 & r \\ r & r & 1 & r & r & r & r & 0 & r & r \\ r & r & r & 1 & r & r & 0 & r & r & r \\ r & r & r & r & 1 & 0 & r & r & r & r \\ r & r & r & r & 0 & 1 & r & r & r & r \\ r & r & r & 0 & r & r & 1 & r & r & r \\ r & r & 0 & r & r & r & r & 1 & r & r \\ r & 0 & r & r & r & r & r & r & 1 & r \\ 0 & r & r & r & r & r & r & r & r & 1 \end{pmatrix}$$

- We assume r to be approximately equal to 0.11

Model (IV)

Motivation of use:

A stochastic volatility model has parsimony of the parameter space which solves the main problem encountered when specifying a multivariate model- the large number of parameters needed.

It can easily be estimated by QML using the Kalman Filter to compute the prediction errors.

By augmenting the vector wt to include cross rates we can specify in the multivariate factor model framework developed by HRS a non-numeraire dependent model for a system of exchange rates.

Model (V)

Shortcomings:

- The restrictions imposed upon the correlation structure of ξ as well as the assumption that the factor variances are approximately equal can leave room for discussion.
- By linearizing the model we lose information about the sign of the cross correlations of ε_{ij}'s.
- The results depend heavily on the normality assumption for ε(t).
- We make use of just one lag for the time varying volatility- which seems to be insufficient as it is shown in the next section.

Descriptive statistics of w_{ij}

	EUR/RON	EUR/HUF	EUR/CZK	EUR/PLN	RON/HUF	RON/CZK	RON/PLN	HUF/CZK	HUF/PLN	CZK/PLN
Mean	-1.1976	-1.4599	-1.8667	-0.7932	-0.5626	-0.6949	-0.5680	-1.0877	-1.0340	-0.9052
Std. dev	2.3581	2.6492	2.4340	2.3294	2.4689	2.2302	2.3704	2.2876	2.3775	2.3484
Skewness	-1.0466	-1.2369	-1.3749	-1.3318	-1.7912	-1.0774	-1.2915	-1.0505	-1.2006	-1.5715
Kurtosis	5.1355	6.4730	6.2801	5.7359	9.4094	4.6683	5.6213	4.6850	5.8621	7.7587
JB Test	277.22*	563.63*	567.92*	451.96*	1671.39*	230.22*	419.85*	224.84*	432.69*	1008.25*
Minimum	-13.4416	-19.2010	-14.4988	-12.2424	-17.9255	-11.1902	-13.1259	-12.2943	-16.3778	-15.7431
Maximum	3.6169	3.9438	3.1522	4.0554	4.2055	3.6469	4.3040	3.4689	4.1036	3.7604
Ljung-Box (30)	265.44*	776.03*	83.45*	113.85*	46.74*	66.41*	77.03*	105.3*	33.25	41.94*
Autocorrelation										
1	0.216	0.313	0.164	0.076	0.027	0.114	0.136	0.109	0.004	0.040
5	0.166	0.204	0.098	0.089	0.180	0.066	0.062	0.145	0.035	-0.008
10	0.125	0.239	0.092	0.047	0.002	-0.006	0.051	0.050	-0.053	-0.033
20	0.065	0.205	-0.002	0.053	0.037	0.019	0.051	0.060	0.017	0.035
25	0.102	0.105	0.006	0.059	-0.025	-0.028	-0.007	0.035	0.037	0.052
30	0.51	0.169	-0.033	0.051	-0.035	-0.008	-0.007	0.032	0.014	0.039
GARCH (1,1)										
c	0.0726	0.0367	-0.0754	-0.0473	-0.1283	-0.1503	-0.1119	-0.1066	-0.0526	0.0221
	(0.0368)	(0.0320)	(0.0261)	(0.0466)	(0.0505)	(0.0482)	(0.0517)	(0.0409)	(0.0425)	(0.0461)
α_0	0.0606	0.0257	0.0397	0.0769	0.6635	0.0599	0.1115	0.0448	0.0863	0.0659
	(0.0133)	(0.0474)	(0.0127)	(0.0337)	(0.1808)	(0.0256)	(0.0344)	(0.0173)	(0.0368)	(0.0291)
α_1	0.1941	0.1057	0.1241	0.1067	0.2202	0.0681	0.1009	0.0843	0.0785	0.0752
	(0.0257)	(0.0171)	(0.0251)	(0.0205)	(0.0429)	(0.0155)	(0.0164)	(0.0170)	(0.0193)	(0.0159)
α_2	0.7834	0.8835	0.8223	0.8532	0.5304	0.9026	0.8547	0.8908	0.8721	0.8883
	(0.0265)	(0.0154)	(0.0335)	(0.0301)	(0.0904)	(0.0226)	(0.0220)	(0.0211)	(0.0356)	(0.0270)

Results (I)

Obs:

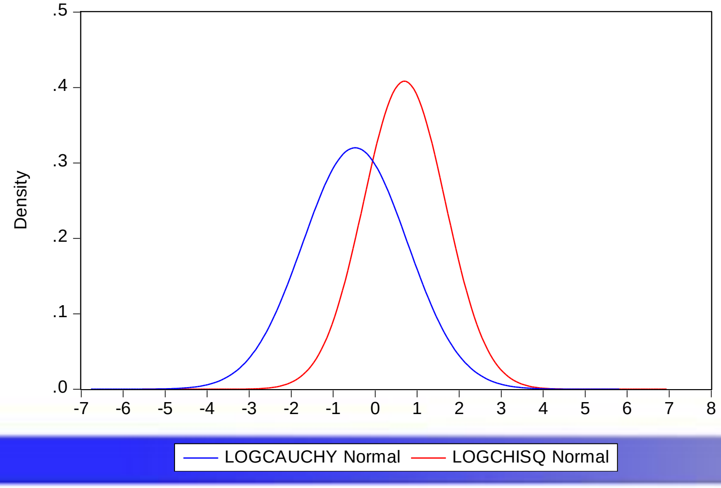
- The innovation covariance matrix Ω= Var[η(t)] was estimated freely;
- All the currencies are positively correlated with the EURO;
- High volatility for the CEE currencies tends to go together with low volatility of the Euro with the exception of the Hungarian Forint

	EUR	RON	HUF	CZK	PLN
ζ	-1.8209 (0.1547)	-0.3451 (0.6931)	-1.0771 (0.3819)	-1.3314 (0.1415)	-0.5409 (0.5235)
aEUR	0.3895 (0.1477)	-0.0702 (0.0302)	0.0566 (0.0508)	0.0816 (0.0963)	-0.0222 (0.0296)
aRON	-3.7216 (2.0220)	0.3848 (0.1815)	0.6938 (0.5873)	2.3594 (1.3307)	0.4897 (0.2583)
aHUF	1.5674 (0.8511)	-0.1628 (0.0940)	-0.1690 (0.2597)	-0.6223 (0.5403)	-0.1247 (0.1120)
aCZK	-0.1180 (0.4406)	-0.0544 (0.0492)	0.1738 (0.1263)	0.4528 (0.2714)	0.0769 (0.0728)
aPLN	-5.2100 (2.5378)	0.1554 (0.0242)	1.2684 (0.7791)	3.2003 (1.6649)	0.5585 (0.3008)
Ω					
EUR	0.7542	0.2702	0.7763	0.8533	0.5475
RON	*0.1458*	3.5541	-0.1447	0.3693	0.1991
HUF	*0.4890*	*-0.05371*	2.3412	-0.1329	0.3106
CZK	*0.8125*	*0.1620*	*-0.0618*	1.4622	0.0047
PLN	*0.2965*	*0.0814*	*0.0794*	*0.0018*	3.5183

Results (II)

- The estimates of ϕ and the residual characteristics provide information about the distribution of ε(t) and $\xi(t)=\ln\{\varepsilon(t)^2\}$
- The error variances have been estimated freely and are approximately close to $\frac{\pi^2}{2}$ which is implied by a log-chi squared distribution
- The prediction errors are also negatively skewed which further evidence of a log-chi squared distribution

ξ_{ij}	EUR/RON	EUR/HUF	EUR/CZK	EUR/PLN	RON/HUF	RON/CZK	RON/PLN	HUF/CZK	HUF/PLN	CZK/PLN
Skewness	-0.7187	-1.0941	-1.1109	-1.2135	-1.2926	-0.8562	-0.9691	-1.0249	-0.9364	-1.6409
Kurtosis	4.0291	4.9677	5.4494	4.9237	5.9422	3.9018	4.4585	5.0793	4.0849	7.8501
Normality	47.5339	131.709	166.329	145.868	233.2975	56.9617	89.4972	133.4622	71.2444	521.5572



Results (III)

Stochastic Volatility tests

Obs:

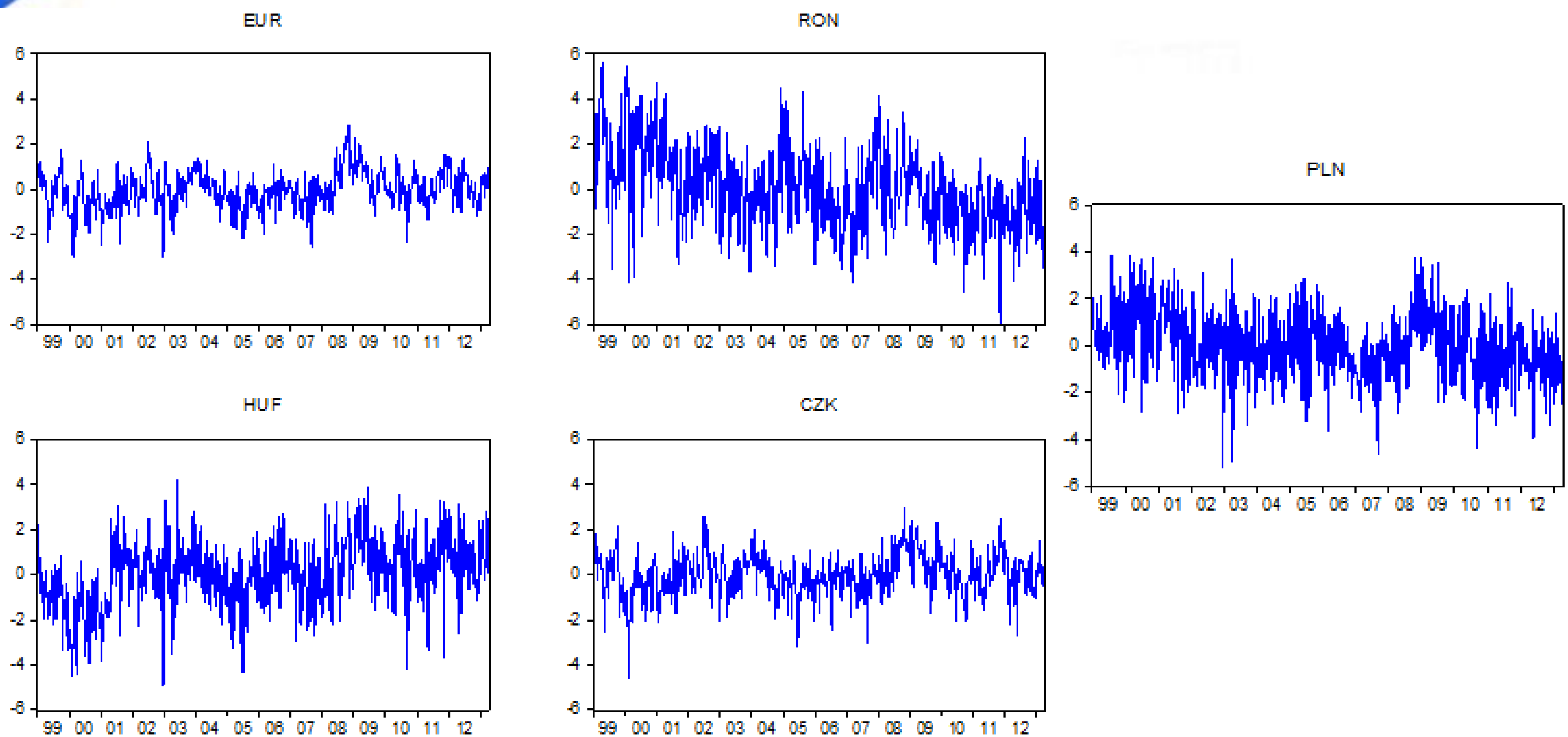
- There seems to be no lagged relationship from the EUR volatility to any other currencies which implies that news from the Euro Area is transmitted within one week

- The Polish Zloty however, strongly influences other currencies

Hypothesis	Wald	df
(1) Equal unconditional variances: $\xi_1 = \xi_2 = \xi_3 = \xi_4 = \xi_5$	79.55*	4
(2) Causality (column wise test)		
$a_{21}=a_{31}=a_{41}=a_{51}=0$ (Euro to other currencies)	7.29	4
$a_{12}=a_{32}=a_{42}=a_{52}=0$ (RON to other currencies)	7.56	4
$a_{13}=a_{23}=a_{43}=a_{53}=0$ (HUF to other currencies)	7.68	4
$a_{14}=a_{24}=a_{34}=a_{54}=0$ (CZK to other currencies)	3.99	4
$a_{15}=a_{25}=a_{35}=a_{45}=0$ (PLN to other currencies)	13.82*	4
(3) Causality (row wise test)		
$a_{12}=a_{13}=a_{14}=a_{15}=0$ (Other currencies to EUR)	16.05*	4
$a_{21}=a_{23}=a_{24}=a_{25}=0$ (Other currencies to RON)	6.21	4
$a_{31}=a_{32}=a_{34}=a_{35}=0$ (Other currencies to HUF)	9.35*	4
$a_{14}=a_{42}=a_{43}=a_{45}=0$ (Other currencies to CZK)	10.36*	4
$a_{51}=a_{52}=a_{53}=a_{54}=0$ (Other currencies to PLN)	6.98	4

Results (IV)

Time series of estimated conditional log-variances of the four series



Conclusions (I)

- This paper analyses the volatility of four CEE currencies using a methodology through which by considering the whole system of exchange rates and the correlation between idiosyncratic shocks we can disentangle the specific volatility for each currency.
- The ranking of the variances is as follows: λRON >λPLN> λHUF> λCZK> λEUR The dominance of Romania in this system is especially due to the period before 2005 where it is approximately 4 times as big as the volatility originating in the other European currencies. However, the RON has been far less volatile after 2008 given due to an increased liquidity and frequent intervention of the monetary authorities on the domestic market.
- We subsequently used the factor structure in a parsimonious multivariate time varying volatility model.

Conclusions (II)

- All the currencies are positively correlated with the Euro, thus an increase in the volatility of the numeraire currency gets transmitted to increased volatility of the other currencies within a week
- The numeraire effect is higher for certain currencies like the Czech Koruna than for others like the Romanian Leu or the Polish Zloty which could be a sign of a weaker convergence towards the Euro for these currencies.
- The Polish Zloty strongly influences other currencies.
- An interesting outcome is the relatively stable and consistent with the Euro pattern of the Czech Koruna. This result can be explained due to the fact that the Czech Coruna is a funding currency for investments in other CEE currencies due to lower interest rates practiced by the Czech National Bank.

Thank You

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