

D ASSESSING SYSTEMIC RISK IN THE EUROPEAN INSURANCE SECTOR

If very large changes in the stock prices of individual insurance undertakings tend to occur simultaneously, it can be said that extreme-value dependence is present. If such dependence is found to be present, it can indicate that these firms are exposed to common sources of risk. With a focus on gaining insight into systemic risk within the insurance sector, this Special Feature examines the incidence of extreme-value dependence across different types of insurance undertakings and it goes on to examine the main drivers of such co-movement, to the extent that it is present. A key finding is that extreme-value dependence is evident among larger composite insurers. In addition, two important drivers of extreme-value dependence between insurance companies are found: exposure to extreme financial market events, and to non-life underwriting.

INTRODUCTION

Individual firms' equity returns do not move independently from one another, mostly owing to common industry and market factors. This Special Feature looks at a particular type of such dependence among insurance undertakings, namely under extreme scenarios. By analysing the co-movement of insurance companies' equity returns during extreme events, it is possible to obtain an insight into the systemic risk dimension of this important financial sector.

The literature on extreme-value dependence is extensive and has recently also been applied to bank returns.¹ Extreme co-movements in the stock returns of financial institutions are likely to be driven by exposures to common observed and unobserved shocks. Insurance companies individually take on event risk either by absorbing it, or by passing it on in some repackaged form (e.g. through securitisation). Therefore, it is necessary from a financial stability perspective to examine whether extreme events could impact on the entire industry as a whole, or whether the exposure

to extreme-event risk is diversified away at the industry level. Clearly, if extreme-event exposure is not diversifiable at the industry level, then a catastrophic event could potentially affect the stability of the insurance sector. Conversely, if exposure to extreme events is sufficiently idiosyncratic, the insurance sector is likely to be able to cope better with such catastrophic events.

In contrast to the interbank market, the insurance sector lacks a direct channel of financial interaction between insurance companies other than through reinsurance, and thus unobserved common shocks are likely to be minimal. As the focus of this Special Feature is on the "pure" dependence between direct insurers, insurance companies that are also active as reinsurers are not included in the sample. The pure form of extreme-value dependence among insurers is likely to stem from their common exposure to financial market risk – as financial market downturns can potentially erode capital buffers dramatically – and from their underwriting activities, particularly in the case of non-life business, where shocks are likely to be more widespread and/or larger.

The findings from an empirical analysis suggest that insurers exhibit extreme-value dependence, particularly those with large non-life activities. This dependence is therefore likely to stem from common exposures resulting from underwriting activities. This finding is in line with the view that the degree of extreme-value dependence between insurance companies is to some extent sector-specific.² In addition to sector-specific factors, a country-specific

1 See for instance S.-H. Poon, M. Rockinger and J. A. Tawn (2004), "Extreme Value Dependence in Financial Markets: Diagnostics, Models and Financial Implications", *Review of Financial Studies*, Vol. 17, pp. 581-610; and P. Hartmann, S. Straetmans and C. de Vries (2005), "Banking System Stability: A Cross-Atlantic Perspective", *ECB Working Paper*, No 527 and references therein. For a detailed discussion of extreme-value dependence, see the Special Feature on "Assessing Banking System Risk with Extreme Value Analysis", in ECB (2006), *Financial Stability Review*, June.

2 See J. F. Slijkerman, D. Schoenmaker and C. G. de Vries (2005), Risk Diversification by European Financial Conglomerates, *Tinbergen Institute Discussion Paper*, No 2005-110/2.

component may also be expected to be an important driver of extreme-value dependence among insurance companies.

This Special Feature first tests the incidence of extreme-value dependence between the different types of insurance undertakings – composite, life and non-life – and reveals differences in extreme-value dependence across the three types of insurers. The subsequent sections look into the potential factors underlying such differences. The last section concludes.

OCCURRENCE OF EXTREME-VALUE DEPENDENCE

The data set consists of 1,568 daily equity returns per company between 1 December 1999 and 30 November 2005 covering 66 insurance companies (32 composite, 22 non-life insurance and 12 life insurance) in 13 different countries.³ Composite insurers which were active in the reinsurance market were not included in the sample.

The extreme-value dependence of pairs⁴ of companies by type – composite insurers (496), non-life insurance companies (231), and life insurers (66) – is estimated through a standard three-step procedure (see Box D.1). The presence of extreme-value dependence for each of the three types of insurers is represented by the percentage of pairs of firms for which extreme-value dependence cannot be rejected (see Chart D.1). Extreme-value dependence

appears least frequently among non-life insurers, and more often among composites and life insurers.

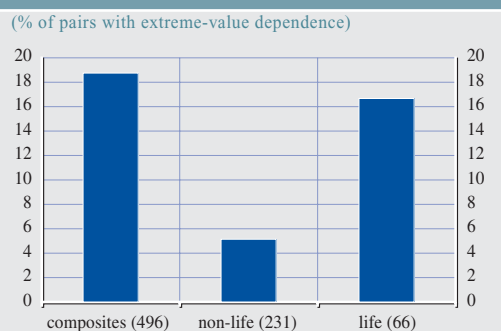
FACTORS UNDERLYING THE EXTREME-VALUE DEPENDENCE OF INSURERS

Whereas exposure to financial market risk and non-life underwriting risk may both be important drivers of extreme-value dependence between insurers, life-underwriting risk should not be expected to be an important factor in driving extreme-value dependence among insurance undertakings: while non-life underwriting potentially exposes an insurer to catastrophic losses, mortality risk is unlikely to expose life-underwriting to catastrophic losses.

Financial market risk is modelled through two variables: the extreme-value dependence with both the domestic and the overall European stock price indices. As national stock price indices are in general not extreme-value dependent, extreme-value dependence on a European index is included to avoid underestimating this type of dependence.

Four underwriting variables – the non-life premium, its share in total premium, the retention rate and the asset multiplier – are included in order to capture the underwriting risk. Non-life underwriting would be expected to have a positive scale effect on extreme-value dependence because insurers with more sizeable non-life businesses might be able to underwrite more risky contracts. Furthermore, as underwriting activity typically extends beyond national boundaries, the geographic distance between two insurers reduces their overlap in exposure to some types of non-life risks, particularly weather-related risks (e.g. flooding). Therefore, the absolute size of the non-life premium is likely to be a contributing factor to extreme-value dependence.

Chart D.1 Sample averages for the occurrence of extreme-value dependence



Source: ECB calculations.

3 The 13 countries are Austria, Belgium, Denmark, France, Finland, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Sweden and the UK.

4 Only non-identical pairs of insurers were of interest for the analysis: a group of n insurers leads to $n(n-1)/2$ of such pairs.

At the same time, the smaller the life business of an undertaking is, the more its non-life business will dominate – irrespective of its absolute size. Therefore, the share of life premium in total premium income might have a negative impact on extreme-value dependence.

Box D.1

ESTIMATING EXTREME-VALUE DEPENDENCE

Testing for extreme-value dependence, and estimating its strength, is performed by means of a procedure well-known in the literature.¹ Data on individual insurers are first transformed into a common marginal distribution, thus filtering out any effect of the marginal distributions. Typically, bivariate returns (X,Y) are transformed into unit Fréchet marginals (S,T) as follows:

$$S = -1/\log(F_X(X)) \text{ and } T = -1/\log(F_Y(Y)),$$

with F_X and F_Y the respective marginal distributions of X and Y.

A useful measure for tail dependence is given by conditional probability $P(s)$:

$$P(s) = \Pr(T > s | S > s) = \Pr(T > s, S > s) / \Pr(S > s).$$

If S and T (or equivalently X and Y) are independent, then $P(s) = \Pr(T > s)$ for all s and $P(s)$ converges to 0 if s increases to infinity. In contrast, if S and T are extreme-value dependent, then $P(s)$ converges to a non-zero limit. This leads to the following non-parametric measure χ of tail dependence:

$$\chi = \lim_{s \rightarrow +\infty} P(s).$$

It follows that $0 \leq \chi \leq 1$. If for S and T $\chi > 0$, then S and T are extreme-value dependent and the value of χ is a measure of the strength of the extreme-value dependence. However, the test of whether χ is significantly different from zero leads to an overestimation of the occurrence of extreme-value dependence, and therefore the following measure² $\bar{\chi}$ is typically used to test for extreme-value dependence:

$$\bar{\chi} = \lim_{s \rightarrow +\infty} \frac{2 \log \Pr(S > s)}{\log \Pr(S > s, T > s)} - 1,$$

where $0 \leq \bar{\chi} \leq 1$. The statistic $\bar{\chi}$ is a measure for the rate at which $P(s)$ approaches zero.

This gives us the following three-step procedure used in this Special Feature:

1. Estimate $\bar{\chi}$.
2. Test whether $\bar{\chi} < 1$, i.e. to see whether extreme-value dependence can be rejected.

¹ See S. Coles, J. E. Heffernan and J. A. Tawn (1999), "Dependence Measures for Extreme Value Analyses", *Extremes*, Vol. 2, No 4, pp. 339-65; and S.-H. Poon, M. Rockinger and J. A. Tawn (2004), op. cit.

² See A. Ledford and J. A. Tawn (1996), "Statistics for Near Independence in Multivariate Extreme Values", *Biométrica*, 83, pp. 169-87.

3. If extreme-value dependence cannot be rejected, estimate χ .

Clearly, as $\bar{\chi}$ is used to test for extreme-value dependence between two insurers, it is the central variable in the above procedure. For a pair of insurers, χ is only estimated after extreme-value dependence has already been found.

The retention rate may also explain extreme-value dependence across pairs of composite insurers. Although a higher retention rate may ex post reflect less risky non-life business (in which case the impact of retention on extreme-value dependence would be negative), it could also reflect an ex ante willingness to absorb risk, whereby the relationship with extreme-value dependence could be positive.

Asset holdings are unlikely to be a driver of extreme-value dependence, as there is no scale effect on the investment side. However, the ratio of total assets over total premium (the asset multiplier) might be important. A higher asset multiplier may on the one hand reflect more risky (fat-tailed) underwriting contracts requiring larger buffers, although on the other it could equally reflect a more prudent holding of reserves or more long-term business. In the case of the former the relationship with extreme-value dependence would be positive, while for the latter it would be negative or insignificant.

In addition to these factors, three other factors may affect the extreme-value dependence between insurance companies: 1) geographical proximity (affecting non-life business), 2) comovement between stock markets across countries, and 3) idiosyncratic behaviour across countries, such as investment. Bi-country dummy variables are added to capture such effects.

The explanatory power of these factors can be tested by regressing an indicator – with a value of zero if extreme-value dependence can be rejected for a pair of insurers and one otherwise – on the set of explanatory variables.

For composite undertakings, the coefficient for the size of the non-life business – measured by

the size of the non-life premium – is positive and highly significant, confirming the prior assumption that a scale effect in non-life underwriting is a driver of extreme-value dependence (see Table D.1). The fact that the relative size of the life business – the life premium expressed as a percentage of the total premium income – is highly statistically significant whereas the size of the total life premium is not (results not shown) suggests that the life business itself does not give rise to a scale effect. Therefore, the more an insurer focuses on life insurance, the smaller the impact of non-life business will be on the total firm.

Table D.1 Probit regression for the occurrence of extreme-value dependence between composite insurers

Variable	Coefficient		t-Stats
NON-LIFE	0.1183		6.9543
PERC LIFE	-2.5171		-2.7680
RETENTION	0.0714		2.3223
ASSET MULT	-0.1945		-4.0621
CHIBAR IND	-0.1473		-0.2330
DOM RES	5.1564		4.9317
43 DUMMIES			
Log likelihood	-100.9591	Akaike	0.6047
Av. log likelihood	-0.2035	Schwarz criterion	1.0202

Source: ECB calculations.

Note: The extreme-value of dependence indicator for a pair of insurance companies is regressed on the various explanatory variables. Except for the country combination dummies, each pair of two insurers is assigned the average of the values of this variable for the two insurance companies. Non-life premium is measured in millions of euro. "CHIBAR IND" is the estimate for $\bar{\chi}$ between an insurer's equity and the European stock index FTSE Local Europe. "DOM RES" contains the residuals of a regression of the (average for each pair) estimate for $\bar{\chi}$ for the domestic stock index on the $\bar{\chi}$ for the European stock index. The reason for this substitution is the high correlation between the last two variables. The Huber/White standard errors are robust for clustering of the error terms. Finally, as the regression includes a full set of dummies for the country combinations, no intercept is included.

The fact that the retention rate is also statistically significant provides further evidence that underwriting is one of the drivers of extreme-value dependence between insurance undertakings. The estimated positive coefficient suggests that a higher retention rate should indicate that an insurance company is retaining more of the risks it underwrites, thus becoming more exposed to extreme events on the liability side.

The asset multiplier of an insurance firm is also found to be highly statistically significant in the probit regression, further supporting the hypothesis that underwriting is a driver of extreme-value dependence. A significant and positive coefficient indicates that insurance undertakings with a higher asset multiplier may underwrite more fat-tailed risks.

Turning to the financial market variables, the measure for extreme-value dependence with the European-wide index is not found to be statistically significant, whereas the coefficient for extreme-value dependence with the domestic stock index – unrelated with the European-wide index – is highly statistically significant. This suggests that extreme-value dependence with a domestic stock index may stem from sub-optimal investment behaviour, and that such insurers might be hit harder during a period of financial market upheaval.

Finally, the dummy variables for the country combinations are jointly statistically significant

in the regression, suggesting that the factors they account for (geographical proximity, comovement between stock markets across countries, and idiosyncratic behaviour across countries, such as in terms of investment) are jointly significant.

Comparing the results of the composite insurers with those of life insurers provides further insight. As only non-life underwriting appears to affect extreme-value dependence for composites, an underwriting effect for life insurers would not be expected (whereas the direct opposite would be the case for non-life insurers). As expected, there is no evidence of a size effect for life undertakings. Furthermore, the asset multiplier also adds no explanatory power to the probit regression (see Table D.2). As these two variables turn out to be jointly insignificant, they are not included.

As for financial market-related risks for life insurance, the results are basically identical to those for composite insurers, i.e. the measure for extreme-value dependence is highly statistically significant for the domestic stock price index, but not significant for the European-wide index. As suggested for composite insurers, this could indicate that sub-optimal investment behaviour increases the exposure of an insurer to the risk of extreme shocks on financial markets.

Finally, the nine dummies for the country combinations are also jointly significant,

Table D.2 Probit regression for the occurrence of extreme-value dependence between life insurers

Variable	Coefficient	t-Stats
CHIBAR IND	2.7953	1.2098
DOM RES	6.2753	2.5074
9 DUMMIES		
Log likelihood	-12.7881	Akaike 0.7209
Av. log likelihood	-0.1938	Schwarz 1.0865
		critereon

Source: ECB calculations.
 Note: Details as per Table D.1.

Table D.3 Probit regression for the occurrence of extreme-value dependence between non-life insurers

Variable	Coefficient	t-Stats
C	0.3655	0.2357
RETENTION	-0.0399	-2.1825
CHIBAR IND	2.8974	1.8586
DOM RES	0.2438	0.2178
COUNTRY_ID	0.7238	2.4637
Log likelihood	-43.1640	Akaike 0.4170
Av. log likelihood	-0.1869	Schwarz 0.4915
		critereon

Source: ECB calculations.
 Note: Details as per Table D.1.

leading to a similar interpretation as with the non-life regression.

The size effect of non-life underwriting and the effect of the asset multiplier both disappear for non-life undertakings and are not included (see Table D.3). Moreover, the dummies for the country combinations are only marginally significant, which contrasts to the findings for the non-life business of composite undertakings. One possible explanation for this is that non-life companies are quite small in comparison with composite insurers – the average gross non-life premium for a composite insurer in the sample is more than five times the average gross premium of non-life insurers – and therefore too small for a significant overlap in geographical markets to occur.

Possibly for the same reason, size (as a proxy for international activity) is less significant in the various regressions. Although these results are quite different from those for composite insurers, they do not invalidate those of the size effect of non-life business.

However, these results do not imply that underwriting risk has no impact on the extreme-value dependence between non-life insurers, as the retention level is still highly significant in explaining the occurrence of extreme-value dependence between non-life companies.

The results for the two variables capturing the effect of exposure to financial market risk are also different, as neither of the two variables used is significant.⁵ Insurance undertakings without life business typically suffer their worst drops in equity value as a result of extreme losses on the underwriting side, as opposed to losses on the investment side, which thus explains the insignificance of the financial market variables.

CONCLUDING REMARKS

The results indicate that exposure to financial market shocks and non-life underwriting affect the occurrence of extreme-value dependence

between European insurance undertakings. Several measures of non-life underwriting appear to have an impact on extreme-value dependence among composite undertakings, but this relationship is much weaker for non-life undertakings, for which only the retention ratio remains important in explaining extreme-value dependence. This suggests that whereas non-life underwriting characteristics in general are important in explaining the incidence of extreme-value dependence, the size effect of non-life underwriting is only significant for composite insurers, which are typically very internationally active. Owing to their lack of – or very limited – international business, non-life insurers show no evidence of a size effect of non-life underwriting on extreme-value dependence. Rather than size itself, international exposure to the risk of large losses seems to be a driver of extreme-value dependence between composite insurers.

At the same time, whereas the extreme-value dependence between composite undertakings increases with the size of their non-life business, they do not become less risky individually, thus possibly indicating that further concentration could make the insurance sector more volatile and more exposed to extreme event risk.

⁵ At the 5% level, however, a Wald test rejects the hypothesis that they are jointly insignificant.