

MODELING METHODOLOGY

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A Composite Capital Measure Unifying Business Decision Rules in the Face of Regulatory Requirements Under New Accounting Standards

Abstract

Prudent credit risk management ensures institutions maintain sufficient capital and limit the possibility of a capital breach. With CECL and IFRS 9, the resulting trend toward greater credit earnings volatility raises uncertainty in capital supply, ultimately causing an increase in required capital. It is ever more challenging for institutions to manage their top-of-the-house capital while steering their business to achieve the desired performance level. This paper introduces an approach that quantifies the additional capital buffer an institution requires, beyond the required regulatory minimum, to limit the likelihood of a capital breach. In addition, we introduce a new measure that allocates capital and recognizes an instrument's regulatory capital requirements, loss allowance, economic concentration risks, and the instrument's contribution to the uncertainty in capital supply and demand. In-line with the Composite Capital Measure introduced in Levy and Xu (2017), this extended measure includes far-reaching implications for business decisions. Using a series of case studies, we demonstrate the limitations of alternative measures and how institutions can optimize performance by allocating capital and making business decisions according to the new measure.

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1. Introduction

Managing an organization's capital is a multifaceted problem. Institutions must manage capital supply, adhere to accounting standards (e.g., IFRS 9 or CECL), and address regulatory capital demand requirements (e.g., Basel III), all of which might not align with fundamental economic risks (e.g., concentration risk). With regulatory and accounting rules constraining strategic business decisions, organizations must manage these factors coherently. Recognizing these challenges, many institutions rely on integrated measures that account for both economic and regulatory requirements within their strategic decision rules. However, many of these integrated measures are constructed in an ad hoc manner without backing by formal economic theories. To address this issue, Levy and Xu (2017) introduced the Composite Capital Measure (CCM), which accounts for both regulatory capital requirements and the credit risk associated with each instrument within a portfolio. This measure has important implications for capital management and business decisions.

This paper builds upon the Levy and Xu (2017) framework, which analyzes optimal portfolio decision rules while recognizing minimum regulatory capital requirements. We incorporate loss allowance into the decision rules using two mechanisms. First, we recognize that loss allowance serves the same purpose as capital — as a reserve against potential future losses. From a decision-metric perspective, loss allowance can be viewed as an additional, implicit capital requirement. An increase in loss allowance decreases earnings, which reduces capital supply. Second, the framework recognizes allowance impacts credit earnings' dynamics.¹ The idea being that adhering to minimum regulatory capital today does not ensure regulatory capital compliance in the future. Capital surplus (the difference between capital supply and capital demand) is typically pro-cyclical, driven by changes in underlying credit quality; loss allowance increases, credit earnings decreases, and regulatory capital often increases with a deteriorated credit environment. In this paper, we also demonstrate that these dynamics become more profound when introducing CECL and IFRS 9 — both tend to increase capital surplus volatility through higher allowance volatility.

Our focus addresses questions related to: (1) how large a capital buffer above the required minimum, recognizing today's loss allowance, an institution should set aside to ensure that the likelihood of a capital breach adheres to their risk appetite; (2) how to allocate this capital buffer to individual assets or sub-portfolios in a way that recognizes the cross-sectional variation in their contribution to allowance volatility and the need to hold the buffer; and (3) how to design a unified risk-based capital allocation measure that accounts for the portfolio-referent economic risks, regulatory requirements, loss allowance, and the need for additional capital buffer due to capital surplus volatility.

We organize the remainder of this paper as follows:

- » Section 2 discusses the mechanisms by which loss allowance and capital surplus dynamics impact capital and credit portfolio management.
- » Section 3 describes the CCM modeling framework that accounts for uncertainty in capital supply and demand.
- » Section 4 examines optimal capital allocation rules.
- » Section 5 studies optimal investment strategies.
- » Section 6 concludes.
- » Appendix A lists definitions of key variables.
- » Appendix B provides proof for theorems and other derivations.

¹ This paper uses the term "earnings" as shorthand for credit earnings and omits the impacts of interest rate and other income streams on earnings. This definition should not lead to confusion, given this paper focuses on credit.

2. Loss Allowance and Capital Surplus Dynamics

Using a series of case studies, this section demonstrates the importance of incorporating loss allowance and capital surplus dynamics into strategic decision rules. Section 3 formalizes the modeling framework and extends Levy and Xu (2017) to account for these dynamics. We begin with the impact allowance has on capital requirements at origination and move on to capital surplus dynamics, linking each with their impact on strategic decision rules.²

The first case study demonstrates viewing loss allowance as an additional capital requirement and considers how it should enter into decision metrics.

Table 1 depicts an institution raising cash to originate one of two loans, A and B. Both loans have \$10,000 notional and \$800 required regulatory (Tier-1) capital. The loss allowances for Loans A and B are \$200 and \$500, respectively. To originate Loan A, the institution must raise at least \$1,000 capital (and issue \$9,000 debt); once the loan is originated, it must write-off a \$200 loss allowance from its available capital immediately, bringing its total available capital level to \$800, just meeting the regulatory requirement. Similarly, to originate Loan B, the institution must raise \$1,300 in capital. Abstracting from the partial offset to Tier-2 capital and the need for additional capital above the required minimum, *effective* capital associated with each asset equals its required regulatory capital plus loss allowance. All else equal, a loan becomes more attractive the lower its effective capital.

TABLE 1

Relationship between Loss Allowance Level and Effective Capital

	Loan A	Loan B
Required Regulatory Capital	\$800	\$800
Total Capital Raised (Effective Capital Required)	\$1,000	\$1,300
Loss Allowance	\$200	\$500
Available Capital (= Total Capital Raised – Loss Allowance)	\$800	\$800

We now turn our attention to capital surplus dynamics and its impact on decision rules. Capital surplus is the difference between capital supply and demand, both of which fluctuate with the credit environment. In a deteriorated environment, increased allowance lowers earnings, which eats away at an organization's capital supply. Meanwhile, deteriorated credit quality often drives regulatory capital to increase capital demand. To ensure fluctuations in capital surplus do not result in a capital breach, institutions hold a capital buffer beyond the required regulatory minimum; the severity of the fluctuations should determine the size of the buffer. The interplay of portfolio composition (e.g., risk profile, maturity, diversification, and concentration) and regulatory and loss-accounting rules determines capital surplus dynamics. The extent to which an organization can diversify holdings tempers capital surplus fluctuations and potentially reduces required capital surplus. Decision rules that recognize this effect can enable organizations to optimize portfolios in this dimension.

The next case study explores the impact of new impairment models on capital surplus dynamics, focusing on capital supply. Earnings from a loan portfolio consist of interest income, change in loss allowance, and net charge-offs. Allowance affects capital surplus as retained earnings, which include credit impairment charges and flow into capital supply. A rise in impairment inevitably depletes the capital adequacy for banks that use the Standardized Approach. Results are more involved for banks under the Internal Ratings Based (IRB) approaches, but the spirit of the dynamics remain; the new standards will affect regulatory capital adequacy dynamics.³

Table 2 illustrates the differences between earnings and the resulting change in capital surplus for an individual loan migrating in credit under IFRS 9, CECL, and incurred loss. The example assumes the loan has a \$10,000 (USD for CECL and, say, CAD for IFRS 9) face value, a five-year maturity, 50% LGD, and a 1% annual coupon rate with quarterly payments. In this example (and for the remainder of this section), we keep regulatory capital fixed for non-defaulted loans, so that earnings drives any change in capital

² Note, we ignore taxes and focus on Tier-1 capital. The case for Tier-2 capital is more complicated, as institutions can use some portion of loss allowance to serve as Tier-2 capital.

³ See the chapter *Integrating into Regulatory Capital Framework* by Adrian Docherty within *The New Impairment Model Under IFRS 9 and CECL* for details of the interactions between the accounting and regulatory capital frameworks.

surplus, enabling us to focus on the allowance impact. To streamline the case studies, we focus on a Loss Emergence Period (LEP) of one year, along with a rating system employing Through-the-Cycle (TTC) properties, to generate the one-year expected loss under incurred loss. Under incurred loss, earnings, which equate to the change in capital surplus, are constant during the first three quarters, as the credit rating and, hence, the loan's TTC PD and loss allowance do not change. Under CECL and IFRS 9, however, earnings and the capital surplus change fluctuate with changes to the credit environment and the loan's forward-looking PD. Comparing IFRS 9 and CECL loss allowance over time, it is clear that allowances are, in general, more sensitive to changes in credit quality under the lifetime measure. During the fourth quarter, the borrower experiences a downgrade from Baa3 to Ba3, causing the loan to be classified as "Stage 2" under IFRS 9. Consequently, the loss allowance under IFRS 9 increases significantly and equates with CECL allowance as the lifetime expected loss is recognized. This flows through and results in large, negative IFRS 9-earnings for the quarter. While earnings under incurred loss is also negative during the quarter, its magnitude is much smaller than under IFRS 9.

TABLE 2

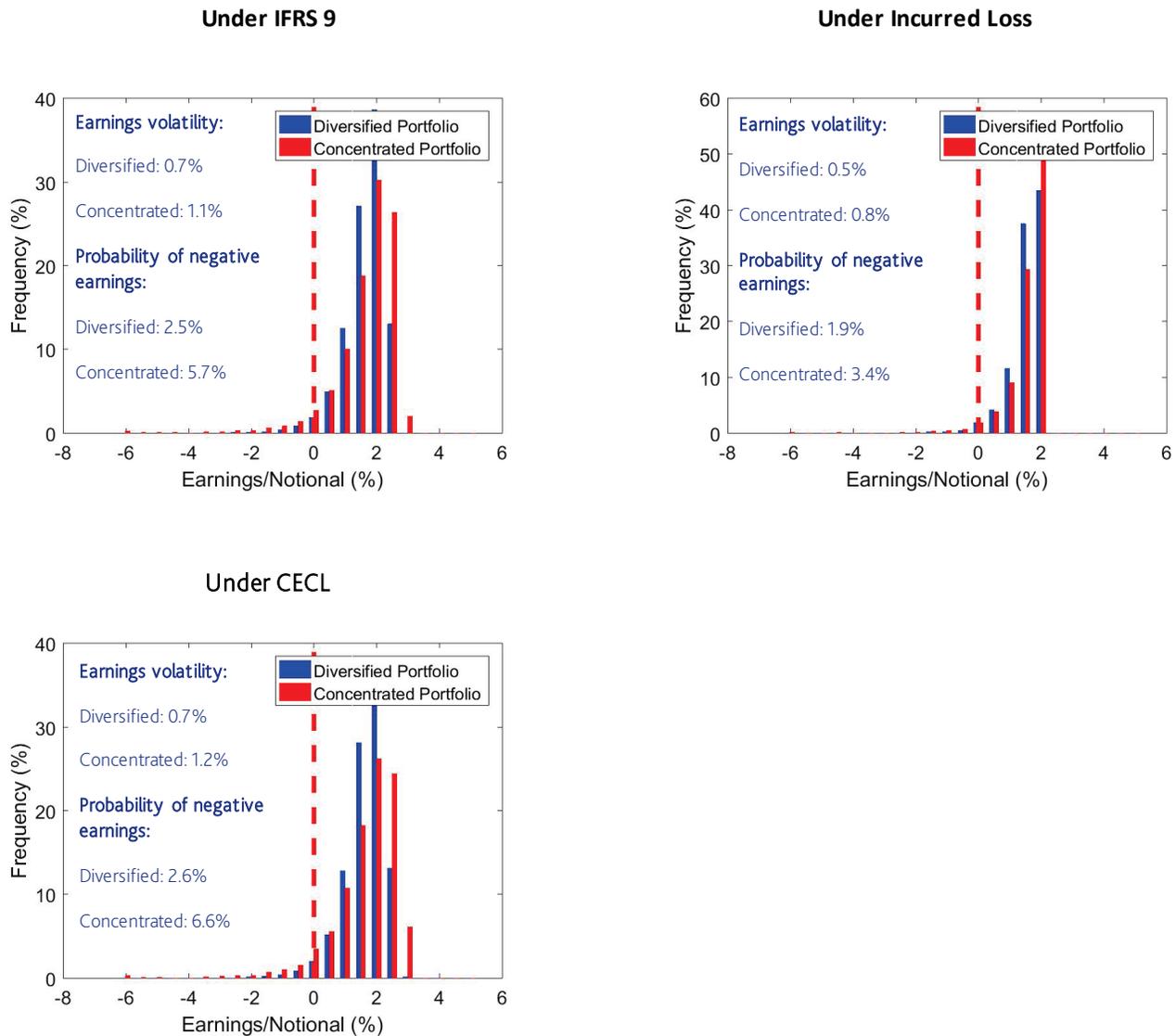
Comparison of Earnings Dynamic Under IFRS 9 and IAS 39 — Stylized Case Study

Time	Maturity (Years)	Rating	PIT PD	TTC PD	Stage	Loss Allowance			Interest Income	Earnings or Δ Capital Surplus (Interest Income - Δ Loss Allowance)		
						Incurred Loss	CECL	IFRS 9		Incurred Loss	CECL	IFRS 9
0	5	Baa3	0.5%	0.5%	1	\$25	\$124	\$25	\$0	\$-25	\$-124	\$-25
Q1	4.75	Baa3	0.4%	0.5%	1	\$25	\$94	\$20	\$25	\$25	\$55	\$30
Q2	4.5	Baa3	0.6%	0.5%	1	\$25	\$134	\$30	\$25	\$25	-\$15	\$15
Q3	4.25	Baa3	0.7%	0.5%	1	\$25	\$147	\$35	\$25	\$25	\$12	\$20
Q4	4	Ba3	2%	2%	2	\$100	\$388	\$388	\$25	\$-50	-\$216	-\$328

While not the focus of this paper, it is interesting to observe that quarter-to-quarter fluctuations in earnings and changes in capital surplus are more pronounced under CECL and IFRS 9 than under incurred loss, as earnings are more closely tied to the forward-looking loss measures. Regardless of the allowance rules, it is clear that fluctuations in earnings, in part driven by fluctuations in loss allowance, flow into capital supply.

The fluctuations in earnings highlighted in Table 2 can have profound implications for credit portfolio management as one recognizes the interplay with portfolio dynamics and the interaction between diversification/concentration and loss recognition. To highlight these portfolio effects, we present the distribution of changes in capital surplus across two portfolios with different concentration levels. Figure 1 compares the distribution of credit earnings of portfolios with different degrees of concentration, where the interest income and loss provisions are computed according to Incurred Loss, IFRS 9, and CECL standards. In general, we see that large negative values for earnings manifest more frequently for portfolios with higher concentration (i.e., portfolio earnings distribution will have a significantly fatter tail in the negative region).

Figure 1 Credit earnings volatility and probability of negative earnings: diversified portfolio versus concentrated portfolio.



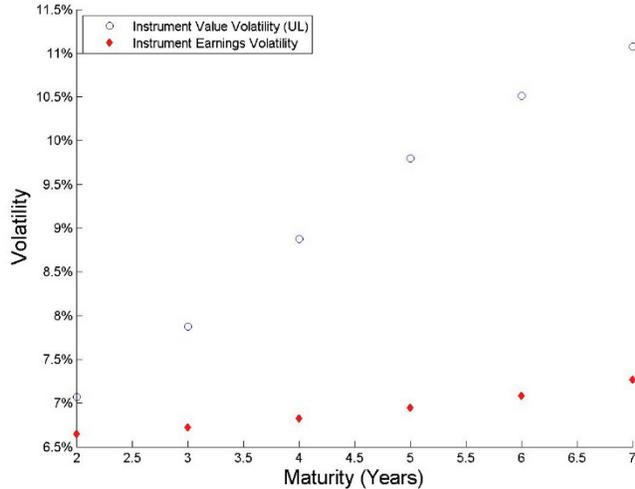
The distribution of portfolio earnings resembles that of portfolio fair value, both of which reflect concentration risks. However, they are not identical. This trait is especially true under IFRS 9, IAS 39, and FAS 5 loss recognition rules, where the impact of credit migration on earnings can be muted when compared with that on fair value.⁴ Under fair value, credit quality deterioration manifests through a higher likelihood of default over the asset's life, whereas, loss provisions typically only account for one to two-year expected loss under the aforementioned accounting rules.⁵ Figure 2 makes this point clear by comparing instruments' credit earnings volatility against their value volatility while controlling for the instrument maturity under IFRS 9. We can see that the fair value volatility increases significantly as maturity increases, reflecting the increased sensitivity of value to changes in credit quality as maturity increases. Meanwhile, credit earnings volatility remains relatively flat. With the asset falling under Stage 1, allowances are set at one-year loss, muting the maturity effect; the slightly positive slope being driven by lifetime loss associated with the asset

⁴ For a comprehensive discussion of these dynamics, please see, Amnon Levy and Jing Zhang, "Measuring and Managing the Impact of IFRS 9 and CECL Requirements on Dynamics in Allowance, Earnings, and Bank Capital," April 2018.

⁵ Under CECL, portfolio earnings distribution is much more similar to portfolio value distribution, due to the fact that loss allowance is based off of lifetime PD. However, portfolio earnings differs from value in its treatment of coupons, which can have a material impact on risk measures under the two lenses.

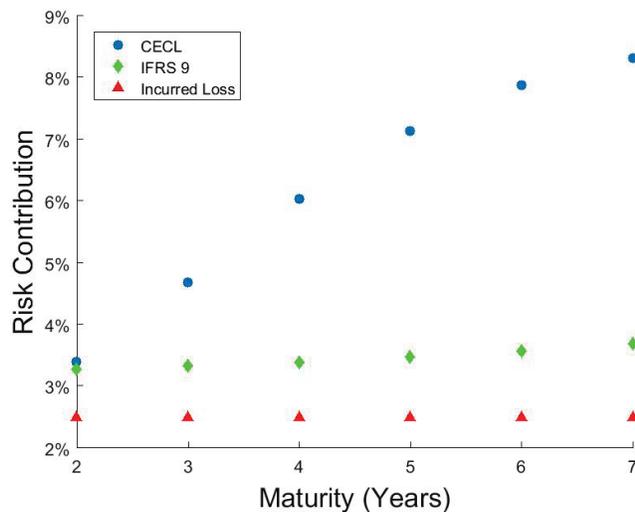
falling into Stage 2 that can occur with a certain likelihood. Focusing on economic or accounting measures alone is insufficient when considering the various risks that an organization faces—a unified approach that recognizes the various nuances is imperative.

Figure 2 Value volatility versus IFRS 9 credit earnings volatility for Instruments with different maturities.



The significant role of credit earnings volatility on capital supply uncertainty can be accentuated under the new accounting rules of IFRS 9 and CECL. A contributing element is the use of Point-in-Time (PD) rather than Through-the-Cycle (TTC) PDs, making loss provisions across instruments more correlated. In addition, the requirement of setting loss allowance to be lifetime expected loss prior to default can lead to large loss provisions with even a small change in credit quality. Figure 3 illustrates the overall impact of IFRS 9 and CECL on portfolio earnings volatility. It shows an instrument's earnings risk contribution is significantly higher under CECL and IFRS 9 than under Incurred Loss.⁶

Figure 3 Earnings risk contributions for instruments with different maturities under different accounting rules.



⁶ For a comprehensive discussion of these dynamics, please see, Amnon Levy and Jing Zhang, "Measuring and Managing the Impact of IFRS 9 and CECL Requirements on Dynamics in Allowance, Earnings, and Bank Capital," April 2018.

While beyond the scope of this paper, it is worth observing that, while lifetime loss allowance under CECL results in earnings distribution more similar to portfolio value distribution than under IFRS 9, the treatment of coupons and discounting can result in a material difference in risk measures under the two lenses.⁷

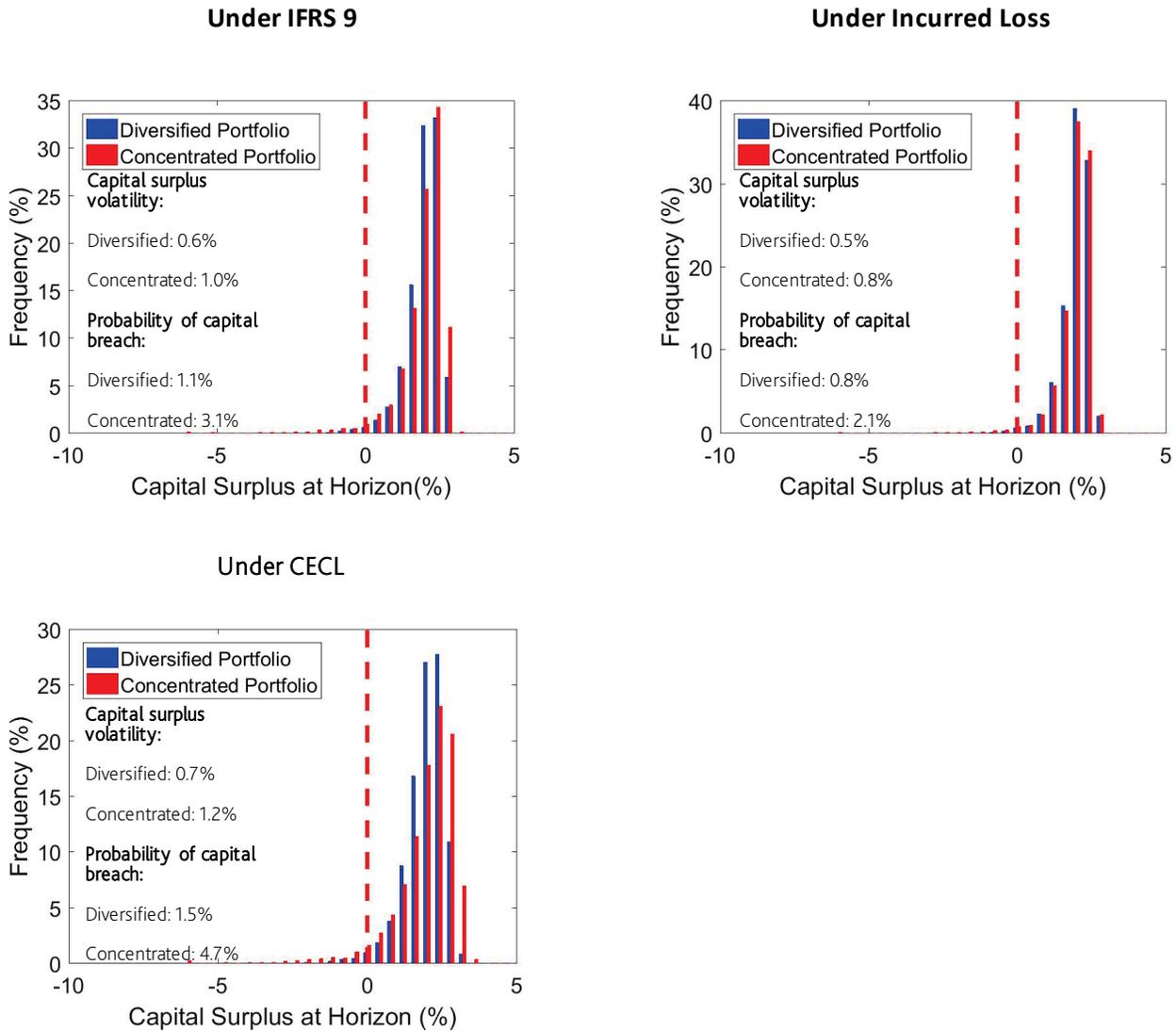
We now transition the discussion to capital regulations (e.g., Basel III) that require institutions maintain a minimum level of capital, which constitutes an institution's capital demand. Just like capital supply, albeit to a lesser degree, capital demand varies over time. First, credit ratings vary over time and often help determine regulatory capital. For example, TTC measures of credit quality typically linked to credit ratings determine Basel III advanced IRB capital.⁸ While TTC PDs are relatively stable when compared with PIT PD, they do vary and drive capital changes over time. Second, specific loss allowance relevant under incurred loss and charge-offs due to defaults can also affect RWA by reducing EAD.

Next, we bring together capital supply and demand and explore capital surplus dynamics. As discussed, during a constraining regulatory capital environment, institutions hold capital beyond the regulatory minimum to the extent that they need to manage the likelihood of a capital breach. Not surprisingly, concentration effects impact the distribution of capital surplus in a way similar to credit earnings distribution. Figure 4 presents the ex ante distributions of changes in capital surplus over one year for two portfolios with different levels of concentration under three accounting rules. Not surprisingly, capital surplus volatility and the probability of capital breach is significantly higher for the concentrated portfolio highlighting the relevance of credit portfolio management; moving toward a more diversified portfolio will aid in limiting the level of surplus an organization needs to set aside. Also similar to the observation in the earning discussion, the capital surplus distribution has higher volatility and fatter tails under IFRS 9 and CECL than under Incurred Loss, suggesting institutions require higher additional capital buffer under the new accounting rules.

⁷ For a comprehensive discussion please see Moody's Analytics Portfolio and Balance Sheet Research, "Comparison of Risk Statistics Based on Economic Versus CECL Accounting Values," February 2018.

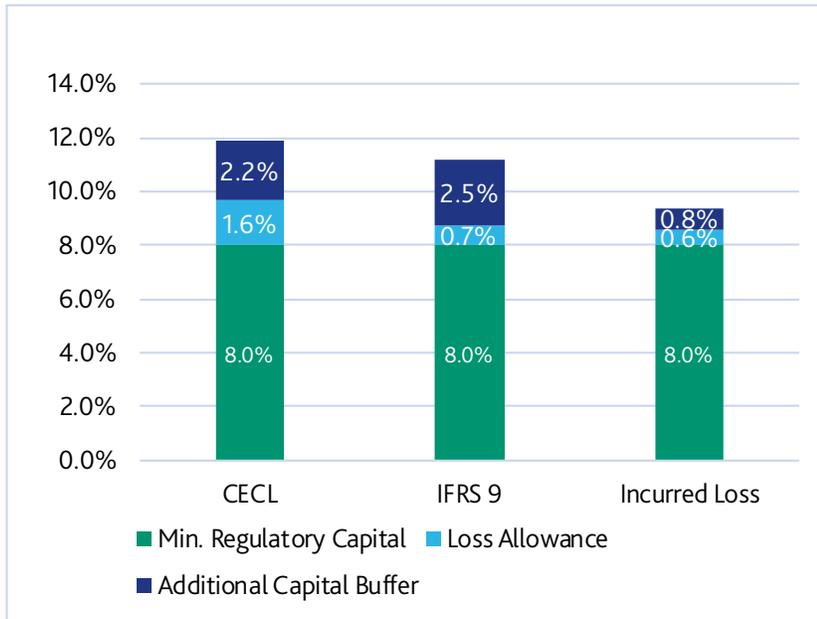
⁸ While subtle, PIT PD dynamics can also affect capital demand, as higher amounts of loss allowance (determined by PIT PD) decrease EAD and, thus, capital demand.

Figure 4 Distributions of portfolio capital surplus at horizon.



To summarize, institutions should hold an effective capital buffer that depends on their portfolio composition, regulatory capital requirements, and accounting regime. One way to examine the overall impact of the accounting regime is to extend the effective capital to be the sum of the minimum required regulatory capital, the loss allowance, and the required capital surplus. Figure 5 illustrates an example for a generic loan portfolio under different accounting rules. Compared to Incurred Loss, both CECL and IFRS 9 induce higher loss allowance and higher additional capital buffer. CECL faces the largest loss allowance, because it accounts for lifetime expected loss for all instruments. IFRS 9 faces the largest capital buffer requirement, because of the possibility of extreme negative earnings associated with the staging rule “cliff effect.” The two impacts together make CECL and IFRS9 require much higher levels of effective capital compared to Incurred Loss.

Figure 5 Effective Capital breakdown.



With institutions holding a higher level of effective capital, it is ever more important to ensure capital is optimally deployed. In order to make optimal decisions, required capital surplus must be allocated to instruments based on their respective contribution to capital surplus dynamics. In Section 3, we extend the CCM introduced in Levy and Xu (2017) to incorporate instruments' loss allowance and contribution to the portfolio-required capital surplus. The measure allocates capital in a way that optimizes the portfolio's risk-return profile while adhering to regulatory capital and loss allowance effects.

3. A Composite Capital Measure that Recognizes Loss Accounting

3.1. Model Assumptions and Specifications

We extend Levy and Xu's (2017) modeling framework by recognizing that capital supply should always be greater than capital demand.

$$\max \left(\mathbf{w}' E(\mathbf{r}) + (1 - \mathbf{w}' \mathbf{1}) r_f - \frac{1}{2} \psi \mathbf{w}' \Sigma \mathbf{w} \right) \quad (1)$$

$$\text{s.t.} \quad \mathbf{w}' (\mathbf{RWC} + \mathbf{ACB}) \leq 1 - \mathbf{w}' \mathbf{LA} \quad (2)$$

Where \mathbf{w} , \mathbf{r} , \mathbf{RWC} , \mathbf{LA} , and \mathbf{ACB} denote, respectively, the vector of holdings, normalized returns, normalized required regulatory capital, normalized loss allowance, and normalized additional capital buffer of N risky assets in an institution's portfolio; symbol $\mathbf{1}$ denotes a constant vector of ones; Σ denotes the assets' return covariance matrix.⁹ We assume a constant borrowing cost equal to the risk-free rate r_f . The latent variable ψ captures the institution's stakeholders' risk aversion levels.

Without loss of generality, we assume the institution's current equity before taking any loss allowance is one unit. The right-hand side of Equation (2) denotes the available equity after loss allowance, i.e., the capital supply, while the left-hand side of the equation denotes the minimum required capital plus additional capital buffer, i.e., the capital demand. Therefore, Equation (2) imposes the constraint that capital supply should always be no less than capital demand.

3.2. Additional Capital Buffer at the Instrument Level

While the framework is flexible enough to accommodate any values of additional capital buffers (\mathbf{ACB}) considered as appropriate by institutions, we next provide our thoughts on how these values can be determined.

As mentioned in Section 2, the amount of capital held today beyond the regulatory minimum at the portfolio level can be determined by analyzing the distribution of change in capital surplus at horizon. More formally, the portfolio level additional capital buffer ($\mathbf{ACB}_{P,t}$) can be set as the level required such that the probability of a capital breach at horizon (i.e., negative capital surplus at horizon) is only α^* . Here, the level of α^* is typically associated with the institution's risk appetite.

After determining portfolio-level additional capital buffer, it is then allocated to each instrument. We propose two methods.

First, recognizing the additional capital buffer is used against the uncertainty in capital surplus, we define Capital Surplus Risk Contribution (CSRC), to measure the marginal increase in portfolio capital surplus volatility due to increase in one-unit holding of instrument or sector i :¹⁰

$$CSRC_{j,t} = \frac{\partial w_P \sigma_{P,t+1}^{CS}}{\partial w_{j,t}} = \frac{cov(w_j CS_{j,t+1}, w_P CS_{P,t+1})}{w_{j,t} \sigma_{P,t+1}^{CS}} \quad (3)$$

Where $\sigma_{P,t+1}^{CS}$ is the normalized portfolio volatility of capital surplus, and $CS_{j,t+1}$ is the normalized instrument-level capital surplus at horizon. With CSRC, we can allocate the portfolio capital buffer to each instrument accordingly:

$$ACB_{j,t} = \frac{w_{j,t} CSRC_{j,t}}{\sigma_{P,t}^{CS}} \times ACB_{P,t} \quad (4)$$

Notice, this approach recognizes that each asset's contribution to the uncertainty in capital surplus is different and depends upon concentration and diversification effects, along with other factors. Consequently, $\mathbf{ACB}_{j,t}$ will generally differ materially across instruments.

Alternatively, we can allocate additional capital buffer according to individual instruments' contribution to the tail risk of capital surplus. Since portfolio capital buffer is used to prepare for any unfavorable tail events in portfolio capital surplus (due to large negative earnings or increase in regulatory capital), instrument-level capital buffer can be allocated according to each instrument's contribution to tail events, where the portfolio capital surplus drops to a certain level. Mathematically, Capital Surplus Tail Risk Contribution (CSTRC) is defined as follows:

⁹ We use bold font to imply that the variable is either an $N \times 1$ column vector or an $N \times N$ matrix, differentiating it from a scalar variable.

¹⁰ See Appendix B for the proof of the derivation of the formula.

$$CSTRC_{j,t} := \frac{\partial(-w_p \Delta CS_{p,t})}{\partial w_j} \Big|_{-\Delta CS_{p,t} = ACB_{p,t}} = E(-\Delta CS_{j,t} | -\Delta CS_{p,t} = ACB_{p,t}) \quad (5)$$

In practice, the conditional expected value in Equation (5) is difficult to estimate. Instead, we can use the following approximation:

$$CSTRC_{j,t} \approx E(-\Delta CS_{j,t} | ACB_{p,t} - \epsilon \leq -\Delta CS_{p,t} \leq ACB_{p,t} + \epsilon) \quad (6)$$

where ϵ is a small positive number. With CSTRC, we can allocate the additional capital buffer to each notional unit of instrument or sector i :

$$ACB_{j,t} = \frac{w_{j,t} CSTRC_{j,t}}{\sum_{i=1}^N w_{i,t} CSTRC_{i,t}} \times ACB_{p,t} \quad (7)$$

Note, under both allocation measures, the additional capital allocated to individual instruments sum to top-of-the-house additional capital by design. The proof is straightforward and omitted for brevity.

4. Capital Allocation In the Presence of Capital Uncertainty

Levy and Xu (2017) derive a composite capital measure (CCM) that can be used to allocate capital across instruments or sectors. However, their measure is based on the same model developed by LKMZ, which does not address the uncertainty embedded in capital supply and demand dynamics. Based on the extended model framework described in Section 3, the CCM that also accounts for an institutions' need for additional capital buffer to counter uncertainty in capital surplus at horizon can be represented as follows

$$CCM_i = EC_i + DelR \times (RWC_i + ACB_i + LA_i) \quad (8)$$

Where

$$DelR = \max\left(1 - \frac{EC_p}{RWC_p + LA_p + ACB_p}, 0\right). \quad (9)$$

Appendix B shows the derivation of the formula. Levy and Xu (2017) point out that CCM has a few desirable characteristics for a capital allocation measure. For example, instrument CCM sum to top-of-the house capital. CCM also accounts for the full spectrum of economic risk, including concentration and diversification risk, and the regulatory capital requirement faced by each instrument. Our revised CCM retains these characteristics. Appendix B demonstrates instrument CCM aggregates to portfolio RWC along with the additional capital buffer. Sections 4.1 and 4.2 show that CCM reflects the full spectrum of economic risk as well as regulatory capital requirements.

4.1. CCM Accounts for RegC Requirement: Representing CCM as EC with a RegC Cost

We can view CCM as EC plus the implicit cost of RegC. As we see from Equation (8), the implicit cost of RegC is simply

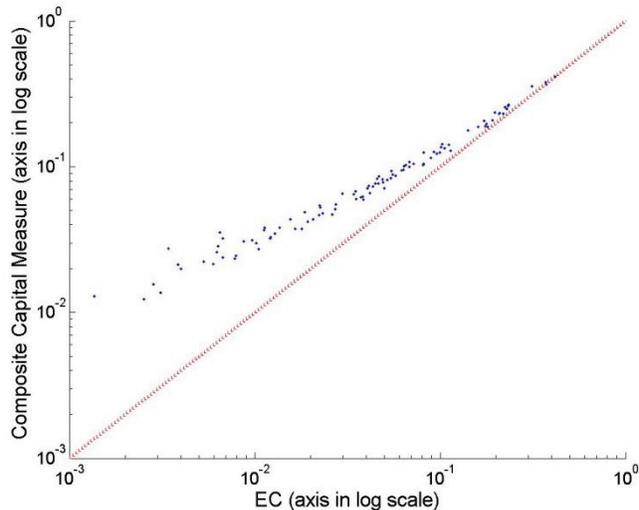
$$Implicit\ Cost\ of\ RegC = DelR \times (RWC_j + LA_j + ACB_j) \quad (10)$$

Note, this implicit cost is instrument-specific but always positive. It is determined by the instrument's minimum regulatory capital, loss allowance, portfolio capital surplus uncertainty contribution, and top-of-the-house deleverage ratio (DelR). DelR describes to what degree the institution is constrained by the total required capital compared to economic capital. Intuitively, the implicit cost of regulatory is higher for all instruments if the institution is constrained more by regulatory capital at top-of-the house level.

To visualize the implicit cost of regulatory capital, Figure 6 plots instrument CCM against EC—the implicit cost of regulatory capital is simply the difference between the two. We can see that the cost is relatively higher for instruments with a low-level of EC and lower for those with a high-level of EC. This dynamic is driven by higher quality credit attracting a relatively higher level of regulatory capital compared with EC under the Basel III rules.

However, it is noteworthy that, while regulatory capital is relatively high for safe instruments, CCM does not over-penalize safe instruments to the same degree as regulatory capital does, as its EC component is generally low for these instruments.

Figure 6 CCM versus EC.



4.2. CCM Accounts for Concentration Risk: Representing CCM as RegC with a Concentration Charge

We can also view CCM as regulatory capital adjusted for economic risk unaccounted by effective capital, most notably concentration/diversification risk.

Mathematically, we can express CCM as the sum of effective capital and the difference between economic capital and deleveraged effective capital:

$$CCM_j = (RWC_j + LA_j + ACB_j) + (EC_j - (1 - DelR) \times (RWC_j + LA_j + ACB_j)) \quad (11)$$

Note, deleveraged effective capital can be written as:

$$(1 - DelR) \times (RWC_j + LA_j + ACB_j) = \frac{RWC_j + LA_j + ACB_j}{RWC_p + LA_p + ACB_p} EC_p \quad (12)$$

Which is portfolio economic capital allocated to individual instruments through instrument-effective capital. The second term on the right-hand side of Equation (11) captures the difference between how economic capital and effective capital are allocated toward individual instruments. Since neither minimum required capital nor the loss allowance of an instrument is affected by portfolio composition, these two metrics do not account for concentration and diversification effects. Consequently, the main difference between economic capital and effective capital comes from concentration and diversification. For an instrument that is highly correlated with the rest of the portfolio, this difference is likely to be large. In this case, CCM is typically higher than effective capital, so that the optimal capital allocation reflects the instrument's high risk contribution to the portfolio.

On the other hand, if an instrument provides significant diversification benefits to the portfolio, CCM can be much lower than the effective capital. At the portfolio level, the instrument concentration and diversification adjustment average out to zero, causing the portfolio CCM to be equal to portfolio-effective capital.

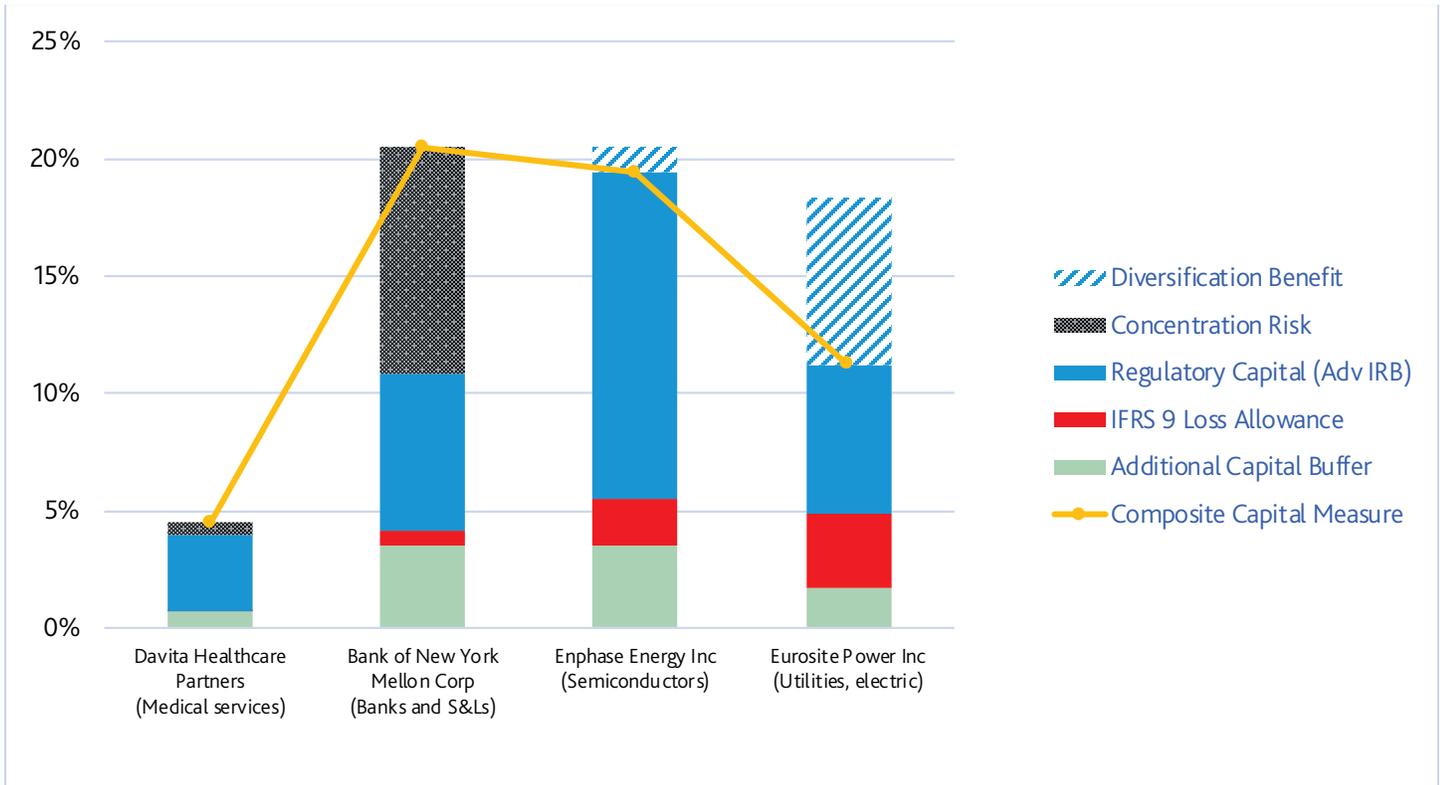
Figure 7 shows the breakdown of CCM for four borrowers in a sample loan portfolio.

Among the four borrowers, Bank of New York Mellon has the highest CCM per unit holding (20%), even though its effective capital is much smaller (11%) than that of Enphase Energy, Inc. (21%) and Eurosite Power, Inc. (18%), because it has large concentration risk, while the other two obligors provide more diversification benefits to the portfolio.

Looking further, the Bank of New York Mellon has relatively low minimum regulatory capital and low loss allowance due to its high credit quality. However, it is also highly sensitive to systematic shocks, and the portfolio is highly concentrated in the financial industry, with 40% allocation. These factors result in high risk contribution and economic capital, despite the borrower's high credit quality and, thus, a large, positive difference between economic capital and effective capital.

In contrast, Eurosite Power and Eurosite Power have much higher regulatory capital requirements due to relatively lower credit qualities. However, since they are less sensitive to systemic macroeconomic shocks, and the portfolio has low allocation to utilities and electric and semiconductors sectors, their economic capital is significantly lower than their effective capital, resulting in a relatively low CCM.

Figure 7 CCM breakdown.



5. Business Decisions In the Presence of Capital Uncertainty

This section explores CCM applications using a number of case studies. We demonstrate how CCM allows an organization to achieve an optimally performing portfolio while recognizing capital constraints.

5.1. CCM RORAC

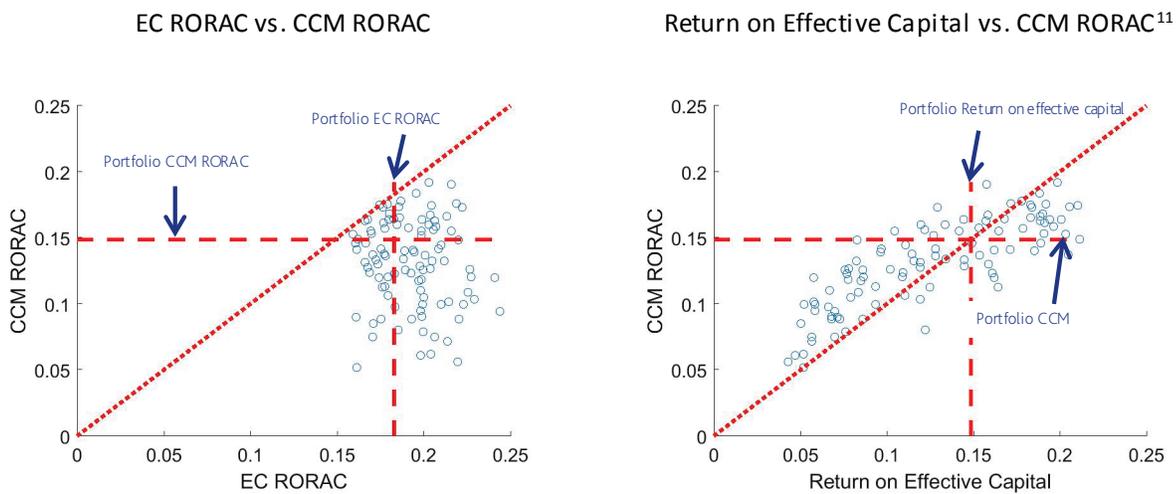
Levy and Xu (2016) show when CCM is used in a RORAC-style business decision rule, a portfolio's risk-return profile will improve, while allowing the organization to adhere to its regulatory capital requirements:

$$CCM\ RORAC_i = \frac{ES_i}{CCM_i} + r_f \quad (13)$$

In the presence of capital uncertainty at horizon, we can also compute CCM RORAC according to Equation (13). In this case, following a RORAC-style business decision rule—buy instruments with high CCM RORAC and sell those with low CCM RORAC—an institution can improve its portfolio risk-return trade-off while adhering to the minimum RegC requirement at present and limiting the likelihoods of a capital breach in the future.

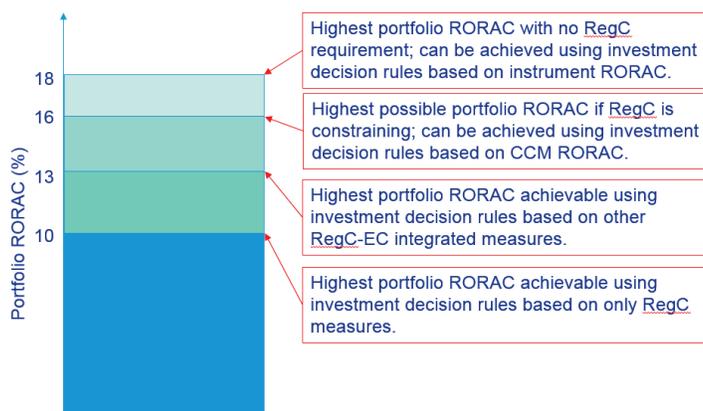
Figure 8 compares CCM RORAC with more traditional measures—EC RORAC and Return on regulatory capital. We can see that CCM RORAC can differ significantly from traditional EC RORAC, even though CCM and EC usually have very high rank correlation, as seen in Figure 6. The distortion occurs due to the relative difference between the effective capital for safe and risky instruments as a percentage of CCM; effective capital only includes the effects of RegC, loss allowance and the additional capital buffer.

Figure 8 CCM RORAC.



In general, managing a portfolio according to CCM RORAC leads to the optimal risk-return profile that adheres to a RegC constraint, as illustrated in Figure 9.

¹¹ Return on effective capital is defined as the expected spread of an instrument divided by the effective capital associated with the instrument, plus the risk-free rate.

Figure 9 Implications of Different RORAC Measures.¹²

5.2. CCM RORAC Case Study

This section illustrates the implications of using CCM RORAC, EC RORAC, and Return on RegC when making business decisions. We explore a small portfolio with four counterparties from different country and industry sectors that are otherwise identical (e.g., PD, LGD, Maturity, etc.). Terms and conditions of each of the exposures are also identical. Table 3 reports EC, RegC (Basel III Adv. IRB), CCM, and corresponding RORAC measures for each.

We can see that regulatory capital is the same for all instruments, as the value of RegC is portfolio-independent and does not account for country and industry concentrations. This means that measures calculated purely based on RegC do not differentiate the four counterparties. Consequently, the Return on RegC for all four names is identical, indicating that no name should be preferred to another. However, the EC allocated to these counterparties is different, as they differ in portfolio-referent risk. In particular, Counterparty 2 is relatively less risky, because it is the only name belonging to the Mining industry, thus providing some diversification benefit. The same goes for Counterparty 4, the only Chinese name. The diversification benefits of 2 and 4 are reflected by their lower level of EC and CCM. As a result, CCM RORAC for these two names is higher than 1 and 3, suggesting the institution can improve portfolio performance by increasing their holdings in 2 and 4, and reducing their holdings in 1 and 3.

TABLE 3

Impact of Industry and Country Concentration on Business Decisions

ID	1	2	3	4
COUNTRY	USA	USA	USA	CHN
INDUSTRY	Banking	Mining	Banking	Banking
MINIMUM REGC	9.0%	9.0%	9.0%	9.0%
EC	18.9%	16.9%	18.9%	16.9%
CCM	22.3%	20.3%	22.3%	20.3%
EXPECTED SPREAD	1.25%	1.25%	1.25%	1.25%
EC RORAC	7.6%	8.4%	7.6%	8.4%
RETURN ON REGC	14.7%	14.7%	14.7%	14.7%
CCM RORAC	6.6%	7.2%	6.6%	7.2%
EC ACTION	Sell	Buy	Sell	Buy
REGC ACTION	Hold	Hold	Hold	Hold
CCM ACTION	Sell	Buy	Sell	Buy

In the above stylized example, the impact of industry and country concentration is straightforward enough, so that one does not necessarily need to know the value of CCM RORAC to make the correct business decision. In many other cases, however, the correct decision is not obvious unless a single statistic such as CCM RORAC is produced. For example, we assume in the following stylized

¹² Exact values of portfolio RORAC in this diagram are for illustration only. Actual values vary by portfolio, even though the order of portfolio RORAC does not change.

example that all four names have different remaining maturities and coupon rates but otherwise identical characteristics. In general, the longer the maturity, the riskier the asset but also the higher the annualized return. In this case, the EC RORAC of 2 and 3 is higher than portfolio EC RORAC—so the institution should increase holdings in 2 and 3, if no RegC requirement existed. However, since Basel requirements are relatively low for long-dated assets, the return on RegC for 3 and 4 is higher than the overall portfolio. This finding is not the case for 2. As a result, the business decisions implied by EC RORAC and return on RegC contradict one another for 2 and 4. To reach the correct business decision for 2 and 4, we must resort to CCM RORAC, which accounts for both the true risk of each name and the relative RegC cost associated with it.

TABLE 4

Impact of Maturity on Business Decisions

ID	1	2	3	4
MATURITY (YRS)	2	4	6	8
MINIMUM REGC	5.8%	7.9%	9.0%	9.0%
EC	9.5%	14.7%	23.7%	32.3%
CCM	11.6%	17.1%	26.1%	34.6%
EXPECTED SPREAD	0.45%	0.95%	1.53%	1.97%
EC RORAC	5.8%	7.5%	7.4%	7.1%
RETURN ON REGC	8.8%	13.0%	17.5%	21.5%
CCM RORAC	4.9%	6.6%	6.8%	6.7%
EC ACTION	Sell	Buy	Buy	Sell
REGC ACTION	Sell	Sell	Buy	Buy
CCM ACTION	Sell	Buy	Buy	Buy

5.3. Portfolio Improvement

The cases in Section 5.2 demonstrate that CCM RORAC measures the risk-return attractiveness of each instrument in a portfolio facing constraining RegC. But what exactly is the implication of making business decisions according to CCM RORAC? Similar to EC RORAC, making decisions according to CCM RORAC increases overall portfolio EC RORAC; it allows one to achieve the maximum EC RORAC while adhering to RegC requirements, while properly buffering for capital surplus dynamics.¹³

Table 5 illustrates how a portfolio can be improved according to CCM RORAC. In this example, we start with a randomly generated portfolio of 10 loans with different characteristics such as PD, LGD, maturity, etc. We then calculate CCM RORAC for each loan and rebalance the portfolio accordingly—invest \$100 in the instrument with the highest CCM RORAC and sell \$100 of the instrument with the lowest CCM RORAC.¹⁴ After the rebalance, we recalculate the CCM RORAC for each instrument in the resulting portfolio and then rebalance again, so on and so forth. Table 5 shows the portfolio composition and instrument's CCM RORAC ranking for the original portfolio and the portfolio after the first two rebalances.

¹³ As a result of the RegC constraint, the optimal achievable EC RORAC is generally lower than the unconstrained case with no RegC requirements.

¹⁴ We place a short selling constraint, so if, at any point during the rebalance process, the instrument has the lowest CCM RORAC and does not have more than \$100 in holdings, we would keep that instrument in the portfolio and sell \$100 dollar of the instrument with the second lowest CCM RORAC instead.

TABLE 5

Example of Portfolio Rebalance According to CCM RORAC

INITIAL HOLDING				- \$100 INSTRUMENT 8; + \$100 INSTRUMENT 2				- \$100 INSTRUMENT 8; + \$100 INSTRUMENT 1		
ID	Holding	Rank		ID	Holding	Rank		ID	Holding	Rank
1	500	2		1	500	1		1	600	2
2	400	1	→	2	500	5	→	2	500	1
3	400	7		3	400	7	→	3	400	7
4	500	5	→	4	500	4	→	4	500	5
5	500	6		5	500	6	→	5	500	6
6	600	8	→	6	600	8	→	6	600	8
7	700	4		7	700	2		7	700	4
8	300	10	→	8	200	10	→	8	100	10
9	300	3		9	300	3	→	9	300	3
10	1000	9		10	1000	9		10	1000	9

Table 6 shows the portfolio EC RORAC, the return on total RegC, and the ratio between portfolio return and capital surplus volatility after the first six rebalances according to CCM RORAC. We can see that after each round of rebalancing, the portfolio EC RORAC and return on equity improves. Furthermore, the ratio of portfolio return over the capital surplus volatility also increases, which implies that the source of capital uncertainty is being better compensated.

TABLE 6

Results of Portfolio Rebalance According to CCM RORAC

STEP	REBALANCE	EC RORAC	ROE	$\frac{ES_p}{\sigma(\Delta CS_p)}$
0	Initial Portfolio	11.5%	8.5%	63.7%
1	+100 Instrument 2 -100 Instrument 8	11.8%	8.6%	64.5%
2	+100 Instrument 1 -100 Instrument 8	11.9%	8.6%	65.2%
3	+100 Instrument 9 -100 Instrument 10	12.2%	8.7%	65.5%
4	+100 Instrument 7 -100 Instrument 10	12.2%	8.8%	66.0%
5	+100 Instrument 4 -100 Instrument 6	12.3%	8.9%	66.6%
6	+100 Instrument 5 -100 Instrument 10	12.6%	9.0%	66.9%

6. Summary

This paper presents a new capital allocation measure that accounts for the economic risks, minimum required regulatory capital, loss accounting, and dynamics in capital demand and supply. Our approach builds on the modeling framework developed in Levy and Xu (2017) and incorporates the need for an additional capital buffer to limit the possibility of a future capital breach resulting from capital surplus volatility. This new measure is particularly relevant for institutions with illiquid assets that cannot be sold quickly to raise capital. The measure is ever more important with the introduction of CECL and IFRS 9, which likely result in higher earnings volatility. Using a series of case studies, we demonstrate how business decisions based on the new measure improve portfolio performance.

Appendix A: Variable Definitions

PORTFOLIO EARNINGS

The normalized portfolio earnings E_p during a period is defined as portfolio interest income during that period minus loss provision minus charge-off due to default normalized by portfolio holding amount. It is the weighted average of instrument-normalized earnings E_i .

PORTFOLIO EARNINGS VOLATILITY

The normalized portfolio earnings volatility σ_p^E during a time period is the standard deviation of portfolio earnings during the period divided by the portfolio holding amount.

EARNINGS RISK CONTRIBUTION (ERC)

Normalized ERC of an instrument is defined as its relative contribution to portfolio earnings volatility due to one unit increase in the holding of the instrument:

$$\text{Normalized ERC}_i := \frac{\partial w_p \sigma_p^E}{\partial w_i} = \frac{\frac{1}{2} \frac{\partial (w_p \sigma_p^E)^2}{\partial w_i}}{\sigma_p^E} = \frac{\frac{1}{2} (2w_i (\sigma_i^E)^2 + 2 \sum_j \text{cov}(E_i, E_j))}{\sigma_p^E} = \frac{\text{Cov}(E_i, E_p)}{w_i \sigma_p^E} \quad (14)$$

PORTFOLIO CAPITAL SURPLUS

The normalized portfolio capital surplus CS_p during a time period is the difference between the total available capital buffer and the required capital divided by the portfolio holding amount.

Appendix B: Derivations

DERIVATION OF EQUATION (3) FROM THE DEFINITION OF CSRC

$$CSRC_{j,t} := \frac{\partial w_P \sigma_{P,t+1}^{CS}}{\partial w_{j,t}} \quad (15)$$

Proof:

First, note portfolio capital surplus volatility has the following form:

$$w_P \sigma_{P,t}^{CS} = \sqrt{\sum_{i=1}^N \sum_{j=1}^N Cov(w_{i,t} CS_{i,t+1}, w_{j,t} CS_{j,t+1})} = \sqrt{\sum_{i=1}^N \sum_{j=1}^N w_{i,t} \times w_{j,t} \times Cov(CS_{i,t+1}, CS_{j,t+1})} \quad (16)$$

Plugging Equation (16) into the definition of CSRC, we have

$$\begin{aligned} CSRC_{k,t} &= \frac{\partial \sqrt{\sum_{i=1}^N \sum_{j=1}^N w_{i,t} \times w_{j,t} \times Cov(CS_{i,t+1}, CS_{j,t+1})}}{\partial w_{k,t}} \\ &= \frac{\sum_{j=1}^N w_{j,t} \times Cov(CS_{k,t+1}, CS_{j,t+1})}{\sqrt{\sum_{i=1}^N \sum_{j=1}^N w_{i,t} \times w_{j,t} \times Cov(CS_{i,t+1}, CS_{j,t+1})}} \end{aligned} \quad (17)$$

Multiply both the numerator and denominator in Equation (17) by $w_{k,t}$, we have

$$CSRC_{k,t} = \frac{\sum_{j=1}^N Cov(w_{k,t} CS_{k,t}, w_{j,t} CS_{j,t})}{N_{k,t} \times \sqrt{\sum_{i=1}^N \sum_{j=1}^N w_{i,t} \times w_{j,t} \times Cov(CS_{i,t}, CS_{j,t})}} = \frac{cov(w_{k,t} CS_{k,t}, w_P CS_{P,t})}{w_k \sigma_{P,t}^{CS}} \quad (18)$$

DERIVATION OF EQUATION (5)

Proof:

Start from the definition of CSTRC:

$$CSTRC_{j,t} := \frac{\partial (-w_P \Delta CS_{P,t+1})}{\partial w_{j,t}} \Big|_{-\Delta CS_{P,t} = ACB_{P,t}} \quad (19)$$

First note, the sum of instrument capital surplus at horizon conditional on the fact portfolio capital surplus is equal to $ACB_{P,t}$ is by construction exactly $ACB_{P,t}$:

$$E \left(\sum_{i=1}^N w_{j,t} \times (-\Delta CS_{i,t}) \mid -\Delta CS_{P,t} = ACB_{P,t} \right) = w_P \times ACB_{P,t} \quad (20)$$

Therefore,

$$CSTRC_{j,t} = \frac{\partial E \left(\sum_{i=1}^N w_{i,t} \times (-\Delta CS_{i,t}) \mid -\Delta CS_{P,t} = ACB_{P,t} \right)}{\partial w_{j,t}} \quad (21)$$

Because both the conditional expectation and the summation in equation (21) are linear operators, the partial derivative operation can be carried out directly inside the summation:

$$CSTRC_{j,t} = E \left(\sum_{i=1}^N \frac{\partial (w_{i,t} \times (-\Delta CS_{i,t}))}{\partial w_{j,t}} \mid -\Delta CS_{p,t} = ACB_{p,t} \right) \quad (22)$$

Since the partial derivative is zero for all $j \neq i$ and is $-\Delta CS_{i,t}$ for $j = i$, we have

$$CSTRC_{j,t} = E(-\Delta CS_{j,t} \mid -\Delta CS_{p,t} = ACB_{p,t}) \quad (23)$$

DERIVATION OF THE FORM OF CCM

The problem can be re-written as

$$\max \left(\mathbf{w}' E(\mathbf{r}) + (1 - \mathbf{w}' \mathbf{1}) r_f - \frac{1}{2} \psi \mathbf{w}' \Sigma \mathbf{w} \right) \quad (24)$$

$$\text{s.t.} \quad \mathbf{w}' \mathbf{RWC}^* \leq 1 \quad (25)$$

$$\mathbf{RWC}^* = \mathbf{RWC} + \mathbf{LA} + \mathbf{ACB} \quad (26)$$

Levy and Xu (2017) proves that at the optimal, the following would hold

$$\frac{E(\mathbf{r}_i) - r_f}{CCM_j^*} + r_f = \frac{E(r_p) - r_f}{CCM_p^*} + r_f \quad (27)$$

And

$$CCM_j^* = EC_j + DelR \times RWC_j^* \quad (28)$$

Substituting Equation (26) into Equation (28)

$$CCM_j^* = EC_j + DelR \times (RWC_j + LA_j + ACB_j) \quad (29)$$

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