Article

# Regulating insurance groups: a comparison of risk-based solvency models

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# Executive summary

**Regulating insurance groups: a comparison of risk-based solvency models**

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Regulators are developing capital standards to monitor insurance groups more effectively. This paper provides a qualitative overview of the current approaches to group-wide solvency regulation through both a numerical and theoretical comparison of a consolidated and a legal-entity approach. The results reveal that the choice of a particular group solvency approach has a substantial influence on capital charges and shortfalls, provoking thinking around future business strategy.

# Regulating insurance groups: a comparison of risk-based solvency models

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**Abstract**
Regulators are currently developing group-wide capital standards that are intended to enable the effective monitoring of insurance groups. Some jurisdictions are taking steps toward models with a focus on the groups' consolidated balance sheets, while other models focus on the interrelations of the groups' legal entities. This paper compares two general approaches to group-wide solvency in light of the regulatory challenges of regulatory inconsistency, risk dependencies, and risk aggregation: a consolidated approach and a legal entity approach. In order to contribute to the current discussion on the regulation and risk management for insurance groups, we support our line of reasoning by using a generalized model of Gatzert and Schmeiser (2011). Our findings show that a solely consolidated viewpoint is likely to underestimate shortfall risks in times of financial crises, whereas while a sole focus on the interrelated legal entities generally makes it possible to display different group structures it cannot control regulatory arbitrage.

**Introduction**

The increasing importance of internationally operating financial groups has given rise to a debate about capital adequacy and appropriate safety levels within the financial services industry. In the past, supervisors and regulators focused primarily on the single legal entity and the protection of its customers' claims. Consequently, capital requirements were typically computed on a stand-alone basis [Mälkönen (2004)]. However, more recent risk-based capital standards also aim to consider group effects by implementing capital requirements at the corporate level. One group-solvency approach, which treats the insurance group as a set of interrelated legal entities, calculates capital charges on a legal entity basis by accounting for capital and risk transfer instruments (CRTIs) [IAIS (2009b)]. Another approach to group-wide solvency assessment takes a consolidated point of view by considering the group as one integrated entity and assuming that the legal entities can access each other's cash flows and freely transfer risks [Keller (2007), IAIS (2009b)].

In practice, a variety of models to group-wide solvency assessment are used, many of which can be regarded as intermediate approaches because they have the characteristics of both a legal entity focus and a consolidated viewpoint. Nevertheless, current examples of group solvency models with a greater emphasis on the legal entity are the NAIC Legal Entity Method of the U.S. and the Swiss Group Structure Model [IAIS (2009b)]. Examples of jurisdictions that are moving towards models with a more consolidated focus are the European Union, Canada, and Australia [IAIS (2009b)].

This paper contributes to the literature by comparing these two approaches to assessing group-wide solvency in order to determine which of the two is more appropriate for regulating insurance groups, given different assumptions and economic circumstances.

To date, the literature on financial groups can be divided into two categories: either they explore the issues and practical challenges regulators face when establishing a risk-based capital standard of group-wide solvency assessment, or they attempt to explore group structures and quantify the risks and diversification effects within financial groups.

In the latter category, a number of studies examine whether financial groups trade at a discount compared to single line firms. While the majority of studies find evidence of a conglomerate discount in financial groups [Ammann and Verhofen (2006), Laeven and Levine (2005), Schmid and Walter (2009)], there is also mixed evidence [van Lelyveld and Knot (2009)] for a sample of European bank-insurance conglomerates. Here, the diversification discount is found to be varying considerably for different conglomerate structures. Furthermore, Gatzert and Schmeiser (2011) simultaneously assess the diversification benefit and conglomerate discount of a two-entity financial conglomerate, given fair pricing for the stakes of equityholders and policyholders. They find that diversification benefits within financial conglomerates are much less considerable when stakeholders obtain risk-adjusted returns. Freixas et al. (2007) compare the risk-taking appetite of single firms and financial conglomerates and find that, in comparison to stand-alone financial institutions, the diversification in conglomerates can increase risk-taking incentives. Analyzing moral hazard within financial groups, Kahn and Winton (2004) propose a model framework to explain the "bipartite" subsidiary structure often found within banking conglomerates. With regard to the group-level Swiss Solvency Test, Keller (2007) and Luder (2007) model risks and diversification effects and calculate capital charges when capital and risk transfers between the legal entities of the insurance group take place. Within the same context, Filipović and Kupper and Filipović and Kupper (2007 and 2008) derive optimal capital and risk transfer instruments in order to explore group diversification under convex risk measures.

Another segment of the literature deals with the group effects of financial conglomerates and their impact on systemic risk. In light of the subprime financial crisis, Harrington (2009) discusses, from a theoretical perspective, the question of whether insurance generally exhibits systemic risk. Other studies take an empirical approach. As an indicator of the systemic risk potential in the U.S. and Europe, De Nicolo and Kwast (2002) and Schüler (2002) examine the interdependencies among banks proxied by the correlations of the banks' stock returns. Both empirical studies find evidence that consolidation contributes to the interdependencies between firms and, thus, to an increase in systemic risk. Allen and Jagtiani (2000) create "synthetic universal banks" in order to analyze the effect of investments and insurance activities on the banks' total risks and conclude that conglomeration leads to an increase in both systematic market risk and systemic risk.

Most of the literature that deals with the issues and practical challenges of establishing group-wide solvency standards takes a nonquantitative perspective. Siegel (2013) provides an overview and comparison of three current supervisory frameworks that regulate group solvency: the "Solo-Plus"-approach of the U.S., Switzerland's Group Structure Model, and the E.U. Solvency II Directive's solvency assessment for groups. The paper reveals a clear need for further revisions regarding the U.S. framework, whereas the European approaches provide a solid solvency assessment, in particular the Swiss Model. Diereck (2004) discusses the legal structures of financial conglomerates and the conglomerates' relevant risks and benefits from a supervisory perspective. Mälkönen (2004), Morrison (2003), and Schilder and van Lelyveld (2003), derive the possible causes of the establishment of financial groups, set out justifications for their regulation, and address the issues and challenges with which supervisors of financial conglomerates are confronted. In addition, Mälkönen (2004) examines limitations to solvency regulation by comparing a silo approach with a consolidated view. Along the lines of these studies, the paper on group-wide solvency assessment and supervision prepared by the International Association of Insurance Supervisors discusses the regulatory issues of the solvency assessment for insurance groups and identifies four main challenges to group supervision [IAIS (2009b)]:

1. Regulatory inconsistency that is "capital gearing" and "regulatory arbitrage"
2. "Fungibility[1] of capital and transferability of assets"
3. "Measurement of risk dependencies and aggregation of risks"
4. "Treatment of nonregulated entities"

The paper also provides a qualitative overview of current approaches to group-wide solvency regulation. Our paper makes both a theoretical and a numerical comparison between the different approaches to group-wide solvency assessment by quantifying risks and capital requirements. It determines which approach is more appropriate in which situation when dealing with different regulatory challenges. Our analyses are based on the model framework proposed by Gatzert and Schmeiser (2011). Their study simultaneously assesses the diversification benefit and conglomerate discount with respect to the capital charges and shortfall risks of a two-entity financial conglomerate with and without accounting for the altered shareholder value. The authors derive capital requirements in the context of the tail value at risk concept of the Swiss Solvency Test.

Generalizing the model framework by Gatzert and Schmeiser (2011) to N+1 legal entities (one parent company and N subsidiaries), we aim to compare the two approaches to assess the solvency of insurance groups in light of different regulatory issues under the real world measure P. Within a one-year solvency horizon, we compare results from a legal entity approach, which takes different capital and risk transfer instruments (CRTIs) into account, and a consolidated approach. Keeping the capital structure fixed, we study shortfall risk and capital charges under different parameter assumptions. In order to derive the capital requirements we apply the value at risk measure of the proposed Solvency II regulatory framework. Since, in general, no closed-form solutions can be derived, numerical results are generated by means of a Monte Carlo simulation. We interpret our findings in light of two main challenges to group-wide solvency regulation: regulatory inconsistency and risk interdependencies, with a special focus on the latter.

## Model framework

### Basic setting

Generalizing the model framework proposed by Gatzert and Schmeiser (2011), we consider a set $F = \{0,\ldots,N\}$ of firms denoted by $i = 0, \ldots, N$ within an insurance group. The index $i = 0$ denotes the parent company; $i = 1, \ldots, N$ stand for the subsidiaries.

The market value of liabilities and the market value of assets of the $i^{th}$ entity are given by $L_{t,i}$ and $A_{t,i}$, respectively, with the time index $t = 0, 1$. $A_{0,i}$ is defined as the sum of the initial payments of equityholders $E_{0,i}$ and policyholders $D_{0,i}$ to firm i: $A_{0,i} = E_{0,i} + D_{0,i}$. The development of assets and liabilities is modeled by means of correlated geometric Brownian motions.

At $t = 1$, two scenarios are possible. In the first, company $i \in F$ is able to cover its liabilities, so policyholders and other debt holders obtain the value of the liabilities and equityholders receive the

1 In the following, we will define "fungibility" as the ability to transfer capital easily and freely within the insurance group [Filipović and Kupper (2007)].

difference between the market value of assets and the market value of liabilities. In the second scenario, the liabilities cannot be met in full, therefore policyholders receive the total value of assets and equityholders leave empty handed. The payoff to policyholders can be expressed by the value of liabilities less the payoff of the default put option at time t = 1 [Doherty and Garven (1986)]:

$$D_{1,i} = L_{1,i} - \max(L_{1,i} - A_{1,i}, 0), \quad (1)$$

Where Max $(L_{1,i} - A_{1,i}, 0) = DPO_{1,i}$ constitutes the default put option value of firm i at time t [Doherty and Garven (1986)]. The payoff to equityholders can be expressed as a call option on the firm's assets, while the liabilities represent the strike price. Thus, for the equityholders of entity i at time 1, one obtains [Doherty and Garven (1986)]:

$$E_{1,i} = A_{1,i} - D_{1,i} = \max(A_{1,i} - L_{1,i}, 0). \quad (2)$$

**Economic Capital**

We derive available and necessary economic capital based on fixed amounts of initial debt and equity payments [Gatzert and Schmeiser (2011)]. In insurance regulation, available economic capital (AEC) is often called risk-bearing capital, as in the Swiss Solvency Test [FOPI (2006)], or risk-based capital, as in the U.S. NAIC method [NAIC (2009c)]. Following Keller (2007), and Filipović and Kupper (2007), we define the AEC of company i at time t as the market value of assets less the market value of liabilities.

The necessary economic capital (NEC), also called solvency capital requirement (Solvency II) or target capital (Swiss Solvency Test), is the economic capital needed at t = 0 to limit the probability of default to a prespecified confidence level [FOPI (2004)]. The $NEC^{\alpha}$ depends on the underlying stochastic model, the input parameters, and the risk measure chosen. For the latter, value at risk (VaR) is applied, in line with Solvency II [EC (2009)]. The value at risk for a given confidence level $1 - \alpha$ is given by the quantile of the distribution $F^{-1}(\alpha)$, such that $VaR^{\alpha}(X_i) = \inf\{x : F_x(x) \geq \alpha\}$. For the i^th^ firm, we set $X_i$ to:

$$X_i = AEC_{1,i} \cdot e_f^{-r} - AEC_{0,i} \quad (3)$$

That is, we define VaR (Xi) as the value at risk of the change of available economic capital of firm i during one time period [FOPI (2006)]. Consequently, the necessary economic capital for i ϵ F is given by:

$$NEC_i^{\alpha} = -VaR^{\alpha}(X_i) \quad (4)$$

We set the minimum level of economic capital (ML) as the level below which financial resources are not supposed to fall [EC (2009)], the so-called minimum capital requirement under E.U. solvency regulations for nonlife insurers, to the maximum of the premium basis (PBi) and the claims basis (CBi) of an insurance company i [EC (2002a)][2]:

$$ML_i = \max(PB_i, CB_i). \quad (5)$$

The premium basis and the claims basis for firm i are calculated according to EC (2002a):

$$PB_i = 0.18 \cdot [\min(p_i; €50\,\text{million})] + 0.16 \cdot [\max(p_i - €50\,\text{million}; 0)] \quad (6)$$

$$CB_i = 0.26 \cdot [\min(C_i; €35\,\text{million})] + 0.23 \cdot [\max(C_i - €35\,\text{million}; 0)] \quad (7)$$

where $P_i$ stands for the net premium income of insurer i at t = 0 and $C_i$ denotes the average net claims of company i – in general based on the last three years.

**Legal entity approach**

A group-wide solvency assessment approach with a legal entity focus treats the insurance group as a collection of interdependent legal entities [IAIS (2009b)]. Capital requirements and risks are determined for each legal entity, taking into account intra-group transactions. In this section, we extend the model framework provided by Gatzert and Schmeiser (2011) to the general case of N + 1 legal entities which are separately capitalized. Within this framework, firm i = 0, the parent company, covers its subsidiaries' liabilities only in the presence of legally binding transfer contracts [Keller (2007)]. This approach, therefore, relies on different assumptions regarding the capital and risk transfer between entities [Gatzert and Schmeiser (2011)].

2 For the sake of simplification we ignore reinsurance coverage.

The first one is that the parent company $i = 0$ can access its subsidiaries' surplus capital.

Furthermore, a going concern assumption for the subsidiaries after $t = 1$ is included, which requires that the subsidiaries $i = 1, \ldots, N$ must at least be endowed with the minimum level of economic capital at time 1, $ML_i$. Thus, the available economic capital of a subsidiary $i = 1, \ldots, N$ in $t = 1$ can be expressed by $\min(A_{I,i} - L_{I,i}, ML_i)$. Taken together, these assumptions imply that the parent can sell its subsidiaries for the value of $\Sigma_{i=1}^{N} \max(A_{1,i} - L_{1,i} - ML_i, 0)$. In line with Gatzert and Schmeiser (2011), our analysis examines two different CRTIs: a guarantee and a quota-share retrocession when each is transferred from the parent company to one subsidiary and when each is transferred from one subsidiary to another.

Under the guarantee, we assume that the transferring company, denoted by $i_{tr}$, covers the shortfall $DPO_{I,ibfc} = \max(L_{I,ibfc} - A_{I,ibfc}, 0)$ of the beneficiary $i_{bfc}$ with $i_{bfc} \neq i_{tr}$ only, when the transferor's available economic capital at time 1 is above the minimum level. Thus, the transfer T to the benefiting firm is restricted to $\max(A_{I,itr} - L_{I,itr} - ML_{itr}, 0)$.

The second type of CRTI considered is a quota-share retrocession in which q denotes the quota that the transferring company is legally obligated to assume.

**Consolidated approach**

Following Gatzert and Schmeiser (2011), we define available economic capital under the consolidated approach as the difference between the sum of the legal entities' assets and the sum of the liabilities. Under this approach, individual and joint shortfall probabilities coincide such that $P^{ind} = P_m^{joint}$ and $P^{ind,ML} = P_m^{joint,ML}$, for any $m = 1, \ldots, N + 1$.

## Numerical analysis and implications

In our numerical analyses, we present results for a stylized example. For the sake of simplicity, we consider an insurance group that is comprised of three legal entities: two subsidiaries and their parent company.

Our analysis examines the introduction of a guarantee and a quota-share retrocession transferred either from the parent company 0 to subsidiary 1 or from subsidiary 2 to subsidiary 1. The numerical example is conducted via a 100,000-run Monte-Carlo simulation, each run employing the same set of random numbers [Glasserman (2004)].

**Parameter settings**

In the following, we assume that the three firms (i.e., the two subsidiaries and their parent) have the same asset-liability structure but that the parent company is twice as large as its subsidiaries. We set the nominal value of the liabilities of subsidiaries 1 and 2 to $L_{0,1} = L_{0,2} = 50$ mln currency units (CU) and the market value of the liabilities of the parent company 0 to $L_{0,0} =$ CU 100 mln. The equity capital of the two subsidiaries $E_{0,1}$ and $E_{0,2}$ is fixed at CU 15 mln and for the parent $E_{0,0}$ at CU 30 mln. The initial values of the default put option are fixed at CU 100,000 for company 0 and at CU 50,000 for the subsidiaries, so the value of the debt capital of subsidiaries 1 and 2 is given by $D_{0,1} = D_{0,2} =$ CU mln, and the value of the debt capital of the parent company is given by $D_{0,0} =$ CU 99.9 mln. Thus, the market value of the assets of the two subsidiaries $A_{0,1}$ and $A_{0,2}$ is CU 65 mln and for the parent company it amounts to $A_{0,0} =$ CU 130 mln. The net premium income of subsidiaries 1 and 2 is set to $P_1 = P_2 =$ CU 7.5 mln and that of the parent is set to $P_0 =$ CU 15 mln. We assume the average net claims over the last three years to be $C_1 = C_2 =$ CU 4.5 mln for the subsidiaries and $C_0 =$ CU 9 mln for the parent company. Drift and standard deviation of the assets and liabilities are given by $\mu_A = 5\%, \sigma_A = 10\%$ (for assets) and $\mu_L = 3\%, \sigma_L = 0.5\%$ (for liabilities). The risk-free rate of return is set to $r_f = 2\%$, and the quota of the quota-share retrocession is assumed to be $q = 5\%$. The correlation coefficients between pairs of assets and liabilities are fixed at: $\rho(A_i, L_i) = 0.2$ and $\rho(A_i, L_j) = \rho(A_j, L_i) = 0.0$, with $i \neq j$ and $i, j = 0, 1, 2$. For a more profound comparison of the two solvency models, we compare results for different values of $\rho = \rho(A_i, A_j) = \rho(L_i, L_j)$, with $i \neq j$ and $i, j = 0, 1, 2$. We show outcomes for the uncorrelated case ($\rho = 0.0$), for a case of moderate correlation ($\rho = 0.4$), and for a case of relatively high correlation ($\rho = 0.8$).

**Numerical results and interpretation**

**Risk dependencies**

We follow the working definition of risk dependencies by the International Association of Insurance Supervisors [IAIS (2009b)]. Our discussion, therefore, focuses on two main drivers of risk dependencies: risk concentration and risk diversification.

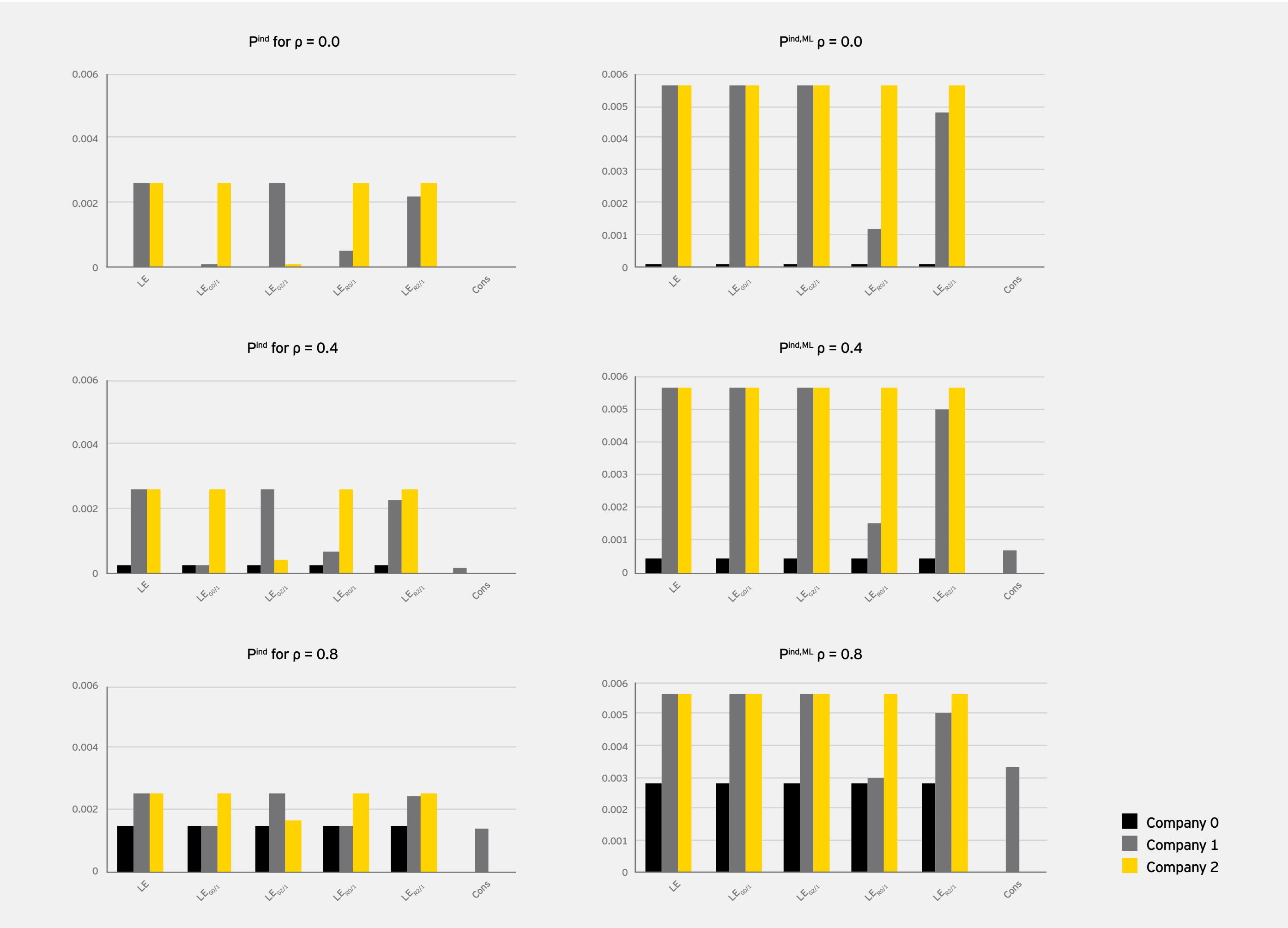


**Figure 1: Individual shortfall probabilities for ρ = 0.0, 0.4 and 0.8**
LE = legal entity approach without CRTIs; $LE_{G0/1}$ = legal entity approach with a guarantee from company 0 to subsidiary 1; $LE_{G2/1}$ = legal entity approach with a guarantee from subsidiary 2 to subsidiary 1; $LE_{R0/1}$ = legal entity approach with a retrocession from company 0 to subsidiary 1; $LE_{R2/1}$ = legal entity approach with a retrocession from subsidiary 2 to subsidiary 1; Cons = consolidated approach

According to the IAIS, risk concentration refers to common risk factors that are able to threaten the financial soundness of the entire insurance group, while diversification effects cause the aggregated risks of the entire group to be in general lower than the sum of the individual companies' risks. We take two perspectives in comparing the different solvency approaches with regard to how they assess shortfall risks and concentration, as well as diversification effects within the insurance group. In the first step, we assess the riskiness of each financial institution by considering individual shortfall probabilities (Figure 1) and the necessary economic capital (Figure 2). In the second step, we focus on the institutions' exposure to common risk factors and their interconnectedness, measured by joint shortfall probabilities (Figure 3).

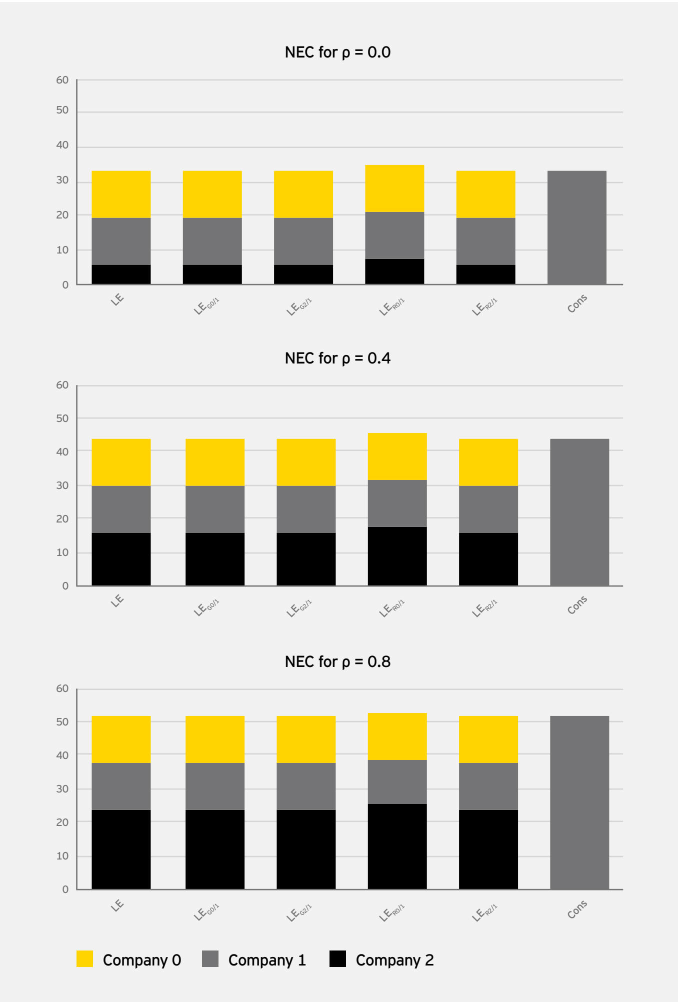


**Figure 2: Necessary economic capital for ρ = 0.0, 0.4 and 0.8**
LE = legal entity approach without CRTIs; $LE_{G0/1}$ = legal entity approach with a guarantee from company 0 to subsidiary 1; $LE_{G2/1}$ = legal entity approach with a guarantee from subsidiary 2 to subsidiary 1; $LE_{R0/1}$ = legal entity approach with a retrocession from company 0 to subsidiary 1; $LE_{R2/1}$ = legal entity approach with a retrocession from subsidiary 2 to subsidiary 1; Cons = consolidated approach

### The riskiness of the individual financial institution

Our simulation results, shown in Figure 1 and Figure 2, are based on the fixed capital structure given above. Figure 1 shows individual shortfall probabilities (left column) as well as the probabilities that the available economic capital in time 1 will fall below the minimum level (ML) (right column) for different specifications of the correlation coefficient ρ. The left column of Figure 1 ($\rho$ = 0.0) shows that under our legal entity approach, the parent company's shortfall probability is practically reduced to zero due to the group diversification [Gatzert and Schmeiser (2011)].[3] The subsidiaries' shortfall probabilities, on the other hand, depend on the transfer case, considered. With no CRTIs in place, the subsidiaries do not participate in the diversification effects.

By contrast, the introduction of a CRTI leads to a considerable reduction in the shortfall probability of the subsidiary benefiting from the transfer, although the extent of the reduction depends on the type of CRTI and on the transferring company's solvency. A guarantee reduces the beneficiary's shortfall probability to practically zero, regardless of whether the transferor is the parent company or another subsidiary. By contrast, the introduction of a quota-share retrocession reduces the benefiting company's shortfall probability to a lesser degree, particularly when it is the other subsidiary that is making the transfer. The parent company's shortfall probability is unchanged and close to zero in all cases, since the transfer from the parent is undertaken only when the company is solvent. Only one bar is shown for the consolidated approach, because the insurance group is treated as one consolidated entity. As a consequence, individual and joint shortfall probabilities are indistinguishable in this framework. Due to a maximum realization of diversification effects and synergies under this solvency approach, the probability of shortfall is close to zero for $\rho$ = 0.0. The right column of Figure 1 shows the probability that the available economic capital at time 1 will fall below the minimum level of economic capital, meaning that the firms will not be able to continue in business unless they raise additional capital. Thus, $P^{ind,ML}$ includes $P^{ind}$. Under the legal-entity approach, the benefiting subsidiary's $P^{ind,ML}$ remains stable both with and without a guarantee, but it is reduced in case of a quota-share retrocession. The parent's individual shortfall probability and the consolidated model's $P^{ML}$ are, again, close to zero. Turning to the second and third row of Figure 1, we find that the higher the correlation coefficient ρ, the more diversification effects are reduced in both group solvency approaches and consequently the individual shortfall probabilities are increased in all cases.

3 Here, diversification effects can arise because assets and liabilities of the three companies are not fully correlated [Gatzert and Schmeiser (2011)].

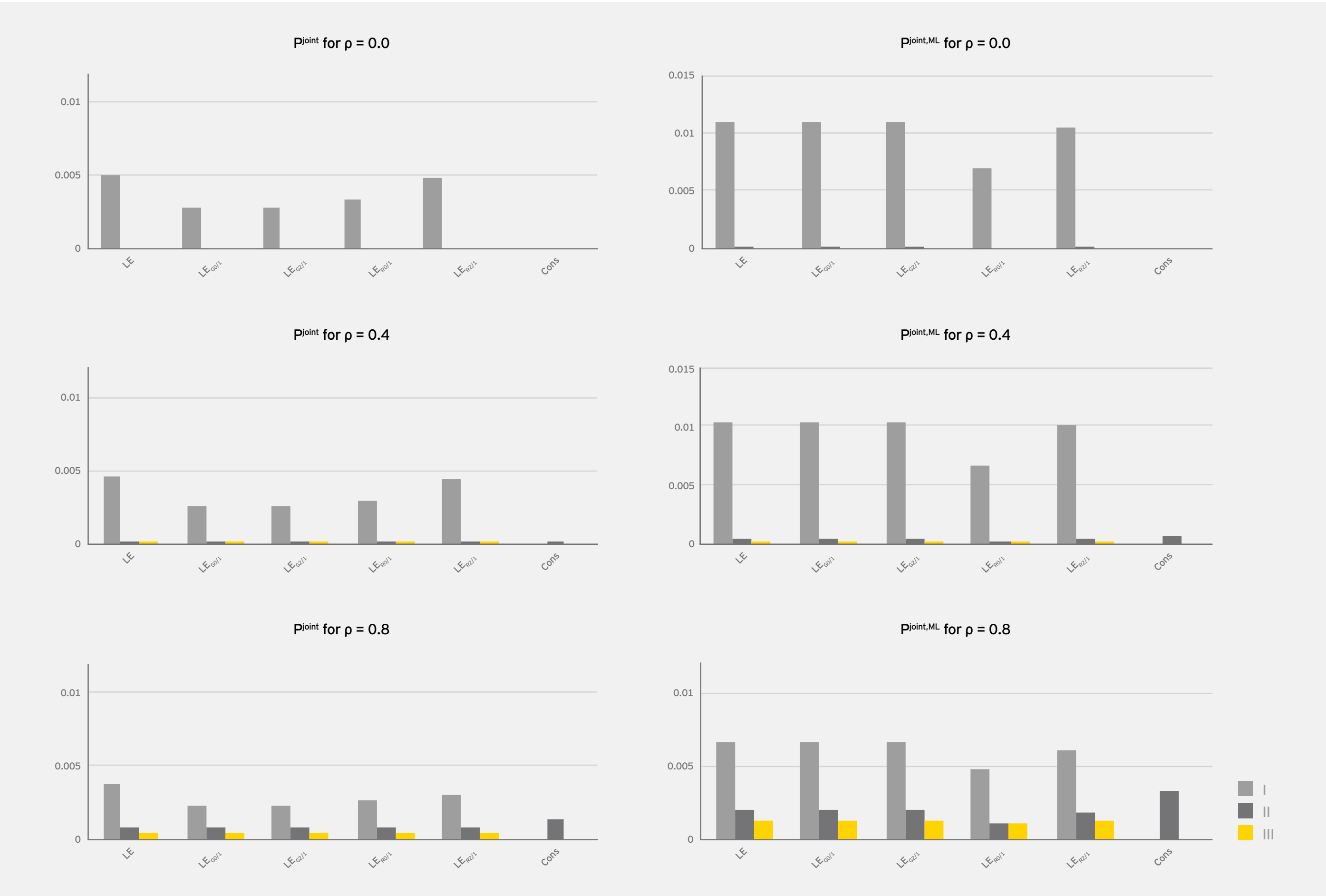


**Figure 3: Joint shortfall probabilities for ρ = 0.0, 0.4 and 0.8**

LE = legal entity approach without CRTIs; $LE_{G0/1}$ = legal entity approach with a guarantee from company 0 to subsidiary 1; $LE_{G2/1}$ = legal entity approach with a guarantee from subsidiary 2 to subsidiary 1; $LE_{R0/1}$ = legal entity approach with a retrocession from company 0 to subsidiary 1; $LE_{R2/1}$ = legal entity approach with a retrocession from subsidiary 2 to subsidiary 1; Cons = consolidated approach

Figure 2 shows the capital requirements for the entire insurance group under both approaches. The different shades of gray in the cases of the legal entity approach indicate the entities' individual contribution to the group capital charge. Considering the uncorrelated case in the first row, we see that under the legal entity approach, the parent's necessary economic capital is substantially lower compared to the NECs of the two subsidiaries. The introduction of a guarantee leads to a slight decrease in the NEC of the benefiting subsidiary, but to a slight increase in the capital requirement of the parent company. Consequently, the group NEC remains relatively constant.

By contrast, when a quota-share retrocession is in place, the increase in the parent's NEC is substantial, so that the group capital requirement is higher than in the case without any CRTIs. Turning to the consolidated approach, where the insurance group is considered on the basis of its consolidated balance sheet, the NEC shown is already the capital requirement for the entire insurance group. Comparing the necessary economic capital of the two solvency models, we find that they are very similar to each other.

With an increase in $\rho$, the necessary economic capital for company 0 increases substantially within the legal entity approach due to group diversification effects. This is particularly evident when looking at the entities' contribution to the overall group capital charge. While the subsidiaries' necessary economic capital remains approximately the same, the capital requirement of the parent company increases considerably. The necessary economic capital under the consolidated approach increases to a similar extent for higher correlation coefficients.

**Interconnectedness within the insurance group** – in the next step, joint shortfall probabilities are calculated based on the capital structure of the numerical example. Results are presented in Figure 3. Again, we consider three different values for $\rho$. In the uncorrelated case (left column of Figure 3), we find that the probability that all three entities, or two out of three of them, will default at the same time ($P_{III}^{joint}$ and $P_{II}^{joint}$) is close to zero for both approaches. Since under the consolidated approach joint shortfall probabilities correspond to the individual ones, $P_{I}^{joint}$ and $P_{II}^{joint}$ are not defined [Gatzert and Schmeiser (2011)]. The probability that exactly one firm defaults ($P_{I}^{joint}$) is lowest for the case of a guarantee under the legal entity approach.

In the case of a quota-share retrocession, $P_{I}^{joint}$ is significantly higher when the transfer is made from one subsidiary to another than when the transfer is made from the parent company to one of the subsidiaries. Similar results can be observed in the right column of Figure 3. However, the legal entity approach results in the lowest probabilities that the available economic capital of exactly one firm will fall below the minimum level of economic capital in the presence of a quota-share retrocession.

The second and last row of Figure 3 depict the results for higher correlations. While the probability that only one entity of the insurance group will default is reduced significantly when assets and liabilities of the different entities are highly correlated, the joint shortfall probabilities II and III are significantly increased in all cases. Comparing the two solvency models, the probability of all three firms defaulting at the same time is approximately three times higher in the consolidated framework than in all cases of the legal entity approach.

**Regulatory inconsistency**

According to Mälkönen (2004), regulatory inconsistency occurs in the presence of regulatory arbitrage and double/multiple gearing of capital. Regulatory arbitrage is the process of taking advantage of the discrepancies between different regulatory regimes and is sometimes referred to as "capital arbitrage" or "jurisdictional arbitrage" [Freixas et al. (2007)]. In the context of financial conglomerates and insurance groups, regulatory arbitrage can be defined as the possibility of separately capitalized legal entities transferring assets to the divisions that are subject to the lowest capital charges.

According to the Joint Forum on Financial Conglomerates (1998), double gearing of capital occurs if one legal entity of a financial group holds solvency capital issued by another legal entity, and the issuing company counts the capital in its own balance sheet. Thus, external capital of the group is counted twice, so it may serve to fulfill capital adequacy requirements in both entities. Multiple capital gearing occurs when the externally generated capital is geared up multiple times, such as when a company that holds regulatory capital issued by another legal entity downstreams this capital to a third-tier legal entity.

With regard to the legal entity approach, intra-group transfers are properly assessed because this approach models the web of CRTIs. However, regulatory arbitrage between countries and financial sectors is generally possible whenever capital charges are calculated differently in different jurisdictions (Table A1 in the Appendix). On the other hand, this approach models the market value of the subsidiaries as an asset of the parent company, so double/multiple gearing is avoided by splitting up the value of a subsidiary i = 1, … ,N into two parts: the transferable value to the parent ($\max(A_{I,i} - L_{I,i} - ML_i, 0)$), and the subsidiary's available economic capital ($\min(A_{I,i} - L_{I,i}, ML_i)$), which at least equals the minimum level [Gatzert and Schmeiser (2011)].

Finally, considering our consolidated approach, we find that due to the implicit assumption of full fungibility and transferability of capital and risks and the fact that capital adequacy requirements are based on one consolidated balance sheet, regulatory arbitrage and double/multiple gearing of capital are not possible [Freixas et al. (2007)].

**Comparison**

The comparison in this section aims to determine which of the two group solvency approaches considered is more appropriate under which circumstances. The consolidated approach treats the insurance group as one integrated entity, so all intra-group transactions cancel out. Thus, the approach implicitly controls for regulatory inconsistency. Yet, Keller (2007) points out that it is a valid group solvency approach only when its assumption of full mobility of capital and risks between members of the insurance group holds, allowing for a maximum realization of synergies and diversification. These effects are reflected in our simulation results for the individual shortfall probabilities, as the consolidated approach produces the lowest probabilities, regardless of the value of $\rho$ (Figure 1). In line with Keller's reasoning, the Committee of European Insurance and Occupational Pensions Supervisors points out, that such an assumption is particularly problematic during financial crises because diversification benefits tend to diminish or at least do not operate the same way they do in normal times [CEIOPS (2009c)]. In addition to the problematic assumption of full transferability, the consolidated approach does not provide any information about the individual entity or its risk contribution to the total risk faced by the insurance group as it is based on a consolidated balance sheet.

On the other hand, the analysis presented above suggests that the consolidated approach is the more conservative approach when it comes to computing the probability that all legal entities within an insurance group will default at the same time (Figure 3). By contrast, the legal entity approach to group solvency provides for the shortfall risk of each institution and its individual capital endowment by taking into account risk and capital transfer instruments. As it is based on the individual entities' balance sheets, and therefore does not need to assume full transferability of capital and risks within the insurance group, Keller (2007) argues that it is a group solvency approach directly compatible with a solo assessment of the solvency of an individual entity. Despite the problem of not being able to account for regulatory arbitrage, in our model framework the legal entity approach is more conservative with regard to the risk assessment of the individual members of the insurance group (Figure 1). It is also able to control for capital gearing. However, it is likely to be the most complex to implement in practice and therefore probably the more expensive group-wide solvency approach [IAIS (2009b)]. Nevertheless, if the web of CRTIs is modeled accurately, the legal entity approach can model all kinds of group structures, including the extreme case of no intra-group transactions at all, as well as the case when capital and risks are freely transferable among the legal entities. Consequently, it is the more generally applicable framework.

**Summary**

This paper compares two approaches to group-wide solvency assessment of insurance groups in light of the regulatory challenges of regulatory inconsistency and risk dependencies: a legal entity approach and a consolidated approach. Generalizing the model framework by Gatzert and Schmeiser (2011), we examine capital charges, individual shortfall risks, as well as joint shortfall for an insurance group of N + 1 legal entities — one parent company and N subsidiaries — and interpret the results with respect to the supervisory challenges of regulatory inconsistency and risk dependencies, with a special focus on the latter one.

Our findings contribute to the current discussion of regulating and managing large financial groups, especially insurance groups. Firstly, we present the two group solvency approaches emphasizing the different implicit and explicit assumptions made in each framework since these are of special relevance from a regulatory perspective. The results of our numerical analyses reveal that the choice of a particular group solvency approach has a substantial influence on capital charges and shortfall risks. Individual shortfall risks decrease considerably with the level of consolidation assumed by each of the different solvency approaches, although this effect diminishes as the correlation between the entities' returns on assets and liabilities increases. Secondly, the two solvency approaches are compared in terms of their advantages and shortcomings, and it is determined under which circumstances each approach is more appropriate. The assumptions of a consolidated framework are particularly problematic when asset and liability returns become highly correlated as the effects of diversification diminish. On the other hand, our numerical analyses show that the consolidated approach is more conservative than the legal entity framework with respect to the calculation of joint shortfall probabilities. In addition, the legal entity approach provides for each entity's individual shortfall risk and capital endowment by taking into account the web of CRTIs, whereas a consolidated approach provides no information about the individual entity or its contribution to total risk [Gatzert and Schmeiser (2011)]. Finally, the legal entity framework is more complex to implement and cannot control regulatory arbitrage.

We conclude from the analyses that a legal entity approach is more generally applicable, as it is able to take different group structures into account and find it therefore, despite its shortcomings, superior to an approach that is solely based on a consolidated viewpoint. Although the models used to assess group-wide solvency in practice are intermediate models with characteristics of both the legal entity and the consolidated approach, a comparison of these two extremes on a theoretical and numerical basis in light of regulatory challenges is especially important as regulators and practitioners alike work toward designing and implementing sound solvency models for the risk management of insurance groups.

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## Appendix

### A. Derivation of individual and joint shortfall probabilities

In line with Gatzert and Schmeiser (2011), we assume that shortfall can occur in two cases:

1. Either the available economic capital in $t = 1$ falls below zero, so the insurer is insolvent, or
2. $AEC_{1,i}$ falls below the minimum level $ML_i$, meaning that firm i is not insolvent, but cannot continue in business, unless it raises additional capital.

Thus, the individual shortfall probabilities for the ith entity can be calculated by [Gatzert and Schmeiser (2011)]:

$$P_i^{ind} = \Pi(AEC_{1,i} < 0) \quad (1)$$

$$P_i^{ind,ML} = \Pi(AEC_{1,i} < ML_i). \quad (2)$$

The probability of a joint shortfall of exactly m = 1, ... ,N + 1 legal entities can be expressed by:

$$P_m^{joint} = \sum_{\substack{F^* \subset F \\ |F^*|=m}} \Pi[(\wedge_{i \in F^*} AEC_{1,i} > 0) \wedge (\wedge_{i \in F \setminus F^*} AEC_{1,i} > 0)] \quad (3)$$

The sum runs over all subsets F* of F counting exactly m elements.[4] The first term inside the square brackets describes the joint shortfall of all legal entities within the subset F*, given that the residual firms of F (the second term inside the square brackets) are solvent at t = 1. Similarly, the probability that the available capital of m = 1, ... ,N + 1 legal entities simultaneously falls below the minimum level, is:

$$P_m^{joint} = \sum_{\substack{F^* \subset F \\ |F^*|=m}} \Pi[(\wedge_{i \in F^*} AEC_{1,i} > ML_i) \wedge (\wedge_{i \in F \setminus F^*} AEC_{1,i} > ML_i)] \quad (4)$$

**B. Legal entity approach — values of the CRTIs**

The value of the guarantee TG can be expressed by:

$$T^G = \min(DPO_{1,i_{bfc}}, \max(A_{1,i_{tr}} - L_{1,i_{tr}} - ML_{i_{tr}}, 0)). \quad (1)$$

For the quota share retrocession, the value can be calculated as:

$$T^R = \min(q \cdot L_{1,i_{bfc}}, \max(A_{1,i_{tr}} - L_{1,i_{tr}} - ML_{i_{tr}}, 0)). \quad (2)$$

**C. Derivation of available economic capital**

1. **Legal entity approach —** considering the case of a transfer from the parent company i = 0 to the benefiting subsidiary, $i_{bfc}$, we can express available economic capital in t = 0 for all i = 0, ... ,N, by: $AEC_{0,i} = A_{0,i} - L_{0,i}$. At time t = 1 the AEC of the beneficiary is:

$$AEC_{1,i_{bfc}} = \min(A_{1,i_{bfc}} - L_{1,i_{bfc}}, ML_{i_{bfc}}) + T. \quad (1)$$

For the parent company i = 0, we obtain at t = 1:

$$AEC_{1,0} = A_{1,0} - L_{1,0} + \max(A_{1,i_{bfc}} - L_{1,i_{bfc}} - ML_{i_{bfc}}, 0) + \sum_{\substack{i=1 \\ i \neq i_{bfc}}}^{N} (\max(A_{1,i} - L_{1,i} - ML_i 0)) - T \quad (2)$$

For all other subsidiaries $i = 1, \ldots, N, i \neq i_{bfc}$, we receive:

$$AEC_{1,i} = \min(A_{1,i} - L_{1,i}, ML_i) \quad (3)$$

For the case in which a transfer is made from one subsidiary $i_{tr}$ to another subsidiary $i_{bfc}$, with $i_{tr}$, given $i_{bfc} \neq 0$, the available economic capital in t = 0 is again defined by $AEC_{0,i} = A_{0,i} - L_{0,i}$ for all i = 0,...,N. The AEC of the transferor and the beneficiary in t = 1 can be expressed by:

$$AEC_{1,i_{tr}} = \min(A_{1,i_{tr}} - L_{1,i_{tr}} - T, ML_{i_{tr}}) \quad (4)$$

and

$$AEC_{1,i_{bfc}} = \min(A_{1,i_{bfc}} - L_{1,i_{bfc}} - T, ML_{i_{bfc}}) + T$$

Finally, we receive for the available economic capital of the parent company in t = 1:

$$AEC_{1,0} = A_{1,0} - L_{0,1} + \max(A_{1,i_{tr}} - L_{1,i_{tr}} - ML_{i_{tr}} - T, 0) + \max(A_{1,i_{bfc}} - L_{1,i_{bfc}} - ML_{i_{bfc}} + T, 0) + \sum_{\substack{i=1 \\ i \neq i_{bfc}; i \neq i_{tr}}}^{N} (\max(A_{1,i} - L_{1,i} - ML_i, 0)) \quad (5)$$

2. **Consolidated approach —** on the basis of consolidated accounts, the available economic capital of the concern can be calculated by [Gatzert and Schmeiser (2011)]:

$$AEC_t^{cons} = \sum_{i=1}^{N} A_{t,i} - \sum_{i=1}^{N} - L_{t,i} \quad (6)$$

for t = 0, 1.

4 |F*| denotes the cardinality of the subset F* (m is the number of legal entities insolvent at t = 1).

**Three-entity example** – for an insurance group comprised of three entities, one parent company and two subsidiaries, the calculation of available economic capital reduces to the following formulas: under the legal entity approach, available economic capital at t = 0 for the $i^{th}$ legal entity is determined by $AEC_{0,i} = A_{0,i} - L_{0,i}$, whereas it is given by $AEC_0^{cons} = A_{0,0} + A_{0,1} + A_{0,2} - L_{0,0} - L_{0,1} - L_{0,2}$ for the consolidated approach.

The AEC for the different transfer cases under the legal entity approach as well as the consolidated available economic capital at t = 1 are summarized in the table below [Gatzert and Schmeiser (2011)].

| | $AEC_{1,0}$ | $AEC_{1,1}$ | $AEC_{1,2}$ |
|---|---|---|---|
| Legal entity | $A_{1,0} - L_{1,0}$<br>$+\max(A_{1,1} - L_{1,1} - ML_{1,0})$<br>$+\max(A_{1,2} - L_{1,2} - ML_{2,0})$ | $\min(A_{1,1} - L_{1,1}, ML_1)$ | $\min(A_{1,2} - L_{1,2}, ML_2)$ |
| Legal entity $G_{0/1}$ | $A_{1,0} - L_{1,0}$<br>$+\max(A_{1,1} - L_{1,1} - ML_{1,0})$<br>$+\max(A_{1,2} - L_{1,2} - ML_{2,0}) - T^G$ | $\min(A_{1,1} - L_{1,1}, ML_1) + T^G$ | $\min(A_{1,2} - L_{1,2}, ML_2)$ |
| Legal entity $G_{2/1}$ | $A_{1,0} - L_{1,0}$<br>$+\max(A_{1,1} - L_{1,1} - ML_1 - T^G, 0)$<br>$+\max(A_{1,2} - L_{1,2} - ML_2 + T^G, 0)$ | $\min(A_{1,1} - L_{1,1}, ML_1) + T^G$ | $\min(A_{1,2} - L_{1,2} - T^G, ML_2)$ |
| Legal entity $R_{0/1}$ | $A_{1,0} - L_{1,0}$<br>$+\max(A_{1,1} - L_{1,1} - ML_{1,0})$<br>$+\max(A_{1,2} - L_{1,2} - ML_{2,0}) - T^R$ | $\min(A_{1,1} - L_{1,1}, ML_1) + T^R$ | $\min(A_{1,2} - L_{1,2}, ML_2)$ |
| Legal entity $R_{2/1}$ | $A_{1,0} - L_{1,0}$<br>$+\max(A_{1,1} - L_{1,1} - ML_1 - T^R, 0)$<br>$+\max(A_{1,2} - L_{1,2} - ML_2 + T^R, 0)$ | $\min(A_{1,1} - L_{1,1}, ML_1) + T^R$ | $\min(A_{1,2} - L_{1,2} - T^R, ML_2)$ |
| Cons | $A_{1,0} + A_{1,1} + A_{1,2} - L_{1,0} - L_{1,1} - L_{1,2}$ | -- | -- |

**Table A1: Available economic capital at t = 1 for the two approaches of group solvency assessment**

Legal entity = legal entity approach without CRTIs; Legal entity $G_{0/1}$ = legal entity approach with a guarantee from company 0 to subsidiary 1; Legal entity $G_{2/1}$ = legal entity approach with a guarantee from subsidiary 2 to subsidiary 1; Legal entity $R_{0/1}$ = legal entity approach with a retrocession from company 0 to subsidiary 1; Legal entity $R_{2/1}$ = legal entity approach with a retrocession from subsidiary 2 to subsidiary 1; Cons = consolidated approach

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