Modelling Financial Markets Comovements During Crises: A Dynamic Multi-Factor Model Approach

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Motivation and related literature

- Empirical evidence of increase of **observed correlations** among the "infected" markets: King and Wadhwani (1990), Engle et al. (1990) and Bekaert and Hodrick (1992).
- The **presence of heteroscedasticity** biases correlation based test for contagion: Longin and Solnik (2001) and **Forbes and Rigobon (2002)**.
- **Testing procedures** robust to the presence of heteroscedasticity: Bae et al. (2003), Pesaran and Pick (2007), Fry et al. (2010) and **Bekaert et al.** (2005, **2009**, 2012).

Motivation and related literature

- A situation of **contagion** is symptomatic of a prolonged episode of market distress altering the functioning of the financial system.
- On the contrary, since conditional heteroscedasticy of financial time series does not display trending behaviour (Schwert, 1989 and Brandt et al., 2010), a situation of **excess interdependence** is a short lasting phenomenon.
- Being able to distinguish between contagion and excess interdependence has a crucial **information content** as to how a crisis develops and spreads out.

Main contribution

Formulation and estimation of a **dynamic factor model** which allows to

- Study **comovements** between financial markets in a multi-asset class and multi-country perspective.
- Test for **contagion vs excess interdependence** (Forbes and Rigobon, 2002; Bekaert et al., 2009, 2012).
- Analyse the **sub-prime** (2007-09) and the **sovereign debt** (2010-2012) crises.

To this purpose, use of the Dummy Saturation approach to econometric modelling via Autometrics in PcGive

Main results

- The global factor is the most pervasive, the asset class factor is the most persistent and the country factor is almost negligible.
- Evidence of contagion from US stock market (late 2000s financial crisis) and presence of excess interdependence (European debt crisis from mid-2010 onwards).
- Lack of evidence of contagion/excess interdependence at the overall average level (some assets acted as a safe haven during crisis periods).

Dataset description

- **Asset classes**:
  - Equity Indices
  - Foreign Exchange Rates
  - Money Market Instruments
  - Corporate Bonds
  - Government Bonds
- **Countries**:
  - US
  - Euro Area
  - UK
  - Japan
  - Emerging Countries (Brazil, India, China, Russia and Turkey)
- **Weekly data** (01-Jan-1999 to 14-Mar-2012, T=690).

Data plot

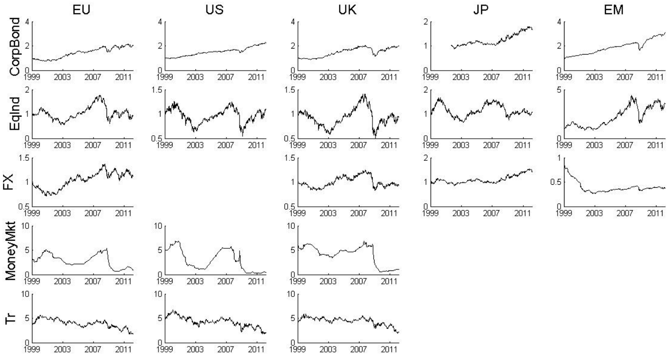

Figure: Plot of the data used in the empirical application.

Preliminary correlation analysis. Tables 3-4

- High correlation intra **asset class groups** (Equity and Government Bonds $\sim$ 70-80% range) as well as intra **countries** (Corporate Bonds and FX markets at country level).
- There is evidence for the presence of both an **asset class and a country effect**.
- The asset class effect seems to be systematically **more pervasive** than the country one.

Model formulation

$$R_t^{i,j} = \mathbf{E}[R_t^{i,j}] + F_t^{i,j}\beta_t^{i,j} + \epsilon_t^{i,j} \quad (1)$$

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j} Z_{t-1} + u_t^{i,j} \quad (2)$$

- $R_t^{i,j}$: weekly return for asset class $i = 1, \ldots, I$ and county $j = 1, \ldots, J$ at time t.
- $F_t^{i,j} \equiv [G_t \ A_t^i \ C_t^j]$, where G_t is the global factor, A_t^i is the i-th asset class factor, C_t^j is the j-th country factor.
- $\mathbf{E}[F_t^{i,j\prime}] = \mathbf{0}$ and $\mathbf{E}[F_t^{i,j\prime} F_t^{i,j}] = \Sigma_{F^{i,j},t}$.
- $\beta_t^{i,j} \equiv [\gamma_t^{i,j} \ \delta_t^{i,j} \ \lambda_t^{i,j}]'$: 3-dimensional vector of dynamic factor loadings.
- $\epsilon_t^{i,j}$ and $u_t^{i,j}$: mutually independent W. N. processes.
- $\beta^{i,j}$: long-run value of $\beta_t^{i,j}$. , $\phi^{i,j}$ and $\psi^{i,j}$: 3-dimensional vectors of parameters.
- Z_t: conditional variable controlling for period of market distress (PCA: VIX, TED, Libor-OIS).

Factor estimation

- Model (1)-(2) is estimated in the **following form**:

$$R_t^{i,j} = \mathbf{E}[R_t^{i,j}] + \hat{F}_t^{i,j}\beta_t^{i,j} + \epsilon_t^{i,j}$$

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j} Z_{t-1} + u_t^{i,j}$$

where $\hat{F}_t^{i,j}$ is an estimate of factor $F_t^{i,j}$.

Factor estimation

- $\hat{F}_t^{i,j}$ is estimated via **PCA**.
- $T \to +\infty$, whereas K is fixed and small.
- Let $r_t^{i,j} \equiv R_t^{i,j} - \mathbf{E}[R_t^{i,j}]$ and stack them into the matrix $\mathbf{r}$.
- Consistently estimate $\Sigma_{\mathbf{r}}$ as $\hat{\Sigma}_{\mathbf{r}} \equiv \frac{1}{(T-1)}\mathbf{r}'\mathbf{r}$.
- Estimate the eigencouples $(l_k, \mathbf{w_k})$ (with $l_1 \geq l_2 \geq \ldots \geq l_K$) of $\Sigma_{\mathbf{r}}$ as $(\hat{l}_k, \hat{\mathbf{w}}_{\mathbf{k}})$, eigencouples of $\hat{\Sigma}_{\mathbf{r}}$.
- The global factor is estimated as:

$$\hat{G} = \mathbf{r}\hat{\mathbf{w}}_{\mathbf{1}}$$

Factor estimation

- Following the same procedure, the estimates of the asset class, $\hat{A}^i$, and the country specific, $\hat{C}^j$, factors are given by:

$$\hat{A}^i = \mathbf{r^i \hat{w}_1^i} \tag{3}$$

$$\hat{C}^j = \mathbf{r^j \hat{w}_1^j} \tag{4}$$

Factor estimation properties

- Consistency and invariance principle for MLE ensure that this estimate is consistent.
- Criteria available to decide on the number of the factors (Bai and Ng, 2002, Econometrica).
- We select the number to be three. On the basis of an economic intuition and on the literature

Factor estimation properties under time-varying factor loading

- **Consistency** of the factor estimation via PCA is a well-established result for the case of stable factor loadings.
- Stock and Watson (1998, 2002 and 2009) for the case of **mild instability** and
- Bates et al. (2013) show that consistency of the PCA is unaffected by the **instability of the factor loading**.

Independent factors

- The system $\hat{F}_t^{i,j} = [\hat{G}_t \ \hat{A}_t^i \ \hat{C}_t^j]$ is orthogonalized, so that the three groups of factors are **independent**.
- We follow this **procedure**:
  - Orthogonalize the asset class factors with respect to the global factor.
  - Orthogonalize the country factors with respect to the asset class and the global factors.
- **Robustness checks** are performed and results do not change.

Conditional time-varying factor loading model

- The **conditional time-varying factor loading model**:

$$\beta_t^{i,j} \equiv \beta(\mathcal{F}_{t-1}, X_t)$$

where $\{\mathcal{F}_t\}_{t=1,\dots,T}$ is the information flow and X_t is a set of conditional variables.

- Our specification (2):

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j} Z_{t-1} + u_t^{i,j}$$

where Z_t is a variable which controls for periods of market distress.

- Consistent estimates of Model (1)-(2) are obtained by applying the Kalman filter.

Nested model specifications

Our factor loading specification (2):

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j} Z_{t-1} + u_t^{i,j}$$

nests alternative model specifications.

- Under the hypothesis:

$$H_0' : \begin{cases} \phi^{i,j} = \mathbf{0} \\ \psi^{i,j} = \mathbf{0} \\ u_t^{i,j} = 0 \end{cases} \qquad \forall i = 1, \dots, I \quad \forall j = 1, \dots, J \quad \forall t = 1, \dots, T$$

  Model (2) boils down to:

$$\beta_t^{i,j} \equiv \beta^{i,j}, \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J$$

  which we label as the **static factor loading model**.
- Consistent estimates of Model (1)-(2) are obtained through OLS.

Nested model specifications

- Under the hypothesis:

$$H_0''^{i,j} = \mathbf{0} \quad \forall i = 1, \ldots, I \quad \forall j = 1, \ldots, J$$

Model (2) is equivalent to:

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + u_t^{i,j}$$

which we label as **time-varying factor loading model**.

- Consistent estimates of Model (1)-(2) are obtained by applying the Kalman filter.

Recap

- **Static factor loading model**:

$$\beta_t^{i,j} = \beta^{i,j}$$

- **Time-varying factor loading model**:

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + u_t^{i,j}$$

- **Conditional time-varying factor loading model**:

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j} Z_{t-1} + u_t^{i,j}$$

General dynamic multi-factor model

- Our proposed general dynamic multi-factor model is:

$$R_t^{i,j} = \mathbf{E}[R_t^{i,j}] + \hat{F}_t^{i,j}\beta_t^{i,j} + \epsilon_t^{i,j}$$

$$\beta_t^{i,j} = diag(\mathbf{1} - \phi^{i,j})\beta^{i,j} + diag(\phi^{i,j})\beta_{t-1}^{i,j} + \psi^{i,j}\hat{Z}_{t-1} + u_t^{i,j}$$

Heteroscedastic factors

- Our modelling framework allows to distinguish between spikes in comovements due to increasing exposures to common risk factors from the case where spikes are triggered by excess volatility in the common factors.
- Increase in **correlations** can be triggered by:
  - increasing exposures to common factors
  - excess volatility in the common factors
- For this reason, besides allowing for dynamic factor exposures, we allow for **heteroscedastic factors**.
  - $G_t \sim \text{GARCH}(1,1)$
  - $\mathbf{A_t} \sim \text{DCC}(1,1)$
  - $\mathbf{C_t} \sim \text{DCC}(1,1)$

$$\mathbf{A_t} \equiv [A_t^i]_{i=1,\ldots,I}$$

$$\mathbf{C_t} \equiv [C_t^j]_{j=1,\ldots,J}$$

Model implied vs residual covariance

- Consider the one-to-one mapping $n \equiv n(i, j)$, with which we identify asset n, belonging to asset class i and country j, so that:

$$R_t^n = \mathbf{E}[R_t^n] + F_t^n \beta_t^n + \epsilon_t^n$$

  with $n = 1, \ldots, N$.
- For $n_1 \neq n_2$:

$$cov_t(R^{n_1}, R^{n_2}) = \mathbf{E}[\beta_t^{n_1\prime} \; F_t^{n_1\prime} F_t^{n_2} \beta_t^{n_2}] + \mathbf{E}[\epsilon_t^{n_1} \epsilon_t^{n_2}]$$

Model implied vs residual covariance

- The empirical counterpart is:

$$\hat{cov}_t(R^{n_1}, R^{n_2}) = \hat{\beta}_t^{n_1\prime} \hat{\Sigma}_{F,t}^{n_1,n_2} \hat{\beta}_t^{n_2} + \hat{\Sigma}_{\epsilon,t}^{n_1,n_2}$$

that we rewrite as:

$$\hat{cov}_{n_1,n_2,t} = \hat{cov}^F_{n_1,n_2,t} + \hat{cov}^\epsilon_{n_1,n_2,t}$$

where:

- $\hat{cov}^F_{n_1,n_2,t}$ is the model implied covariance,
- $\hat{cov}^\epsilon_{n_1,n_2,t}$ is the residual covariance.

Model implied vs residual covariance

- The **covariance** between R^{n_1} and R^{n_2} can rise through three different channels:
  - the **factor loadings** β_t
  - the **covariance of the factors** $\Sigma_{F,t}$
  - the **residual covariance** $\Sigma_{\epsilon,t}$
- **Bekaert et al. (2005, 2012)**: contagion as the comovement between financial markets in excess of what implied by an economic model ($\Sigma_{\epsilon,t}$)
- **In this paper** (consistently with Forbes and Rigobon, 2002, pp.2230–1):
  - **Contagion**: episode of financial distress characterized by increasing interlinkages between markets (β_t)
  - **Excess Interdependence**: spiking conditional covariances between the common factors ($\Sigma_{F,t}$)

Model implied vs residual covariance

- We define the average measure of **model implied comovements** as:

$$\Gamma_t^F \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t}^F$$

- Similarly, we define the **residual comovement measure** as:

$$\Gamma_t^\epsilon \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t}^\epsilon$$

Comovements by sources

- From the independence of the system $[G_t \; A_t^i \; C_t^j \; \epsilon_t^{i,j}]$, we get:

$$cov_t(R^{n_1}, R^{n_2}) = \mathbf{E}[\gamma_t^{n_1}{}' G_t{}' G_t \gamma_t^{n_2}] + \\ + \mathbf{E}[\delta_t^{n_1}{}' A_t^{i_1}{}' A_t^{i_2} \delta_t^{n_2}] + \mathbf{E}[\lambda_t^{n_1}{}' C_t^{j_1}{}' C_t^{j_2} \lambda_t^{n_2}] + \mathbf{E}[\epsilon_t^{n_1} \epsilon_t^{n_2}]$$

- The empirical counterpart:

$$cov_t(R^{n_1}, R^{n_2}) = \hat{\gamma}_t^{n_1}{}' \hat{\Sigma}_{G,t}^{n_1,n_2} \hat{\gamma}_t^{n_2} + \\ + \hat{\delta}_t^{n_1}{}' \hat{\Sigma}_{A,t}^{n_1,n_2} \hat{\delta}_t^{n_2} + \hat{\lambda}_t^{n_1}{}' \hat{\Sigma}_{C,t}^{n_1,n_2} \hat{\lambda}_t^{n_2} + \hat{\Sigma}_{\epsilon,t}^{n_1,n_2}$$

which we rewrite as:

$$\hat{cov}_{n_1,n_2,t} = \hat{cov}_{n_1,n_2,t}^G + \hat{cov}_{n_1,n_2,t}^A + \hat{cov}_{n_1,n_2,t}^C + \hat{cov}_{n_1,n_2,t}^\epsilon$$

Comovements by sources

- We define a measure of comovement prompted by the **global factor** as:

$$\Gamma_t^G \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t}^G$$

where $\hat{corr}_{n_1,n_2,t}^G$ is defined as:

$$\hat{corr}_{n_1,n_2,t}^G \equiv \frac{\hat{cov}_{n_1,n_2,t}^G}{\sqrt{\hat{var}_{n_1,t}^F \hat{var}_{n_2,t}^F}}$$

- In the same manner, we define Γ_t^A and Γ_t^C.
- By construction we have: $\Gamma_t^F \equiv \Gamma_t^G + \Gamma_t^A + \Gamma_t^C$.

Comovements at the asset class and country level

- Let:

$$\mathcal{I}_i = \left\{ n \middle| n = n(i,j); j = 1, \ldots, J \right\}$$
$$\mathcal{J}_j = \left\{ n \middle| n = n(i,j); i = 1, \ldots, I \right\}$$

- We define the model implied comovement measure for **asset class** i as:

$$\Gamma_t^i \equiv \frac{1}{|\mathcal{I}_i| \left(|\mathcal{I}_i| - 1 \right) / 2} \sum_{n_1 \in \mathcal{I}_i} \sum_{\substack{n_2 \in \mathcal{I}_i \\ n_2 > n_1}} \hat{corr}^F_{n_1, n_2, t}$$

- We define the model implied comovement measure for **country** j, we have:

$$\Gamma_t^j \equiv \frac{1}{|\mathcal{J}_j| \left(|\mathcal{J}_j| - 1 \right) / 2} \sum_{n_1 \in \mathcal{J}_j} \sum_{\substack{n_2 \in \mathcal{J}_j \\ n_2 > n_1}} \hat{corr}^F_{n_1, n_2, t}$$

Contagion vs excess interdependence

- Alongside the previous definitions, we propose a modification of them, to test for **contagion** versus **excess interdependence**.
- In the case of:

$$\Gamma_t^F \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t}^F$$

we also consider:

$$\Gamma_{t,ED}^F \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t,ED}^F$$

$$\Gamma_{t,VD}^F \equiv \frac{1}{N(N-1)/2} \sum_{n_1=1}^{N} \sum_{n_2>n_1}^{N} \hat{corr}_{n_1,n_2,t,VD}^F$$

Contagion vs excess interdependence

where $\hat{corr}^F_{n_1,n_2,t,ED}$ and $\hat{corr}^F_{n_1,n_2,t,VD}$ are the correlation coefficients respectively associated with the following covariances:

$$\hat{cov}^F_{n_1,n_2,t,ED} \equiv \hat{\beta}^{n_1\prime}_t \hat{\Sigma}^{n_1,n_2}_F \hat{\beta}^{n_2}_t$$

$$\hat{cov}^F_{n_1,n_2,t,VD} \equiv \hat{\beta}^{n_1\prime} \hat{\Sigma}^{n_1,n_2}_{F,t} \hat{\beta}^{n_2}$$

- We consider the same alternative definitions for Γ^G_t, Γ^A_t and Γ^C_t, as well as for Γ^i_t and Γ^j_t.

Testing for contagion vs excess interdependence

- **Structural breaks** as a sign of contagion and excess interdependence.
- Break detection using **Autometrics**^{TM} (Hendry and Krolzig, 2005, Doornik, 2009, Castle et al., 2011).
- We look for structural breaks in the generic $\Gamma_t^{(\cdot)}$ average comovement measures, by estimating the **regression** (Castle et al., 2012):

$$\Gamma_t^{(\cdot)} = \mu + \eta_t$$

  where μ is a constant and η_t is assumed to be white noise.
- We then saturate the above regression using the **Impulse-Indicator Saturation (IIS)** technique.
- **Segments of dummy variables** will occur in block between the dates of the breaks.

Definitions: contagion vs excess interdependence

- **Definition 1 (Contagion)**. A situation of *contagion* is defined as the case in which a segment of dummy variables is detected through the IIS procedure for the average comovement measure $\Gamma_{t,ED}^{(\cdot)}$.
- **Definition 2 (Excess Interdependence)**. A situation of *excess interdependence* is defined as the case in which a segment of dummy variables is detected through the IIS procedure for the average comovement measure $\Gamma_{t,VD}^{(\cdot)}$.

Factor estimates

- The extracted factors account for $\sim 83\%$ of the overall **variance**, in particular:
  - Global factor $\sim 40\%$
  - Asset class and country factors $\sim 50 - 80\%$
- Stock indices are the most correlated with the global factors ($\sim 80 - 90\%$) $\Rightarrow$ global factor as the **momentum factor**.
- Grouping by asset class more than by country $\Rightarrow$ **Asset class effect** over country.
- Interpretation of the **asset class factors** not polluted.

Model selection. Table 6

	Alternative model	
Null model	**Time-varing factor loading**	**Conditional time-varying factor loading**
Static factor loading	260142.36***	261869.86***
Time-varing factor loading		1727.50***

Table: Likelihood ratio test statistic for the alternative models (*** indicates rejection of the null model at the 1% significance level).

Model implied vs residual average correlation measures. Figure 2

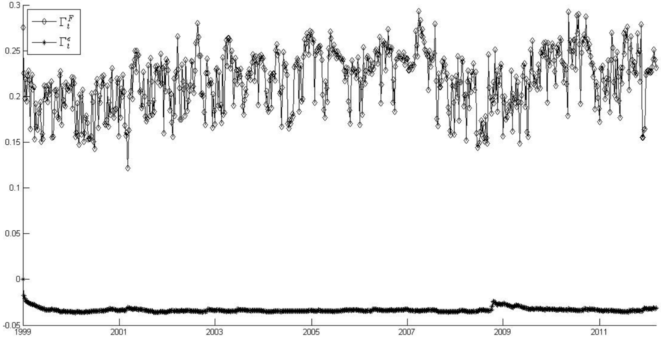

Figure: Model implied versus residual average correlation measures.

Model implied vs pure contagion comovements

- Stationary behaviour of the **model implied measure**.
- No **crisis episodes** can be identified at this stage.
- The **residual component** is neglegible.

Comovements source. Figure 3

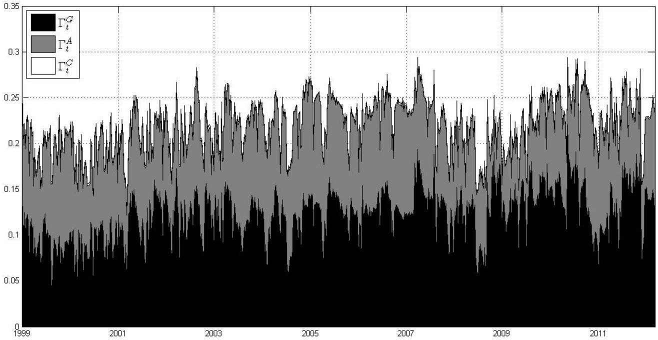

Figure: Decompositions of the overall average comovements by source of the shock.

Comovements source

- The **global factor** appears to be the most pervasive.
- The **asset class factor** is the most persistent.
- The **country factor** is almost negligible.
- Comovements typically propagate through **two channels**: a global one (time varying contribution) and an asset class channel (constant contribution).

Comovements analysis - Overall. Figure 5

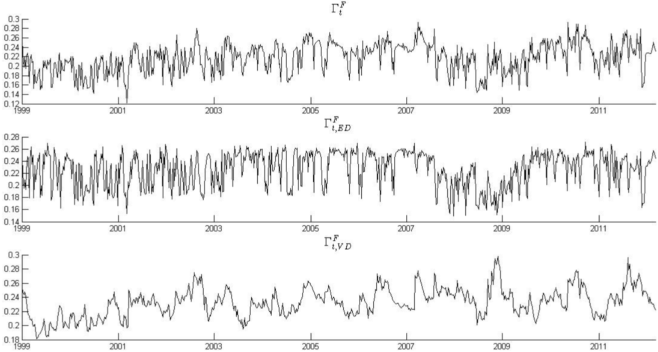

Figure: Average correlation measures (aggregate, exposure driven and volatility driven).

Comovements analysis - Overall. Table 7

[plain]

Γ_t^F		
Outliers		
26/02/1999	-0.0583	**
. . .		
16/12/2011	-0.0584	**
Constant	0.2230	***

$\Gamma_{t,ED}^F$		
Segments		
17/08/2007 - 21/11/2008	-0.0670	***
Outliers		
07/04/2000	-0.0608	**
30/06/2000	-0.0607	**
09/03/2001	-0.0746	***
25/11/2011	-0.0646	***
02/12/2011	-0.0583	**
Constant	0.2282	***

$\Gamma_{t,VD}^F$		
Segments		
31/10/2008 - 05/12/2008	0.0564	***
12/08/2011 - 26/08/2011	0.0594	***
Outliers		
23/04/1999	-0.0507	***
Constant	0.2320	***

Comovements analysis - Overall. Table 7

- Γ_t^F: only **outliers** are found.
- $\Gamma_{t,VD}^F$: evidence of **excess interdependence** (late 2000s and Aug-2011).
- $\Gamma_{t,ED}^F$: average **de-correlation** of more than 6% in late 2000s and outliers in proximity of the Dot-Com bubble burst.

Comovements analysis - Asset class. Figure 6

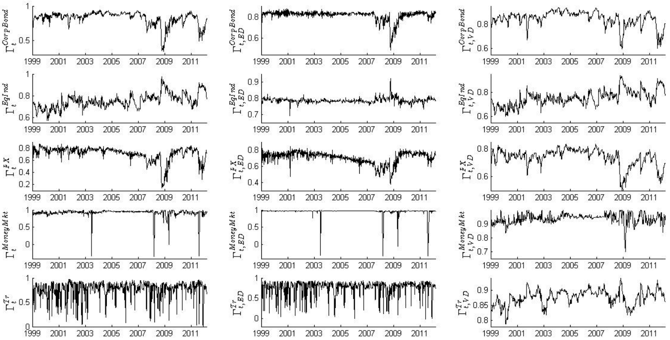

Figure: Average correlation measures at the asset class level: the aggregate, the exposure driven and the volatility driven.

Comovements analysis - Equity. Table 8

- Evidence of **contagion** (Aug-07 to mid-09), with correlation up by 5% from the average level of 79%.
- Evidence of **excess interdependence** (2008–2009, May-2010 and from Aug-2011 on), with a surge of 13-15% in the average correlation.
- At **aggregate level**, the 2007–09 crisis and the EU debt crisis are the most relevant.

Comovements analysis - Corporate Bond and FX. Table 8

- Overall **slump in correlations** in the last part of 2008 ($\sim -40\%$).
- **Same phenomenon** at the contagion and excess interdependence levels.
- **Appreciation** of the Yen during the crisis and **growth** of the Japanese Corporate Bond market (Shim, 2012).

Comovements analysis - Corporate Bond and FX. Figure 8

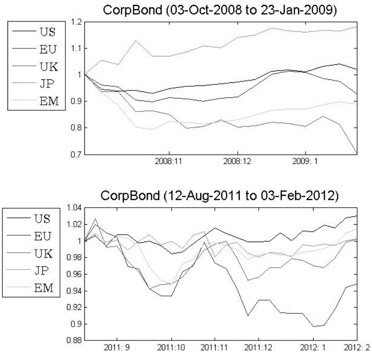

Figure: Comparison among selected securities during the detected regimes (price indices, rebased).

Comovements analysis - Money Markets and Government Bonds

- **Money markets**:
  - Shocks of **alternate signs** (aggregate level and excess interdependence).
  - **Negative breaks**: asymmetries in the shocks on the interbank markets and the differences in the reactions of the monetary policy to the spreading of the crisis (2007 and early 2008).
  - **Positive** sign at the aggregate level in correspondence to the joint monetary policy intervention in October 2008.
- No evidence of contagion for **government bonds**.

Comovements analysis - Country. Figure 7

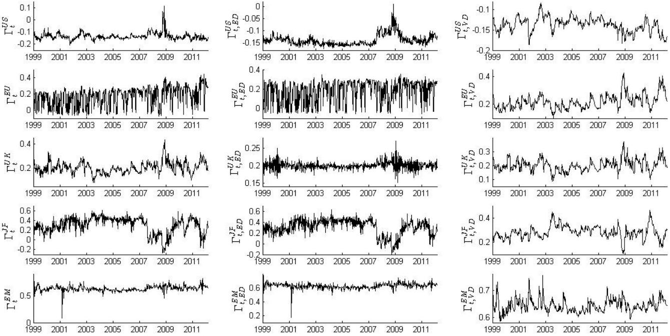

Figure: Average correlation measures at the country level: the aggregate, the exposure driven and the volatility driven.

Comovements analysis - Country. Table 9

- **US**: peak in the overall comovements and evidence of worsening contagion effect (2007-09 crisis).
- **Europe**: excess interdependence (2008–2012).
- **UK**: positive breaks at the aggregate level and at the volatility driven level (2007-09 crisis and for the EU sovereign debt crisis).
- **Japan**: de-correlation phenomenon (see above).
- **Emerging Markets**: excess interdependence (2008 and 2011).

Comovements analysis

- **2007-2009 global crisis**: first evidence of *contagion* for US and Equity market.
- **EU sovereign debt crisis**: most extended period of *excess interdependence* recorded for Equity indices and for Europe.
- Former extent is **persistent**, latter is **temporary**.

Conclusions

- We proposed a **dynamic factor model** to study comovements in a multi-country and a multi-asset class framework.
- We use **Dummy Saturation** approach to distinguish **contagion vs excess interdependence**
- The **global factor** appears to be the most pervasive, the **asset class** factor is the most persistent, the **country factor** is negligible.
- Evidence of contagion from the US and the stock market jointly (sub-prime 2007-2009 crisis). Presence of excess interdependence from mid-2010 onwards (European sovereign debt crisis).
- No contagion on the global financial markets at the aggregate level (presence of safe havens).

Future work

- Inclusion of **Credit Indices**.
- Further developments of the **volatility modelling**.
- Use of the the proposed framework by considering **Great Financial Depression** (2007-2009), the **Sovereign Debt Crisis** (2010-2012) and also **the end of the turmoil period** (2012-present).
- Implications for **asset allocation** and **risk management**.

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