Academy of Economic Studies
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Contagion Phenomenon and Volatility Transmission during US crisis

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Dissertation paper outline

- Introduction
- Data description
- Methodology
- Estimation results
- Conclusions
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Introduction

- The recent Global Financial Crisis has made a tremendous impact on the global economy and has been considered the worst financial crisis spread since the Great Depression of the 1930s.

- In the light of the recent global financial crisis, **contagion phenomenon and volatility spillovers** have become one of the major topic of interest for researchers, due to their important consequences for the global economy in relation to monetary policy, optimal asset allocation, asset pricing, capital adequacy and risk measurement

- There is no generally accepted interpretation of the notion "contagion" in literature and the methodologies employed vary with the definitions for contagion

- Many studies have attempted to test whether the **correlations significantly change between stable and turmoil periods** in order to investigate the existence of financial contagion .

Introduction
Brief literature review

- King and Wadhwani (1990) were the first to measure contagion as a significant increase in the correlation between assets returns
- Forbes and Rigobon (2002)- pointed out that these tests based on correlation coefficients can be biased because of heteroskedasticity or the omitted variable problem
- Corsetti (2005, 2010), Bekaert, Harvey and Ng (2005)
- Chiang (2007), Hong-Ghi Min (2012) - multivariate GARCH models; the methodology proposed corrects the problems of bias in the contagion test used in the initial literature
- Engle, Ito and Lin (1990), Hamao (1990), Beine and Spagnolo (2008) –GARCH and multivariate GARCH models – volatility spillovers
- Diebold and Yilmaz (2009, 2012) – Volatility spillover index -VAR models

Introduction

The aims of this paper

- To detect if there exists contagion effects of US global financial crisis on European stock markets
  - Definition of contagion used in this paper:

"Contagion occurs when cross-country correlations increase during 'crisis times' relative to correlations during 'tranquil times".

- To compute a simple, but rigorous measure of volatility spillovers across European stock markets, that provides answers related to:
  - How much of the spillover effects can be attributed to a specific market (or country) or to what extent a specific market transmits (receives) spillover effects to (from) other market(s)
  - What is the behaviour of volatility spillover effects during economic downturns.

"Spillovers or cross variance shares are defined as the fractions of the H-step-ahead error variances in forecasting y_i due to shocks to y_j

The Data

- Daily closing stock prices for four emerging European countries: Czech Republic (PX index), Hungary (BUX index), Poland (WIG20 index), Romania (BET index), two developed European countries: France (CAC40 index), Germany (DAX) and US (SP500 index). The data is obtained from Bloomberg

- The data spans between January 2000 and December 2012

- All series in levels display a unit root, as evident from the ADF test results. Hence the series are transformed into log-differences and we obtain the continuously compounded percentage stock market returns (which are I(0)):

$$y_t = 100 * (\ln(S_t) - \ln(S_t - 1))$$

Where S_t is the stock price

Methodology

Contagion

- We use **Dynamic Conditional Correlation GARCH model** (DCC-GARCH) introduced by Engle(2002) to estimate time-varying conditional correlations

- This model considers a series of restrictions imposed by the literature, namely:
  - **Heteroskedasticity** - the model estimates correlation coefficients of the standardized residuals and accounts for heteroskedasticity directly
  - **The dynamic nature of correlations**
  - **Omission of the relevant variable-** the model allows to include additional explanatory variables in the mean equation to measure a global factor

- Detection of changes in the dynamic correlations across the markets due to the financial crisis of 2008 by means of a dummy variable. There is contagion between markets when the **dummy variable is significant and positive** in the mean of the pair-wise correlation coefficients

Methodology

Dynamic Conditional Correlation -GARCH model

Mean equation: $\mathrm{r_t} = \gamma_0 + \gamma_1 r_{t-1} + \gamma_2 r_{t-1}^{US} + \varepsilon_t$ $\quad r_t$ is a 2×1 vector of stock returns

$\varepsilon_t | \zeta_{t-1} \sim N(0, H_t)$ $\quad r_{t-1}^{US}$ used to account for global factor

$$H_t = D_t R_t D_t$$

The **DCC-GARCH** model is designed to allow for **a two-stage estimation** of the conditional variance matrix H_t

1. In the first stage, univariate volatility models are fitted to each of the stock return residuals and estimates of $\sqrt{h_{it}}$ are obtained ; $\sqrt{h_{it}}$ are the variance equation for the stock returns

$$D_t = diag\{\sqrt{h_{it}}\} \qquad h_{ii,t} = \theta_i + \alpha_i \varepsilon_{ii,t-1} + \beta_i h_{ii,t-1}$$

2. In the second stage, stock return residuals are transformed by their estimated standard deviations as $u_{i,t} = \varepsilon_{i,t} / \sqrt{h_{ii,t}}$ Then, $u_{i,t}$ is used to estimate the correlation parameters

Methodology

Dynamic Conditional Correlation -GARCH model

- The evolution of the correlation in the standard DCC-GARCH model is given by

$$Q_t = (1-a-b)\overline{Q} + a u_{t-1} u_{t-1}^{'} + b Q_{t-1} \qquad Q_t = [q_{ij,t}] \quad 2\times 2$$

time-varying covariance matrix of $\boldsymbol{u_t}$

$$\overline{Q_t} = E\left[u_t u_t^{\prime}\right] \qquad 2\times 2$$

unconditional variance matrix of $\boldsymbol{u_t}$

a and b are nonnegative scalar parameters satisfying $(a+b) < 1$

$$R_t = (diag(Q_t))^{-1/2} Q_t (diag(Q_t))^{-1/2}$$

time-dependent correlation matrix

where $(diag(Q_t))^{-1/2} = diag(1/\sqrt{q_{11,t}}, 1/\sqrt{q_{22,t}})$

Correlation coefficient is of the form:

$$\rho_{ij,t} = q_{ij,t} / \sqrt{q_{ii,t} q_{jj,t}} \qquad i,j=1,2 \text{ and } i \neq j$$

Estimation Results

Dynamic Conditional Correlation - GARCH model

		BET	BUX	PX	WIG20	CAC40	DAX	SP500
Mean equations	γ_0	0.0914***	0.0540***	0.0807***	0.0468***	0.0406**	0.0687***	0.0419***
	γ_1	0.0825***	-0.0348***	-0.0427**	-0.0467**	-0.2251**	-0.1830***	-0.0560***
	γ_2	0.1478***	0.2632***	0.2792***	0.2571**	0.4219***	0.3407***	-
Variance equations	C	0.0126***	0.0062***	0.0040***	0.0018***	0.0015***	0.0019***	0.0013***
	Arch Term	0.1461***	0.0930***	0.1198***	0.0557***	0.0860***	0.0890***	0.0808***
	Garch Term	0.8216***	0.8803***	0.8619***	0.9367***	0.9087***	0.9036***	0.9103***

Conditional correlations coefficients		BET_SP500	BUX_SP500	PX_SP500	WIG20_SP500	CAC40_SP500	DAX_SP500
	a	0.0141**	0.0171***	0.0044***	0.0119***	0.0089***	0.0197***
	b	0.8881***	0.9533***	0.9936***	0.9732***	0.9857***	0.9552***

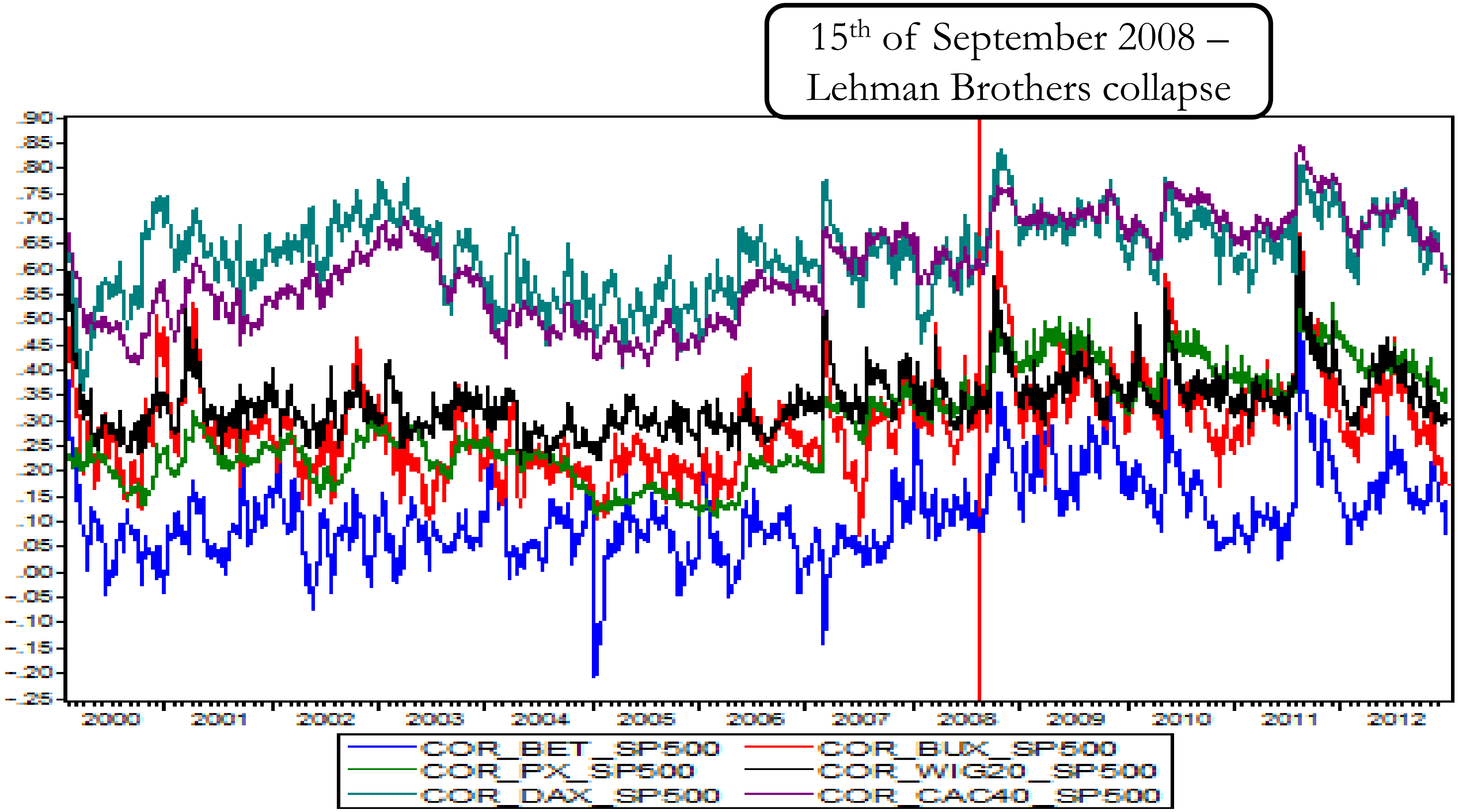
***, ** and * denote statistical significance at the 1%, 5% and 10% level

The coefficients of US lagged stock returns are significant and consistently large in magnitude in emerging as well as developed countries, ranging from 0.147 (Romania) to 0.42 (France), which is consistent with the empirical finding that US stock return is an important determinant of stock returns in European countries

The coefficients of lagged conditional variance and squared innovations terms in the variance equation are highly significant and justifies the appropriateness of the GARCH(1,1) specification;

a and b are positive and less than unity ->mean reversion of the stock return correlations

Time-varying conditional correlations obtained from Dynamic Conditional Correlation-GARCH model



Remarks

- Stock market correlations between US and European analyzed countries have rather similar patterns over time
- Advanced countries, namely France and Germany, exhibit higher correlation with US then do emerging economies
- Two phases of the crisis: **contagion** around the Lehman Brothers collapse and a transition to **herding** after that
- Contagion and herding behavior are distinguished in the sense that **contagion** describes the spread of shocks from one market to another with a **significant increase** in correlation between markets, while **herding** describes the simultaneous behavior of investors across different markets with a **continued high** correlation coefficients in all markets

Contagion analysis

- The effect of the financial crisis on the correlations has been studied introducing a dummy variable, $Crisis_t$ for the financial crisis of 2008. There is **contagion** between markets when the **dummy variable is significant and positive** in the mean of the pair-wise correlation coefficients The variable takes the value 1 from 9/15/2008 to 08/30/2009 and 0 otherwise.

- The applied equations system is described as:

$$\rho_{ij,t} = \mu + \sum_{p=1}^{P} \phi_p \rho_{ij,t-p} + \alpha Crisis_t + \varepsilon_{ij,t}$$

$$h_{ij,t} = \omega_0 + \omega_1 \varepsilon_{ij,t}^2 + \omega_2 h_{ij,t-1}$$

where $\rho_{ij,t}$ the pair-wise correlation coefficient between the stock returns of United States and stock returns of European developed and emerging markets
i=United States and j= Czech Republic, Hungary, Poland, Romania, Germany and France

Estimation results

		BET	BUX	PX	WIG20	CAC40	DAX
Mean equations	μ	0.0032***	0.0076***	0.0008	0.0152***	0.0039***	0.0145***
	α	**0.0047*** **	**0.0037*** **	**0.0032*** **	**0.0038*** **	**0.0012** **	**0.0024** **
	Φ_1	0.9625***	0.8086***	0.5107***	0.7037***	0.8910***	0.9485***
	Φ_2		0.2336***	0.3784***	0.2501***	0.1376***	0.0713**
	Φ_3		-0.0701***	0.1088***		-0.0351*	-0.0433**
Variance equations	ω_0	0.0002***	0.0002***	0.00001***	0.00001***	0.0001***	0.0001**
	Arch Term	0.1101***	0.0448***	0.0987***	0.0254***	0.1842***	0.0081**
	Garch Term	0.3820***	0.5193***	0.7958***	0.7301***	0.3503***	0.6753***

***, ** and * denote statistical significance at the 1%, 5% and 10% level

All dummy variable in mean equations are positive and statistically significant for all analyzed European countries, indicating a notable increase in correlations during the global financial crisis. This confirms the **existence of contagion** process between the United States and both emerging and developed European countries

The crisis has hit EU members to a different degree. We notice that the effects of contagion on asset prices are greater **on emerging markets than in developed markets**

Remarks:

- Factors that can explain the higher sensitivity of emerging European countries to the crisis are:
  - Emerging markets have higher level of asymmetric information than developed markets (Pritsker, Kodres, 2002)
  - Declining foreign investment and capital inflows
  - Dependence on foreign trade
  - Major changes in investor's behavior –amid increased risk aversion there has been a shift from global excess liquidity to liquidity crunch

Methodology

The volatility spillover index- Diebold and Yilmaz(2011)

- Generalized VAR framework of Koop, Pesaran and Potter (1996)
- Consider a N-variable vector y_t modeled as a pth-order stationary VAR:

$$y_t = \sum_{i=1}^{p} \Pi_i y_{t-i} + \varepsilon_t \qquad \varepsilon_t \sim i.i.d(0, \Sigma)$$

- The moving average representation : $y_t = \sum_{i=1}^{\infty} A_i \varepsilon_{t-i}$

- KPPS H-step-ahead forecast error variance decompositions:

$$d_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Sigma e_j \right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Sigma A_h' e_i \right)}$$

σ_{ii} is the standard deviation of the error term for the ith equation

e_i the selection vector with 1 as the ith element and 0 otherwise

Σ the variance matrix for the error vector ε

- Each entry of the variance decomposition matrix is normalized, so that each row in the variance decomposition table to equal to one $\tilde{d}_{ij}^{g}(H) = \frac{d_{ij}^{g}(H)}{\sum_{j=1}^{N} d_{ij}^{g}(H)}$

- **Spillovers** or cross variance shares- the fractions of the H-step-ahead error variances in forecasting y_i due to shocks to y_j, for i, j = 1, 2,.., N, and $i \neq j$
- **Total volatility spillover index** determines the contribution of spillovers of volatility shocks across all variables to the total forecast error variance

$$s^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{d}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{d}_{ij}^{g}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{d}_{ij}^{g}(H)}{N} \times 100$$

- Directional volatility spillovers received by market *i* from all other markets *j*

$$S_{i<-j}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{d}_{ij}^{g}(H)}{\sum_{j=1}^{N} \tilde{d}_{ij}^{g}(H)} \times 100$$

- Directional volatility spillovers transmitted by market *i* to all other markets *j*

$$S_{i->j}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{d}_{ji}^{g}(H)}{\sum_{j=1}^{N} \tilde{d}_{ji}^{g}(H)} \times 100$$

Net volatility spillovers

$$S_i^g(H) = S_{i->j}^{g}(H) - S_{i<-j}^{g}(H)$$

Estimation results

Volatility spillovers across emerging European markets

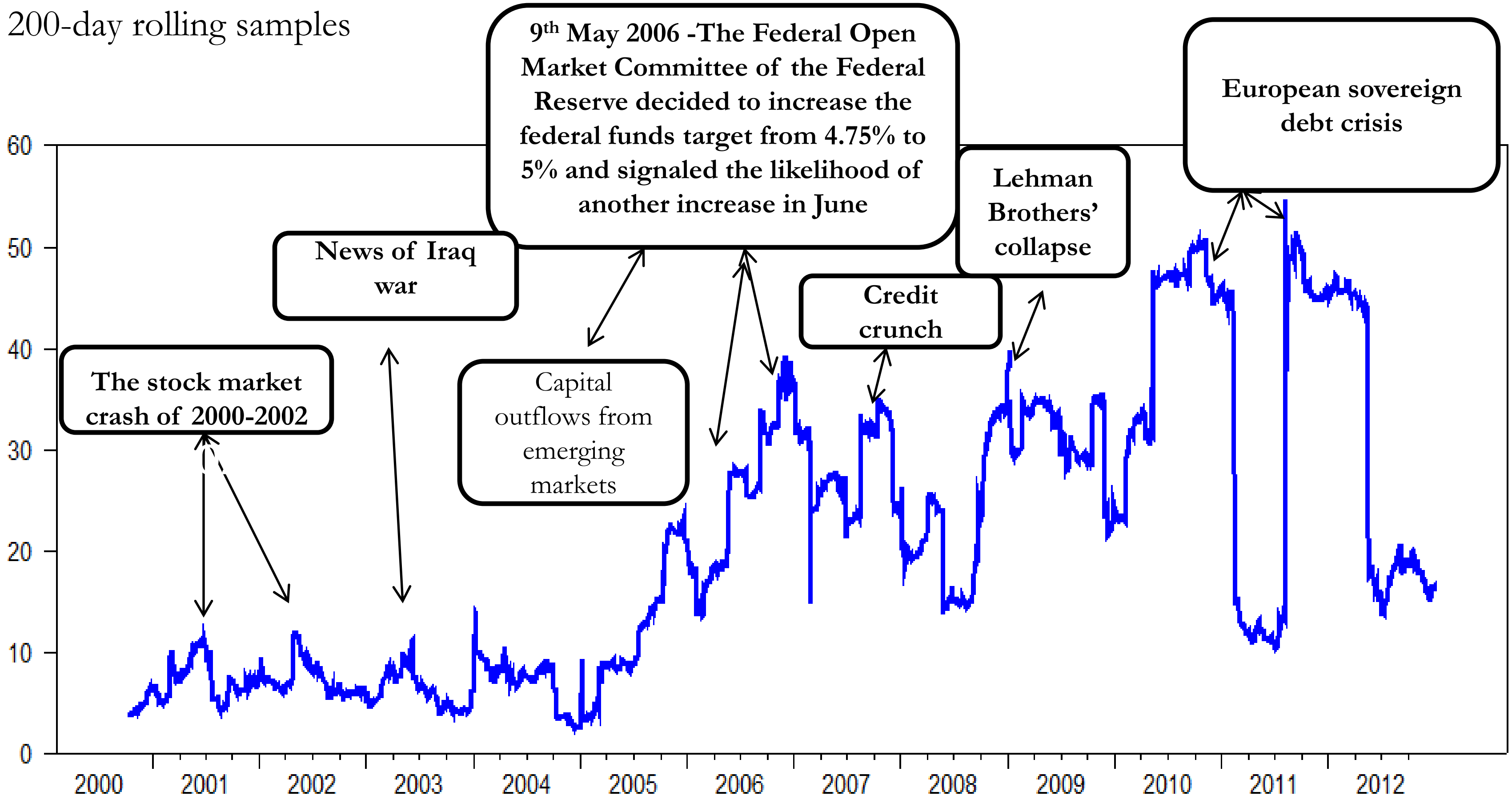
Stable period: Jan 2000 - July 2007		FROM(j)				
		HU	RO	CZ	PO	From Others
TO(i)	HU	**91.7**	0.1	3	5.2	8
	RO	0.1	**99.1**	0.7	0.1	1
	CZ	3.7	0.4	**90.7**	5.2	9
	PO	4.8	0.1	5.3	**89.8**	10
Contribution to others		9	1	9	10	29
Contribution including own		100	100	100	100	**Total Spillover Index**
Net spillover		1	0	0	0	**7.2%**

Turbulent period: Aug 2007-Dec 2012		FROM(j)				
		HU	RO	CZ	PO	From Others
TO(i)	HU	**69.7**	2.1	14.8	13.5	30
	RO	0.8	**96.3**	2	0.9	4
	CZ	11.5	2.1	**70.7**	15.8	29
	PO	13.7	0.7	16.2	**69.3**	31
Contribution to others		26	5	33	30	94
Contribution including own		96	101	104	99	**Total Spillover Index**
Net spillover		-4	1	4	-1	**23.5%**

Remarks

- The estimated conditional volatilities parameters of the analyzed countries obtain from the DCC GARCH model are used as the input variable for VAR models
- The appropriate number of lags for each VAR model is determined using the information criteria; We use a 10 step-ahead forecast error variance, similar to Diebold and Yilmaz(2011)
- The results reveal that **on turbulent periods, volatility spillovers are, on average, higher then on stable periods.** Specifically, 23.5 % of volatility forecast error variance in all four stock markets comes from volatility spillovers in turmoil period, while only 7.2 % in stable period.
- Diagonal elements have higher values compared to the off diagonal meaning that **own market volatility spillovers explain the highest share of forecast error volatility**. However, in the turbulent period, own market volatility spillovers decrease leading to a considerable increase in cross-market volatility spillovers
- All indices are affected by the contributions of other markets' volatility this indicating **bidirectional volatility spillovers** rather then unidirectional volatility spillovers between the analyzed markets.
- **BET** index is the **lowest receiver and transmitter** of volatility in both analyzed periods

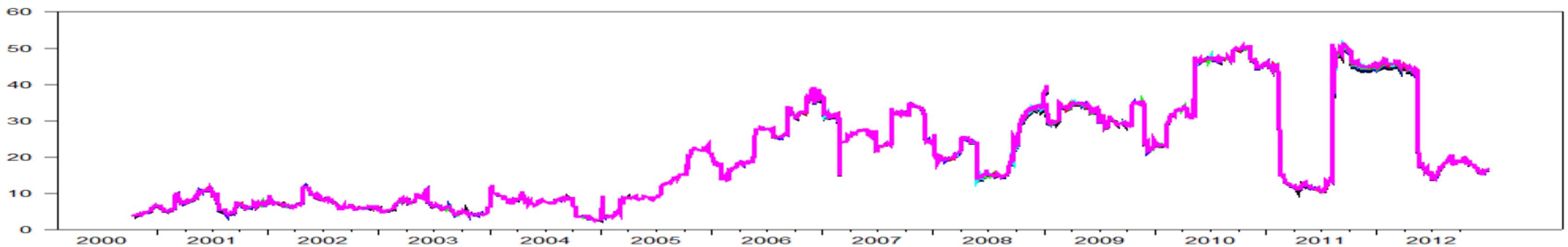
In order to assess the magnitude of spillovers over time and their movements due to specific news, policy announcements or important and severe economic events, we estimate volatility spillovers using 200-day rolling samples



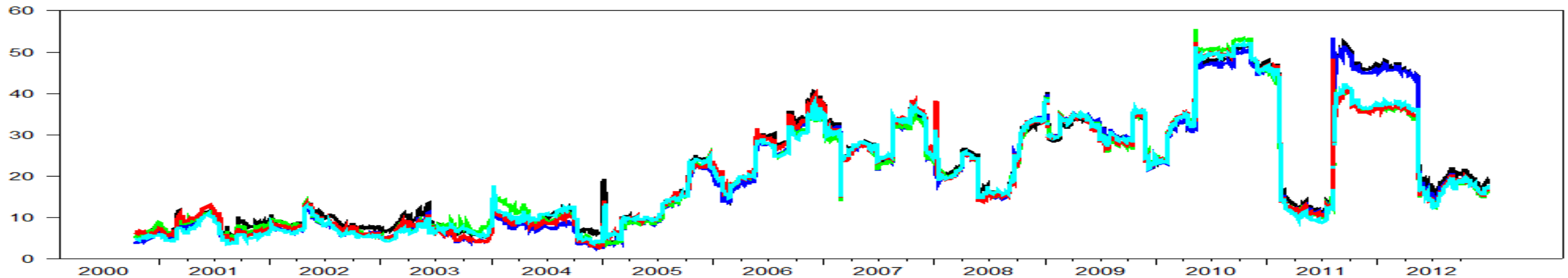
Volatility spillovers show large variability and are positively associated with extreme economic episodes, such as stock market crashes, debt crises and US recessions

Robustness check

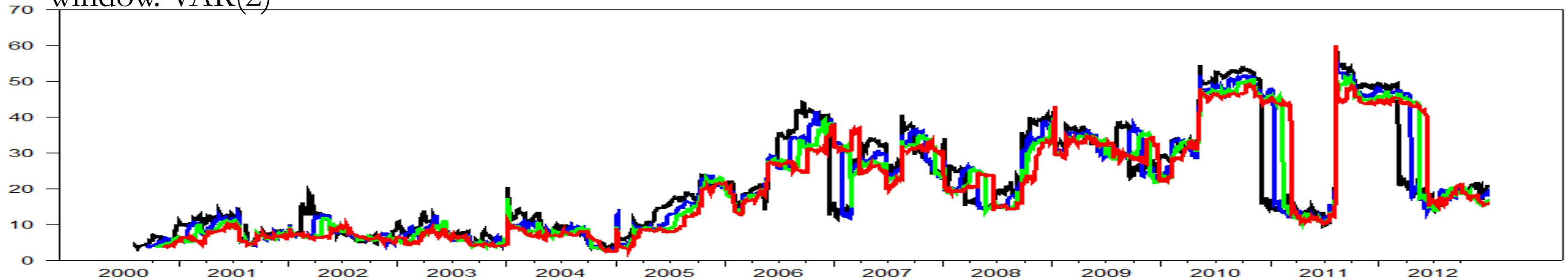
Volatility spillover plot. 200 days rolling window. 5 through 10 days forecast horizons. VAR(2)



Volatility spillover plot. 200 days rolling window. 10 days forecast horizon. VAR(2)->VAR(6)



Volatility spillover plot. 200 days rolling window. 10 days forecast horizon. 150, 180, 200, 230 days rolling window. VAR(2)



Conclusions

- The analysis of the dynamic correlation coefficients provide substantial evidence in favor of **contagion effects in the financial markets of both emerging and developed European markets** around Lehman Brothers'collapse
- This study identifies **2 phases** of the Global Financial crisis: **contagion** around Lehman Brothers'collapse and then a transition to **herding** behaviour
- **The effects** of contagion on asset prices are **greater on emerging markets than in developed markets**
- Diebold spillover index results reveal that the **magnitude of the volatility spillovers increases significantly during periods of market uncertainty**
- Volatility spillovers are **positively associated with extreme economic episodes**, such as stock market crashes, debt crises and US recessions

- The results of our study are of particular **interest for both policy makers and investors**
- investors can improve their hedging and **portfolio diversification strategies** exploiting the knowledge regarding the way the markets influence one another
- Understanding of financial contagion would clearly be beneficial for policy makers providing them useful information about the formulation of possible decoupling strategies to insulate the economy from contagious effects and thus **avoiding future spread of crisis and preserving the stability of financial system**

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