Rating System Dynamics and Bank-Reported Default Probabilities under the New Basel Capital Accord

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Abstract: This paper uses a stylized model of credit rating systems to examine the interaction between a bank's rating philosophy and the default probabilities (PDs) it will be required to report under new regulatory capital standards being developed by the Basel Committee on Banking Supervision (Basel II). I show that the process of assigning obligors to rating grades and then estimating long-run average pooled PDs for each grade prescribed by the Basel Committee does not draw a direct link between the actual likelihood of default associated with an individual obligor and the pooled PD associated with the grade to which the obligor is assigned. As a result, the dynamic properties of the PDs assigned to obligors under Basel II depend on a bank's rating philosophy. This finding has implications for the cyclicality of regulatory capital requirements. Capital requirements for banks that adopt point-in-time rating systems can be expected to be more cyclical than those for banks that adopt through-the-cycle rating systems. It also has implications for the supervisory validation of the pooled PDs that banks report. Accurately benchmarking pooled PDs across banks will require that supervisors account for differences in rating philosophies. Backtesting pooled PDs against observed default frequencies will be most effective when banks adopt point-in-time rating systems.

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* The views expressed here are solely those of the author. They do not reflect the opinions of the Board of Governors of the Federal Reserve System or its staff.

1. Introduction

New bank capital adequacy rules being developed by the Basel Committee on Banking Supervision are intended to more closely align minimum regulatory capital requirements with the underlying economic risks embedded in bank asset portfolios. Under the more advanced internal ratings-based (IRB) capital standards included in the new accord, sophisticated banks will be required to report estimated one-year probabilities of default (PDs) for their credit exposures. These PDs, along with other risk parameters such as recovery rates and maturities, will be used by supervisors to determine IRB banks' credit-risk capital requirements.

The process by which IRB banks must assign PDs to obligors is clearly articulated in the Basel Committee's third consultative paper (CP3) released in June of last year (BCBS, 2003). An IRB bank must first slot obligors into "risk buckets" corresponding to internal rating grades. All obligors within a bucket should share the same credit quality as assessed by the bank's internal credit rating system. Once obligors have been grouped into risk buckets the bank must calculate a "pooled PD" for each bucket that reflects the observed long-run average default frequency for that bucket. The capital charges associated with credit exposures to an obligor will be determined by the pooled PD for the risk bucket to which the obligor is assigned.

CP3 establishes minimum standards for IRB banks' credit monitoring processes, but it permits banks a great deal of latitude in determining how obligors are assigned to risk buckets. In practice, approaches to rating credit exposures can be grouped into two broad categories: point-in-time (PIT) approaches, and through-the-cycle (TTC) approaches. Under PIT rating systems, obligors are slotted into risk buckets based on the best available information about their current credit quality. Obligors are rapidly transitioned to new buckets as their current credit quality changes. In general, PIT ratings tend to rise during business expansions as most obligors' creditworthiness improves and tend to fall during recessions. Under TTC rating systems, obligors are assigned to rating grades based on evaluations of their abilities to remain solvent at the trough of a business cycle or during severe stress events. Because they place weight on stress conditions rather than current conditions, TTC ratings tend to change less often than PIT ratings and they tend to be more stable over the business cycle.

This paper uses a stylized model of obligor credit quality and bank rating systems to examine the interaction between a bank's rating philosophy and the pooled PDs it would be required to estimate under Basel II. I show that the process of assigning obligors to risk buckets and then estimating long-run average default frequencies for each risk bucket prescribed in CP3 does not draw a direct link between the actual likelihood of default associated with an individual obligor and the pooled PD associated with the grade to which the obligor is assigned. As a result, the dynamic properties of the PDs assigned to obligors under Basel II depend on a bank's rating philosophy. Under a PIT philosophy the PDs assigned to individual obligors will be more volatile and can be expected to move counter-cyclically. In contrast, the PDs arising from a TTC system will be more stable and will be cyclically neutral.

This result has important implication for Basel II capital requirements. Since the new accord will apply a fixed rule mapping pooled PDs to regulatory capital charges, the minimum capital requirements imposed on banks with PIT rating systems will be more volatile and will move more counter-cyclically than those imposed on similar banks with TTC rating systems. During economic downturns the capital required for banks with TTC rating systems may not be sufficient to meet a fixed regulatory solvency target.

The result also has implications for the way bank-reported pooled PDs are evaluated by bank supervisors. Supervisors plan to validate pooled PDs using two empirical techniques: benchmarking and backtesting. Benchmarking involves comparing reported PDs for similar obligors across banks. The idea is that banks that systematically misrepresent PDs or simply do not estimate them effectively will report different PDs from their peers. The analysis of this paper suggests that because reported PDs can be expected to vary from bank to bank depending on each bank's rating philosophy, supervisors must account for differences in rating philosophies when benchmarking pooled PDs.

Backtesting compares the reported pooled PD for a grade with observed default frequencies for that grade. Because there are significant cross-sectional correlations in defaults, the observed default frequency for a given grade in a given year is unlikely to match that grade's pooled PD. However, the effects of different systematic shocks should tend to cancel one-another out on average, so that over time a risk bucket's average default rate can be expected to converge to a it's true pooled PD. This paper shows that the variation in observed default frequencies around a grade's true pooled PD is greater for TTC rating systems than for PIT rating systems. Obligors assigned to a PIT risk bucket should share the similar one-year-ahead default probabilities regardless of the stage of the business cycle, whereas the one-year-ahead default probabilities for obligors assigned to a TTC risk bucket will change in a systematic way over the business cycle. As a result, the observed default frequencies for a TTC bucket exhibit cyclical variation as well as variation associated with systematic risk, while observed default frequencies for a PIT risk bucket only exhibit variation arising only from systematic risk. Over a fixed time horizon, backtesting will be more accurate when banks deploy PIT rating systems.

This paper is organized as follows. Section 2 describes the proposed Basel II capital accord in some detail, and briefly discusses recent academic research on the differences between PIT and TTC rating systems. Section 3 develops a simple analytical model of obligor default and defines PIT and TTC rating systems in the context of this model. Section 4 derives closed-form solutions for the "true" pooled PDs associated with PIT and TTC risk buckets and shows how the distribution of pooled PDs assigned to obligors over a business cycle depends on a bank's rating philosophy. Sections 5 and 6 examine the implications the results developed in Sections 3 and 4 for the design and implementation of a risk-based capital framework. Section 5 shows how the capital required to meet a fixed solvency target will depend on a bank's rating philosophy. Section 6 shows how a banks' rating philosophy will affect the supervisory validation of the pooled PDs it reports. Section 7 illustrates the major conclusions of this paper using historical data from a stylized PIT rating system and a TTC rating system.

2. Background and related literature

In drafting the Basel II capital accord, the Basel Committee has had to confront a tradeoff between bank managers' desire to leverage their own internal economic capital management processes to the fullest extent possible and bank supervisors' need to ensure that capital rules are applied in an effective and consistent manner across banks. The proposed internal-ratings based approach to calculating credit risk capital requirements reflects a studied balancing of these objectives. Subject to supervisory review, IRB banks will be allowed to make use of their own internal credit rating systems and data warehouses to associate a probability of default (PD), a loss-given-default (LGD), and an exposure-at-default (EAD) parameter with each of their credit exposures. However, Basel II stops short of allowing IRB banks to apply their internal economic capital models directly. Instead, a stylized portfolio credit-risk model will be used to derive regulatory capital requirements from bank-reported PDs, LGDs, and EADs.

To determine the capital charge for an individual exposure, the Basel Committee uses a simple Merton (1974) default-threshold model similar to that underlying industry-standard credit risk management tools. Gordy (2003) shows that such a model can be used to derive a value-at-risk capital rule under stylized assumptions about the way common shocks generate correlations in realized lose rates across exposures. These assumptions are discussed briefly in Section 5. Collectively they are called the asymptotic-single-risk-factor (ASRF) framework. ¶241 of CP3 proposes a function derived from the ASRF/Merton model that maps an exposure's PD, LGD, and EAD to a regulatory capital charge.

CP3 requires that bank-reported PDs be derived from a two-stage process.[1] In the first stage a bank must assign to each of its obligors a rating grade (called a risk bucket in Basel parlance) based on well-articulated rating criteria. In the second stage a "pooled PD" is calculated for each grade, and this PD is assigned to each obligor in a given grade. CP3 ¶409 requires that the pooled PD for a grade must be "a long-run average of one-year realized default rates for borrowers in the grade." These pooled PDs are a step removed from the default probabilities a forecasting model would associate with individual obligors. Because pooled PDs are assigned to rating grades rather than directly to individual obligors, a bank's approach to determining credit ratings can have a material effect on the PDs it reports, and hence, on its regulatory capital requirements.

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1 CP3, ¶408 through ¶413 set out broad standards for the quantification of IRB risk components including PDs. ¶423 through ¶425 discuss specific requirements for assigning pooled PDs to risk buckets. ¶254 stipulates that pooled PDs should be linked to risk buckets rather than directly to obligors. ¶414 through ¶419 define the default event that PDs are intended to forecast.

Practitioners typically classify rating systems as embodying either a point-in-time philosophy or a through-the-cycle philosophy. Though these terms are often poorly defined, a PIT rating system is commonly understood to focus on the current conditions faced by an obligor, whereas a TTC rating system takes a longer-term view of an obligor's creditworthiness. In a survey of bank rating practices the Basel Committee's Models Task Force proposes the following characterization of PIT and TTC rating systems (BCBS, 2000, pg. 3).

> In a point-in-time process, an internal rating reflects an assessment of the borrower's current condition and/or most likely future condition over the course of the chosen time horizon. As such, the internal rating changes as the borrower's condition changes over the course of the credit/business cycle. In contrast, a "through-the-cycle" process requires assessment of the borrower's riskiness based on a worst-case, "bottom of the cycle scenario", i.e. its condition under stress. In this case, a borrower's rating would tend to stay the same over the course of the credit/business cycle.

CP3 lays out minimum standards for the design and implementation of internal rating systems including the assessment horizon used for rating obligors. While CP3 does not explicitly require that a bank adopt either a point-in-time or a through-the-cycle rating approach, CP3 ¶376 and ¶377 suggest a preference for TTC methodologies.

> A borrower rating must represent the bank's assessment of the borrower's ability and willingness to contractually perform despite adverse economic conditions or the occurrence of unexpected events…A bank may satisfy this requirement by basing rating assignments on specific, appropriate stress scenarios. Alternatively, a bank may satisfy the requirement by appropriately taking into account borrower characteristics that are reflective of the borrower's vulnerability to adverse economic conditions or unexpected events, without explicitly specifying a stress scenario. The range of economic conditions that are considered when making assessments must be consistent with current conditions and those that are likely to occur over a business cycle within the respective industry/geographic region.

In practice, there appears to be a great deal of heterogeneity among banks' rating methodologies. Because different people use the terms "point-in-time" and "through-the-cycle" differently, evaluating risk managers' subjective characterizations of their banks' rating philosophies is problematic. However, one can get a sense of the differences among banks' rating approaches from the time horizons they use for assessing credit quality. The aforementioned Models Task Force survey finds that a majority of banks in Basel Committee member countries report using a one-year time horizon, but a significant number report using horizons of between three and seven years or using a horizon linked to the maturity of each loan (BCBS, 2000, pg. 21). In a related survey of rating practices at the 50 largest US banks, Treacy and Carey (1998, 2001) report similar findings. While they conclude that bank internal ratings generally attempt to capture the current conditions faced by obligors, different banks use different time horizons for assessing creditworthiness; some use a one-year horizon, others focus on the life of the loan, and still others do not use an explicit horizon (Treacy and Carey, 1998, pg. 899).

The analysis that follows complements findings in research by Taylor (2003) and Carey and Hrycay (2001) on the implications of PIT and TTC rating philosophies. Taylor argues that a bank may wish to make adjustments to grade-based pooled PDs in order to manage the dynamics of its loss provisioning and economic or regulatory capital requirements. He points out that if the PD assigned to each rating grade is fixed, a TTC rating system will tend to imply relatively stable regulatory capital charges under Basel II, whereas a PIT system will produce capital requirements that move counter to the business cycle. Carey and Hrycay use empirical simulations to evaluate alternative approaches to quantifying the pooled PDs assigned to rating grades. Their work uncovers many potential sources of bias in estimated pooled PDs, including inconsistencies between the rating philosophies applied by banks and the rating philosophies applied by public rating agencies whose data may be needed to estimate pooled PDs.

3. A simple model of obligor credit quality and bank rating systems

This section develops a stylized model of obligor credit quality and its connection to point-in-time and through-the-cycle rating approaches. The model is quite simple, but capture the idea that credit quality is determined by both obligor-specific and systematic risk factors, only some of which can be observed by a bank at the time a credit rating is assigned. A PIT rating system is characterized as one which links an obligor's rating to its current likelihood of default. A TTC rating system is characterized as one which links an obligor's rating to its likelihood of default given a prescribed stress event. The modeling framework developed in this section is similar to that used by Löffler (2004) to study the information content of the through-the-cycle bond ratings provided by public rating agencies. The model developed here is a bit less general than that proposed by Löffler in that it imposes stronger assumptions about the number and dependence structure of stochastic risk factors. These simplifications allow one to derive relatively simple closed-form expressions for parameters of interest.

Default is modeled using a latent index of credit quality Z_{it}. that is unique to each obligor i and each date t. Obligor i defaults at date t if the realized value of Z_{it} lies below zero so Z_{it} can be viewed as a measure of obligor i's distance to default. Z_{it} evolves over time, and is assumed to depend on observable and unobservable risk factors and model parameters according to the formula

$$Z_{i,t+1} = \alpha + \beta_W W_i + \beta_X X_{it} + \beta_Y Y_t + U_{i,t+1}$$

W_i is a fixed risk factor intended to capture characteristics of obligor i that do not very over time such as industry and management quality. Y_t is a risk factor that affects the credit quality of all obligors in a bank's portfolio. It is intended to summarize that component of the macroeconomic environment that can be observed by a bank at date t. Lower (negative) values of Y_t correspond to economic recessions while higher (positive) values correspond to expansions. The risk factor X_{it} captures those dynamic characteristics of obligor i that are observable at date t and could not have been predicted given Y_t, so X_{it} is independent of Y_t. Taken together W_i, Y_t, and X_{it} represent the full set of information available to a bank for assessing the credit quality of obligor i at date t. The β parameters are assumed to be positive so that each risk factor is negatively related to credit quality.

$U_{i,t+1}$ reflects that information that affects an obligor's default status at t+1 that cannot be observed by a bank at date t. Even after accounting for macroeconomic conditions observable at t, systematic risk will generate correlations in default outcomes across obligors. To capture this phenomenon we assume

$$U_{i,t+1} = \omega V_{t+1} + \sqrt{1-\omega^2} E_{i,t+1}$$

where V_{t+1} is a systematic risk factor shared by all obligors, and $E_{i,t+1}$ is an idiosyncratic risk factor that is unique to obligor i. The parameter ω determines the sensitivity of default to the unobservable systematic risk factor. A value of ω near one implies that conditional on observable information at date t, defaults among obligors at date t+1 are highly correlated events. Conversely, setting ω equal to zero implies that conditional on observable information at date t defaults at date t+1 are independent.

For simplicity, we assume that all risk factors have standard normal marginal distributions. Subject to this restriction, Y_t may depend on lagged values of V_t and Y_t. All other variables are assumed to be iid. Throughout this paper lower-case Greek letters denote model parameters, upper case Latin letters denote random variables, and lower-case Latin letters denote realizations of those random variables.

Given this simple model, one can calculate the one-year-ahead probability of default for obligor i at date t, given all information observable at date t. This is the unstressed PD for obligor i at date t, and is given by

$$\begin{aligned} UPD_{it} &= \Pr\left[Z_{i,t+1} < 0 \mid W_i = w_i, X_{it} = x_{it}, Y_t = y_t\right] \\ &= \Phi\left(-\left(\alpha + \beta_W w_i + \beta_X x_{it} + \beta_Y y_t\right)\right) \end{aligned} \tag{1}$$

It is also possible to derive the conditional likelihood that the obligor will default given the assumption of a severe economic downturn. In the default model developed here, the state of the macro economy at date t+1 is described by a weighted sum of the observable risk factor Y_t and the unobservable risk factor V_{t+1}. Thus an adverse stress scenario can be defined as the restriction

$$\beta_Y Y_t + \omega V_{t+1} = -\psi$$

where ψ is a fixed parameter. The larger is ψ, the more pessimistic is the stress scenario. The stress PD for obligor i at date t that incorporates this scenario is given by

$$\begin{aligned} SPD_{it} &= \Pr\left[Z_{i,t+1} < 0 \mid W_i = w_i, X_{it} = x_{it}, \beta_Y Y_t + \omega V_{t+1} = -\psi\right] \\ &= \Phi\left(-\frac{\alpha + \beta_W w_i + \beta_X x_{it} - \psi}{\sqrt{1-\omega^2}}\right) \end{aligned} \tag{2}$$

By examining (1) one can see that obligor i's unstressed PD will tend to move counter-cyclically. It will increase during recessions as y_t falls, and it will decrease during expansions as y_t rises. In contrast (2) implies that i's stress PD does not depend on y_t, so it will not be correlated with the observed state of the business cycle.

In assigning obligors to risk buckets, banks use exactly the same information needed to estimate default probabilities. As a result, for modeling purposes it is reasonable to assume that a bank will group obligors into risk buckets in such a way that obligors within a bucket share similar default probabilities. This approach is consistent characterizations of prototype rating systems suggested by Krahnen and Weber (2001) and Crouhy, Galai, and Mark (2001). Viewed in this light, the two canonical rating philosophies – point-in-time and through-the-cycle – reflect differences in the PDs that banks use for risk bucketing. Under a point-in-time rating system all obligors in a bucket should share similar unstressed PDs. Under a through-the-cycle rating system all obligors in a bucket should share similar stress PDs.

To abstract from complications associated with the definition of rating buckets we will assume that rating systems are continuous in the sense that each unique obligor PD is associated with a unique rating grade. The PIT rating assigned to obligor i at date t is defined by the mapping function

(3) $$\Gamma^{PIT}\left(w_i, x_{it}, y_t\right) = \alpha + \beta_W w_i + \beta_X x_{it} + \beta_Y y_t$$

so that the unstressed PD for any obligor assigned the PIT rating γ is the constant

(4) $$UPD^{PIT}\left(\gamma\right) = \Phi\left(-\gamma\right)$$

In similar fashion, the TTC rating assigned to obligor i at date t is defined by the mapping function

(5) $$\Gamma^{TTC}\left(w_i, x_{it}\right) = \alpha + \beta_W w_i + \beta_X x_{it}$$

so that the stress PD for any obligor assigned the TTC rating γ is the constant

(6) $$SPD^{TTC}\left(\gamma\right) = \Phi\left(\frac{-\gamma + \psi}{\sqrt{1 - \omega^2}}\right)$$

In both cases higher ratings correspond to lower PDs.

By construction, the stress PD associated with a particular TTC rating will be fixed over the business cycle. This is not true of the unstressed PDs , however, as can be seen by observing that

(7) $$UPD^{TTC}\left(\gamma\right) = \Phi\left(-\gamma - \beta_Y y_t\right)$$

Recall that y_t describes the observed state of the business cycle at date t, so (7) must move counter-cyclically. This makes sense since holding obligor characteristics fixed, one would expect to observe higher unstressed default probabilities during recessions than expansions.

A PIT rating system is designed so that the unstressed PD associated with a particular rating will be fixed over time, but this does not imply that the stress PDs for associated with a particular PIT rating will remain fixed. The stress PD for an obligor with a PIT rating of γ is

$$(8) \qquad SPD^{PIT}(\gamma) = \Phi\left(\frac{-\gamma + \psi + \beta_Y y_t}{\sqrt{1-\omega^2}}\right)$$

y_t enters (8) with a positive sign so the stress PD associated with γ^{PIT} moves pro-cyclically. It rises during economic expansions and falls during recessions. This somewhat surprising result arises from the fact that as overall economic conditions improve, higher quality obligors (those with better realizations of W_i and X_{it}) transition to higher PIT grades so for a given PIT grade the average quality of obligors declines.

Equations (4), (6), (7), and (8) imply our first result concerning the relationship between a bank's ratings philosophy and the one-year-ahead PDs associated with rating grades

RESULT 1: *The PDs for obligors assigned to a given rating grade will exhibit the following behavior over the business cycle*

		Rating Philosophy	
		PIT	*TTC*
PD Type	*Unstressed*	*Fixed*	*Counter-cyclical*
	Stress	*Pro-cyclical*	*Fixed*

As we shall see in the next section this result does not apply to the pooled PDs that must be calculated under Basel II. Rather it applies to the actual unstressed and stress PDs for the obligors in a grade.

4. Assigning pooled PDs to rating grades and obligors

Having described a stylized model of obligor default and defined two classes of rating systems, we are now in a position to examine the pooled PDs associated with rating grades. To abstract from the process of estimating pooled PDs, this section will focus on properties of the "true" pooled PD for each grade. It will present analytic expressions for the expected observed default frequencies for rating grades that do not condition on the current state of the business cycle. These pooled PDs correspond to the population analogues of the "long-run average of observed default frequencies" prescribed in CP3. They are the pooled PDs that banks would report if they had complete information on of the parameters of the stochastic obligor default model specified in Section 2.

Let D_{it} be an indicator variable that is equal to one of obligor i defaults at date t and is equal to zero otherwise. The true pooled PD for a PIT risk bucket is given by

$$(9)\qquad \begin{aligned} PPD^{PIT}(\gamma) &= E\left[D_{i,t+1} \mid \Gamma^{PIT}(W_i, X_{it}, Y_t) = \gamma\right] \\ &= \Pr\left[Z_{i,t+1} \le 0 \mid \alpha + \beta_W W_i + \beta_X X_{it} + \beta_Y Y_t = \gamma\right] \\ &= \Phi(-\gamma) \end{aligned}$$

Recall that under Basel II the relevant PD for assessing a capital charge for an exposure to obligor i at date t is the pooled PD for the rating grade assigned to that obligor. Substituting (3) into (9) yields an expression for this pooled PD.

$$(10)\qquad PPD_{it}^{PIT} = \Phi\left(-\left(\alpha + \beta_W w_i + \beta_X x_{it} + \beta_Y y_t\right)\right)$$

Comparing (10) and (1) shows that the pooled PD for the PIT grade is the same as the unstressed PD of each of the obligors assigned that grade. This is an appealing result. It implies that under a PIT rating system the pooled PDs that are required by Basel II should provide a good indication of the actual unstressed PDs for the obligors in a bank's portfolio.

This cannot be said of the pooled PDs generated by a TTC rating system. The pooled PD generated by a TTC rating system is given by

$$(11)\qquad \begin{aligned} PPD^{TTC}(\gamma) &= E\left[D_{i,t+1} \mid \Gamma^{TTC}(W_i, X_{it}) = \gamma\right] \\ &= \Pr\left[Z_{i,t+1} \le 0 \mid \alpha + \beta_W W_i + \beta_X X_{it} = \gamma\right] \\ &= \Phi\left(\frac{-\gamma}{\sqrt{1+\beta_Y^2}}\right) \end{aligned}$$

Substituting (5) into (11) yields the pooled PD assigned to obligor i under a TTC rating system.

$$(12) \qquad PPD_{it}^{TTC} = \Phi\left(\frac{-(\alpha + \beta_W w_i + \beta_X x_{it})}{\sqrt{1+\beta_Y^2}}\right)$$

(12) does not match either (1) or (2). Under a TTC rating system, the pooled PD assigned to an obligor reflects neither its unstressed nor its stress PD. Thus, when a bank adopts a TTC rating system, one cannot expect the pooled PDs required by Basel II to provide direct information on the likelihood of default of the obligors in the bank's portfolio.

The pooled PD assigned to obligor i at date t under a TTC system is independent of the observed macroeconomic risk factor y_t, whereas the pooled PD assigned under a PIT system is negatively related to y_t. Since other observable risk factors do not depend on macroeconomic conditions, we can draw the following conclusion.

RESULT 2: *The pooled PDs assigned to obligors under a TTC rating system are uncorrelated with observable macroeconomic conditions whereas those assigned under a PIT system are negatively correlated with observable macroeconomic conditions.*

Result 2 arises because of Basel II's two-stage approach to assigning PDs to obligors. Under a PIT system obligors with similar unstressed PDs are given the same grade, so the long-run average default frequency for a PIT grade provides a good approximation of the unstressed PDs of the obligors assigned that grade. As an obligor's unstressed PD changes over the business cycle, its rating grade and associated pooled PD changes as well. Under a TTC system the grade assigned to an obligor is not directly linked to its unstressed PD. An obligor's TTC grade and pooled PD tends to remain relatively stable over the business cycle even as its unstressed PD changes. As we shall see in Sections 5 and 6, the differing dynamics of pooled PDs under PIT and TTC rating systems have important implications for level and cyclicality of regulatory capital charges as well as the supervisory validation of pooled PDs.

5. Pooled PDs and risk-based capital requirements

Gordy (2003) demonstrates that if one assumes that a bank's portfolio is well-diversified and that cross-exposure dependence in realized losses is driven by a single systematic risk factor, then one can derive a simple economic capital rule. This rule can be applied on an exposure-by-exposure basis and results in a portfolio capital requirement that satisfies a specified value-at-risk solvency target π. Under this asymptotic-single-risk-factor (ASRF) framework, the capital assigned to an individual exposure is equal to the conditional expectation of losses on that exposure given a $1-\pi$ percentile draw of the systematic risk factor.

Assuming for simplicity that the loss given default for a credit exposure to obligor i is λ_i, one can apply the ASRF framework to derive economic capital charges under the default model developed in Section 3.[2] Conditional on all factors observable at date t, the only source of dependence in realized default rates is the systematic risk factor V_{t+1}. The $1-\pi$ percentile of V_{t+1} is $\Phi^{-1}(1-\pi)$, so the ASRF capital charge for exposure i at date t is

$$\text{(13)}\quad \begin{aligned} k_{it}^{\pi} &= \Pr\left[Z_{i,t+1} < 0 \mid W_i = w_i, X_{it} = x_{it}, Y_t = y_t, V_{t+1} = \Phi^{-1}(1-\pi)\right]\cdot\lambda_i \\ &= \Phi\left(\frac{-\left(\alpha + \beta_W w_i + \beta_X x_{it} + \beta_Y y_t\right) - \omega\Phi^{-1}(1-\pi)}{\sqrt{1-\omega^2}}\right)\cdot\lambda_i \end{aligned}$$

Notice that, all else equal, an exposure will receive a higher capital charge during a recession (when y_t is low). As economic conditions deteriorate a bank must hold more capital against each credit exposure to maintain the fixed solvency target π.

Substituting (10) into (13) allows us to express the capital charge for exposure i at date t as a function of its pooled PD under a PIT rating system:

$$\text{(14)}\quad k_{it}^{\pi} = \Phi\left(\frac{\Phi^{-1}\left(PPD_{it}^{PIT}\right) - \omega\Phi^{-1}(1-\pi)}{\sqrt{1-\omega^2}}\right)\cdot\lambda_i$$

Equation (14) is nearly identical to the regulatory capital function for a one-year-maturity loan proposed in CP3.[3] This is no coincidence; the Basel II capital function was derived

2 The assumption of fixed recovery rates is much more restrictive than necessary. In fact, we need only assume that recovery rates are independent of the systematic risk factor. The stronger assumption is made here purely to minimize distracting notation.
3 The regulatory capital function for corporate exposures is defined in CP3 ¶241. The Basel Committee applies the solvency standard $\pi = 0.999$ and assumes that ω varies from $(0.24)^2$ to $(0.12)^2$ depending on the PD of the obligor. The Basel II capital function includes an adjustment intended to capture the effects of changes in market value for loans with maturities greater than one year. This maturity adjustment is ignored in the model presented here. Recently, the Basel Committee has proposed partitioning credit

by applying the ASRF framework to a distance-to-default model similar to the one developed in Section 3. Importantly, (14) does not directly depend on the observed state of the economy y_t but it does imply a counter-cyclical capital requirement. As economic conditions get worse and y_t falls an obligor's PIT pooled PD will tend to rise, resulting in a higher capital charge.

What happens when pooled PDs are used to calculate capital requirements under a TTC rating system? Substituting (12) into (13) yields

$$(15) \qquad k_{it}^{\pi} = \Phi\left(\frac{\Phi^{-1}\left(PPD_{it}^{TTC}\right) - \beta_Y y_t - \omega\Phi^{-1}\left(1-\pi\right)}{\sqrt{1-\omega^2}}\right)\cdot\lambda_i$$

Unlike equation (14), equation (15) is negatively dependent on the observed state of the economy at date t. In other words, a VaR capital rule based on pooled PDs under a TTC rating system must be adjusted over the business cycle in order to achieve a fixed solvency target in every period. For a given pooled PD, the capital rule must be more strict during recessions and less strict during expansions

The difference between (14) and (15) illustrates a sort of "conservation principle" with respect to cyclical variation in capital charges. Since capital must move counter-cyclically to maintain a fixed solvency target in each period, one faces a choice. One can either specify a stable capital rule based on counter-cyclical PIT pooled PDs, or a counter-cyclical rule based on relatively stable TTC pooled PDs.

RESULT 3: *A value-at-risk capital rule that relies on pooled PDs derived from a PIT rating system will be stable over the business cycle. A value-at-risk capital rule that relies on pooled PDs derived from a TTC rating system will be negatively related to current business conditions.*

Result 3 implies some important shortcomings of the fixed capital rule proposed by the Basel Committee. Since this rule does not distinguish between pooled PDs derived under PIT and TTC systems a bank that adopts a TTC rating philosophy can expect to experience less counter-cyclical regulatory capital requirements than one which

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risk charges into an unexpected loss component covered by regulatory capital and an expected loss component covered by provisions.

adopts a PIT rating philosophy. As a result, two banks with identical risk exposures but different rating philosophies could be assessed quite different regulatory capital requirements. This would seem to violate the principle that regulatory capital requirements provide a level playing field across institutions. Moreover, a bank that adopts a TTC rating system may not meet the Basel Committee's target solvency standard during an economic downturn. As noted earlier, the Committee proposes to allow IRB banks to use a rule comparable to equation (14) regardless of their rating philosophies. For a given pooled PD, equation (14) lies below equation (15) during recessions (when $y_t < 0$) so the Basel rule will tend to understate the capital requirement for a bank with a TTC rating system during these periods.

These problems could be resolved by applying different capital rules for banks with different rating philosophies along the lines suggested Result 3. A bank with a PIT rating system would be assessed capital charges according to a fixed rule that would not change over the business cycle. The capital rule applied to a bank with a TTC rating system would be adjusted counter-cyclically in response to changing macroeconomic conditions. The problem with this approach is that it places a heavy burden on supervisors, who would have to determine whether each bank's rating system should be treated as a PIT system or a TTC system. As noted by Taylor (2003), many banks may in practice use hybrid rating approaches that embody elements of both PIT and TTC systems and therefore defy easy classification. Moreover, calibrating a capital rule for TTC banks akin to equation (15) would be difficult, as it requires detailed information on the effects of changing macroeconomic conditions on obligor credit quality.

A more direct and tractable approach to dealing with the implications of Result 3 would be to simply change the definition of the PD parameters that banks are required to report. Rather than requiring that a rating grade's pooled PD match the long-run average of realized default rates for that grade, the Basel Committee might instead stipulate that the reported PD for a grade match the expected year-ahead default rate for obligors *currently* assigned the grade. That is, the PD associated with a grade would reflect the mean unstressed PD for the obligors in the grade. This change would facilitate a stable value-at-risk capital rule under both PIT and TTC rating systems. This can be seen by substituting (1) into (13) to obtain

(16) $$k_{it}^{\pi} = \Phi\left(\frac{\Phi^{-1}\left(UPD_{it}\right) - \omega\Phi^{-1}\left(1-\pi\right)}{\sqrt{1-\omega^2}}\right)\cdot\lambda_i$$

(16) is identical to (14) because for the continuous rating system described here a PIT bucket's pooled PD exactly matches its unstressed PD.

Requiring that banks report unstressed PDs rather than pooled PDs would have no effect on the quantification of PDs for a bank with a PIT rating philosophy. Such a bank could, for example, estimate the unstressed PD for a grade by calculating the long-run average default frequency for that grade. In contrast, a bank with a TTC rating system would need to adjust its reported PDs over the business cycle. As shown by Result 1 the unstressed PD associated with a given TTC rating grade is higher during recessions and lower during expansions. To estimate the expected unstressed PD for obligors with a given TTC grade, a bank could make use of an empirical default prediction model such as Moody's KMV Credit Monitor. These models map observable data to unstressed PD estimates for individual obligors. Averaging such estimates across the obligors currently assigned a particular grade provides a proxy for that grade's expected unstressed PD.

Requiring that banks report unstressed PDs rather than pooled PDs that reflect long-run averages is not without its drawbacks. Supervisors tasked with confirming the accuracy of the PDs that banks report may have difficulty determining whether the changing PD reported by banks with TTC rating systems accurately reflect changing macroeconomic conditions. However, as we shall see in the next section, requiring that TTC banks report long-run average pooled PDs for their grades imposes important validation challenges of its own.

6. Benchmarking and backtesting pooled PDs

To ensure that capital rules are applied consistently across institutions, bank supervisors will need to validate the accuracy of the pooled PDs that IRB banks report. In practice empirical supervisory validation efforts are likely to fall under one of two approaches: backtesting.and benchmarking.

Backtesting involves comparing the reported pooled PD for a given grade with historically observed default frequencies for that grade. One should expect that the annual default frequency averaged over a number of years will approximate the grade's true pooled PD. However over any fixed time horizon this average will not perfectly match the pooled PD. This is true even if the number of obligors assigned to a grade is very large, because cross-obligor default correlations imply that in any given year realized *ex post* default rates can differ significantly from *ex ante* forecasts.[4] Since in practice only limited historical data on default rates are available, supervisors will have to assess the extent to which short data histories can lead to differences between the average of observed default rates for a bucket and its "true" pooled PD. One can view the average default frequency for a grade taken over a fixed number of years as an estimator of the bucket's pooled PD. These estimators have different properties under PIT and TTC rating systems.

If a PIT risk bucket contains an arbitrarily large number obligors, its observed one one-year default frequency converges to

$$\begin{aligned} DF_{t+1}^{PIT}(\gamma) &= E\left[D_{i,t+1} \mid i \in \Gamma_t^{PIT}(\gamma), Y_t = y_t, V_{t+1} = v_{t+1}\right] \\ &= \Phi\left(-\frac{\gamma + \omega v_{t+1}}{\sqrt{1-\omega^2}}\right) \end{aligned}$$

Note that the bucket's default frequency depends on the realization of the systematic risk factor V_{t+1}, but it does not depend on the observed state of the economy at date t (y_t). The long-run default frequency is simply the average of the observed yearly default rates

$$(16) \qquad LRDF_T^{PIT}(\gamma) = \frac{1}{T}\sum_{t=0}^{T-1}\Phi\left(-\frac{\gamma + \omega v_{t+1}}{\sqrt{1-\omega^2}}\right)$$

It is easy to show that the expected value of (16) is equal to (9) so the long-run average default frequency is an unbiased estimator of true pooled PD for a PIT risk bucket. The variance of the estimator is

$$(17) \qquad V\left[LRDF_T^{PIT}(\gamma)\right] = \frac{1}{T}\left(F\left(-\gamma,-\gamma;\omega^2\right) - \Phi\left(-\gamma\right)^2\right)$$

where $F(x_1,x_2;\rho)$ is the bivariate normal CDF with correlation parameter ρ.

For a TTC risk bucket, the observed one-year default frequency is

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4 Such correlations arise from the presence of systematic shocks to obligor credit quality that cannot be forecast and cannot be diversified away. In the model presented here, these shocks are represented by the variable V_t.

$$
(18) \quad \begin{aligned} DF^{TTC}_{t+1}(\gamma) &= E\left[d_{i,t+1} \mid i \in \Gamma^{TTC}_t(\gamma), Y_t = y_t, V_{t+1} = v_{t+1}\right] \\ &= \Phi\left(-\frac{\gamma + \beta_Y y_t + \omega v_{t+1}}{\sqrt{1-\omega^2}}\right) \end{aligned}
$$

Unlike the one-year default frequency for a PIT bucket, this default rate is sensitive to both the systematic risk factor and the observable state of the business cycle. TTC ratings do not change to reflect changes in current macroeconomic conditions so the observed default rate for a TTC grade tends to rise during recessions and fall during expansions. It is easy to show that the long-run average default frequency

$$
(19) \quad LRDF^{TTC}_T(\gamma) = \frac{1}{T}\sum_{t=0}^{T-1}\Phi\left(-\frac{\gamma + \beta_Y y_t + \omega v_{t+1}}{\sqrt{1-\omega^2}}\right)
$$

is an unbiased estimator of (10). If Y_t is iid,[5] the variance of the estimator is

$$
(20) \quad V\left[LRDF^{TTC}_T(\gamma)\right] = \frac{1}{T}\left(F\left(\frac{-\gamma}{\sqrt{1+\beta_Y^2}}, \frac{-\gamma}{\sqrt{1+\beta_Y^2}}; \frac{\omega^2+\beta_Y^2}{1+\beta_Y^2}\right) - \Phi\left(\frac{-\gamma}{\sqrt{1+\beta_Y^2}}\right)^2\right)
$$

One cannot directly compare equations (17) and (20) because the grades that enter each equation are arbitrary. To compare the variance of the two backtesting estimators on an equal footing one must hold the true pooled PDs constant across risk buckets. This is done by comparing the estimators when

$$
\gamma_{PIT}\sqrt{1+\beta_Y^2} = \gamma_{TTC}
$$

so that equations (9) and (10) are equal. Under this restriction

5 This assumption is made purely for analytical convenience. If, as is assumed elsewhere in the paper, Y_t is correlated over time then the variance in (20) would be larger than stated. Note that in this case Result 4 would continue to hold.

$$
\begin{aligned}
V\left[\mathrm{LRDF}_T^{\mathrm{PIT}}\left(\gamma_{\mathrm{PIT}}\right)\right] &= \frac{1}{T}\left(F\left(-\gamma_{\mathrm{PIT}}, -\gamma_{\mathrm{PIT}}; \omega^2\right) - \Phi\left(-\gamma_{\mathrm{PIT}}\right)^2\right) \\
&< \frac{1}{T}\left(F\left(-\gamma_{\mathrm{PIT}}, -\gamma_{\mathrm{PIT}}; \frac{\omega^2+\beta_Y^2}{1+\beta_Y^2}\right) - \Phi\left(-\gamma_{\mathrm{PIT}}\right)^2\right) \\
&= \frac{1}{T}\left(F\left(\frac{-\gamma_{\mathrm{TTC}}}{\sqrt{1+\beta_Y^2}}, \frac{-\gamma_{\mathrm{TTC}}}{\sqrt{1+\beta_Y^2}}; \frac{\omega^2+\beta_Y^2}{1+\beta_Y^2}\right) - \Phi\left(\frac{-\gamma_{\mathrm{TTC}}}{\sqrt{1+\beta_Y^2}}\right)^2\right) \\
&= V\left[\mathrm{LRDF}_T^{\mathrm{TTC}}\left(\gamma_{\mathrm{TTC}}\right)\right]
\end{aligned}
$$

The inequality holds because the correlation parameter in the second line is larger than the correlation parameter in the first line. The backtesting estimator has a lower variance for a PIT risk bucket than for a comparable TTC risk bucket. This implies our final result.

RESULT 4: *For any given pooled PD and finite T, the long-run average default frequency is an unbiased estimator of the pooled PD for both PIT and TTC risk buckets. All else equal, the long run average default frequency is a more efficient estimator (in a mean-squared error sense) for a PIT risk bucket.*

We can conclude from Result 4 that backtesting will be a more effective tool for validating the pooled PDs of banks that adopt PIT rating systems than for those that adopt TTC rating systems.

Benchmarking provides an alternative to backtesting pooled PDs. Benchmarking involves comparing PDs reported by different banks for the same or similar obligors. The principle behind benchmarking is that significant cross-bank differences in the pooled PDs assigned to similar obligors suggests that one or more banks are not reporting pooled PDs accurately. However, Result 2 implies that two banks with different rating philosophies can be expected to report different pooled PDs for the very same obligor. Under a PIT rating system the pooled PD assigned to a given obligor will tend to rise during recessions and fall during expansions while the pooled PD assigned to the same obligor under a TTC rating system will remain stable over the business cycle.

Result 2 suggests that supervisors will need to account for differences in rating philosophies when benchmarking pooled PDs. They can do this by either restricting peer groups to banks with similar rating philosophies, or by making adjustments to reported pooled PDs to reflect cross-bank differences in rating philosophies. In practice both options are likely to pose difficulties. Supervisors would need to make judgments about each bank's rating philosophy. Adjusting PDs to reflect differences in rating philosophy would also require an empirical assessment of the magnitude of these differences.

Section 4 suggested that banks be required to report PDs that reflect the mean unstressed default probability for obligors currently assigned to a bucket rather than the long-run average default frequency for that bucket. Backtesting could be used to validate such PDs under a PIT rating system but not under a TTC rating system. As shown in Section 3, the long-run average default frequency for a TTC rating grade is not directly related to the unstressed PD associated with the bucket. On the other hand, benchmarking would be greatly simplified if all banks were required to report unstressed PDs. Because banks would be held to the same standard regardless of their rating philosophy, reported PDs would be directly comparable across institutions with different rating systems.

7. An illustrative historical simulation

The model developed in Sections 3 and 4 is quite stylized. It assumes that obligor credit quality is determined by a limited set of risk factors and that banks apply continuous rating systems capable of making very fine distinctions across obligors. Real-world settings are, of course, much more complicated. A multiplicity of risk factors -- some observable and some not -- affect obligor credit quality, and different obligors have different sensitivities to different factors. By and large, banks still use relatively granular rating systems, so that there may be a fair amount of heterogeneity across obligors within a particular grade. This section uses historical simulations to illustrate some of the conclusions drawn in earlier sections under these more realistic conditions.

The simulations presented here are derived from data on obligors that were rated by both Standared and Poors and KMV during the 60 months preceding January 2004. The sample consists entirely of US publicly-traded corporations. The population of rated obligors changes slightly from month to month as some new obligors are rated and some existing obligors cease being rated. It is important to note that the sample used here is not likely to be representative of a typical bank's corporate loan portfolio. Rated obligors tend to be significantly larger than most, and the composition of obligors in a bank's portfolio is likely to change over the business cycle in ways different from the population of rated obligors. The purpose of the simulations presented here is to illustrate differences between PIT and TTC rating systems, not to provide accurate estimates of the PDs or capital requirements that real-world banks can be expected to face.

Following previous research by Löffler (2004) and others, S&P rating grades are assumed to embody a through-the-cycle rating philosophy. Further, I assume that the KMV EDF assigned to an obligor at a particular date is equal to that obligors' true unstressed PD. This is consistent with the rating strategy employed by KMV, which uses a Merton-style model to infer an obligor's likelihood of default at a point in time based on equity price and liability data. Seven granular PIT rating grades are created by constructing unstressed PD buckets. PD thresholds for these grades are defined so that the overall distribution of obligors across PIT grades is roughly proportional to the distribution of obligors across S&P grades.[6]

The distribution of PIT rating grades over time is shown in Figures 1. The distribution of PIT grade changes significantly over the business cycle. As the US economy turns downward during 2000 and 2001 many obligors receive lower EDFs and the distribution of PIT ratings reflects this. As overall economic conditions improve during 2003, PIT ratings shift upward. This cyclicality contrasts with the relative stability of the TTC rating distribution shown in Figure 2. Over time, one observes a general downward trend in TTC ratings, but not the month-to-month variation observed among PIT grades. This difference reflects the different underlying rating philosophies. Grades keyed to unstressed PDs tend to change rapidly as overall business conditions change. S&P's rating approach is designed, in part, to limit transitory transitions between grades.

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6 The PIT rating system contains a somewhat larger fraction of obligors in the highest and lowest grades than the TTC rating system. This is because KMV imposes a ceiling of 30% and a floor of 0.3% on reported EDFs. The highest PIT grade contains all obligors subject to the ceiling and the lowest grade contains all obligors subject to the floor.

Figures 3 plots the average unstressed PD (KMV EDF) for obligors assigned to each PIT grade in each month. Since the PIT system is designed to adjust an obligor's rating as its unstressed PD changes, it is not surprising to find that the grade average PDs are stable over time. The average unstressed PDs for the TTC grades, shown in Figure 4, exhibit much greater cyclical variation. They rise significantly during the 2000-02 economic downturn and fall over the course of 2003. These features are consistent with Result 1. Because TTC ratings are more stable, the average unstressed PDs for obligors assigned those ratings must be more volatile.

Figure 5 shows how average unstressed PDs and average pooled PDs can differ from one another. The black line in Figure 5 plots the average unstressed PD taken across all obligors in the population in each month. As expected, the overall average PD is negatively related to the business cycle. The blue line plots the average pooled PD assigned to obligors in the sample in each month under the PIT rating system. These pooled PDs are derived using the two-step process prescribed in CP3. First the overall average PD for a PIT grade (taken across all months) is calculated. The pooled PD assigned to a particular obligor in a particular month is then set to the pooled PD for its current grade. Because the pooled PD for a PIT grade is a close approximation to the average unstressed PD for the obligors assigned to that grade, the average PIT pooled PD taken across obligors in a particular month is quite close to the average unstressed PD taken across obligors in that month. This is why the black line and the blue line in Figure 5 are close together. Differences between these lines arise solely because of the granularity of the PIT rating system. The red line in Figure 5 plots the average pooled PD in each month under the TTC rating system. As implied by Result 2, the average pooled PD under the TTC rating system exhibits much less variation over time than the average pooled PD under the PIT rating system. The average TTC pooled PD bares little relation to the overall average unstressed PD in each month.

Figure 6 illustrates the effect of differences in rating philosophy on risk-based capital requirements. The black line plots the 99.9% VaR capital requirement for an equal-weighted portfolio of loans derived from equation (16).[7] As expected, the capital

7 For the purpose of this calculation all exposures are assumed to have a maturity of one year and an LGD of 45%.

needed to maintain a fixed solvency target changes over the business cycle and is greatest at the cycle's trough. The blue line plots the capital requirement generated by plugging each exposure's PIT pooled PD into the Basel II capital rule akin to equation (14) This capital requirement closely matches the VaR requirement. The blue line lies above the black line because of the granularity of the PIT rating system and the concavity of the capital function. The red line in Figure 6 shows the capital requirement that arises when each exposure's TTC pooled PD is plugged into the fixed Basel II capital rule. The capital requirement generated by the TTC system is more stable than that implied by the PIT system. Note that TTC capital requirement is insufficient to meet the 99.9% VaR target at the trough of the business cycle.

8. Conclusion

Using a highly stylized model of bank rating systems, this paper has examined the relationship between banks' rating philosophies and the pooled PDs that they will be required to report under Basel II. The model of obligor credit quality is not intended to be general. However, it does capture the idea that credit quality is determined by both obligor-specific and systematic risk factors, some of which can be observed at the time a rating is assigned and some of which cannot. The characterization of rating philosophies in this paper is similarly abstract, but captures the notion that in designing rating systems banks can choose how much emphasis to place on current observable macroeconomic conditions.

The analysis presented here suggests that a bank's choice of rating philosophies can have a significant effect on its risk-based regulatory capital requirements. Given the rules described in the Basel Committee's third consultative document, a bank that adopts a more dynamic point-in-time rating system should face more volatile and more counter-cyclical regulatory capital requirements than a bank that adopts a more stable through-the-cycle rating system. The reason for this is that Basel II does not require that an IRB bank report an accurate one-year-ahead forecast of the probability of default for each of its obligors. Rather it requires that an IRB bank report a long-run average pooled PD for a rating grade which is then linked to the obligors currently assigned that grade. Because Basel II prescribes pooled PDs that are stable over time, banks that design their rating systems to be insensitive to current economic conditions will face less counter-cyclical capital requirements.

This result implies that the approach to determining regulatory capital proposed in CP3 will not provide a level regulatory playing field for banks with different rating philosophies. Moreover, the fixed capital rule proposed in CP3 cannot be expected to generate sufficient capital to satisfy the Basel Committee's 99.9% VaR target for banks with TTC rating systems during economic downturns. The Basel Committee could address these problems by amending its proposed rules to require that an IRB bank report the average unstressed PD for the obligors currently assigned to a risk bucket rather than a long-run average default frequency for that bucket.

Assuming that the criteria for determining pooled PDs embedded in CP3 do not change, this analysis suggests that supervisors should control for differences in rating philosophies when benchmarking pooled PDs across peer groups. Failing to do so could lead supervisors to erroneously attribute the effects of cross-bank differences in rating philosophies to inaccuracies in reported pooled PDs. This analysis also suggests that backtesting pooled PDs by comparing them with historical observed default rate data will be more effective for some types of rating systems than others. Backtesting is likely to be most effective when a bank's rating system fully incorporates available information on current economic conditions.

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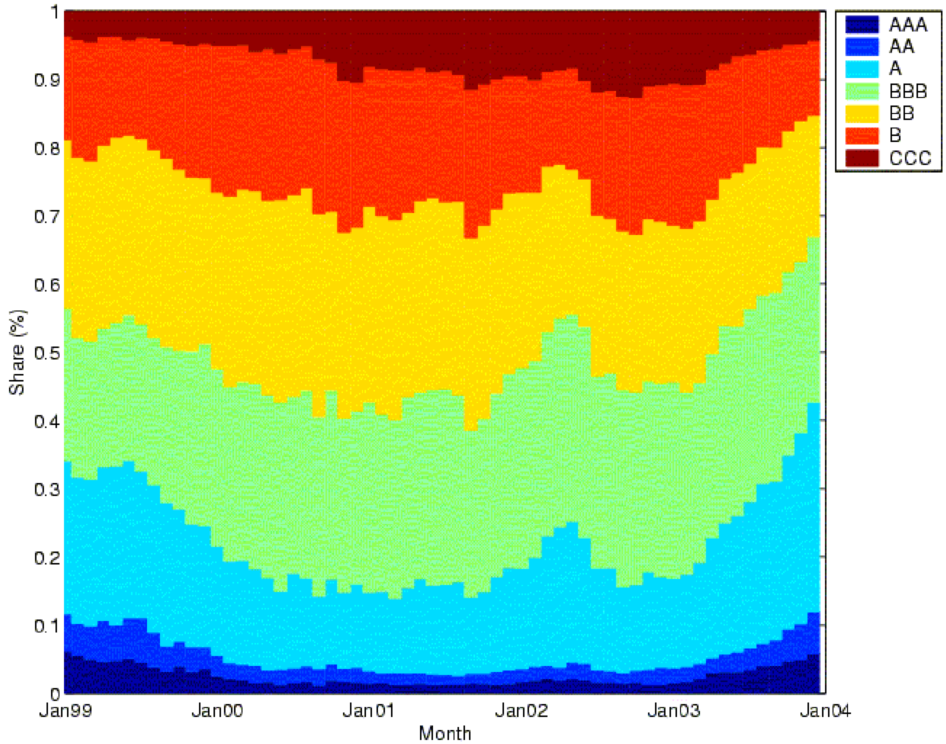

Figure 1: This figure shows the distribution of obligors across PIT rating grades over time. During the trough of the business cycle the share of obligors with low PIT grades increases and the share of obligors with high PIT grades declines.

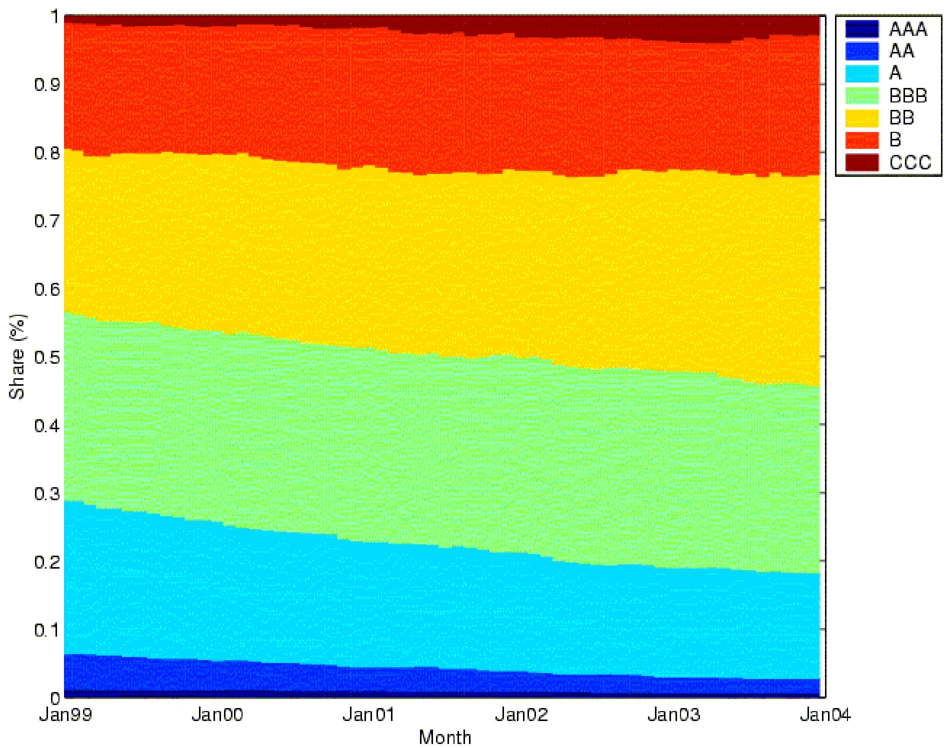

Figure 2: This figure shows the distribution of obligors across TTC rating grades over time. The distribution of TTC grades shifts lower over time, but there is little cyclical variation.

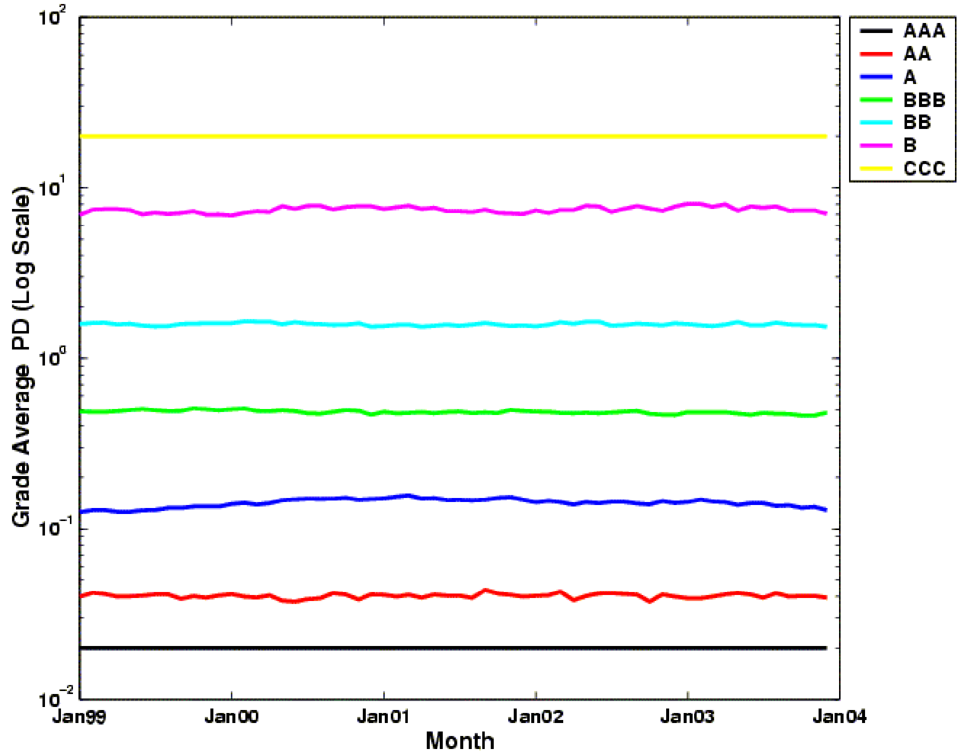

Figure 3: Each line on this chart plots the average unstressed PD for obligors assigned to a PIT grade. By design, the average unstressed PDs are stable over time.

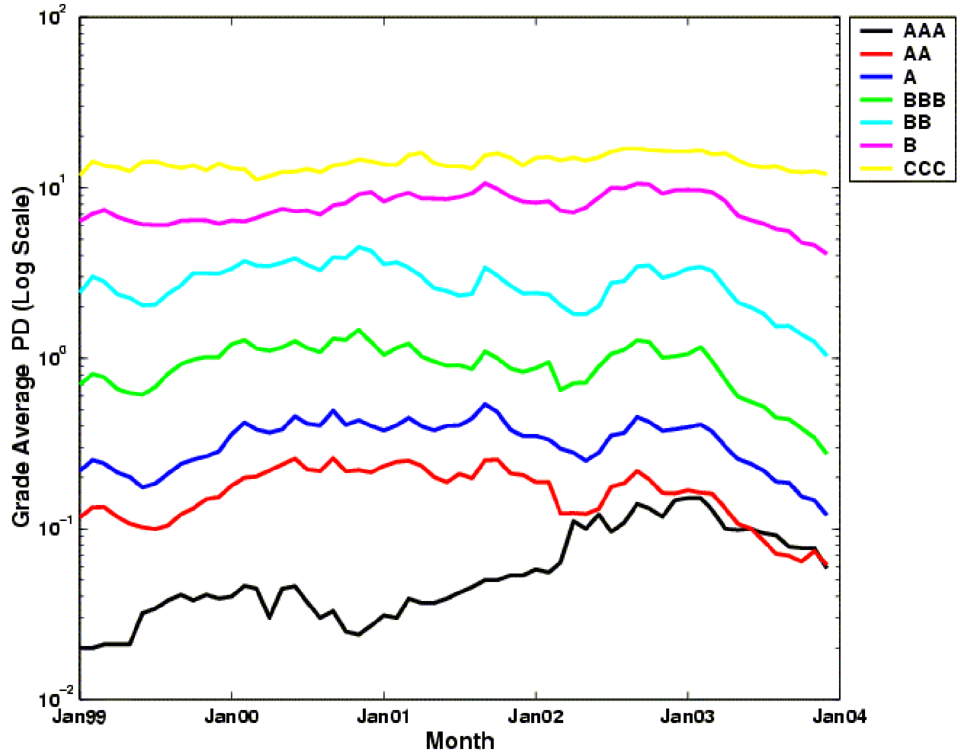

Figure 4: Each line on this chart plots the average unstressed PD for obligors assigned to a TTC grade. Because TTC grades tend not to change with current business conditions, the average unstressed PD associated with a TTC grade tends to move counter-cyclically.

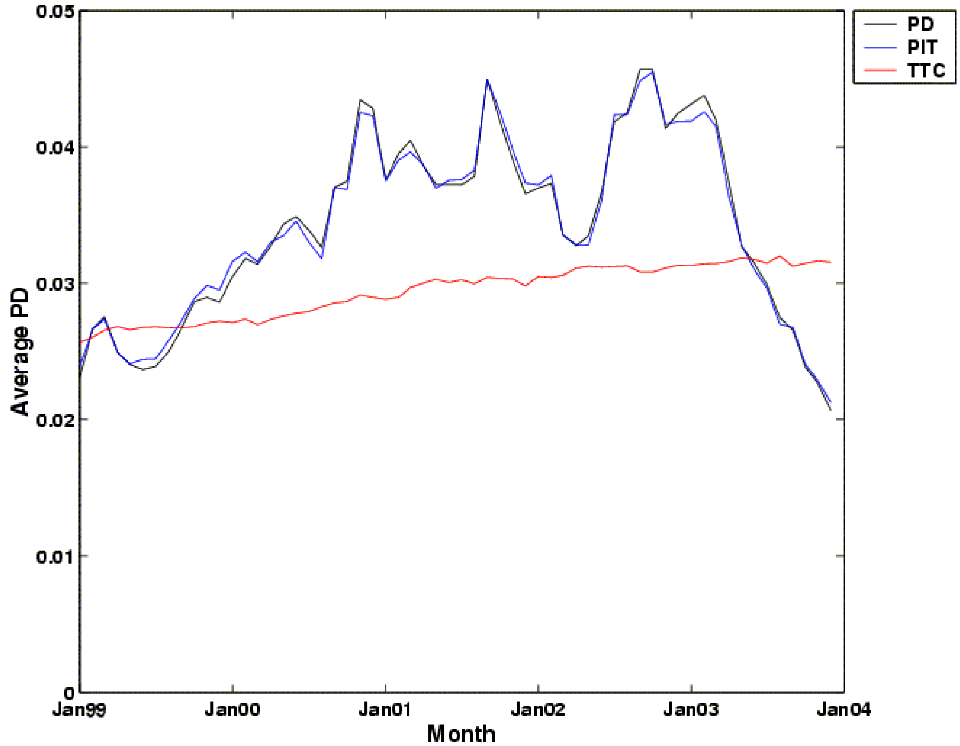

Figure 5: This chart compares the averages of the pooled PDs assigned to obligors under PIT and TTC rating systems with the average of the unstressed PDs for those obliges. The average pooled PD under a PIT rating system lies close to the average unstressed PD and exhibits significant cyclical variation. The average pooled PD under a TTC rating system lies farther from the average unstressed PD and is more stable over time.

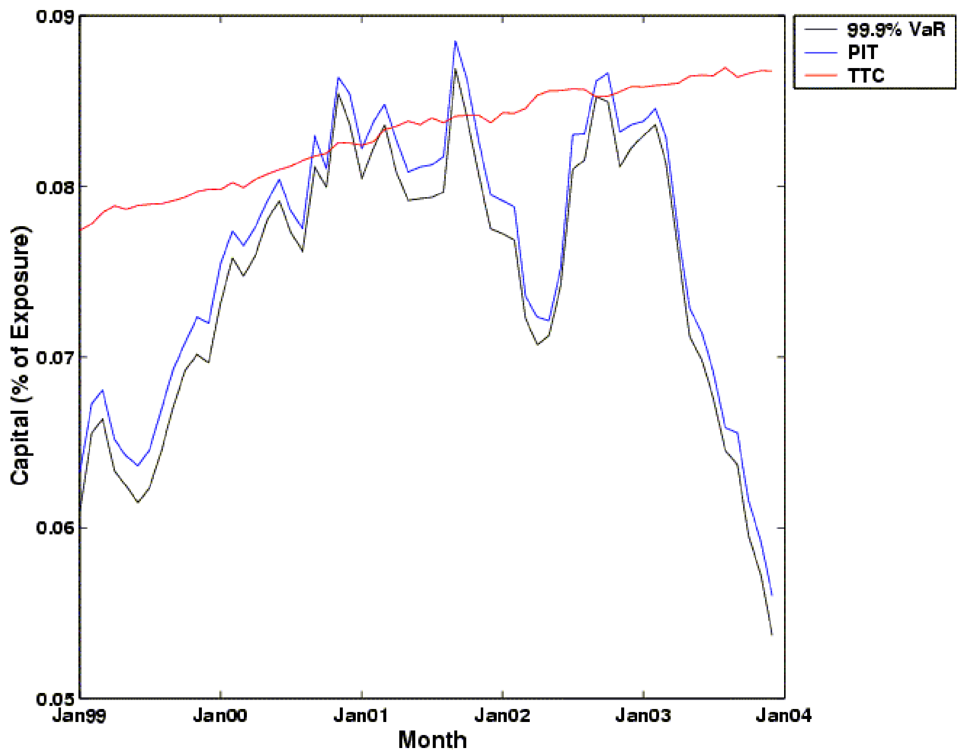

Figure 6: This chart compares the capital needed to achieve a 99.9% solvency target with the capital generated by applying the proposed Basel II capital rule under PIT and TTC rating systems. The TTC system generates less volatile regulatory minimums that do not always provide sufficient capital to meet the solvency target.