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Calculating systemic risk capital: A factor model approach

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ABSTRACT

We treat the banking system as a traded credit portfolio and calculate systemic risk capital as the amount of capital that insures the portfolio's value against unexpected losses. Using data from the largest global financial institutions, we find evidence of extreme event dependence between banks during the recent financial crisis. Subsequently, we extend the existing Gaussian approach by proposing a model that accounts for the extreme event dependence, and we quantify the level of capital shortfall when this characteristic is ignored. Furthermore, the mark to market valuation approach incorporates the economic loss of credit downgrades into the estimates.

1. Introduction

The need for a comprehensive approach to the exposure of the financial sector to systemic risk was highlighted well before the recent financial crisis (Eisenberg and Noe, 2001). However, it was not until the collapse of Lehman Brothers in September 2008 that this topic became central to policy makers with the introduction of "macro-prudential" regulation – i.e. policies that seek to safeguard the entire financial system from extreme shocks. Consequently, various proposals have been put forward aimed at dealing with the too-big-to fail problem and the risks that are associated with systemically important financial institutions. Possibly, the most explicit macro-prudential policy proposed so far is by the Financial Stability Board (2010) and it requires systemically important financial institutions to have a higher loss absorbency capacity to reflect the greater risks that these institutions pose to the global financial system.[1]

Academic discussion on macro-prudential policy has centered on the appropriate way to measure contributions of individual banks to systemic risk. As we discuss in more detail below, the present paper introduces a systemic risk capital attribution procedure using a factor model and it aims to contribute to this strand of literature by explicitly modeling two important and formerly neglected aspects.

A widely cited systemic risk measure is the marginal expected shortfall – i.e. an estimate of a bank's contribution to the system's total capital shortfall, proposed by Acharya et al. (2010). It is a systemic fragility metric that can also be used to determine an optimal taxation policy based on systemic risk. However, a limitation of this approach is that it implicitly assumes that the cost of recapitalization represents the total cost due to systemic risk, thereby

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[1] Gauthier et al. (2012) examine different risk allocation mechanisms used in the literature and show that capital charges based on systemic risk can differ by as much as 25% from existing capital levels. They conclude that "*financial stability can be substantially enhanced by implementing a systemic perspective on bank regulation*".

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ignoring losses to credit holders. In contrast, the approach in the present paper considers losses to credit holders (including depositors and other bank bondholders) by explicitly taking into account the total liabilities of banks. This differentiation is substantial especially when it comes to capital requirement calculations.

Eisenberg and Noe (2001) use a network approach to introduce a single clearing mechanism that produces the number of defaults required to induce a firm to fail. Elsinger et al. (2006) extend this model to include indirect linkages through correlation and Lee (2013) puts forward a method for calculating systemic liquidity shortages due to interbank linkages. Network models like the above are useful in explaining the mechanisms of the domino effect within the financial system but they do not provide an attribution process for capital requirements. On similar lines, Giesecke and Kim (2011) propose a dynamic hazard model of failure time which does not depend on asset-implied but on actual failures. Their formulation seeks to capture the spillover effects channeled through a complex network of relationships in the economy but falls short of providing a mechanism for internalizing negative externalities.

Adrian and Brunnermeier (2011) propose the ΔCoVaR measure of systemic risk that gauges the increase in Value at Risk of the system attributed to the distress of a particular institution. They use quantile regressions of equity returns to estimate CoVaR. However, as highlighted in Puzanova and Düllmann (2013) this methodology is applicable only in the Gaussian setting since otherwise, it returns controversial outcomes. When applied to data with positive tail dependence, it can produce lower systemic estimates as compared to a Gaussian (no tail dependence) setting. Furthermore, the approach of Adrian and Brunnermeier (2011) is a bottom-up approach where the system-wide risk is the sum of the individual risks from the banks within the system. Our approach is a top-down approach where we derive independently the system-wide risk and we gauge individual systemic risk as the contribution of each bank.

Tarashev et al. (2010) put forward an alternative measure of systemic importance using the so-called Shapley value, a methodology that is based on game theory. They explore two different attribution mechanisms, one that captures the contribution of individual institutions to systemic risk and another that reflects institutions participation in systemic events. While this is, beyond doubt, an innovative approach its main shortcoming is that it can be applied only in specific cases due to computational complexity.[2]

Puzanova and Düllmann (2013) address various shortcomings of the earlier models. They derive systemic risk capital contribution via a credit portfolio approach using a Gaussian factor model. Within this framework, the financial sector is treated like a portfolio of debt represented by financial institutions' liabilities. Systemic risk is gauged by the tail risk of the portfolio loss distribution and capital contributions are modeled as incremental credit Value at Risk derived via the Euler principle on homogenous functions (Emmer and Tasche, 2005). Correlation between financial institutions is incorporated through the dependence on common factors. The adopted Euler allocation approach also allows an application to large and heterogeneous portfolios, an improvement over Tarashev et al. (2010).

Our model builds on Puzanova and Düllmann (2013), and thus, shares many of the desirable characteristics mentioned above. However, at the same time, it differs in two important aspects. As observed by Puzanova and Düllmann (2013) their approach does not go beyond the notion of linear correlation, namely the implicit extreme event dependence is zero. Using data on bank equity returns, we show that the tail dependence during the period of our study is positive which suggests that a Gaussian model is inappropriate. Moreover, Puzanova and Düllmann (2013) treat the credit portfolio as a "hold to maturity" loan book, where default risk is the only source of uncertainty.

Our first contribution is that we propose two alternative factor models, the double *t*-factor and the *t*-factor model that imply higher extreme event dependence. This is a novel departure from the Gaussian dominated regulatory capital framework used in earlier studies. This type of dependence among institutions is manifested during periods of distress in line with empirical evidence from markets (Rodriguez, 2007) and banks (Anginer and Demirguc-Kunt, 2011). To highlight the importance of extreme event dependence, we derive the systemic risk estimates under the proposed method and calculate the expected capital shortfall generated if we ignore this property.

Our second contribution is that, within the context of tradable credit portfolio, we propose a mark to market approach that yields capital charges against default losses as well as losses due to the downgrade of credit state. The rationale for modeling this particular aspect lies in the recent crisis which has shown that uncertainty in the financial system increases by credit quality downgrades, even if the implied default risk remains low. The phenomenon gets more notable when clusters of downgrades occur simultaneously.[3] To the extend that regulators aim at the convergence between regulatory and economic capital, we believe that the trading portfolio approach constitutes a useful alternative to applying capital charges based on systemic risk.

The main results, obtained from the application of the model to an international dataset of the largest 82 financial institutions can be summarized as follows. First, banks exhibit significant extreme event dependence during the period of 2006–2012. Second, the systemic risk estimates reflect the peaks of 2008 (the subprime loans crisis) and 2011 (the European sovereign debt crisis), and they also reveal that global financial institutions remained under-capitalized since 2008. Specifically, a comparison between the reported capital and the capital required due to systemic risk for the largest global financial institutions reveals a consistent capital shortfall, raising doubts about the current ability of the financial system to sustain a financial crisis of the magnitude of 2008. Third, the estimates obtained from the model that ignores extreme event dependence (Gaussian model) are considerably lower than those obtained from the extreme event dependence models (double *t*-factor and the *t*-factor model). In fact, the Gaussian model does not yield any capital shortfall, with the exception of the year 2008. These findings highlight the risks of ignoring the increasing dependence of banks during times of financial distress.

The remainder of the paper is organized as follows. Section 2 introduces the model setup and presents the three model variations educed by varying the structural form. Section 3 summarizes the systemic risk calculation and allocation procedures. Applications using empirical data of financial institutions are presented in Section 4. Finally, Section 5 concludes with a summary of the findings.

[2] Puzanova and Düllmann (2013) argue that this approach is applicable only in the case of small or homogenous portfolios. Huang et al. (2012) also highlight the problem of computational burden, mentioning that: "*Under its general application, the Shapley value approach tends to suffer from the curse of dimensionality problem in that, for a system of N banks, there are* 2*N possible subsystems for which the systemic risk indicator needs to be calculated*" (p. 63).

[3] The five top US banks (J.P. Morgan, Bank of America, Citigroup, Goldman Sachs and Morgan Stanley) were among the 17 largest global banks whose credit rating was downgraded by Moodys and S&P in 2011. Their credit ratings remained in the investment grade, which effectively meant very low default risk. Yet, the impact of the downgrade was estimated to $20bil in borrowing costs.