① 데이터 기반 OLS분석 및 net predicted value($\tilde{R}^i_{2010}$) 추정

LoB IV. Fire	$\hat{Y}^{i,pr}_{2010}$	$\hat{Y}^{i,cl}_{2010}$	$\hat{Y}^{i,exp}_{2010}$	$\hat{Y}^{i,o.exp}_{2010}$
2000				
...	...			
2009				
2010	7.63	4.71	2.10	0.12

	LoB	$\hat{Y}^{i,pr}_{2010}$	$\hat{Y}^{i,cl}_{2010}$	$\hat{Y}^{i,exp}_{2010}$	$\hat{Y}^{i,o.exp}_{2010}$
I	Motor Vehicle Liability	6.82	5.13	1.26	−0.01
II	Other Motor	5.41	3.86	0.92	0.03
III	Marine, Aviation, Transport	0.48	0.32	0.12	0.008
IV	Fire	7.63	4.71	2.10	0.12
V	Third Party Liability	1.63	0.90	0.33	0.02
VI	Credit, Suretyship	0.55	1.03	0.37	0.02
VII	Legal Expenses	0.19	0.09	0.04	0.0009
VIII	Assistance	0.74	0.53	0.13	0.01
IX	Miscellaneous	1.96	0.77	0.69	0.04
X	N.P. Property	1.84	0.69	0.34	–
XI	N.P. Casualty	0.07	0.03	0.02	–
XII	N.P. MAT	0.23	0.46	0.39	–

- $\tilde{Y}^{i,s}_t = \beta^{i,s}_0 + \beta^{i,s}_1 t + \epsilon^{i,s}_t$
- $\mathbf{\Sigma Y_{2010}} = \tilde{\boldsymbol{R}}^{\boldsymbol{i}}_{\boldsymbol{2010}}\ (= \mathbf{0.8})$

② LoB간 종속관계를 고려한 joint CDF $\tilde{R}_{T+1}$ 추정

copula함수를 이용해서 joint cdf 계산

- $[0,1]^d \rightarrow [0,1]$
- $F_{\tilde{R}^i_{2010}} \sim N\left(E\left[\tilde{R}^i_{2010}\right], var\left[\tilde{R}^i_{2010}\right]\right)$
- $C^{Ga}_P(Z) = C(F^{-1}_{\tilde{R}^1_{T+1}}(u_1), \ldots, F^{-1}_{\tilde{R}^n_{T+1}}(u_n))$
- **multivariate random variable $\tilde{R}_{T+1}$**, where **each marginal function** represents the distribution of the random variable $\tilde{R}^i_{T+1}$.

③ 최종 SCR 산출하여, standard approach 방식으로 산출한 SCR과 비교

- estimated the SCR for this internal model **as the difference between 99.5% value-at-risk** and the **expected value** of random variable $\tilde{R}_{T+1}$.
- $SCR\ = VaR_{99.5\%}\left(\tilde{R}_{T+1}\right) - E[\tilde{R}_{T+1}]$

TABLE 3

SCR: STANDARD MODEL VERSUS INTERNAL MODEL.

Degrees of Freedom	Standard Model	Gaussian Margins: Gaussian Copula	Gaussian Margins: Student's t-Copula	Student's t-Margins: Gaussian Copula	Student's t-Margins: Student's t-Copula
Independence Correlation Matrix					
4	4.15	4.15	4.62	4.72	5.28
10	–	–	4.39	4.31	4.56
35	–	–	4.22	4.17	4.25
QIS-5 Correlation Matrix					
4	7.18	6.74	7.30	7.65	8.53
10	–	–	7.03	7.06	7.38
35	–	–	6.83	6.84	6.94
Comonotonicity Correlation Matrix					
4	11.03	10.22	10.25	12.93	12.92
10	–	–	10.25	11.22	11.28
35	–	–	10.22	10.47	10.49

Source: Authors' own. Based on data for the Spanish market 2000 to 2010. Results are expressed in thousands of million Euros.

아래 조건에 따른 SCR을 산출.

- 2가지 margin(gaussian, Student's t)와 2가지 copula((gaussian, Student's t))
- 상관관계 P를 반영할 때, (i) independence, (ii) QIS-5 correlation matrix, (iii) comonotonicity correlation matrix를 고려하여 실험을 진행함.
- Student's t분포를 사용할 때, 자유도(ν)를 4, 10, 35일 때로 설정하여 진행

		Copula: Gaussian	Copula: Student's t
margin	Gaussian	• $P \in \{indepen, QIS5, comon\}$ • $\nu \in \{4, 10, 35\}$	
	Student's t		

Bermúdez et al. (2013)