OpenRisk White Paper

Confidence Capital

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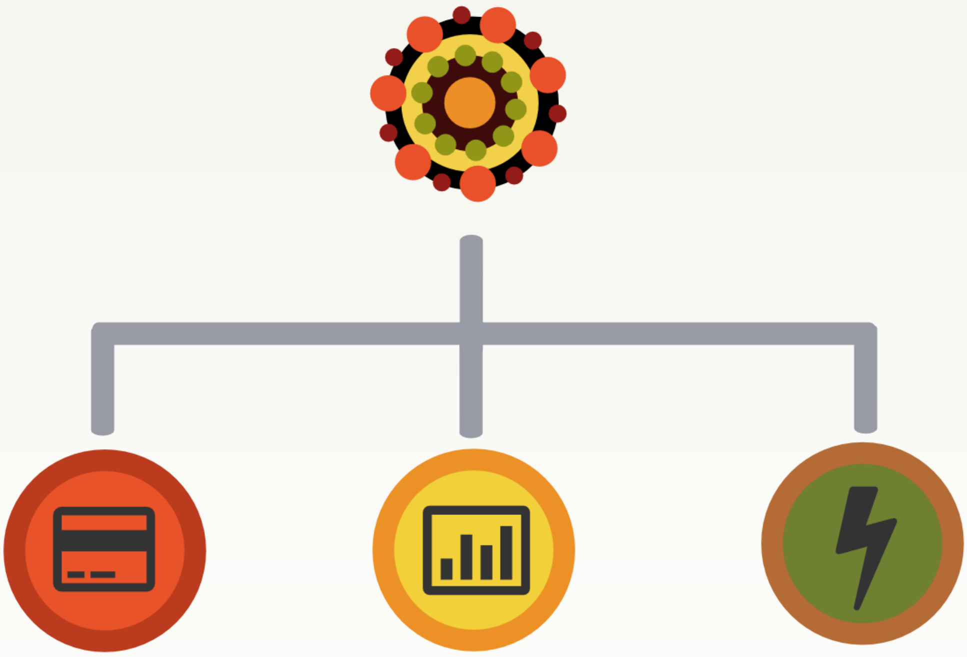

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SUMMARY

We review the structure of economic capital frameworks commonly used within financial institutions and identify why the derived capital metrics do not explicitly address the needs for maintaining ongoing confidence on the soundness of the firm. In the follow up to the financial crisis the need for more explicit such tests has been highlighted by regulatory stress testing methodologies.

The likelihood and severity of a future ratings downgrade (as opposed to a default within the risk horizon) are the two key new ”risk appetite” inputs required for the framework. The temporal correlation of losses beyond the risk horizon with those within the horizon is one of the main new risk parameters that are highlighted by the framework.

We derive explicit formulas for implementing a confidence capital framework in a two period setup that can lead to tractable implementations. We include a brief quantitative study that addresses a very simplified case that is solvable in terms of simple formulas. We explore the relation of confidence capital to economic capital for various choices of risk appetite and inter-temporal loss correlations

The white paper has two sections:

- A *concept* section discussing the issues and the proposal in non-technical terms,
- a *technical paper* offering precise definitions of economic capital for credit portfolios and numerical studies in a simplified setup.

Further Resources

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Concept Paper

The new world of stress testing bank capital

The question of what constitutes adequate risk "capital" (own financial means, equity) for a banking firm is undeniably one of the most debated topics in the post-2008 financial crisis. Many banks have frameworks that produce "internal" estimates for required capital, which typically go under the umbrella of "economic capital", commonly abbreviated as EC. The existence and use of an economic capital framework is considered best practice and in fact regulatory methodologies have on many occasions adopted aspects of such internal measurement methods to support more risk sensitive regulatory capital approaches.

The conceptual foundation of economic capital goes back to Merton [1] and the first formal publication of its practical use appears to be in [2]. It is important to stress that the theoretical framework introduced by Merton is a "top-down" and stylized structural model for the firm (not necessarily a bank). The academic literature has since used more elaborate versions to explore issues related to more realistic corporate debt structures, including the complexities with multiple debt tranches of different maturities [3]. Focusing more specifically on banks, a compilation of theoretical work is available in [4]. On the other hand practical EC work has gradually developed into detailed "bottom-up" calculation methods that build detailed representations of the bank's assets risk profile. A full review of the economic capital concept and key implementation choices is available in[5]. It is remarkable that in the practical usage of EC framework the linkages with the liability side of the bank are rather limited, which leads sometimes to its characterization as a "risk allocation framework" rather than a true "capital" framework[1].

Since the financial crisis there have been substantial revisions to the regulatory capital regime both qualitative and quantitative in nature. Of particular interest conceptually is the set of practices around coordinated multi-bank "stress testing", see e.g.,[6]. Without going into the many technical details of a stress testing framework, conceptually it is built on specific, multi-period, macro-economic scenarios, which are translated to risk estimates for current and future balance sheets. Given the long risk horizons (e.g., four years), assumptions must be made on future business and portfolio parameters. There are various conceptual weak points inherent in using stress testing as an all encompassing capital framework (see Box 1) but there is one significant new aspect that has significant implications for the adequacy of economic capital frameworks.

Stress tests as now practiced identify future regulatory capital requirements of the firm *after* it has sustained losses in early periods within the stress testing horizon and require that available regulatory capital ratios remain above a certain threshold. The implication is that a high enough ratio will ensure that the bank is considered viable ("going concern"), with a confidence level that roughly corresponds to

[1] We note that the use of Economic Capital by Insurance Companies does include insurance liabilities

the "degree of stress" embedded in the selected stress scenario.

This requirement aims to address one of the pathologies identified in the crisis (and easily conjectured before), namely that a bank financing itself in a range of markets and using a variety of products may get into difficulties with refinancing short term liabilities long before its nominal equity is depleted to zero.

Box 1. Stress testing is not a coherent internal capital framework

- Lack of intrinsic and complete scenarios: Stress testing is using macroeconomic scenarios and may not cover uniformly the vulnerabilities of any specific bank portfolio. A framework that covers the range of plausible scenarios along with their best estimate likelihoods will produce more stable, fair and usable estimates
- Inconsistent attitude towards RWA: Stress testing derives explicit correlation estimates of portfolio losses to macro economic factors, yet uses regulatory capital (RWA) which is based on simplified economic capital models based on yet other sets of correlations, a mixup of concepts and estimates

Confidence Capital Concept and Use

We discuss in this white paper some key required elements of an approach to internalize the going concern consideration in an economic capital framework. While firms may informally use existing economic capital calculators in various ways to achieve similar objectives[2], we develop a theoretically and practically coherent framework.

Our setup is sufficiently different that it requires a distinct name to avoid confusion. We will call it "confidence capital", indicating it is the capital required for short term liability holders to maintain confidence in the firm. We are after a capital calculation algorithm that aims to obtain the required capital to guarantee continuing access to funds to a desired confidence level, as opposed to the requirement to meet losses with risk capital up to some (different) confidence level.

In such an internal framework "continuing access to funds" is not established with reference to sufficient regulatory capital or to external ratings (although all of these metrics will obviously be correlated) but with reference to the internal risk assessment of the firm's set of risks. In this sense the derived capital is an *extension* of the economic capital framework.

How might one use such confidence capital measures? As with economic capital, the primary use will a more realistic and accurate representation and allocation of risks internally. The focus on going-concern metrics will naturally force a more careful treatment of long-term risks and in particular the degree to which future losses might be expected to be correlated with early losses. Similarly with the computations of standard economic capital, regulators and/or rating agencies may choose not to take internal measures at face value, but may use them as informative.

[2] E.g., simulating losses at lower confidence levels to calculate the impact on regulatory capital ratios

A framework that allows us to compare and contrast different definitions of solvency

In the first instance we need to create a "model" of the firm which will enable to link the risk profile of the portfolio to a measure of ongoing ability to refinancing bank liabilities. This is naturally done in a multi-period framework[3]

To remedy the significant weakness of stress testing (incompleteness) we must insist that *all relevant scenarios* are included in the assessment. To avoid the explosive growth of scenarios when the number of periods grows we construct a *two-period framework*. The first period is the well known "risk horizon", typically taken to be one year. The second period is the maturity of any asset that exceeds the risk horizon.

Box 2. Key design elements of the confidence capital framework

- Confidence Capital captures a complete set of scenarios on a two-period basis: the first period is the well known 1-yr risk horizon, the second period is the maturity of long-term assets
- The confidence metric is based on a proxy "rating" computed on a one-year forward basis

The framework allows us to setup stylized expressions for the value of assets and liabilities at different time points. In particular we can express the standard measures of economic capital and the new metric of confidence capital in a uniform language:

- The probability of zero equity (insolvency) under the assumption that liabilities can be repurchased at "market" value. This, most aggressive definition, coincides with the so called "default only" approach to economic capital which focuses entirely on incurred losses within the first year period and assumes that remaining performing assets can be liquidated and redeem liabilities in a liquid and efficient market
- The probability of zero equity (insolvency) under the assumption that liabilities can only be redeemed early at par. This definition coincides with the standard economic capital definition which includes in the asset portfolio assessment at the risk horizon not only realized losses but also "market" value declines versus the *nominal* value of liabilities.
- The probability of future expected (hold-to-maturity) losses depleting equity capital, as assessed at the one-year risk horizon, exceeds a worst case "implied rating" threshold. The capital required for achieving a given level of confidence around this threshold is the definition of confidence capital.

Preliminary Insights

In this analysis we only develop a simplified calculation tool to help elucidate the main characteristics we might expect from more sophisticated confidence capital frameworks.

We note first that the *loss distribution at the risk horizon*, this iconic explanatory tool of the economic capital framework is the result of the simplifications associated with the single period setup of economic

[3] A reminder that Value-at-Risk and Economic Capital are one-period risk management frameworks

capital. Namely in a single period framework one can calculate the loss distribution and then "simply" invert to obtain losses at a desired confidence level. In a multi-period framework there are multiple loss distributions and subsequent ones are conditional on events in prior periods. The implication is that, computationally, confidence capital is more complicated than economic capital as it requires an *iterative* approach for estimating the required equity.

Box 3. Summary of insights for this analysis

- Confidence Capital requires an iterative approach to establish required equity
- A confidence metric can be based on a proxy rating computed on a one-year forward basis
- There is a key new risk parameter, namely the temporal correlation of losses across periods
- In a simplified setup we can derive and explore outcomes using simple formulas
- The quantitative differences in confidence capital versus economic capital can be significant

Technical Paper

Balance Sheet in a discrete time multi-period framework

Portfolio assets with total notional exposure size N which is comprised of exposure distributed over maturity buckets as $\{N^k\}$ and

$$N = \sum_{k=1}^{T} N^k \tag{1}$$

For simplicity we assume that all assets are zero coupon bonds issued at discount. Each one of the maturity buckets k will experience credit losses at times $i \leq k$, captured by the random variables l_i^k.

l_t is the observed value of the portfolio credit loss at intermediate times $t \in [0, T]$

$$l_t = \sum_{k=1}^{t} \sum_{i=1}^{k} l_i^k \tag{2}$$

$l_T \in [0, N]$ is the total credit loss variable (random and unknown at $t = 0$), fully realized and known at time T.

In this paper we will be primarily interested in a simplified two-period analysis where the initial time $t = 0$, and the timepoints $t = 1$ and $t = T$ are the key observation points. Thus l_1 is the loss experienced up to the first observation point and $l_2 = l_T - l_1$ will be any additional losses occurring in subsequent periods till the full maturity of the portfolio.

Initial relationships

We consider now how a *stylized* bank is setup at the initial time ($t = 0$) to finance zero coupon assets with uniform maturity T and notional N.

The expected credit loss with the information available at $t = 0$ is $E[l_T|F_0]$. We will assume that this expectation is ”market based”, or in any case a ”best estimate” expectation. The ”filtration” $\{F_t\}$ is the information set being revealed about the portfolio. It will minimally include the revelation of portfolio losses, but may include other uncertainties such as the dynamics of credit spreads.

Market value of assets

The market value M_0 of the credit risk assets (zero coupon bonds) at $t = 0$ is

$$M_0 = E[N - l_T|F_0] = N - E[l_T|F_0] \tag{3}$$

Market value of liabilities

The firm issues at time $t = 0$ a zero coupon bond with notional D which is also repayable at T The complement of assets is financed via equity.

The market value B_0 of the firm debt at $t = 0$ is

$$B_0 = E[\min(D, N - l_T)|F_0] \tag{4}$$

which is the cash amount from the selling of the zero coupon debt to bond investors.

The market value C_0 of the firm's equity at $t = 0$ is

$$C_0 = E[\max(N - D - l_T, 0)|F_0] \tag{5}$$

which is the cash amount required from equity investors to acquire the assets.

At $t = 0$, assuming efficient markets in all three types of securities (credit assets, bank debt and bank equity) we get a no-arbitrage relationship linking the market values of debt and equity with the firm's assets

$$M_0 = B_0 + C_0 \tag{6}$$

On a "book" basis, the equation

$$N = D + K_0 \tag{7}$$

defines the amount of "nominal equity" K_0 available at $t = 0$. The market value of equity is connected with its nominal value via

$$C_0 = E[\max(K_0 - l_T, 0)|F_0] \tag{8}$$

Note that the nominal value K_0 is the payoff to equity investors if there is zero loss (maximum payoff) and the market value for a non-zero loss probability will always be lower.

Relationships at maturity

At time T all the credit loss has materialized (l_T is known). The market value M_T of the credit risk assets (zero coupon bonds) at $t = T$ is simply their nominal value

$$M_T = N - l_T \tag{9}$$

The market value B_T of the firm debt is its payoff function

$$B_T = \min(D, N - l_T) \tag{10}$$

The market value of equity is its corresponding payoff function

$$C_T = \max(K_0 - l_T, 0) \tag{11}$$

and

$$M_T = B_T + C_T \tag{12}$$

continues to hold.

Relationships at the risk horizon t=1

By convention we denote $t = t_H = 1$ as the "risk horizon". We take $t_H < T$, i.e, the maturity of the portfolio is strictly later than the risk horizon. Introducing a relatively short risk horizon is a necessity for portfolios that include long-dated assets and where short maturity assets are continuously replenished.It is also commonly assumed that in all but the most extreme stress scenarios there are portfolio steering and other management actions that can significantly alter the forward risk profile of the portfolio.

The market value M_1 of the credit risk assets at $t = 1$ is

$$M_1 = N - E[l_T|F_1] \tag{13}$$

where $E[l_T|F_1]$ is the expected credit loss at T with the information available at $t = 1$.

Given that some losses l_1 have already been realized at $t = 1$, we can separate them out as follows:

$$M_1 = N - l_1 - E[l_T - l_1|F_1] = N - l_1 - E[l_2|F_1] \tag{14}$$

where l_1 is the observed value of portfolio credit loss at the risk horizon. $E[l_2|F_1]$ is the expected *additional loss* till maturity with the information available at the risk horizon.

The residual nominal equity at the risk horizon is $K_1 = \max(0, K_0 - l_1)$. If large losses realize early, nominal equity can be zero already at the risk horizon.

The market value C_1 of the firm's equity at $t = 1$ is

$$C_1 = E[\max(K_0 - l_T, 0)|F_1] = E[\max(K_0 - (l_T - l_1) - l_1, 0)|F_1] \tag{15}$$

which can be rewritten as

$$C_1 = 1_{\{l_1 < K_0\}} E[\max(K_1 - l_2, 0)|F_1] \tag{16}$$

In words, if nominal equity is not zero at the risk horizon but has some residual value K_1, then the "market" value of that residual at that time depends on the expected further erosion of equity from second period losses.

Similarly the market value of the debt at the horizon is:

$$\begin{aligned} B_1 &= E[\min(D, N - l_T)|F_1] && (17)\\ &= M_1 - C_1 && (18)\\ &= N - l_1 - E[l_2|F_1] - 1_{\{l_1 < K_0\}} E[\max(K_1 - l_2, 0)|F_1] && (19) \end{aligned}$$

Definitions of Solvency

We now link "solvency" to various possible metrics that can be constructed within the framework we laid thus far.

Zero equity event

The equity value C_1 at $t = 1$ is zero if realized losses l_1 within the risk horizon already exceed initial nominal equity K_0. This corresponds to the so-called "default only" mode in credit economic capital literature.

The likelihood of this event is expressed as

$$q_\alpha = P(l_1 > K_0) \tag{20}$$

This event is equivalent to assume that the solvency event is linked with a liquidation of the asset portfolio at the risk horizon, realizing a value M_1, with which the liabilities are repaid early - at market value B_1.

The likelihood of insolvency on this basis is thus expressed as

$$P(l_1 > K_0) = P(C_1 = 0) = P(M_1 < B_1) \tag{21}$$

Debt acceleration event

The assumption of being able buy back debt at discount to avoid default is quite aggressive. E.g., if the debt has an acceleration covenant this would imply that at $t = 1$ the asset value M_1 must match liabilities at the nominal value D rather than the discounted value B_1.

The likelihood of this event is expressed as

$$q_\gamma = P(M_1 < D) = P(l_1 + E[l_2|F_1] > K_0) \tag{22}$$

We see that this is the classic "economic capital" approach, where realized losses l_1 within the first period *and* "mark-to-market", or credit migration losses $E[l_2|F_1]$ expected over the subsequent period, must be less than the available equity.

While more conservative than the zero equity definition, this approach does not directly address the concern that at the risk horizon the firm may not be able to refinance its debt. While in our simplified setup the firm does not *have* to refinance, nevertheless in any realistic situation there would be a need to issue debt on an ongoing basis.

It is worth noting that the repricing discount $E[l_2|F_1]$ is potentially correlated with first period loss l_1. Hence a proper implementation of the "standard" economic capital framework should include the additional risk factors such as term structure of credit losses and the temporal correlations of loss, yet this aspect is normally the least developed (and is completely ignored in the A-IRB simplifications). Even with a refined EC approach, though, there would still no explicit handle on constraining (setting a risk appetite) on the amount of refinancing risk due to residual portfolio risks. We now consider how to address this constraint explicitly within our modeling framework. We call these class of solvency tests "going concern" tests.

Going concern test

In order not to complicate the analysis we will assume that the new debt that needs to issued at $t = 1$ is infinitesimal in size, hence it does not affect the risk characteristics of existing debt and equity.

In terms of the equity value C_1 at the risk horizon, it would be maybe natural to require that for "going concern status" the equity value cannot not drop below a non-zero, positive threshold C_H. The value of that threshold is assumed to be given exogenously as a risk appetite statement, e.g. as a fraction of initial nominal equity K_0. While possible within the framework, the problem with such an approach is that there are no obvious benchmarks of "going concern status" in terms of equity value.

Another approach to a going concern test that offers better benchmarks is to focus on the outstanding debt and its credit discount or "implied credit rating". More specifically, the forward likelihood of default as seen at the risk horizon $t = 1$ is

$$q_1^T = P(l_T > K_0 | F_1) \tag{23}$$

It can be decomposed as

$$q_1^T = 1_{\{l_1 > K_0\}} + 1_{\{l_1 < K_0\}} P(l_2 > K_1 | F_1) \tag{24}$$

Hence this likelihood is already unity if nominal equity has been exhausted at $t = 1$, but if not, it depends on the balance between remaining equity and anticipated second period losses.

If the forward likelihood at $t = 1$ increases beyond a certain level the firm will not be deemed viable. The required threshold of confidence must be introduced as a "risk appetite" parameter. It is economically equivalent to asking that the credit spread does not widen beyond a level, or the rating does not drop below a certain class but in contrast to these external metrics, here we are constructing an internal estimate.

Concretely, we monitor the probability:

$$q_\beta = P(q_1^T > q_H) \tag{25}$$

where q_H is the maximum allowed future default likelihood.

This equation is the central expression for the "confidence capital" framework and must be solved for the required capital K_0 once both the going concern rating q_H and the appetite of breaching in q_β have been set. It is analogous to eq. 22 of the economic capital framework.

There are some unavoidable technical complications. Whereas the loss simulation of the asset portfolio can be performed independently of the determination of economic capital, which is then set as a particular quantile or other risk measure, this separation is not possible for the calculation of confidence capital.

Indeed it should be obvious that one needs to have a running estimate of remaining capital at the risk horizon before computing the risk of its further depletion. The implication is that, in general, confidence capital must be computed iteratively as a one-dimensional root finding method. An initial amount is estimated using a previous calculation or other approach, and it is then iterated (increasing or decreasing) until the required risk appetite metric is satisfied.

A second complication would arise if the calculation framework is not analytic but based on simulation. Namely it may be the case that for each first period simulation one may need to calculate second period realizations also by simulation, hence a simulation within simulation approach which increases computational requirements. At the same time harnessing large scale computational power is increasingly more tractable and/or judicious simplifications can eliminate some of the load of brute force approaches.

A Simple Two Period Illustration of Confidence Capital

In this section we explore the concept discussed previously in a concrete calculation framework that will allow us obtain some first quantitative insights.

We use a simple two period risk model as the focus at this stage is on making the concept of confidence capital tangible rather than demonstrate realistic calculations.

Time correlation is the key new risk parameter

Assume normalized portfolio "profit and loss" drivers (l_1, l_2) that are distributed as normal variables with zero expectation and unit variance. Positive realizations indicate loss.

Simplify away all the detailed assessment of losses *within* each one of the uncertainty periods, to bring out the remaining structure. Such a simple model does not capture correctly the quantitative elements of the risks involved. But these effects are technical rather than essential elements of the two period risk profile and can needlessly complicate the formulas.

We assume a non zero correlation across time period of the two loss variables: $Corr(l_1, l_2) = \rho$ The total loss over two periods is the simple sum $l_T = l_1 + l_2$ The variance of the cumulative loss is

$$Var[l_T] = \sigma_T^2 = 2(1 + \rho) \tag{26}$$

and thus is a function of the time correlation. When losses over the two periods are fully positively correlated the total loss variance is twice the single period variance. In the opposite extreme, if gains in one period always undo losses in the other there is zero total variance.

Standard Value-at-Risk

In this simplified framework, VaR capital K_α to achieve a worst case failure rate q_α is simply

$$q_\alpha = P(l_1 > K_\alpha) = 1 - N(K_\alpha) \tag{27}$$

where N stands for cumulative normal, hence inverting

$$K_\alpha = N^{-1}(1 - q_\alpha) \tag{28}$$

This is just the standard "economic capital" calculation stripped of all its technical complications. It says essentially that economic capital is a suitable confidence level of the loss distribution.

Forward risk rating

We now derive the forward probability of depleting initial capital K_0 if losses after the first period were l_1. Denote that probability as q_1 and think of it as proxy of firm rating at the risk horizon. Given the correlation structure we can write

$$l_2 = \rho l_1 + \sqrt{1 - \rho^2}\epsilon \tag{29}$$

where ϵ is an independent normal variable (zero expectation, unit variance)

The residual capital once first period losses are realized is $K_1 = K_0 - l_1$ (ignoring the possibility that already first period losses deplete all capital). We are looking at the probability that second period losses

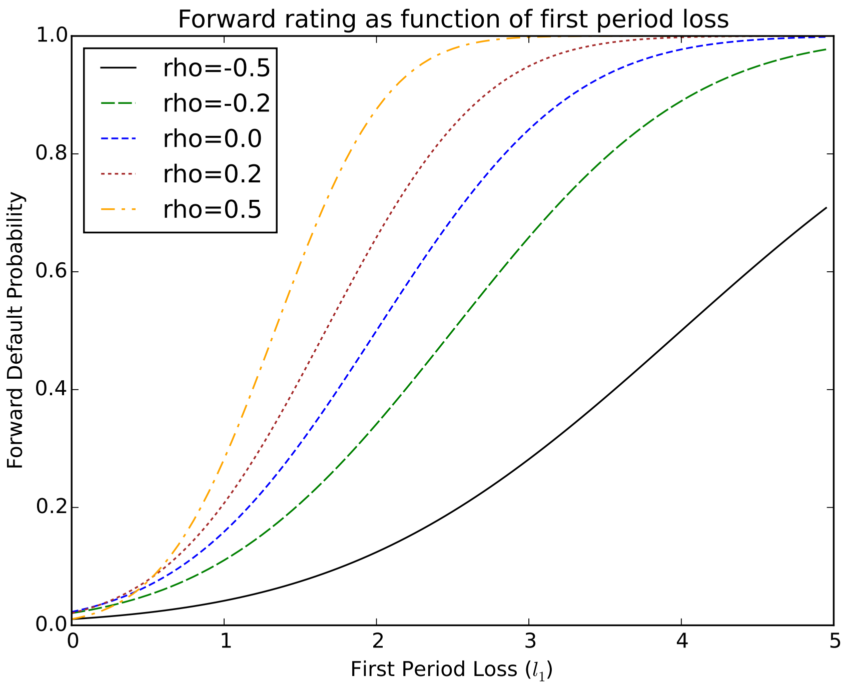

Figure 1: The profile of future default probability as function of first period loss and temporal correlation.

exceed K_1 (which depends on l_1):

$$q_1 = P(l_2 > K_1) \tag{30}$$

$$= P(l_2 > K_0 - l_1) = P(\rho l_1 + \sqrt{1-\rho^2}\epsilon > K_0 - l_1) \tag{31}$$

$$= P(\epsilon > \frac{K_0 - (1+\rho)l_1}{\sqrt{1-\rho^2}}) \tag{32}$$

$$= 1 - N(\frac{K_0 - (1+\rho)l_1}{\sqrt{1-\rho^2}}) \tag{33}$$

Figure (1) illustrates this expression for different values of correlation and first period loss. In a more realistic model, e.g. a simulation framework the probability q_1 would be computed per simulation scenario. The probability that it will take any value in its range is given by the probability of the underlying first period loss.

Going concern capital

The probability that the *forward rating* q_1 exceeds a *going concern rating threshold* q_H is given by

$$\begin{aligned}
P(q_1(l_1) > q_H) &= P(1 - N(\frac{K_0 - (1+\rho)l_1}{\sqrt{1-\rho^2}}) > q_H) && (34)\\
&= P(\frac{K_0 - (1+\rho)l_1}{\sqrt{1-\rho^2}} < N^{-1}(1-q_H)) && (35)\\
&= P(l_1 > \frac{K_0 - \sqrt{1-\rho^2}N^{-1}(1-q_H)}{1+\rho}) && (36)\\
&= 1 - N(\frac{K_0 - \sqrt{1-\rho^2}N^{-1}(1-q_H)}{(1+\rho)}) && (37)
\end{aligned}$$

Setting the risk appetite for exceeding the going concern rating at q_β allows us to derive the desired ”going concern” capital K_β:

$$K_\beta = (1+\rho)N^{-1}(1-q_\beta) + \sqrt{1-\rho^2}N^{-1}(1-q_H) \quad (38)$$

The triangular identity

Once we define a minimum acceptable rating q_H and a given level of capital we have the following relationship between the three key probabilities (q_α, q_H, q_β) (i.e, the probability of default, acceptable rating and probability of exceeding the acceptable rating), in order of growing magnitude.

$$N^{-1}(1-q_\alpha) = (1+\rho)N^{-1}(1-q_\beta) + \sqrt{1-\rho^2}N^{-1}(1-q_H) \quad (39)$$

This equation constrains the possible configurations of a firm’s ”risk appetite” for a given type of risk portfolio (here captured by the single inter-temporal correlation parameter).

We can parameterize confidence capital in terms of economic capital as

$$K_\beta = ((1+\rho)\frac{N^{-1}(1-q_\beta)}{N^{-1}(1-q_\alpha)} + \sqrt{1-\rho^2}\frac{N^{-1}(1-q_H)}{N^{-1}(1-q_\alpha)})K_\alpha \quad (40)$$

which shows that confidence capital and economic capital are linked by a multiplier that is a ”risk appetite” weighted average of temporal correlation factors.

The triplet $(0.1\%, 1\%, 10\%)$ represents a plausible set of risk appetite (1 in 1000 years for economic capital, ”investment grade” as minimum rating and 1 in 10 years appetite for a below investment grade drop)

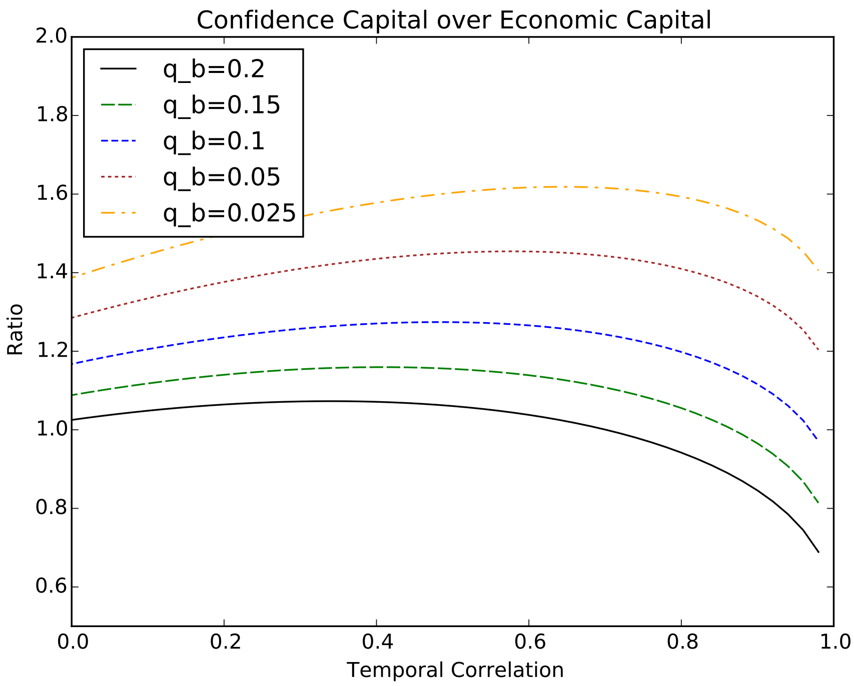

Figure 2: The ratio of confidence capital over economic capital as function of correlation and q_b ,the going concern threshold crossing appetite for $(q_a = 0.1\%, q_H = 1\%)$. The excess required can be substantial, even for a zero correlation assumption between forward and first period losses

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