DEUTSCHE BUNDESBANK
EUROSYSTEM

Euro area banks' interest rate risk exposure to level, slope and curvature swings in the yield curve

Daniel Foos[1], Eva Lütkebohmert[2], Mariia Markovych[2], **Kamil Pliszka**[1]

[1]**Deutsche Bundesbank,** [2]**University of Freiburg**

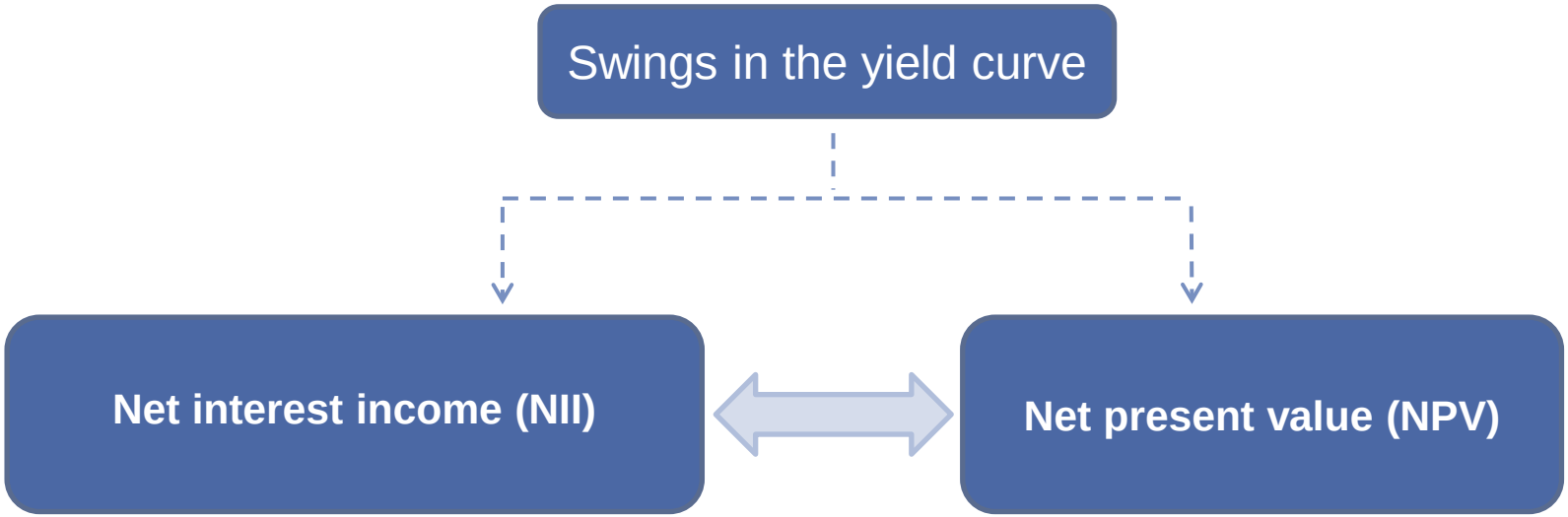
2017 EBA Policy Research Workshop
„The future role of quantitative models in financial regulation"

28-29 November 2017

1 Motivation

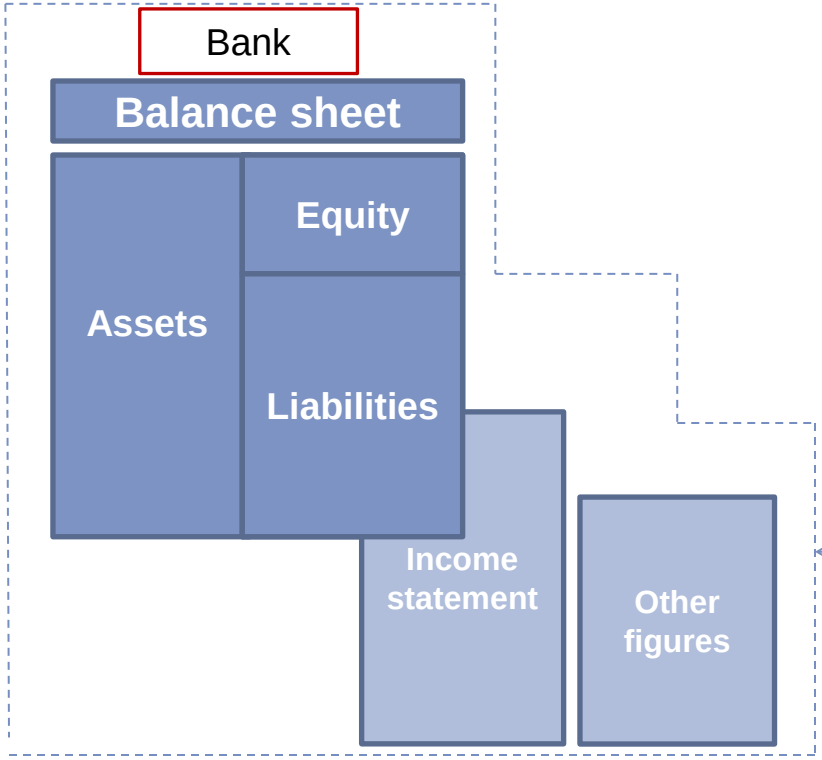
Interest rate risk

- One of the major risk sources for financial institutions
- Interest rate increases in the low interest rate environment in the euro area: Prospect for higher net interest income vs losses in present value

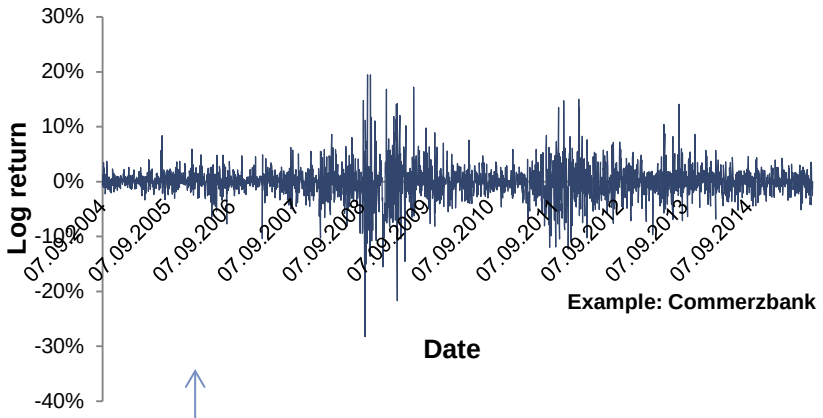


1 Motivation

II Explaining interest rate risk
Banks‘ rate sensitivity ↔ Banks‘ balance sheet composition and other figures

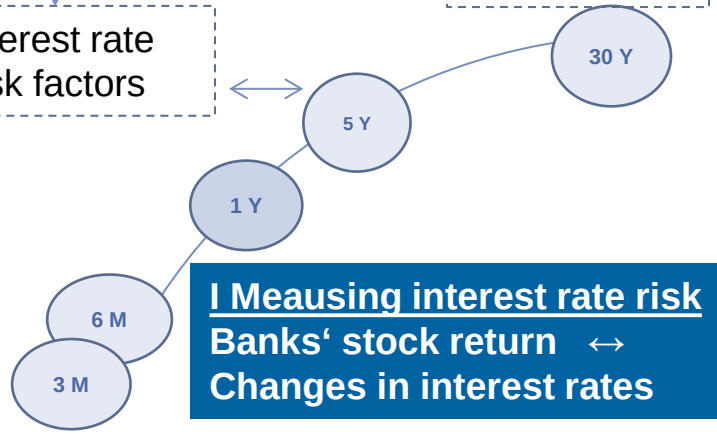


Bank‘s stock return



Interest rate risk factors

Yield curve



I Measuing interest rate risk
Banks‘ stock return ↔ Changes in interest rates

2 Literature

Negative impact of interest rate increases on equity

- Flannery/James (1984, JF)
- Fraser/Madura/Weigand (2002, FR)
- English/van den Heuvel/Zakrajšek (2014,Wharton School WP)

Positive or inconclusive impact of rate increases on equity

- Schuermann/Stiroh (2006, Fed NY WP)
- Ballester/Gonzales/Soto (2009, UCLM WP)
- Hasan/Kalotychou//Staikouras/Zhao (2013, WP)

Positive impact on the net interest margin

- Hanweck/Ryu (2005, FDIC WP)
- English/van den Heuvel/Zakrajšek (2014,Wharton School WP)

DCC M-GARCH model: Engle (2002, JBE)

Bayesian DCC M-GARCH model: Fioruci/Ehlers/Filho (2014, JAS)

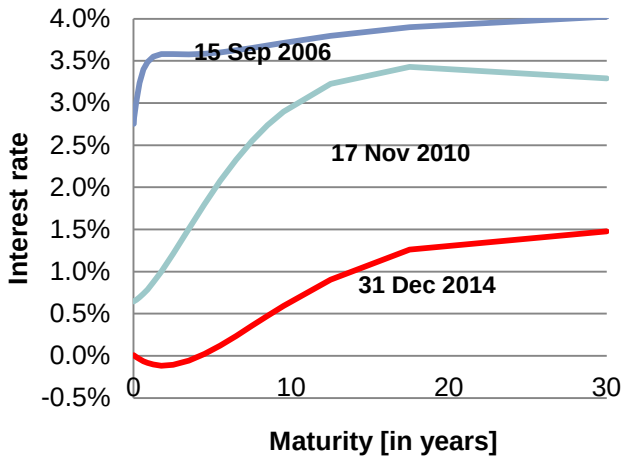
Contribution

- Sample: Major euro area banks (listed SSM banks)
- Time period 2005 to 2014 covers the low interest rate environment in the euro area
- Time-varying sensitivities via the Bayesian DCC M-GARCH model
- Combined analysis: (i) Analysis of sensitivities; (ii) Bank-specific factors

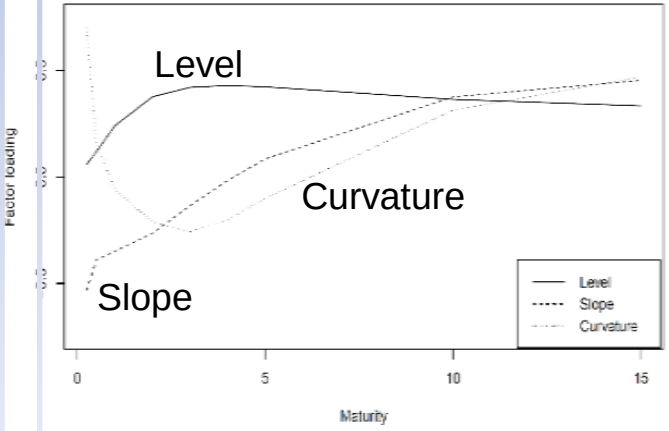
3 Measuring SSM banks' interest rate risk exposure
3.1 Methodology

Yield curve → Principal components → Bayesian DCC M-GARCH

Source of the yield curve
Svensson model based on AAA euro area government bonds (source: ECB)



Methodology for capturing yield curve swings
First PC: **level** (76.29%); second PC: **slope** (11.59%); third PC: **curvature** (8.21%)
[in brackets: explained variance]



Methodology for estimating sensitivities of banks' stock returns to changes in level, slope and curvature of the yield curve

3 Measuring SSM banks' interest rate risk exposure
3.1 Methodology

Sensitivities to swings in the yield curve via **Bayesian DCC M-GARCH**

$$\widehat{\beta_{IR,t}^{(i)}} = \frac{Cov\,(r_{it}\,\Delta IR_t)}{Var\,(\Delta IR_t)}$$

i: bank, IR: interest rate risk factor (i.e. level, slope, curvature)
r_{it} : stock price log return

- $Var(\Delta IR_t)$ and $Cov(r_{it,}\,\Delta IR_t)$ are estimated based on the Bayesian Dynamic Conditional Correlation multivariate GARCH model (Bayesian DCC M-GARCH)
- **Output:** conditional variance-covariance matrices at each point in time for each bank
- **Bayesian DCC M-GARCH:** $y_t = (r_t r_{mt} pc_{1t} pc_{2t} pc_{3t})^T \sim Distr(\mu, H_t)$ with $H_t = D_t R_t D_t$
  - Elements of D_t (standard deviations) follow a GARCH (1,1) process
  - Elements of R_t (conditional correlations) depend on the unconditional correlations, the standardized returns of y_t and its history (function of R_{t-1})
  - Bayesian extension (*t*/normally/GED (generalized error distribution)-distributed variables)

3 Measuring SSM banks' interest rate risk exposure
3.2 Data

Data

- **Dependent variable:** banks' stock close prices (log returns) of listed SSM banks (total: 36 banks)

	AT	BE	CY	DE	ES	FR	GR	IE	IT	PT	Total
No. of banks	1	2	1	4	5	3	4	3	12	2	36

- **Explanatory variables:** market returns (EuroStoxx 50 (excl. banks, log returns)), principal components of the yield curve (level, slope, curvature)

$$\begin{bmatrix} r_{i,1} & r_{m,1} & pc_{1,1} & pc_{2,1} & pc_{3,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{it} & r_{m,t} & pc_{1,t} & pc_{1,t} & pc_{3,t} \end{bmatrix}$$

Matrix is calculated for each bank separately

Bank i's stock (log returns)

EuroStoxx 50 (excl. Financials) **index** (log returns)

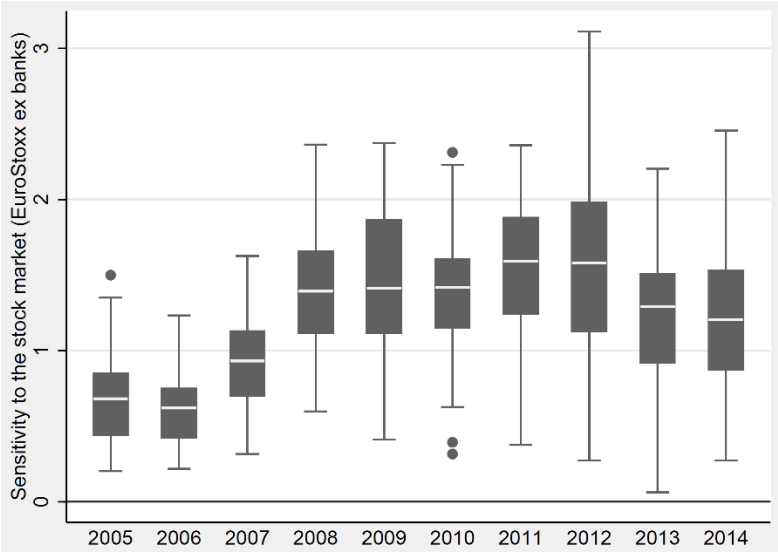
Principal components of the yield curve (differences in shape parameters of the yield curve)

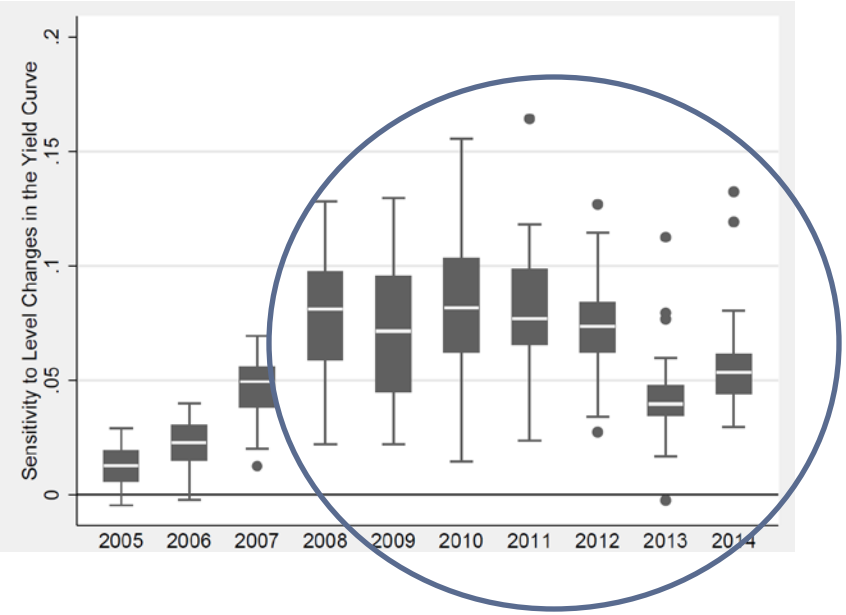
- Time period: **01/2005 to 12/2014,** frequency: daily; data source: ECB and Datastream

3 Measuring SSM banks' interest rate risk exposure
3.3 Results (aggregate level)

Sensitivity to market (left figure) and to level changes (right figure)

- Box plots show the average sensitiy in each year over the sample of 36 banks
- Market: banks exhibit a positive exposure to the market risk factor
- Level: sensitivity is positive, but increased considerably from 2008 onwards

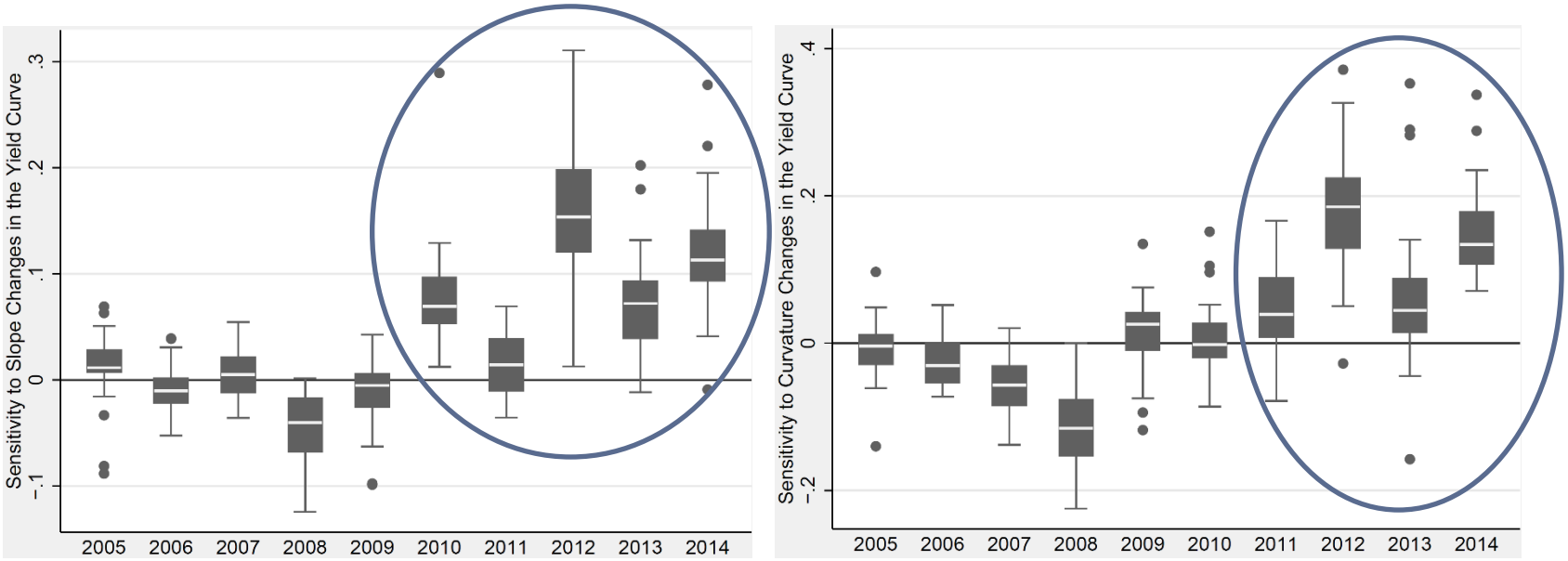




3 Measuring SSM banks' interest rate risk exposure
3.3 Results (aggregate level)

Sensitivity to slope (left figure) and to curvature changes (right figure)

- Box plots show the average sensitiy in each year over the sample of 36 banks
- Slope: in 2005 to 2009, the sensitivity is slightly negative or close to zero. From 2010 onwards, it becomes clearly positive
- Curvature: in 2005 to 2010, the sensitivity is slightly negative or close to zero. From 2011 onwards it becomes clearly positive



3 Measuring SSM banks' interest rate risk exposure
3.3 Results

- SSM banks' stock prices react to all types of interest rate movements
- The **exposure to level, slope and curvature changes over time:** call for a dynamic model
- **Curvature** swings account for a **significant amount of total variation** in the yield curve (8.21%)

- On average, there is a **positive exposure to**
- **level** (i.e. share prices **increase** if the yield curve's level increases),
- **slope** (i.e. share prices **increase** if the yield curve becomes steeper) and
- **cuvature swings** (i.e. share prices **increase** if the yield curve is affected by a combination of decreases in mid-term rates and increases in short-term and long-term rates)

4 Explaining SSM banks' interest rate risk exposure
4.1 Methodology

Linear model

$$\widehat{\beta_{IR,t}^{(i)}} = X_{it}^{T} b + Y_{it}^{T} \theta + \varepsilon_{it}$$

with

$\widehat{\beta_{IR,t}^{(i)}}$: sensitivity (IR ∈ {level ($pc_{1,t}$), slope ($pc_{2,t}$), curvature ($pc_{3,t}$)})
[results from the first step]
X_{it}: bank-specific characteristics (accounting data, key indicators)
Y_{it}: year- and country-fixed effects
$\epsilon_{i,t}$: i.i.d. error terms

Reminder

- Most banks have a **positive exposure to level, slope and curvature.** A **positive coefficient** means that **increasing independent variables leads to higher sensitivities** and, thus, expose the **bank more strongly to swings** of the respective interest rate risk factor
- In contrast, a **negative coefficient pulls the sensitivities closer to zero** and, thus, **reduces the sensitivity** to slope swings

4 Explaining SSM banks' interest rate risk exposure
4.2 Data

Data

- **Dependent variables**: bank-specific interest rate sensitivities to level, slope and curvature (yearly averages)
- **Independent variables:** accounting data (SNL Financial: IFRS, annual basis) and key indicators
- Sample: 36 banks; time period: 2005 to 2014 (yearly data)
- Models: Full period, 2005 to 2009 and 2010 to 2014

Balance sheet composition

I Asset side

- Total financial assets to total assets
  - Securities to total assets
  - Net customer loans to total assets

II Liability side

II.1 Equity

- Core Tier capital ratio

II.2 Liabilities

- Deposits to total liabilities (and equity
- Term deposits to total liabilities (and equity)
- Total debt to total liabilities (and equity)
- Subordinated debt to total liabilities (and equity)
- Senior debt to total liabilities (and equity)
- Derivative liabilities to total liabilities (and equity)

Profitability

- Net interest income to operating revenue
- Net fee income to risk-weighted assets
- ROAA

Comparision between assets and liabilities

- Net customer loans minus deposits to total assets

Asset quality

- Loan loss reserves to gross customer loans

Bank size

- Size = ln(total assets)

4 Explaining SSM banks' interest rate risk exposure
4.3 Results

Balance sheet composition **I Asset side**	**Expected sign**	**Empirical results w.r.t.**		
		Level	**Slope**	**Curvature**
• Total financial assets to total assets	+	~	~	~
• Securities to total assets	+	~	~	+
• Net customer loans to total assets	+	+	+	+
II Liability side **II.1 Equity**				
• Core Tier capital ratio	-	+	-°	+
II.2 Liabilities				
• Deposits to total liabilities (and equity)	-	-	~	~
• Term deposits to total liabilities (and equity)	-	~	-	-
• Total debt to total liabilities (and equity)	-	-	~	-
• Subordinated debt to total liabilities (and equity)	+/-	+	~	~
• Senior debt to total liabilities (and equity)	-	-	~	-
• Derivative liabilities to total liabilities (and equity)	+/-	+°	~	+

~: inconclusive; °: results only significant in the period 2005-2009

4 Explaining SSM banks' interest rate risk exposure
4.3 Results

Profitability	**Expected sign**	**Empirical results w.r.t.**		
		Level	**Slope**	**Curvature**
• Net interest income to operating revenue	+/-	-	~	~
• Net fee income to risk-weighted assets	-	~	-	-
• ROAA	+/-	-	+°	~
Other				
• Net customer loans minus deposits to total assets	+	~	+	+
• Loan loss reserves to gross customer loans	-	-	~	+
• Size = ln(total assets)	+	+	+	+

5 Conclusions

- Interest rate **sensitivities vary in time**
- Curvature swings have been significant in the recent years
- SSM banks hold a **positive exposure to level, slope and curvature** shifts
  - SSM banks share prices benefit from interest rate level, slope and curvature increases
  - Ballester/Gonzales/Soto (2009, UCLM WP) come to the same finding for Spanish banks
- Banks with larger balance sheets, higher capital ratios, a higher part of customer loans and lower part of deposits are more sensitive to interest rate risk

Bibliography

- Ballester, L., Ferrer, R., Gonzales, C., & Soto, G. (2009). Determinants of interest rate exposure of Spanish banking industry. UCLM Working Paper
- Czaja, M., Scholz, H., & Wilkens, M. (2010). Interest Rate Risk Rewards in Stock Returns of Financial Corporations: Evidence from Germany. European Financial Management, 16 (1), 124-154
- Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate autoregressive conditional heteroskedasticity models,. Journal of Business & Economic Statistics, 20 (3), 339-350
- English, W., Van den Heuvel, S., & Zakrajsek, E. (2014). Interest Rate Risk and Bank Equity Valuations. Working Paper, Wharton School, University of Pennsylvania
- Esposito, L., Nobili, A., & Ropele, T. (2015). The management of interest rate risk during the crisis: Evidence from Italian banks. Journal of Banking & Finance, 59, 486-504

Bibliography

- Fioruci, J., Ehlers, R., & Filho, M. (2014). Bayesian multivariate GARCH models with dynamic correlations and asymmetric error distributions. Journal of Applied Statistics, 41 (2), 320-331
- Flannery, M., & James, C. (1984). The effect of interest rate changes on the common stock returns of financial institutions. The Journal of Finance, 39 (4), 1141-1153
- Fraser, D., Madura, J., & Weigand, D. (2002). Sources of bank interest rate risk. The Financial Review, 37 (3), 351-367
- Hasan, I., Kalotychou, E., Staikouras, S., & Zhao, G. (2013). Financial intermediaries and their risk exposure to level and slope. Working Paper

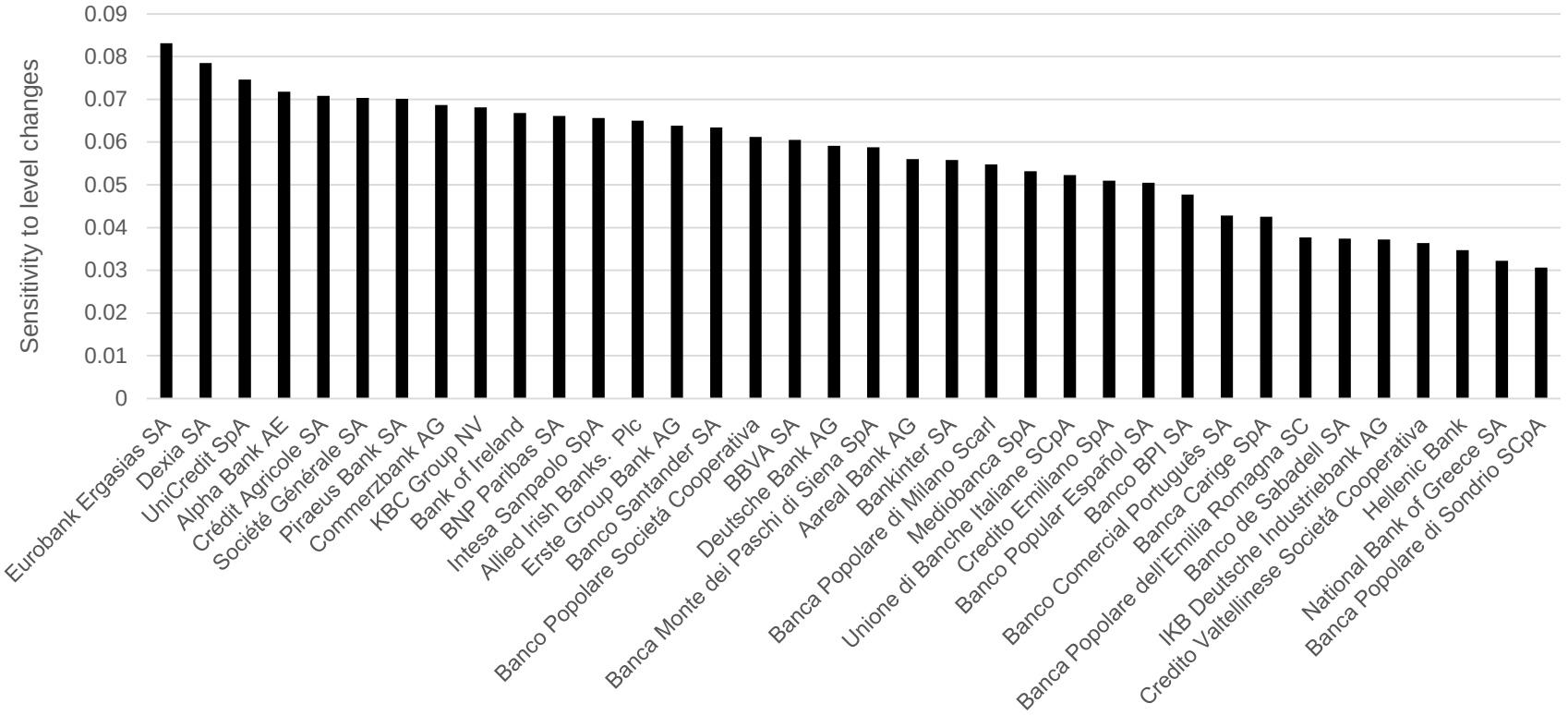
Bibliography

- Hanweck, G. & Ryu, L. (2005): The Sensitivity of Bank Net Interest Margins and Profitability to Credit, Interest-Rate, and Term-Structure Shocks Across Bank Product Specializations, FDIC WP
- Litterman, R., & Scheinkman, J. (1991). Common Factors Affecting Bond Returns. The Journal of Fixed Income, 1 (1), 54-61
- Reichert, A., & Shyu, Y. (2003). Derivative activities and the risk of international banks: a market index and VaR approach. International Review of Financial Analysis, 12 (5), 489-511
- Schuermann, T., & Stiroh, K. (2006). Visible and hidden risk factors for banks. Working Paper, Federal Reserve Bank of New York

Backup I: Measuring SSM banks' interest rate risk exposure - Results (bank level)

Sensitivity to level changes

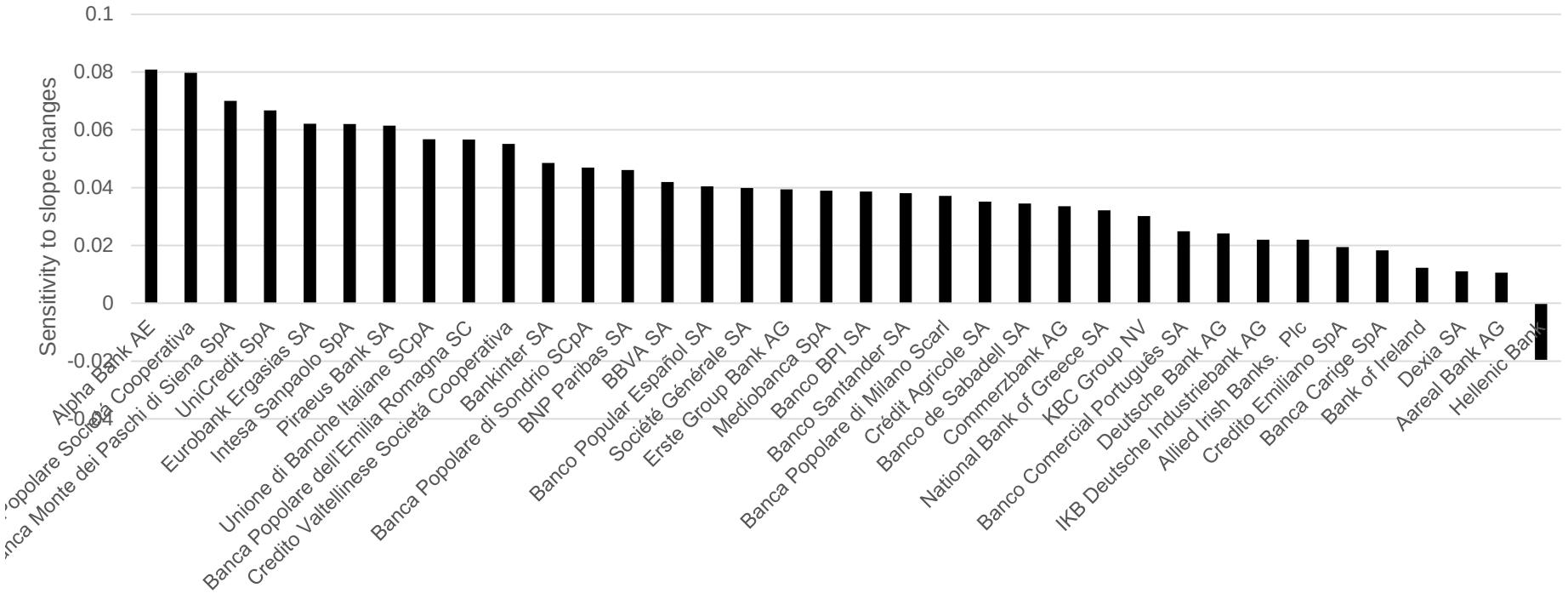
- Averaging over all years for each bank: All banks have a positive exposure to level changes



Backup I: Measuring SSM banks' interest rate risk exposure - Results (bank level)

Sensitivity to slope changes

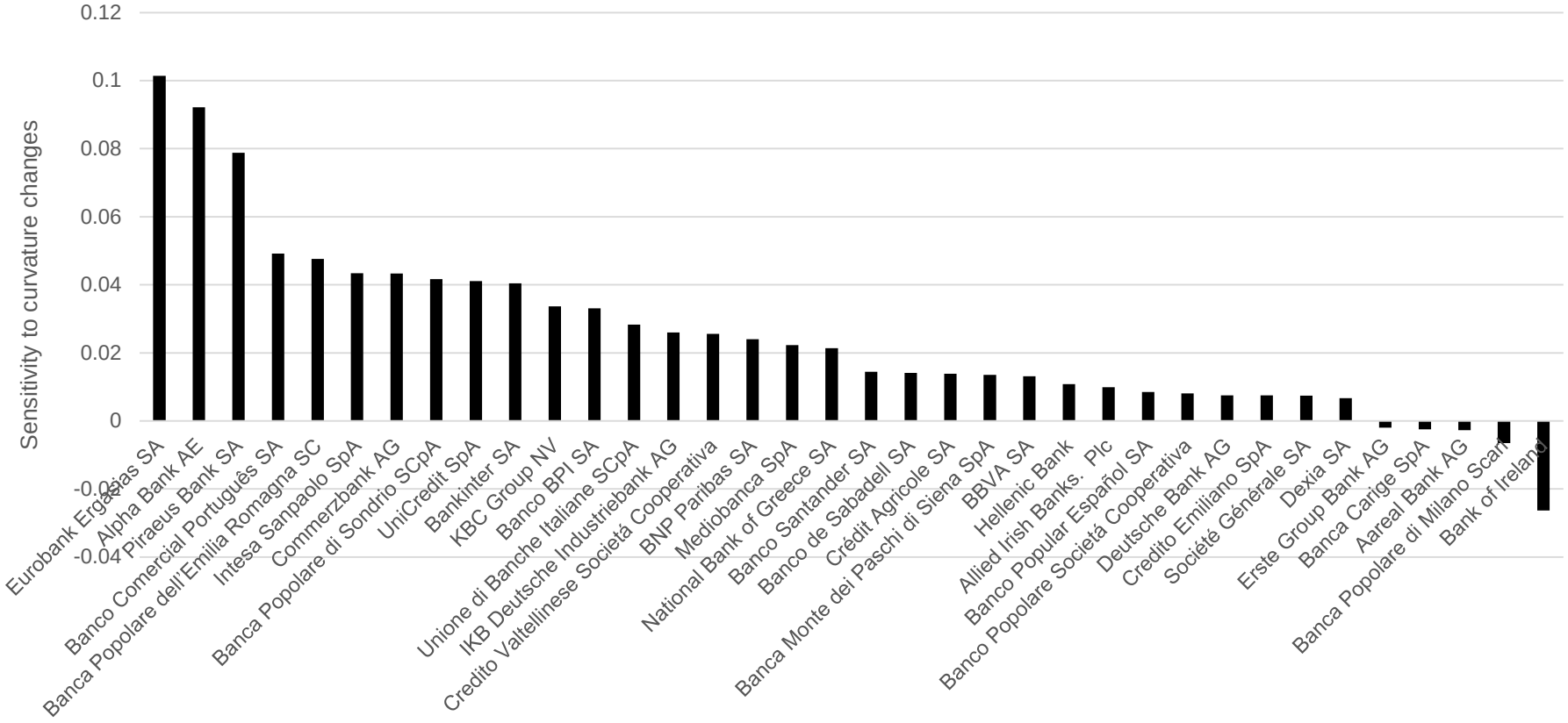
- Averaging over all years for each bank: 35 banks a positive exposure, one bank is negatively realted to slope changes



Backup I: Measuring SSM banks' interest rate risk exposure - Results (bank level)

Sensitivity to curvature changes

- Averaging over all years for each bank: 31 banks a positive exposure, five banks are negatively realted to cuvature changes



Backup II: Explaining SSM banks' interest rate risk exposure: Results

Explaining sensitivity to level swings in the yield curve

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
Regressors	Full period	2005 – 2009	2010 – 2014	Full period	2005 – 2009	2010 – 2014
Total financial assets to total assets	0.047	0.066	0.047			
	(0.75)	(0.71)	(0.73)			
Securities to total assets				0.024	-0.062	0.003
				(0.62)	(-0.99)	(0.05)
Net customer loans to total assets				**0.088***	-0.049	0.090
				(2.03)	(-0.84)	(1.32)
Core Tier capital ratio	**0.114****	0.208	**0.170*****	**0.103****	0.153	**0.101***
	(2.48)	(1.38)	**(3.67)**	**(2.25)**	(1.16)	**(1.79)**
Deposits to total liabilities (and equity)				**-0.119*****	-0.027	**-0.155****
				(-3.78)	(-0.70)	**(-2.50)**
Term deposits to deposits				0.020	0.026	0.000
				(0.99)	(0.67)	(0.02)
Total debt to total liabilities (and equity)	-0.048	0.013	**-0.076***			
	(-1.62)	(0.31)	**(-1.87)**			
Subordinated debt to total liabilities (and equity)				**0.377****	0.309	0.198
				(2.41)	(1.56)	(0.78)
Senior debt to total liabilities (and equity)				**-0.110*****	0.010	**-0.177*****
				(-3.22)	(0.19)	**(-2.88)**
Derivative liabilities to total liabilities (and equity)	0.008	-0.020	0.045	0.082	**0.215****	0.075
	(0.19)	(-0.49)	(0.74)	(1.27)	**(2.48)**	(0.82)
Net interest income to operating revenue	**-0.011*****	0.009	**-0.009*****	-0.003	-0.001	-0.007
	(-6.34)	(0.59)	**(-5.29)**	(-0.31)	(-0.03)	(-0.62)
Net fee income to RWA	0.062	0.015	-0.035	0.097	0.625	-0.414
	(0.20)	(0.03)	(-0.11)	(0.26)	(1.30)	(-0.98)
ROAA	**-0.461****	**-1.469****	**-0.428****	**-0.348****	**-1.942*****	-0.224
	(-2.59)	**(-2.38)**	**(-2.62)**	**(-2.09)**	**(-4.58)**	(-1.39)
Net customer loans minus deposits to total assets	0.050	-0.008	0.056			
	(1.66)	(-0.19)	(1.58)			
Loan loss reserves to gross customer loans	**-0.180*****	-0.163	**-0.241*****	**-0.169*****	-0.189	**-0.202****
	(-2.79)	(-0.41)	**(-2.81)**	**(-3.01)**	(-0.54)	**(-2.55)**
Size	**0.008*****	**0.008*****	**0.007*****	**0.005****	0.002	**0.007****
	(4.91)	**(3.28)**	**(3.39)**	**(2.04)**	(0.76)	**(2.34)**
Observations	275	119	156	241	105	136
R^2	0.61	0.70	0.58	0.66	0.78	0.61

Backup II: Explaining SSM banks' interest rate risk exposure: Results

Explaining sensitivity to slope Swings in the yield curve

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
Regressors	Full period	2005 – 2009	2010 – 2014	Full period	2005 – 2009	2010 – 2014
Total financial assets to total assets	0.105	-0.024	0.112			
	(0.66)	(-0.23)	(0.34)			
Securities to total assets				0.116	0.012	0.105
				(1.16)	(0.10)	(0.52)
Net customer loans to total assets				**0.182****	-0.054	**0.282***
				(2.09)	(-0.44)	**(1.74)**
Core Tier capital ratio	-0.014	**-0.597*****	0.059	0.051	**-0.394***	0.042
	(-0.12)	**(-3.26)**	(0.48)	(0.40)	**(-1.99)**	(0.32)
Deposits to total liabilities (and equity)				-0.054	0.140	-0.153
				(-0.62)	(1.62)	(-0.98)
Term deposits to deposits				**-0.059***	**-0.073***	-0.013
				(-1.82)	**(-1.72)**	(-0.37)
Total debt to total liabilities (and equity)	-0.046	0.055	-0.127			
	(-0.80)	(0.91)	(-1.38)			
Subordinated debt to total liabilities (and equity)				0.227	0.343	0.321
				(0.69)	(1.13)	(0.42)
Senior debt to total liabilities (and equity)				-0.110	0.097	-0.214
				(-1.09)	(1.00)	(-1.27)
Derivative liabilities to total liabilities (and equity)	0.065	0.025	0.104	0.094	0.041	0.129
	(1.11)	(0.52)	(0.86)	(0.98)	(0.29)	(0.83)
Net interest income to operating revenue	-0.004	-0.005	-0.004	-0.020	0.010	-0.039
	(-0.86)	(-0.16)	(-0.73)	(-0.86)	(0.40)	(-1.37)
Net fee income to RWA	-0.852	-0.324	-1.715	**-2.208*****	**-1.569****	**-2.799*****
	(-1.16)	(-0.50)	(-1.66)	**(-3.05)**	**(-2.49)**	**(-2.76)**
ROAA	-0.064	**1.891*****	-0.124	-0.029	**2.426*****	0.005
	(-0.14)	**(2.91)**	(-0.27)	(-0.06)	**(4.03)**	(0.01)
Net customer loans minus deposits to total assets	0.057	-0.041	**0.121***			
	(1.20)	(-0.84)	**(1.79)**			
Loan loss reserves to gross customer loans	0.104	0.187	-0.168	0.091	0.065	-0.116
	(0.52)	(0.41)	(-0.47)	(0.53)	(0.15)	(-0.48)
Size	**0.005****	-0.004	**0.012****	**0.008*****	0.000	**0.016*****
	(2.19)	(-1.32)	**(2.46)**	**(2.74)**	(0.05)	**(3.51)**
Observations	275	119	156	241	105	136
R^2	0.76	0.54	0.59	0.76	0.58	0.55

Backup II: Explaining SSM banks' interest rate risk exposure: Results

Explaining sensitivity to curvature Swings in the yield curve

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
Regressors	Full period	2005 – 2009	2010 – 2014	Full period	2005 – 2009	2010– 2014
Total financial assets to total assets	0.103	0.153	0.180			
	(0.73)	(0.86)	(1.20)			
Securities to total assets				**0.221***	0.116	**0.339****
				(2.02)	(0.83)	**(2.09)**
Net customer loans to total assets				**0.392*****	0.194	**0.495*****
				(3.30)	(1.39)	**(2.83)**
Core Tier capital ratio	**0.558*****	-0.080	**0.682*****	**0.556****	-0.052	**0.647****
	(3.02)	(-0.25)	**(2.84)**	**(2.55)**	(-0.17)	**(2.37)**
Deposits to total liabilities (and equity)				-0.149	0.041	-0.143
				(-1.48)	(0.33)	(-1.01)
Term deposits to deposits				**-0.093*****	-0.019	-0.073
				(-2.77)	(-0.36)	(-1.53)
Total debt to total liabilities (and equity)	**-0.193****	-0.072	**-0.258****			
	(-2.48)	(-0.79)	**(-2.20)**			
Subordinated debt to total liabilities (and equity)				-0.411	-0.084	-0.097
				(-1.21)	(-0.23)	(-0.15)
Senior debt to total liabilities (and equity)				**-0.290****	-0.084	**-0.301***
				(-2.34)	(-0.58)	**(-1.79)**
Derivative liabilities to total liabilities (and equity)	**0.217****	**0.133**	**0.269***	0.194	0.071	0.271
	(2.40)	(1.54)	**(1.70)**	(1.50)	(0.37)	(1.00)
Net interest income to operating revenue	0.003	0.033	-0.000	0.046	0.045	0.007
	(0.59)	(1.22)	(-0.02)	(1.25)	(1.19)	(0.12)
Net fee income to RWA	**-1.995***	-1.295	**-1.948***	**-4.244*****	**-4.161*****	**-3.958*****
	(-2.02)	(-0.99)	**(-1.80)**	**(-4.01)**	**(-4.55)**	**(-3.45)**
ROAA	0.428	0.984	0.376	0.426	1.813	0.348
	(0.86)	(0.70)	(0.56)	(0.74)	(1.30)	(0.50)
Net customer loans minus deposits to total assets	**0.135****	0.071	**0.169****			
	(2.20)	(0.89)	**(2.14)**			
Loan loss reserves to gross customer loans	**0.418***	-0.259	0.304	0.344	-0.694	0.261
	(1.73)	(-0.35)	(1.06)	(1.50)	(-1.03)	(1.04)
Size	0.003	0.002	0.003	**0.010*****	**0.009****	**0.010***
	(0.94)	(0.34)	(0.56)	**(2.86)**	**(2.29)**	**(1.81)**
Observations	275	119	156	241	105	136
R^2	0.78	0.68	0.66	0.79	0.71	0.66

Backup III: The DCC M-GARCH model

DCC M-GARCH model

- We consider the quasi-return vector $y_t = (r_t r_{mt} pc_{1t} pc_{2t} pc_{3t})^T \sim N(\mu, H_t)$
  - The centered random variable y_t^* can be expressed as: $y_t^* = H_t^{1/2} \epsilon_t$
- The **conditional variance-covariance matrix $\boldsymbol{H_t}$** is a (5×5) positive definite matrix. It can be decomposed into conditional standard deviations, D_t, and a correlation matrix, R_t:

$$H_t = D_t R_t D_t$$

  - The elements $h_{ii,t}^{1/2}$ in the diagonal matrix $D_t = diag(h_{r_t}^{1/2} \dots h_{pc_{3t}}^{1/2})$ are standard deviations. Each **conditional variance $\boldsymbol{h_{ii,t}}$** is assumed to follow a GARCH (1,1) process:

$$h_{ii,t} = \omega_i + \alpha_i (y_{i,t-1}^*)^2 + \beta_i h_{ii,t-1}$$

  - R_t is a symmetric positive definite matrix, which elements are time-dependent conditional correlations $\rho_{ij,t}$ with $\rho_{ij,t} = 1$ when $i = j$. Hence, the **conditional covariance** (elements of H_t) can be expressed as $h_{ij,t} = \rho_{ij,t} \sqrt{h_{ii,t}\, h_{jj,t}}$
  - We decompose the conditional correlation matrix $R_t = diag(Q_t)^{-\frac{1}{2}} Q_t \, diag(Q_t)^{-\frac{1}{2}}$ where Q_t is defined by

$$Q_t = \underbrace{(1 - \alpha - \beta)R}_{\text{constant}} + \underbrace{\alpha u_{t-1}^T u_{t-1}}_{\text{standardized returns}} + \underbrace{\beta Q_{t-1}}_{\text{lag}}$$

    with standardized returns $u_{t-1} = D_{t-1}^{-1} y_{t-1}^* = D_{t-1}^{-1} H_{t-1}^{1/2} \epsilon_{t-1}$ and unconditional covariance matrix R of u_t