Exchange rate comovements, hedging and volatility spillovers on new EU forex markets

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Motivation - general

- Correlations and linkages between different asset classes unfold over time as macroeconomic conditions change and new information is released (e.g. Brenner et al., 2009; Yang et al., 2009)
- Correlations between markets increases during volatile periods, especially during bear markets and decreases in bull markets
  - Investors tend to follow the crowd when times are uncertain; they begin to doubt their own judgment and run in herds → *herding behavior*
- It is recognized that the time variation in the correlations between different assets has critical inference for asset allocation and risk management (optimal portfolio theory; Markowitz, 1991)
  - Should the new EU forex markets be treated as a whole or is it better to select assets individually from each country to improve portfolio diversification?
  - Hedge ratios and portfolio weights based on DCC model are computed

Motivation – emerging markets

- Developed and emerging markets are interdependent and integrated (Bekaert and Harvey, 1997; Ng, 2000; Diebold and Yilmaz, 2009)
- Stability of foreign exchange rates is important part of international trade and determinant of inflation
  - Czech Republic, Poland, Hungary are open export-oriented economies
  - According to Hau, 2002 more open economies exhibit less volatile real exchange rates

Motivation – emerging markets

- European forex market experienced a lot of changes during last two decades
  - 1999: Euro was introduced
  - 2002: Euro began to circulate in 12 European countries
  - 2008: Global Financial Crisis (GFC)
  - 2012: EU debt crisis
- How interdependencies and spillovers evolve on new EU forex markets? (Czechia, Hungary and Poland)
  - They are much less researched but attract substantial capital inflows in foreign currencies (Ahmed and Zlate, 2014)
  - New EU foreign exchange markets have gained particular importance after joining EU in 2004 (Hanousek and Kočenda, 2011), especially via their trade and banking sector links (Gray, 2014)

Data and assessment strategy

- Variables: exchange rates of CZK/EUR, PLN/EUR, HUF/EUR (new EU) plus USD/EUR (*proxy for the world forex market*); daily exchange rate returns
- Sample period: January 1, 1999 – May 31, 2018 (4 970 observations)
    - Before GFC: January 1, 1999 – September 14, 2008
    - GFC: September 15, 2008 – April 30, 2010
    - EU debt crisis: May 3, 2010 – July 26, 2012
    - After EU debt crisis: July 27, 2012 – May 31, 2018

(Note: periods based on real events plu Bai and Perron; 1998, 2003 and Chow; 1960 tests applied)

Methodology- comovements and spillovers

- **Time varying forex co-movements** → assessed via the DCC – GARCH model (Engle; 2002) with GED distribution
- **DCC model:**

$$H_t = D_t R_t D_t \qquad D_t = diag(h_{11t}^{1/2}, \cdots, h_{NNt}^{1/2})$$

$$R_t = diag(q_{11t}^{1/2}, \cdots, q_{NNt}^{1/2}) Q_t diag(q_{11t}^{1/2}, \cdots, q_{NNt}^{1/2})$$

$$Q_t = (1 - \alpha - \beta)\overline{Q} + \alpha u_{t-1} u'_{t-1} + \beta Q_{t-1}$$

- **Volatility spillovers** → assessed via the Diebold-Yilmaz Spillover Index (2012) based on forecast error variance decomposition from vector auto regressions (VAR(5))

Hedge ratios and portfolio weights

- Time-varying co-movements (DCC) can be used for international portfolio diversification (Kroner and Sultan, 1993)
- Korner and Ng (1998) suggest optimal portfolio weights
- The hedge ratio is calculated as: $\beta_{ij,t} = h_{ij,t}/h_{jj,t}$
  - $h_{ij,t}$ is the conditional covariance of *i* and *j* exchange rates
  - $h_{jj,t}$ is the conditional variance of *j* exchange rate
- The hedge ratio implies that a long position in one exchange rate (for example *i*) can be hedged by short position in another exchange rate (for example *j*)

Hedge ratios and portfolio weights

- Optimal portfolio weights between exchange rate *i* and *j* are calculated as:

$$w_{ij,t} = \frac{h_{jj,t} - h_{ij,t}}{h_{ii,t} - 2h_{ij,t} + h_{jj,t}}$$

- $w_{ij,t}$ is the weight of the first exchange rate (*i*) in a 1-euro portfolio, consisting of two exchange rates *i* and *j* at time *t*. The weight of the exchange rate *j* in the same portfolio is 1 - $w_{ij,t}$

- $$w_{ij,t} = \begin{cases} 0, & if\ w_{ij,t} < 0 \\ w_{ij,t}, & if\ 0 \le w_{ij,t} \le 1 \\ 1, & if\ w_{ij,t} > 1 \end{cases}$$

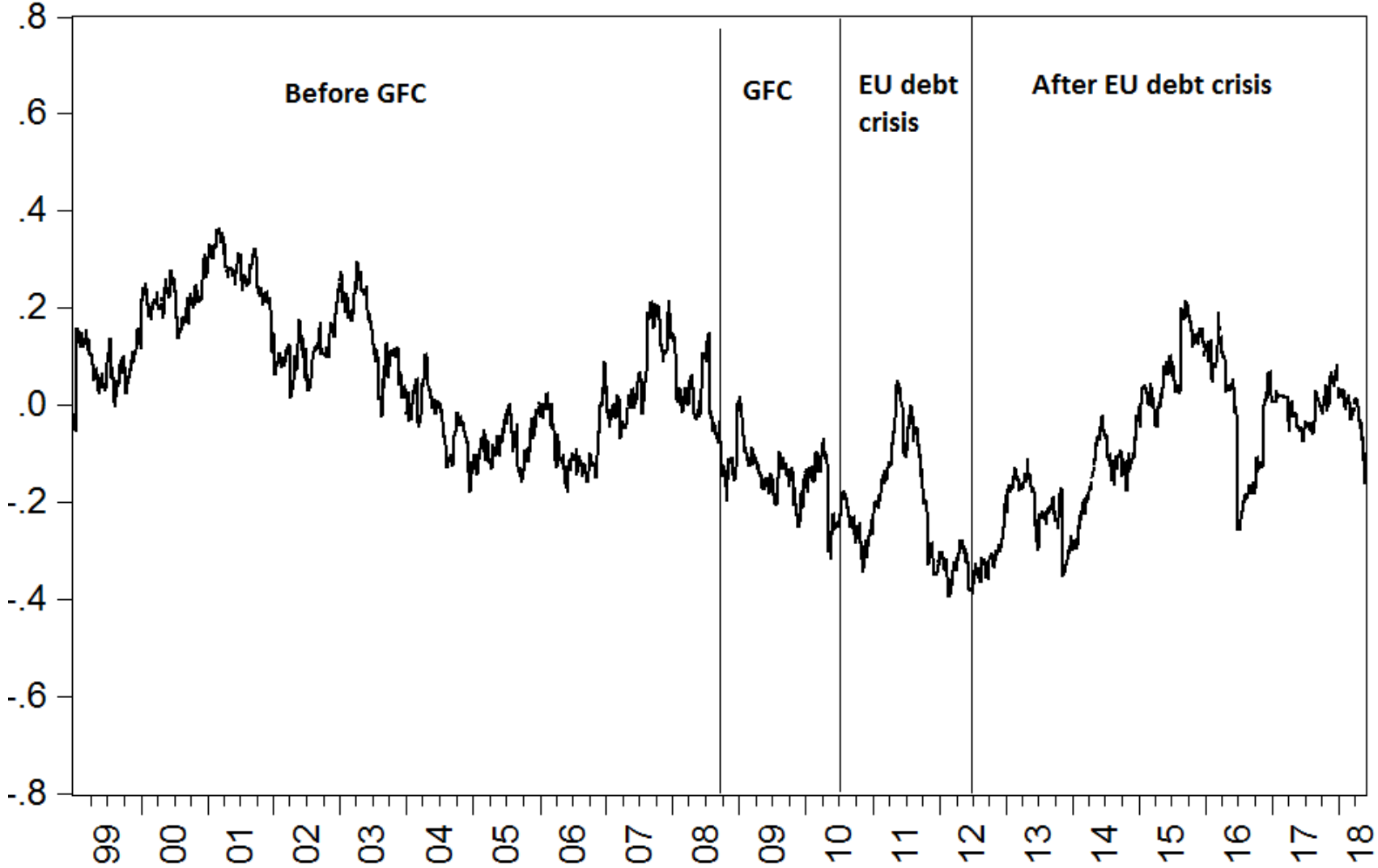
Hypotheses

- **Hypothesis 1:** The dynamic conditional correlations between new EU currencies and the U.S. dollar do not change pattern and magnitude across four examined periods (*rejected*)
- **Hypothesis 2:** Hedge ratios are not stable over all four periods examined (*not rejected*)
- **Hypothesis 3:** The value of the total volatility spillover index is not stable during the examined time period (*not rejected*)
- **Hypothesis 4:** None of the examined new EU exchange rates are dominant currencies in terms of volatility transmission mechanisms (*rejected*)

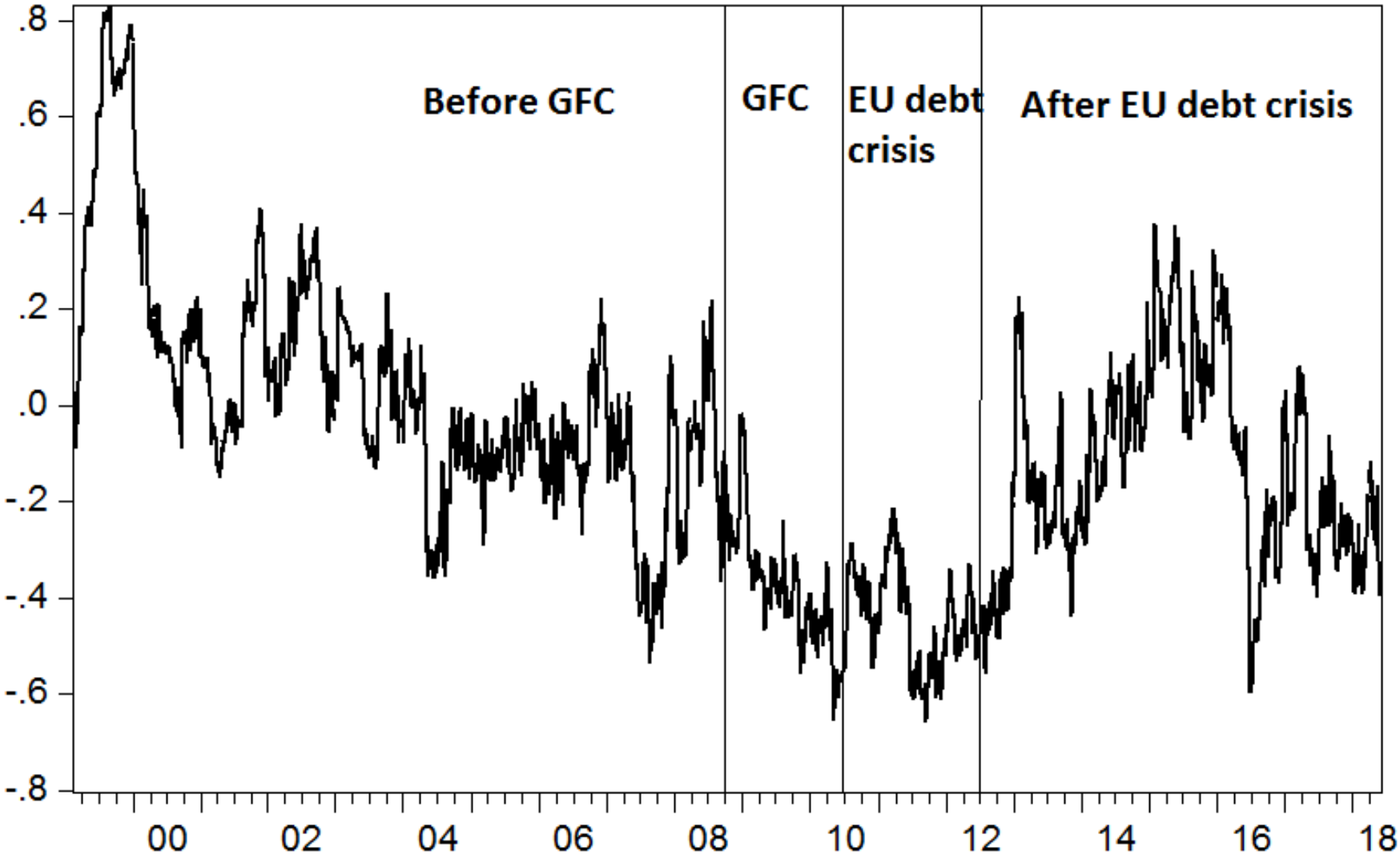
Results: co-movements

- First dynamics in a graphical presentation
- Then verbal summary
- Additional detailed values in Appendix

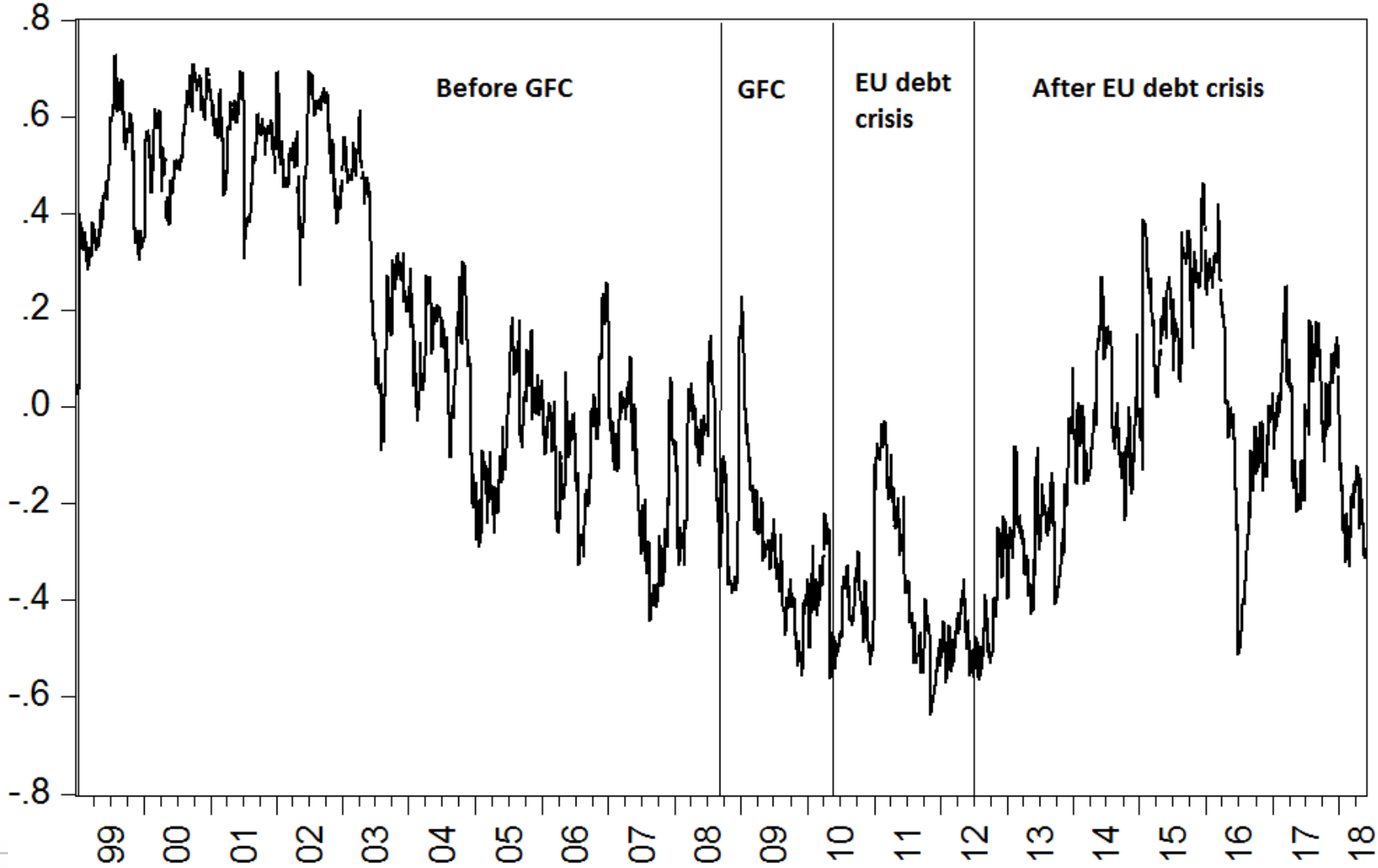
Co-movements CZK/EUR & USD/EUR



Co-movements HUF/EUR & USD/EUR



Co-movements PLN/EUR & USD/EUR



Results: Conditional correlations I

- **Conditional correlations change over time and may be evaluated from the perspective of economic events**
- **1999 – 2002 Euro used as accounting currency:** strong correlations between USD/EUR and new EU FX rates (ρ close to 0.8 for PLN/EUR, HUF/EUR)
- **2002 – 2008 before GFC:** Conditional correlations between new EU FX rates & the U.S.D. slopes down
- **2008 – 2010 GFC:** Correlations are negative, stable and oscillate around -0.2 (CZK/EUR); -0.4(HUF/EUR) and -0.3(PLN/EUR)
- **2010 – 2012 EU debt crisis:** Correlations are negative (*minimum reached*), stable and oscillate around -0.3(CZK/EUR) and -0.5(PLN/EUR, HUF/EUR)
- **2012 – 2018 after EU debt crisis:** Conditional correlations rise up to 0.2 in January 2015. ECB announced QE program (2015) → correlations fall to negative territory. Recovering in 2016 and falling back to negative in early 2017 (US trade protectionism, FED monetary tightening)

Results: Conditional correlations II

- New EU currencies behave homogenously in individually examined time periods
- But new EU currencies demonstrate weaker cond. corr. with the dollar than the currencies of developed countries.
  - Antonakakis (2012) shows that the cond. corr. between the FX rates of major currencies are entirely positive and range from 0.32 (JPY/GBP) to 0.87 (CHF/EUR)
- Negative values of correlation coefficients during the GFC and EU debt crisis → *absence of herding behavior* → investing in new EU currencies provides investors with *good diversifying opportunity against the U.S. dollar*
  - Miyajima et al. (2015) show that benefits from diversification in emerging market bonds have increased since 2008, and emerging market government bonds (including those of Hungary and Poland) have been resilient to global risk shocks. Gilmore and McManus (2002) confirm that US investors can obtain benefits from diversification into Central European equity markets

Results: Hedge ratios and portfolio weights

- First, detailed results computed for different periods
- Then verbal summary

Hedge ratios and portfolio weights

Before GFC period (1.1.1999 - 14.9.2008)				
Hedge ratio (long/short)				
	Mean	Std. dev.	Min	Max
CZK/PLN	0.3151	0.1953	-0.2840	0.8418
CZK/HUF	0.2325	0.1618	-0.2863	0.6677
PLN/HUF	0.4370	0.1733	-0.0229	0.8656
Portfolio weights (currency i/currency j)				
CZK/PLN	0.5055	0.1524	0.0612	1.0866
CZK/HUF	0.5349	0.1981	0.1524	0.9842
PLN/HUF	0.5673	0.1981	0.1291	1.1216

GFC period (15.9.2008 - 30.4.2010)				
Hedge ratio (long/short)				
	Mean	Std. dev.	Min	Max
CZK/PLN	0.5610	0.0818	0.2702	0.8342
CZK/HUF	0.5809	0.0399	0.4565	0.6741
PLN/HUF	0.7158	0.0644	0.5288	0.8593
Portfolio weights (currency i/currency j)				
CZK/PLN	0.5002	0.0906	0.1681	0.7800
CZK/HUF	0.4962	0.0529	0.3743	0.6897
PLN/HUF	0.4914	0.0868	0.2478	0.7425

EU debt crisis (3.5.2010 - 26.7.2012)				
Hedge ratio (long/short)				
	Mean	Std. dev.	Min	Max
CZK/PLN	0.4298	0.1009	0.2254	0.6513
CZK/HUF	0.4188	0.0531	0.3065	0.5125
PLN/HUF	0.6355	0.0780	0.3724	0.8731
Portfolio weights (currency i/currency j)				
CZK/PLN	0.5001	0.0461	0.3944	0.6526
CZK/HUF	0.5010	0.0263	0.4474	0.5997
PLN/HUF	0.4968	0.1066	0.1026	1.0434

After EU debt crisis (27.7.2012 - 31.05.2018)				
Hedge ratio (long/short)				
	Mean	Std. dev.	Min	Max
CZK/PLN	0.3175	0.1533	-0.0088	0.8333
CZK/HUF	0.1932	0.1241	-0.1514	0.5884
PLN/HUF	0.4967	0.1434	0.1266	0.8306
Portfolio weights (currency i/currency j)				
CZK/PLN	0.3897	0.1324	0.1084	0.8102
CZK/HUF	0.3972	0.1089	0.1641	0.7718
PLN/HUF	0.5243	0.0995	0.2449	0.7844

Hedge ratios and portfolio weights

- **Hedge ratios:** excessive market volatility during GFC → *hedging more expensive*
  - Example: 1-euro long position in CZK can be hedged with short 0.32 PLN before GFC and with 0.56 PLN during GFC

  = We need 75% more PLN to hedge our 1-euro long position in the CZK (hedging is 75% more expensive)

- The cheapest hedge position is long position in the CZK and short in the HUF except for the GFC period

- The most expensive hedge position is long in the PLN and short in the HUF

Hedge ratios and portfolio weights

- **Portfolio weights** are stable across all examined periods and close to 50%
  - However, the average weight for the CZK in the portfolio decreased after EU debt crisis. This can be explained by the CZK appreciation after the Czech National Bank terminated currency interventions on the FX market
  - Example: 1-euro portfolio → 0.5349 euros should be invested in the CZK, and 0.4651 euros in HUF prior the GFC. After EU debt crisis: 0.3972 euros should be invested in the CZK, and 0.6028 euros in the HUF → decreasing the weight of the CZK by 25.7% and increasing the weight of the HUF by 29.6%

Results: volatility spillovers

- First, dynamics in a graphical presentation
- Then, detailed results computed for different periods
- Finally, verbal summary

Total volatility spillover index

Volatility spillovers

Before GFC	*From j*				
To i	CZK/EUR	PLN/EUR	HUF/EUR	USD/EUR	Contribution from others
CZK/EUR	96.90	0.96	1.20	0.94	3.1
PLN/EUR	1.01	94.16	2.45	2.39	5.8
HUF/EUR	0.68	2.10	96.30	0.92	3.7
USD/EUR	0.69	1.66	1.61	96.03	3.9
Contribution to others	2.4	4.7	5.3	4.3	Index:
Contribution including own	99.3	98.9	101.6	100.3	4.13%
Net Spillover	-0.7	-1.1	1.6	0.4	

GFC period	*From j*				
To i	CZK/EUR	PLN/EUR	HUF/EUR	USD/EUR	Contribution from others
CZK/EUR	76.28	8.27	10.39	5.06	23.7
PLN/EUR	8.68	77.70	9.33	4.29	22.3
HUF/EUR	8.86	9.79	76.67	4.68	23.3
USD/EUR	6.20	5.00	5.97	82.83	17.2
Contribution to others	23.7	23.1	25.7	14.0	Index:
Contribution including own	100.0	100.7	102.4	96.9	21.60%
Net Spillover	0.00	0.8	2.4	-3.2	

EU debt crisis	*From j*				
To i	CZK/EUR	PLN/EUR	HUF/EUR	USD/EUR	Contribution from others
CZK/EUR	95.81	1.11	1.39	1.69	4.19
PLN/EUR	1.53	86.77	7.94	3.76	13.23
HUF/EUR	1.43	8.82	87.18	2.57	12.82
USD/EUR	2.10	1.34	2.19	94.38	5.63
Contribution to others	5.06	11.27	11.52	8.02	Index:
Contribution including own	100.87	98.04	98.70	102.40	8.96%
Net Spillover	0.87	-1.96	-1.30	2.39	

After EU debt crisis	*From j*				
To i	CZK/EUR	PLN/EUR	HUF/EUR	USD/EUR	Contribution from others
CZK/EUR	95.94	1.70	1.61	0.75	4.10
PLN/EUR	0.99	94.01	3.97	1.04	6.00
HUF/EUR	2.36	3.75	93.42	0.47	6.60
USD/EUR	1.08	0.71	0.72	97.50	2.50
Contribution to others	4.40	6.20	6.30	2.30	Index:
Contribution including own	100.40	100.20	99.70	99.80	4.80%
Net Spillover	0.40	0.20	-0.30	-0.20	

Volatility spillovers

- Considerable levels of variability in the index – Spillover index peaks above 20%
- Some key events associated with heightened spillovers:
  - 1999 –2000: the introduction of the euro
  - 2008 - 2009 (GFC)
  - 2010 (EU debt crisis)
  - 2017: Donald Trump inaugurated as the U.S. president. Withdrew the United States from the Trans-Pacific Partnership (U.S. trade protectionism). The inflation acceleration in the United States resulted in the series of interest rate hikes in 2017 (Fed monetary tightening)

Note: see chart on slide 20

Volatility spillovers: New EU forex market characteristics

- *Own-market volatility* spillovers explain substantial share of forecast error volatility.
  - *Diagonal volatility* in new EU markets is higher comparing to general results in commodity, stock markets
- The biggest *off-diagonal volatility* spillovers are during GFC → highest total spillover index (21.6%); twice as much during EU debt crisis (8.96%); 4-5 times bigger than before GFC.
- During the GFC higher levels of volatility spill over to individual currencies from their forex counterparts.
  - The highest off-diagonal spillover values can be observed between the forint and the zloty and between the forint and the koruna

Note: see table on slide 21

Volatility spillovers: individual effects

- The *Hungarian forint* is the dominant currency in terms of volatility transmission for each individually examined time period. Diffusion of the contagion from Hungary to surrounding countries via currency spillovers (problem with mortgages denominated in the CHF)
- The *Czech koruna* transmits the lowest proportion of volatility prior to the GFC and during the EU debt crisis. However, the CZK becomes the source of volatility in 2017, when the Czech National Bank finishes the currency interventions and CZK is freely tradable again
- *Polish zloty* assumes a leading role as volatility spillovers receiver prior to the GFC and during the EU debt crisis
- *USD/EUR* is a net receiver of volatility from 2004 to 2006 and during the GFC. However, USD/EUR becomes source of volatility transmissions to the new EU currencies with the start of the EU debt crisis and in 2017

Conclusion

- Conditional correlations between new EU currencies and the U.S.D. change over time and may be evaluated from the perspective of major economic events
- The conditional correlations reach the lowest values during the GFC and the EU debt crisis → against general perception of herding behavior
  - negative correlations of new EU forex markets with the U.S. dollar during periods of distress offer valuable diversification opportunities, but at higher hedging costs
  - → It is worth to *treat new EU currencies individually and not a as group*
- The highest levels of cross-currency volatility is present during the GFC
- Own-currency volatility spillovers explain a substantial share of the total volatility. Volatility spillovers between individual currencies can be characterized as bidirectional

Thank you for your attention

Appendix: DCC model

	Before GFC (1.1.1999-14.9.2008)			GFC crisis (15.9.2008 - 30.4.2010)			EU Debt crisis (3.5.2010-26.7.2012)			After EU debt crisis (27.7.2012-31.5.2018)		
1st step univariate GARCH model and diagnostic tests												
Mean Eq.	**CZK/EUR**	**PLN/EUR**	**HUF/EUR**	**CZK/EUR**	**PLN/EUR**	**HUF/EUR**	**CZK/EUR**	**PLN/EUR**	**HUF/EUR**	**CZK/EUR**	**PLN/EUR**	**HUF/EUR**
Constant	-0.0002**	-0.0003**	0.0000	-0.0001	-0.0001	-0.0002	0.0000	-0.0001	-0.0000	-0.0000*	-0.0001	-0.0000
	(0.0022)	(0.0003)	(0.6092)	(0.6167)	(0.7167)	(0.5626)	(0.8984)	(0.5321)	(0.7445)	(0.0353)	(0.1440)	(0.5860)
Variance Eg.												
Constant	0.0000**	0.0000**	0.0000**	0.0000	0.0000	0.0000	0.0000	0.0000*	0.0000*		0.0000**	0.0000
	(0.0002)	(0.0002)	(0.0000)	(0.4352)	(0.3641)	(0.1719)	(0.1556)	(0.0292)	(0.0331)		(0.0029)	(0.1163)
α	0.0699**	0.0885**	0.0488**	0.0883**	0.0736**	0.1167**	0.0680**	0.0412*	0.0312*	0.1677**	0.1276**	0.0317**
	(0.0000)	(0.0000)	(0.0000)	(0.0013)	(0.0016)	(0.0002)	(0.0071)	(0.0345)	(0.0213)	(0.0000)	(0.0000)	(0.0001)
β	0.9029**	0.8945**	0.9486**	0.9042**	0.9185**	0.8762**	0.9174**	0.9189**	0.9515**	0.7901**	0.8373**	0.9637**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
GED param.	1.2184**	1.4001**	1.5000**	1.5488**	1.5233**	1.4561**	1.3821**	1.4235	1.5344**	1.1257**	1.4022**	1.5304**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Q(30)	13.1960	39.1860	16.0630	38.1710	25.6370	19.5450	23.2320	28.4040	26.2310	22.2180	25.2990	23.6220
	(0.9970)	(0.1220)	(0.9820)	(0.1450)	(0.6940)	(0.9280)	(0.8060)	(0.5490)	(0.6630)	(0.8460)	(0.7100)	(0.7890)
$Q^2(30)$	15.1510	29.0830	0.7264	20.7560	22.2590	17.6920	22.9460	36.8240	14.2490	3.6778	18.8010	33.437
	(0.9890)	(0.5130)	(1.0000)	(0.8950)	(0.8440)	(0.9630)	(0.8170)	(0.1820)	(0.9930)	(1.0000)	(0.9440)	(0.3040)
2nd step DCC model. correlations												
ρ (corr)	-0.0221	0.2631	0.0560	-0.1694	-0.3273	-0.3730	-0.2963	-0.4819	-0.4927	-0.0721	-0.0601	-0.1107
α	0.0076**	0.0287**	0.0413**	0.0307	0.1091**	0.0714*	0.0206*	0.0331*	0.0132	0.0099**	0.0186**	0.0188**
	(0.0010)	(0.0000)	(0.0000)	(0.3861)	(0.0015)	(0.0414)	(0.0172)	(0.0301)	(0.6084)	(0.0026)	(0.0000)	(0.0001)
β	0.9905**	0.9651**	0.9552**	0.7300	0.7110**	0.8087**	0.9657**	0.8962**	0.7864	0.9784	0.9703	0.9704
	(0.0000)	(0.0000)	(0.0000)	(0.0592)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.2308)	(0.0000)	(0.0000)	(0.0000)
Log-Lik	25.8242	232.4878	96.39579	6.8990	37.4631	36.4078	31.6512	80.5613	80.3013	9.6228	18.7375	22.5271