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Do capital buffers mitigate volatility of bank lending? A simulation study

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Discussion Paper
Series 2: Banking and Financial Studies
No 03/2011

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Internet http://www.bundesbank.de

ISBN 978-3–86558–686–5 (Printversion)
ISBN 978-3–86558–687–2 (Internetversion)

Abstract

Critics claim that capital requirements can exacerbate credit cycles by restricting lending in an economic downturn. The introduction of Basel 2, in particular, has led to concerns that risk-sensitive capital charges are highly correlated with the business cycle. The Basel Committee is contemplating a revision of the Basel Accord by introducing counter-cyclical capital buffers. Others claim that capital buffers are already large enough to absorb fluctuations in credit risk. We address the question of the pro-cyclical effects of capital requirements in a general framework which takes into account banks' potential adjustment strategies. We develop a dynamic model of bank lending behavior and simulate different regulatory frameworks and macroeconomic scenarios. In particular, we address two related questions in our simulation study: How do business fluctuations affect capital requirements and bank lending? To what extent does the capital buffer absorb fluctuations in the level of mimimum required capital?

JEL classification: C61, E32, E44, G21

Keywords: Minimum capital requirements, regulatory capital, capital buffer, cyclical lending, pro-cyclicality

Non-technical summary

As part of the reform of the Basel 2 framework – often referred to as Basel 3 – the issue of how to dampen pro-cyclicality is under intense discussion. The debate focuses on two types of measures: One approach is to smooth capital requirements and make them less sensitive to volatile credit risk developments. Another approach is to require banks to build up capital buffers during good times of the business cycle that can be released in bad times. The paper addresses the question of whether a reform of the capital framework is necessary as banks already hold significant capital buffers. These issues are addressed using techniques from dynamic stochastic optimization in order to model a bank's capital decisions. In the optimization problem, a bank's capital is the state variable, while dividend payments and loan supply are the decision variables in each period. In the model, capital is important because it restricts the scope for lending. In addition, the bank incurs costs if it fails to meet the capital requirements.

Based on these modeling assumptions, the impact of changes in the prevailing macroeconomic conditions and credit risk on banks' capital decisions is analyzed by distinguishing between unexpected shocks and expected cyclical variations.

The main results can be summarized as follows:

- Even in the absence of capital regulation, banks hold a significant amount of capital. In the restricted cases, the bank holds a capital buffer well above the minimum capital requirements (both in Basel 1 and 2).
- The capital buffer does not mitigate the volatility of capital requirements under the risk-sensitive capital framework of Basel 2. Minimum capital requirements and actual capital are highly correlated. As a result lending under Basel 2 is significantly more volatile.
- The impact strongly depends on whether or not the change in credit risk is unexpected. A sudden rise in credit risk may have a serious impact on loan supply. In the case of expected changes, the effect hinges on the size of the interest margin. If it is low, volatility in lending might be high.

Given these observations, both a smoothing of minimum required capital over the business cycle and the introduction of capital buffers might be appropriate solutions from a regulatory perspective. However, banks have a genuine incentive to hold capital cushions on top of minimum required capital in order to avoid default through breaking regulatory capital requirements. Therefore, mandatory regulatory buffers might be considered as an additional capital requirement by banks as well as markets. Consequently, buffers have to be defined in such a way that they can "breath" with the cycle: It has to be ensured that they are build up in an expansion phase and can be drawn down during a recession. Furthermore, when designing a capital buffer, regulators need to take account of behavioral

changes in the capital management processes of banks as a response to the introduction of the risk-sensitive capital framework. According to our simulation results, bank lending depends in a highly non-linear way on interest rates, PDs and other parameters that have an impact on banks' expected profits. Therefore, the selection of macroeconomic variables that control the size of the buffer poses a key challenge.

Nichttechnische Zusammenfassung

Bestandteil der gegenwärtig geplanten Reformen des Basel 2-Regelwerkes – die bevorstehenden Regeländerungen werden häufig auch als "Basel 3" bezeichnet – sind insbesondere Maßnahmen zur Dämpfung unerwünschter pro-zyklischer Wirkungsketten. Dabei werden zwei verschiedene Mechanismen diskutiert: Zum einen wird die Glättung der Mindesteigenkapitalanforderungen erwogen, um die Sensitivität der Kapitalanforderungen gegenüber Schwankungen des Kreditrisikos zu mildern. Darüber hinaus soll die Einführung antizyklischer Kapitalpuffer bewirken, dass im Boom zusätzliches Kapital aufgebaut wird, von dem die Banken im Abschwung zehren könnten. Das Papier erörtert die Frage, inwieweit eine Korrektur der bestehenden Regeln notwendig ist, da die Banken ohnehin größere Puffer halten. Hierbei werden mathematische Verfahren der dynamischen stochastischen Optimierung angewendet, um die Entscheidungssituation der Banken abzubilden. Im betrachteten Optimierungsproblem bildet das Eigenkapital der Banken die Zustandsvariable, die Steuerungsvariablen sind die Höhe der Dividenzahlung sowie der Kreditvergabe in jeder Periode. Kapitalanforderungen sind in zweifacher Hinsicht bedeutsam: Erstens stellen sie eine Begrenzung der möglichen Kreditvergabe dar. Zweitens entstehen bankseitig Kosten, falls die Bank durch Unterschreitung der regulatorischen Mindesteigenkapitalanforderungen ausfällt.

Basierend auf diesen Modellannahmen wird der Einfluss des makroökonomischen Umfelds untersucht. Dabei wird zwischen unerwarteten Schocks und erwarteten zyklischen Schwankungen unterschieden.

Die Hauptergebnisse können wie folgt zusammengefasst werden:

- Selbst unter der Annahme, dass die Banken keinen regulatorischen Kapitalanforderungen unterliegen, zeigen die Simulationen, dass Eigenkapital in beachtlicher Höhe vorgehalten wird. Bei Gültigkeit von Basel 1- und Basel 2- Kapitalanforderungen halten die Banken erhebliche Kapitalpuffer über dem geforderten Minimum (sowohl unter Basel 1 als auch Basel 2).
- Andererseits zeigt der Kapitalpuffer keine mildernde Wirkung hinsichtlich der Schwankungen der Kreditvergabe. Aktuelles Eigenkapital und Mindesteigenkapitalanforderungen sind stark miteinander korreliert. Folglich ist auch die Kreditvergabe unter dem risikosensitiven Basel 2-Regelwerk wesentlich volatiler.
- Der Einfluss hängt stark davon ab, ob die Änderungen des Kreditrisikos von den Banken erwartet wurden, oder ob sie unerwartete Schocks darstellen. Ein plötzlicher Anstieg hätte unter Umständen deutliche Auswirkungen auf die Kreditvergabe. Bei erwarteten Änderungen hängt der Einfluss von der Zinsmarge ab. Ist diese niedrig, so kann sich auch hier eine deutliche Volatilität der Kreditvergabe ergeben.

Diese Ergebnisse der Simulationen zeigen, dass sowohl die Glättung der Mindesteigenka-

pitalanforderungen als auch die Einführung eines Kapitalpuffers aus regulatorischer Sicht angemessene Handlungsoptionen sind. Banken haben jedoch ein eigenes Interesse, einen Kapitalpuffer zusätzlich zum geforderten Minimum vorzuhalten, um zu verhindern, dass eine Unterschreitung des Mindestlevels zum Bankausfall führt. Daher besteht die Gefahr, dass verpflichtende regulatorische Puffer von Banken als auch vom Markt als zusätzliche Kapitalanforderungen verstanden werden. Folglich sind Kapitalpuffer so zu definieren, dass sie mit dem Zyklus “atmen”: Es muss sichergestellt sein, dass sie in Expansionsphasen aufgebaut werden, und ein Abbau während Rezessionphasen möglich ist.

Regulatoren müssen bei der Ausgestaltung des Kapitalpuffers Verhaltensanpassungen im internen Kapitalmanagement, die durch die Einführung der risikosensitiven Eigenkapitalregulierung bedingt sind, mit berücksichtigen. Die vorliegenden Simulationen zeigen, dass die Kreditvergabe stark nichtlinear von Kreditzinsen, Ausfallwahrscheinlichkeiten und anderen Parametern, die einen Einfluss auf die Profitabilität der Bank haben, abhängt. Daher stellt die Auswahl geeigneter Variablen für die Steuerung der Größe des Puffers die gegenwärtig größte Herausforderung dar.

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Do capital buffers mitigate volatility of bank lending? A simulation study[1]

1 Introduction

In 2006, the Basel Committee on Banking Supervision established a new framework (BCBS, 2006) for capital measurement and capital standards, which has now been introduced in many countries. It has replaced the capital framework of 1988, which had been criticized for its inadequate risk weighting. Whereas, in the old framework, the risk weights of financial assets were largely determined by asset class, in the new framework they are a function of obligors' creditworthiness, as measured by their probability of default (in the *Internal Ratings Based* approaches). On the other hand, as the mean creditworthiness of debtors usually correlates with the business cycle, the new capital requirements might give rise to regulatory induced volatility in capital holdings, and as a result in lending. This might in turn aggravate economic downturns when banks have to cut their lending in response to eroding capital buffers. This problem had been identified even under the old framework, but with time-dependent risk weights, the pro-cyclical effect of minimum capital requirements might have become more severe.

The recent financial crisis has brought the need to reform the Basel framework back onto the international regulatory agenda (BCBS, 2009). The Basel Committee (BCBS, 2010) now suggests counteracting cyclicality of existing capital requirements by including two "macroprudential" buffers in the framework. The fixed buffer requires banks to retain part of their earnings if capital falls under a certain level of capital. The time-varying capital buffer links capital to the rate of growth in lending.

Critics claim that these measures tend to reduce the risk sensitivity of capital requirements and counteract the initial purpose of risk-sensitive capital requirements, namely to improve the measurement of risk.

They purport that claims of pro-cyclical effects may be overstated as banks usually hold a significant capital buffer on top of the required minimum. Thus, banks would simply reduce their capital buffer when capital requirements increase. However, we argue that it is not clear whether capital buffers mitigate the problem of cyclicality in lending or actually make it worse if one takes banks' risk-return considerations fully into account. In order to analyze the problem in greater detail, we present a model for a bank's optimizing behavior under regulatory constraints. We also differentiate between expected and unexpected

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[1] The authors would like to thank the participants of the Eurobanking conference in Maribor in 2008, the "Workshop on the Potential Pro-Cyclicality of the New Regulatory Framework" at the ECB in 2008 and the Workshop "Assessing the Impact of Financial Regulation" at the Bank of Italy in Rome 2009 for comments on earlier versions of this paper.

changes in credit risk.

There is a large stream of literature that analyzes the cyclical effects of risk-sensitive capital requirements. Catarineu-Rabell et al. (2006), Goodhart et al. (2006), and Kashyap and Stein (2004) focus on the impact of macroeconomic conditions on the probabilities of default and the magnitude of cyclical variations in minimum capital requirements. By contrast, Estrella (2004) determines the optimal level of capital in the presence of capital costs and costs of failure. He shows that minimum capital requirements based on *Value at Risk* are likely to be pro-cyclical. Heid (2007) studies the effect of minimum capital requirements in a macroeconomic framework and confirms the view that a risk-sensitive capital framework is likely to be pro-cyclical but also that the capital buffer plays an important role in mitigating capital-driven cyclicality in lending.

Our study is more closely related to several other studies which analyze capital requirements in a stochastic dynamic optimization framework. Zhu (2007) introduces an equilibrium model in which banks maximize expected discounted dividend payments but are constrained in their lending behavior by minimum capital requirements. Peura and Keppo (2006) study banks optimal capital choice as a trade-off between the opportunity cost of equity capital, the loss of franchise value following a regulatory minimum capital violation, and the cost of recapitalization. The assumed recapitalization results in a positive probability of capital adequacy violation. Repullo and Suarez (2008), who model relationship banking with endogenous loan rates, find that capital buffers are counter-cyclical under risk-insensitive capital requirements and pro-cyclical under risk-sensitive capital requirements.

2 The framework

In our model, the representative bank generates interest income from a credit portfolio that it funds with deposits and equity capital. Its objective is to maximize expected discounted dividends net of capital costs. As equity capital is more costly than deposits, the bank faces a trade-off between high profitability with low capital ratios and greater solvency with higher capital ratios. In determining the optimal level of capital, it is assumed that the bank can only build up capital by retaining earnings but cannot raise new capital on the capital market. This assumption is made to keep the analysis tractable as otherwise the degree of freedom in the bank's decision problem would become too large.

The bank's second decision parameter is its portfolio composition. In particular, it can choose between bonds and loans. The former pay a safe interest rate r, while the latter pay an interest rate of κ_t which exceeds r due to the loans' credit risk.

The bank enters period t with capital C_t and customer deposits D. We assume the latter to be fixed over time. As stated above, the bank determines its current dividend payments

d_t and its level of loans L_t. The level of safe bonds in its portfolio is implicitly derived from its budget constraint:

$$C_t - d_t + D = L_t + B_t. \tag{1}$$

All loans have an *ex ante* equal probability of default p_t, which may however vary over time. By contrast, the loss given default given by LGD is fixed. The default correlation is implicitly determined by the *asset correlation* ρ.[2] Vasicek (2002) showed that under certain conditions the (random) default rate q converges to the following distribution:

$$q \sim F(x, p, \rho) = \Phi\left(\frac{\sqrt{1-\rho} \cdot \Phi^{-1}(x) - \Phi^{-1}(p)}{\sqrt{1-\rho}}\right). \tag{2}$$

The bank's (random) profit before dividend pay-outs in period $t+1$ is given by

$$\pi_{t+1} = r \cdot (C_t - d_t) + (\kappa_t - r) \cdot L_t - LGD \cdot L_t \cdot dr_{t+1}. \tag{3}$$

Thus capital before dividend pay-outs is given by

$$C_{t+1} = C_t - d_t + \pi_{t+1}. \tag{4}$$

The bank's balance sheets at t and $t+1$ are depicted in Figure 1.

Assets	Liabilities
L_t	$C_t - d_t$
B_t	D

Assets	Liabilities
L_{t+1}	$C_t - d_t + \pi_{t+1} - d_{t+1}$
B_{t+1}	D

Figure 1: Balance sheet of the bank at times t and $t+1$.

The (opportunity) costs of capital are equal to z per unit capital invested. We assume that a bank's dividend pay-outs may not exceed its current level of equity capital. If losses in the bank's loan portfolio deplete its capital and the bank becomes insolvent, it will disappear from the market and capital once invested is lost. Summing up, the bank's optimization problem reads as follows:

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[2] The asset correlation can be interpreted as the correlation in the borrowing firms' assets.

$$
\begin{aligned}
\max_{\{d_t, L_t\}_{t=0,\ldots,\infty}} \quad & E\left(\sum_{t=0}^{\infty} \beta_t \cdot (d_t - z \cdot C_t^*)\right) && (5)\\
\text{s.t.} \quad & L_t \leq C_t - d_t + D && (6)\\
& d_t \leq C_t && (7)\\
& C_{t+1} = \begin{cases} C_t - d_t + \pi_{t+1} & \text{if } C_t \geq 0 \\ 0 & \text{otherwise} \end{cases} && (8)\\
& C_{t+1}^* = \begin{cases} C_{t+1} & \text{if } C_{t+1} \geq 0 \\ C_t & \text{otherwise.} \end{cases} && (9)
\end{aligned}
$$

The target function (5) is defined as the discounted dividend payments net of capital costs. The constraint (6) corresponds to the budget constraint (1), and (8) is the default constraint. For the discount factor we set $\beta_t = \left(\frac{1}{1+r}\right)^t$.

The bank's optimization problem is a stochastic dynamic system with state variable C_t, transition equation (8) and decision variables d_t and L_t. Thus, the following Bellman equation holds:

$$
\begin{aligned}
V(C) = \max_{(d,L)\in A_t} \{ & d - z \cdot C + \beta \cdot E[V(C - d + \pi) | C - d + \pi \geq 0] && (10)\\
& - \frac{1}{1-\beta} \cdot C \cdot \mathrm{P}(C - d + \pi < 0)\}
\end{aligned}
$$

for all C. The sets A_t include all feasible (d, L) as determined by the constraints (6) to (9). The right hand side of equation (10) is split into two parts. The first term refers to the case where the bank survives in the following period, whereas the second part reflects the cost of default.

Minimum capital requirements, also referred to as MCRs throughout this paper, restrict the bank's leverage and riskiness. Both fixed MCRs and risk-sensitive MCRs can be described in terms of risk weighted assets (RWA), which are defined as the weighted average of a bank's assets, where the risk weights are determined according to the perceived risk of the particular asset. Under fixed MCRs and risk-sensitive MCRs, a bank's risk weighted assets must not exceed a certain multiple of its capital, or, equivalently, the ratio of capital to risk weighted assets (*regulatory capital ratio*) must exceed a certain threshold a, ie

$$
\frac{C}{RWA} \geq a. \qquad (11)
$$

Under fixed MCRs and risk-sensitive MCRs, the threshold a is given by 8%. However, fixed MCRs and risk-sensitive MCRs differ in the way risk weights are calculated. Under fixed MCRs, risk weights are determined by the type of the respective asset, eg 100%

for loans, 20% for interbank exposures and 0% for OECD sovereign exposures. By contrast, under the Internal Ratings Based approaches, risk weights are determined by the estimated probability of default and other risk parameters. For our model, we assume a positive risk weight w for loans and a zero weight for riskless bonds for both fixed MCRs and risk-sensitive MCRs. The regulatory requirement can therefore be rewritten as:

$$\frac{C}{w \cdot L} \geq a. \tag{12}$$

In our model, we assume that regulatory requirements have to be fulfilled both at the beginning and at the end of an investment period. The former imposes a binding restriction on the choice of the bank's portfolio. The latter is of indirect nature. As a result of credit risk, it is uncertain *ex ante* whether the bank will be able to meet capital requirements at the end of the investment period when losses have materialized. However, we assume that a bank that fails to meet regulatory requirements is closed down by regulators. Summing up, the decision problem with regulatory requirements can be written as:

$$\max_{\{d_t, L_t\}_{t=0,\ldots,\infty}} \quad E\left(\sum_{t=0}^{\infty} \beta_t \cdot (d_t - z \cdot C_t^*)\right) \tag{13}$$

$$\text{s.t. } L_t \leq C_t - d_t + D_t \tag{14}$$

$$w_t \cdot L_t \leq a^{-1} \cdot C_t \tag{15}$$

$$d_t \leq C_t \tag{16}$$

$$C_{t+1} = \begin{cases} C_t - d_t + \pi_{t+1} & \text{if } C_t \geq a \cdot w \cdot L_{t-1} \\ 0 & \text{otherwise} \end{cases} \tag{17}$$

$$C_{t+1}^* = \begin{cases} C_{t+1} & \text{if } C_{t+1} \geq 0 \\ C_t & \text{otherwise.} \end{cases} \tag{18}$$

The Bellman equation now reads

$$V(C) = \max_{(d,L) \in A_t} \{d - z \cdot C + \beta \cdot E[V(C - d + \pi) | C - d + \pi \geq a \cdot w_t \cdot L_t] - \frac{1}{1-\beta} \cdot C \cdot \mathrm{P}(C - d + \pi < a \cdot w_t \cdot L_t)\}. \tag{19}$$

As in the unconstrained case, the second term reflects the cost of default, which occurs in this case if the bank does not meet the minimum capital requirements.

3 Scenario analysis

In this paper we measure the pro-cyclicality of the bank's behavior in terms of its equity capital, dividend payments, and lending. If the dynamic system is shocked, i.e. if one assumes shocks in the exogenous variables, these will deviate from its long-term average. Depending on the bank's characteristics and the general regulatory framework, the deviation might be modest, which would indicate mild pro-cyclical behavior, or large, in which case it is strong. In our case, the key exogenous variable measuring the state of the economy is the probability of creditors' default (PD). If the PD is low, the economy is in good shape, and vice versa. We assess the dependence of capital and lending on PDs by means of a scenario analysis. We study and compare the results of three different settings:

(i) The unrestricted case: The bank is constrained by the insolvency condition but not by any capital requirements.

(ii) The fixed MCR case: Risk weights are fixed over time for non-defaulted loans ($w = 1$).

(iii) The risk-sensitive MCR case: Capital requirements depend on the bank's credit risk, i.e. on PD.

In particular, for the risk-sensitive MCR case (BCBS, 2006, para 272)

$$w = LGD \cdot \left(\Phi \left(\frac{\Phi^{-1}(PD) + \rho(PD) \cdot \Phi^{-1}(0.999)}{\sqrt{1 - \rho(PD)}} \right) - PD \right) \cdot \frac{1}{1 - 1.5 \cdot b(PD).} \tag{20}$$

Note that this formula represents the risk weight function for corporate obligors.[3]

In the scenario analysis below, the return on equity is set to $z = 10\%$ and the riskless rate to $r = 4\%$. We further assume a loss given default of $LGD = 45\%$, which is the rate implicitly assumed in Basel 2's *Foundation IRB approach*.[4] The correlation parameter is set to $\rho = 30\%$. Finally, the amount of deposits is assumed to be fixed over time and normalized to $D = 3$.

Note that a rise in PDs has two effects. First, expected credit losses will be higher. In particular, since a constant loss rate was assumed, the credit loss will be equal to $LGD \cdot PD$. Second, credit risk as measured by the deviation of the loss from its expected value will change too. Usually this deviation – frequently called the *unexpected loss* – is

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[3] In particular we assume a residual maturity of 2.5 years and the respective maturity adjustment $b(PD) = (0.11852 - 0.05478 \cdot \ln(PD))^2$.

[4] Under the Foundation IRB, banks are required to use their own estimates of the risk-parameter PD, while LGDs and EADs are specified by the supervisory framework, eg LGD = 45% for unsecured loans.

measured by a suitable percentile of the normalized loss distribution. The bank will take into account both the expected and the unexpected loss when determining its reaction to a change in PDs.

In this regard, an important factor will be whether or not the bank had anticipated the change in PDs. Unanticipated changes are likely to induce more abrupt shifts in lending than anticipated ones. For instance, in the case of the latter the bank may build up sufficient capital buffers in order to protect itself against unexpected losses in its credit portfolio.

3.1 Unanticipated credit risk shocks

In this section we analyze the effects of an *unanticipated* shock to credit risk and capital. We assume that the economy is in a stable equilibrium with no fluctuations in expected credit risk.

In the following we compare three different regimes: the absence of any capital requirements, fixed capital requirements, and risk-sensitive capital requirements. In order to ensure that the comparison of the latter two is not distorted by level effects, the long-term level of borrowers' *PD* is set to 126bp. In this case, risk-sensitive risk weights exactly match fixed risk weights *ex ante*. All future deviations (after the assumed shocks to PDs) are thus the result of differences in the two frameworks' design and not because of differences in the levels of initial capital.

As a result of this assumption, the lending policies for fixed MCRs and risk-sensitive MCRs coincide. The same holds true for dividend policies. The policy functions are depicted as solid lines in Figure 2. Clearly, they have a distinct, non-linear shape. The dividend policy function remains flat and equal to zero up to a certain capital threshold. Thereafter it is linearly upward sloping. By contrast, the loan policy is linearly upward sloping in the first section, which ends at approximately the same level of capital as in the case of the dividend policy, and flat thereafter. This suggests the following interpretation: For low levels of (initial) capital, the bank primarily aims to build up its capital buffer through retained earnings. It therefore refrains from paying out any dividends to its shareholders. Step by step, however, and in line with capital accumulation, it increases its volume of loans. For high levels of capital, the process reverses. Then dividend payments take priority and surplus capital is paid out to shareholders. At the same time, the bank does not change its volume of loans until a new equilibrium is reached, which is presumably somewhere near the kink in the policy function. We determine the long-run level of capital and loans by simulating the bank's investment and capital decisions. We start with a given value of initial capital and simulate the subsequent development in random profits, capital, dividends, and loan supply. Thus we generate a total of 200 independent random paths. We take the capital after 20 periods as a realization of long-term capital, provided that the bank neither became insolvent nor violated minimum capital requirements in the preceding periods. The average of such values serves as the estimate for the expected value of long-term capital in the subsequent analysis. The long-term values for capital as well as for lending and dividend payments are shown in Table 1.

Table 1: Overview: Long-term capital, loans, dividends

	Unrestr.	**Fixed MCRs**	**Risk-sens. MCRs**
Capital	0.16	0.48	0.48
Dividend payments	0.06	0.08	0.08
Volume	3.0	3.4	3.4

All remaining fluctuations are random, resulting from random losses in the bank's loan book. Importantly, as long as credit risk remains constant, those fluctuations are expected, and there is no need for the bank to change its *policies* as opposed to the respective realized levels of capital and lending in one particular point in time.

Before analyzing a shift in PDs, it is instructive to analyze an *unanticipated* reduction in capital. This drop in capital may for instance result from extraordinary losses in the bank's loan book. So we assume that the model bank incurs a drop in capital in the amount of 5%, which roughly corresponds to the 90% quantile of the capital loss distribution. From the policy functions we infer that in the unrestricted case the bank reduces its dividend payments by 13% compared with its long-term average. Under fixed MCRs and risk-sensitive MCRs the shift is more pronounced, with dividend payments falling by 30%. At the same time, one observes no reduction in lending. In other words, even larger losses in capital do not affect lending. The situation would change, of course, if we assumed very extreme losses in capital.

We now simulate a sudden and isolated one-time rise in the borrower's PD by 100%. As a result, required regulatory capital under risk-sensitive MCRs rises by 22.5%. As risk weights are fixed, the rise in credit risk has no effect on regulatory capital under fixed MCRs. Note however, that it may still have a significant effect on desired capital as a result of a change in the *unexpected loss*.

As above, we assume that the shock in credit risk is a one-time event and that credit risk returns to its previous level thereafter. In contrast to the sudden shift in capital discussed above, the bank will change its dividend and lending policies. Although it did not anticipate the change in PDs, the old policies are no longer optimal against the background of higher credit risk. It is easy to show that the optimization problem boils down to solving a profit maximization problem in two periods. In particular, we denote by V the value function derived from the solution with fixed PDs. Obviously, the optimal policies *after* the PDs have returned to their long-term levels are those which are optimal

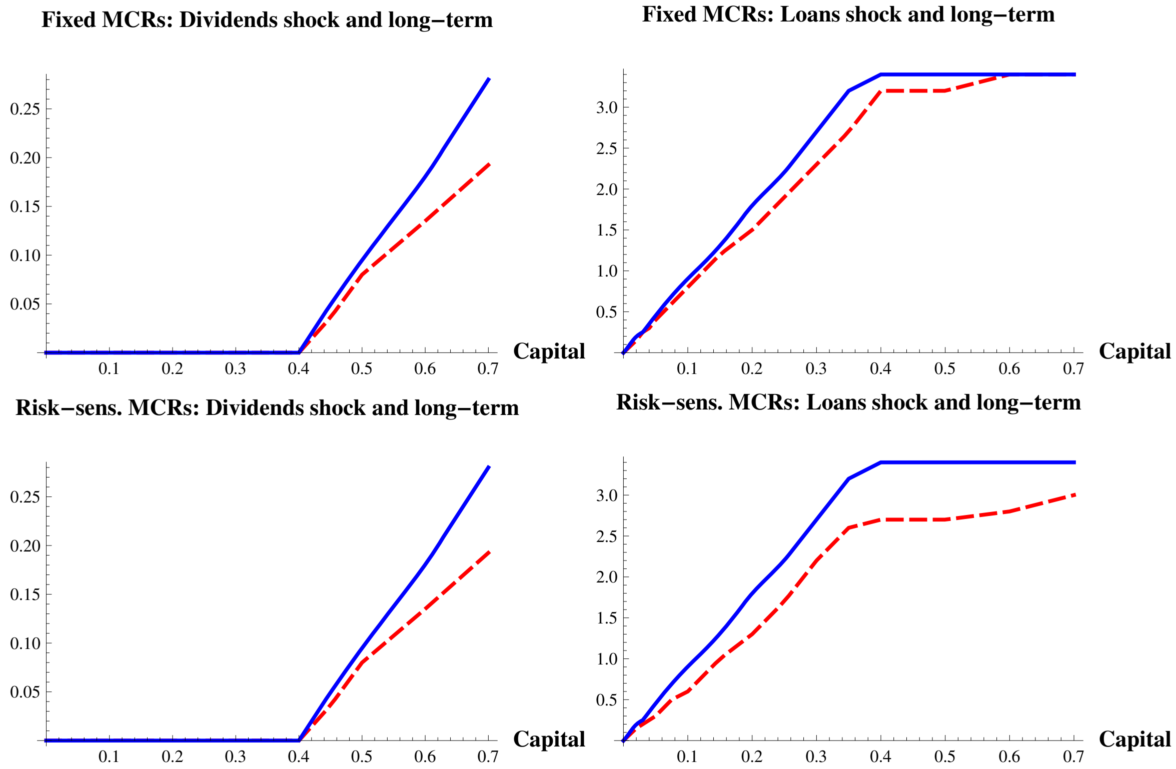

Figure 2: Comparison of policies (shock versus long-term)

with respect to V. Hence, the optimal policy *prior* to the shock is given by

$$(d, L) = \text{argmax}_{d,L}\{d - z \cdot C + \beta \cdot E[V(C - d + \pi)]\} \tag{21}$$

for any given level of capital C.

Table 2 summarizes the effects on dividend payments and loan volumes. For the unrestricted case, virtually no change in lending takes place. At the same time, dividend payments are cut by nearly 30% in order to keep the loan-to-capital ratio constant in times of higher expected losses. Under the regime with fixed capital requirements, the bank moderately reduces its lending (by approximately 6%) when faced with higher PDs. The reduction in dividend payments is significant, equalling nearly 20%. Under the regime with risk-sensitive capital requirements, we observe a significant reduction of lending (minus 21%). The drop in dividend payments is similar to the case with fixed capital requirements.

Figure 3 shows the evolution of mean lending over time for the three regimes under consideration (solid line). For the two scenarios with capital requirements, we added a line that shows the maximum permitted loan volume under the respective capital regime (dashed line). It is important to note, that the bank reduces its loan exposure although it still has sufficient capital buffers that would allow it to lend more. Therefore, it is

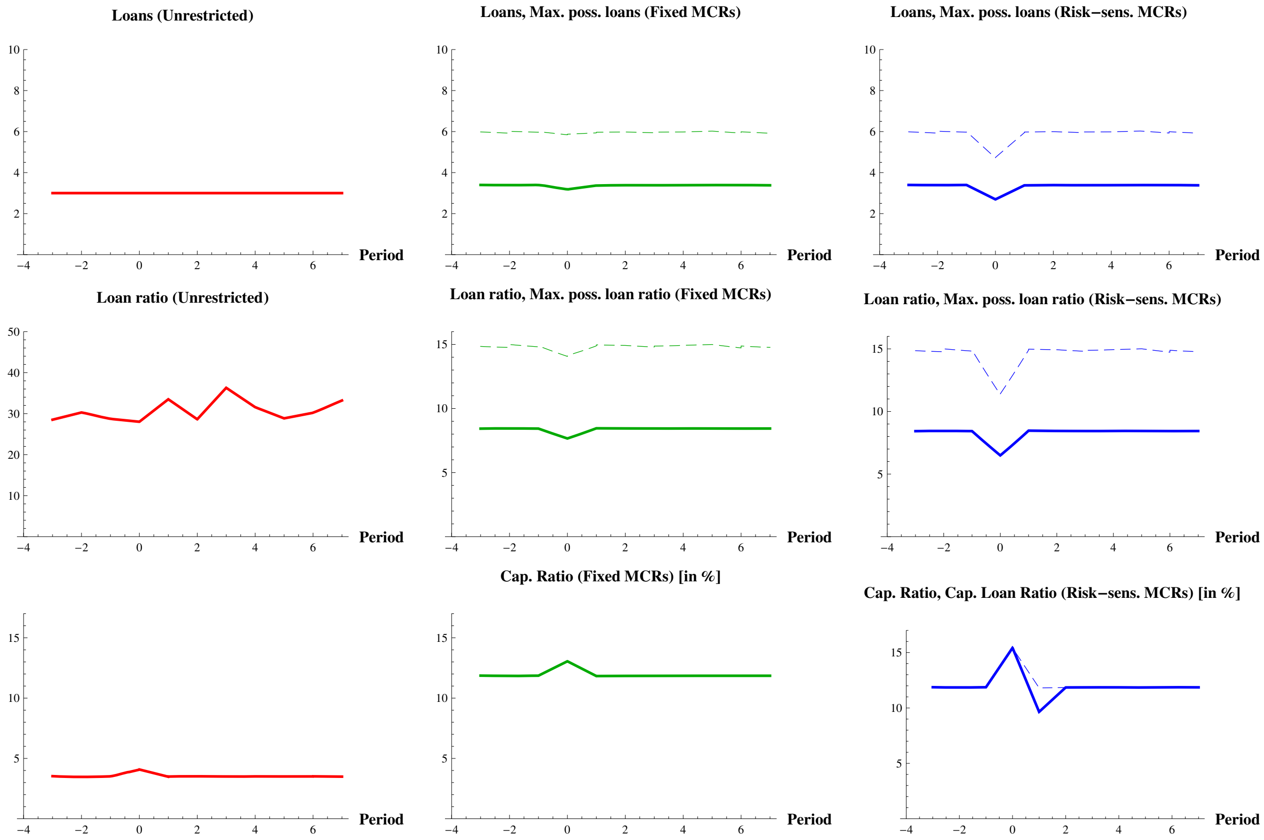

Figure 3: Evolution of loans, loan-to-capital ratios, and capital ratios

not because capital requirements became a binding constraint that the bank reduces its risk exposure. Rather it is the combination of stricter capital requirements, which makes a default more likely, and bigger risks that induces the bank to reduce its credit risk exposure.

Table 2: Policy changes (shock versus long-term) in response to a sudden rise in credit risk [in %]

	Unrestr.	**Fixed MCRs**	**Risk-sens. MCRs**
Dividend payments	-28.2	-19.5	-19.5
Loan volume	0	-5.9	-20.6

3.2 Expected credit risk fluctuations

Having discussed unanticipated shocks in credit risk and capital, we now move to expected fluctuations in PDs and profits. In order to do so, we incorporate a very simple model of business fluctuations into our framework. In particular, we assume that the (relevant part of the) macroeconomy is represented by the evolution of the mean probability of default (PD). We take the assumed default correlation between *individual* borrowers at a particular point in time and leave it at that. We assume that the underlying probability distribution of the PD process is known to the bank. Therefore, to the extent that the bank can predict the future state of the economy, it will be able to provision against changes in mean credit risk.

It is assumed that the evolution of mean PDs follows a Markov process. The two states of the economy, which we call *Good* and *Bad*, represent an upturn or respectively downturn of the economy. The mean PD in each state is equal to p_G and p_B. The transition matrix is given by

$$\Omega_2 = \begin{pmatrix} \omega_{GG} & \omega_{GB} \\ \omega_{BG} & \omega_{BB} \end{pmatrix}.$$

The Bellman equations for the corresponding dynamic optimization problem are as follows:

$$V_i(C) = \max_{(d,L)\in A_t} \{d - z \cdot C + \beta \cdot \omega_{ii} \cdot E[V_i(C - d + \pi_i)] + \beta \cdot \omega_{ij} \cdot V_j(C - d + \pi_j)]\}. \quad (22)$$

In the scenario analysis below, we distinguish between two settings. In the “persistence” scenario, we assume that the mean PD has the tendency to remain in a particular state. In the “reversion” scenario we assume that the economy always reverts to the good state relatively quickly.

Persistence scenario

For the persistence scenario, each state occurs with unconditional probability 0.5 and the following symmetric transition matrix is assumed:

$$\Omega_P = \begin{pmatrix} 0.7 & 0.3 \\ 0.3 & 0.7 \end{pmatrix}. \quad (23)$$

As mentioned above, any fair assessment of risk-sensitive capital requirements should abstract from pure level effects. However, with time-varying PDs, risk-sensitive capital requirements necessarily vary over time. In the scenario analysis below, conditional PDs are set such that *on average* risk-sensitive capital requirements and fixed capital requirements coincide. As was noted above, that holds true if unconditional PDs are equal to 0.0126. As the unconditional state probabilities are equal to 0.5, this constrains the choice

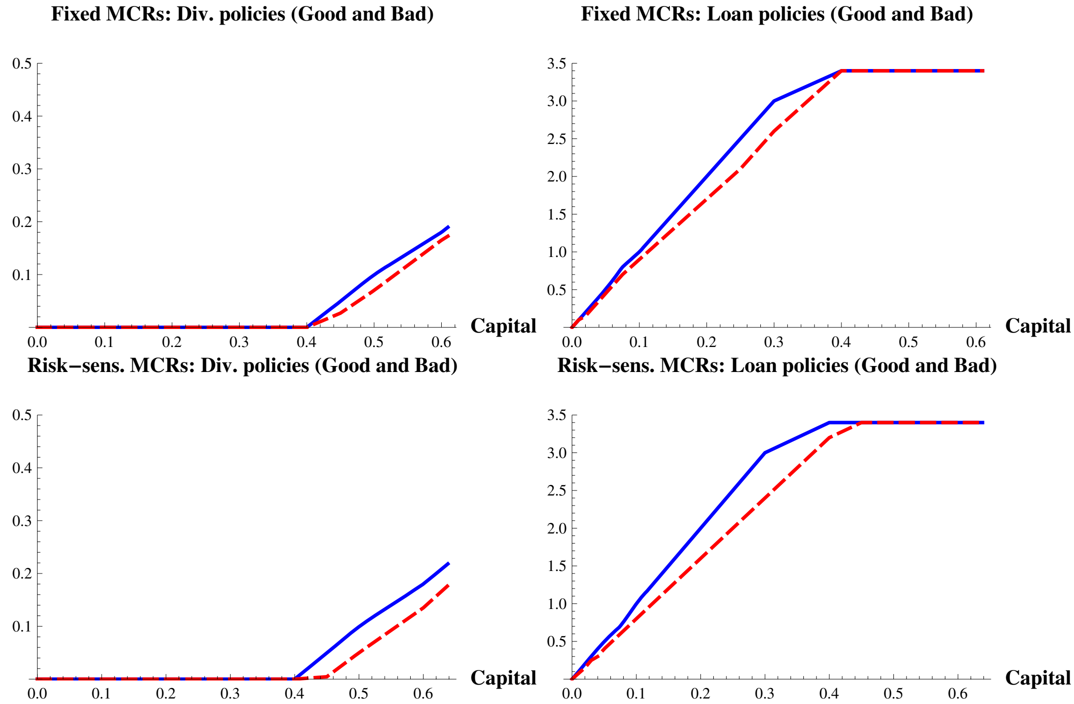

Figure 4: Comparison of the policies for good and bad states of the business cycle: fixed and risk-sensitive MRCs, persistence scenario, Table 3, $\kappa = 691bp$

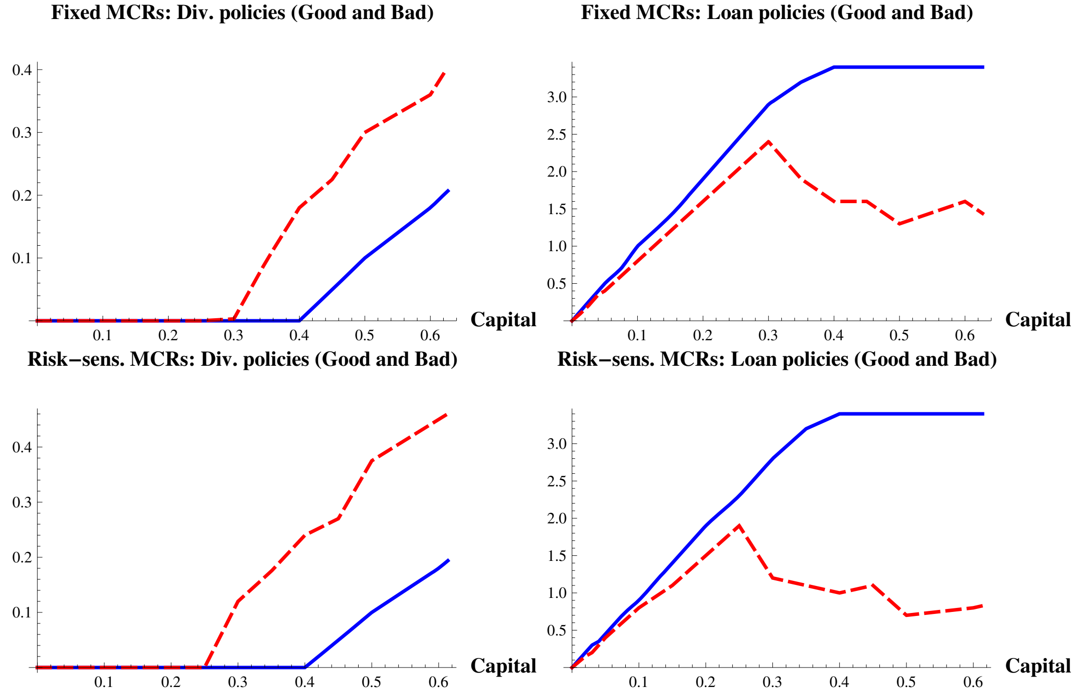

Figure 5: Comparison of the policies for good and bad states of the business cycle: fixed and risk-sensitive MRCs, persistence scenario, Table 4, $\kappa = 643bp$

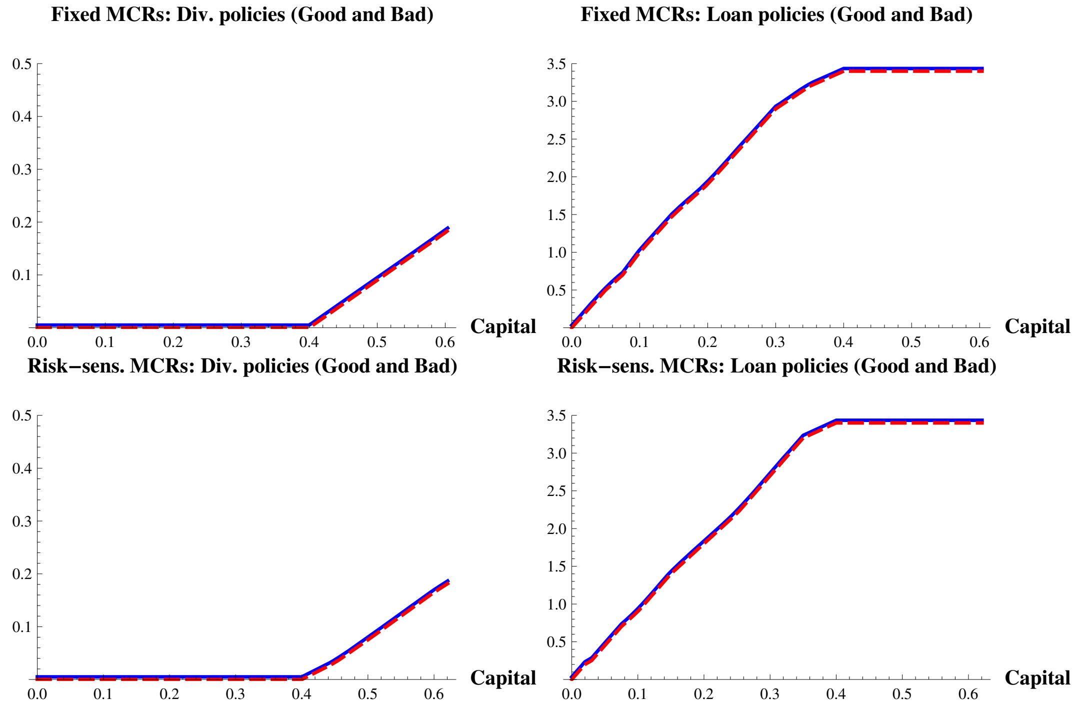

Figure 6: Comparison of the policies for good and bad states of the business cycle: fixed and risk-sensitive MRCs, reversion scenario, Table 5, $\kappa = 709bp$

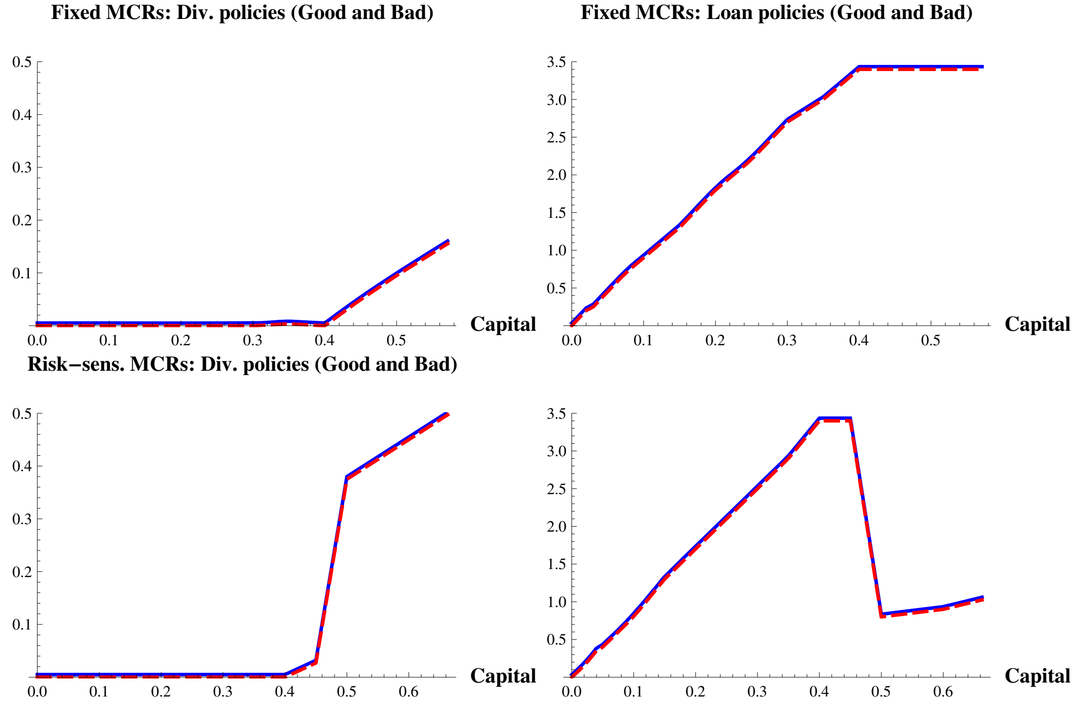

Figure 7: Comparison of the policies for good and bad states of the business cycle: fixed and risk-sensitive MRCs, reversion scenario, Table 6, $\kappa = 643bp$

of conditional PDs implicitly by

$$0.5 \cdot p_{\text{Good}} + 0.5 \cdot p_{\text{Bad}} = 1.26\%. \tag{24}$$

To fully determine the conditional PDs, we assumed the difference in conditional PDs to be one percentage point. This leaves us with PDs given by $p_{\text{Good}} = 0.76\%$ and $p_{\text{Bad}} = 1.76\%$.

For the loan interest rate, standard economic models predict that the spread over the riskless rate should cover both expected loss and capital costs for unexpected losses. Assuming a LGD of 45%, the expected loss is given by

$$EL = LGD \cdot (0.5 \cdot p_{\text{Good}} + 0.5 \cdot p_{\text{Bad}}) = 0.63\%. \tag{25}$$

The unexpected losses are usually defined as some quantile of the loss distribution. In our case we assumed the 99.99% quantile.[5] Therefore, for the total spread we have

$$\kappa - r = EL + z \cdot UL = 2.81\%. \tag{26}$$

As a further robustness check, we assume an additional stress scenario. In a low interest rate scenario the spread is set to 2.33%.

Figures 4 and 5 show the respective policy functions for the moderate and low interest rate scenario. For moderate interest rates, the general pattern of the respective policy functions for dividend payments and lending resembles those above for time-invariant PDs. In particular for lending, it is upward sloping in the first part, up to a certain capital level, and flat thereafter. Moreover, lending – and for that matter dividend payments – are lower in the bad state than in the good state given a certain level of capital. All in all, however, the policy functions for the good and bad state are fairly close.

The situation reverses for the low interest rate scenario. In this case, lending falls significantly (for a given level of capital) when the economy moves from the good into the bad state, at least if capital exceeds a certain threshold. Interestingly, the policy function for dividend payments in the bad state is – from a certain capital threshold – *above* the one for dividend payments in the good state.

In a second step, we simulated the behavior of banks with the aforementioned policy functions. Results are shown in Tables 3 and 4. For our key variables, such as loans, capital and capital ratios, we determined the average value as well as the conditional mean given a good or bad state of the economy. Results of Table 3 show that dividend payments are approximately 40% higher in good times compared to bad times under fixed MCRs. For risk-sensitive MCRs the difference is even bigger and approximately equals 69%. As a result, the difference in capital levels for the respective states of the economy is

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[5] Often a lower p-value is assumed. The higher level accounts for additional liquidity risk, which is not explicitly modelled here.

small. With regard to lending, the difference is negligible. Moving to a scenario with lower interest rates, the differences between good and bad states become more pronounced, in particular with regard to lending.

Some interesting observations can be made with regard to the leverage ratio, which has received considerable regulatory attention recently: First, under both regulatory regimes this ratio is higher in the good state than in the bad state. Second, as expected, the difference in the leverage ratios of the good and the bad state is bigger under risk-sensitive MCRs than under fixed MCRs. Third, under both regimes, leverage is much lower than under the unregulated system. Fourth, the unregulated system is much more cyclical – as measured by the difference between leverage ratios in the good and bad state – than both regulated systems.

Reversion scenario

In the reversion scenario we simulate an economy which is more often in the good state than in the bad state. Moreover, once the economy is in the bad state it is likely to revert to the good state in the following period.

To simulate this setting, we assume the following transition matrix:

$$\Omega_R = \begin{pmatrix} 0.7 & 0.3 \\ 0.7 & 0.3 \end{pmatrix}. \tag{27}$$

The transition matrix is symmetric, which means that the (conditional) probability of moving to a particular state, e.g. the bad state, does not depend on the current state of the economy. The loan interest rate, which is assumed to be constant, is determined in a similar fashion as above. For the high interest rate sub-scenario we chose $\kappa = 7.09\%$ and $\kappa = 6.43\%$ for the low interest rate scenario.

The policy functions for the two scenarios are depicted in figures 6 and 7. Since the conditional probabilities do not depend on the current state, the (conditional) policy functions for the good and the bad state coincide, unlike in the persistence scenario. As was the case for the persistence scenario, we find the same strong non-linear pattern for the low interest rate scenario. As policies do not vary between good and bad states of the economy, any fluctuations in the conditional means of loans and dividends is purely the result of different loss distributions for each state. In particular, expected losses are higher in the bad state than in the good state. However, the variation in lending and dividends are very small (Tables 5 and 6). We do not discuss the results for the high interest scenario here, which are similar.

Table 7 compares the findings for fixed and risk-sensitive capital requirements. As expected, lending is more volatile under the latter than under the former. The degree of volatility depends largely on the level of expected earnings. If the loan interest rate is high, volatility is negligible whereas if it is low, volatility can become very significant. This holds true even for the reversion scenario where policies for the good and bad state are equal. Obviously, the degree of volatility results less from a change in policies than from the sensitivity, for a given policy, of lending with regard to the level of capital. The results also show that capital buffers partially absorb the volatility in minimum capital requirements as shown by the high degree of correlation.

4 Conclusion

This paper aims to explain the evolution of capital and capital buffers over time and compares different regulatory frameworks (fixed MCRs, risk-sensitive MCRs and the absence of any regulatory capital framework). The general framework uses models of stochastic dynamic optimization in order to study banks' adjustment strategies vis a vis changes in macroeconomic conditions. The model can explain the presence of substantial capital buffers on top of required holdings. The model predicts that banks will reduce lending and cut dividend payments during economic downturns even if they still hold sufficient capital buffers to meet capital requirements. Importantly, large capital buffers do not necessarily mitigate the problem of cyclicality: Minimum required and actual capital often move in sync. The drop in lending is more pronounced if the random shock to PDs is unexpected. However, even if they are expected – in the sense that banks know their probability distribution – cyclicality can be significant, in particular if interest margins are relatively small.

The findings suggest that the problem of cyclicality in the current Basel framework does indeed need to be addressed. However, there might be no easy way to fix the problem, as any change in regulatory measures will provoke an adaptive reaction. Making capital requirements less cyclical might not necessarily mean that *actual* lending becomes less volatile. In designing new *macro-prudential* instruments, it is therefore essential to take into account the reaction function of financial intermediaries.

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A Results

Table 3: Loans, Dividends and Capital-Loan Ratios conditional on good and bad stage for constant interest rate $\kappa = 691bp$ and transition matrix Ω_P (persistence scenario)

	Avg	**Avg ($\cdot$ | good state)**	**Avg ($\cdot$ | bad state)**
Constant interest rate			
Unrestr.			
Gross capital C	0.22	0.21	0.23
Dividend yield D/C	0.32	0.47	0.15
Net capital $C - D$	0.15	0.11	0.19
Loans L	3.1	3.0	3.2
Leverage $L/(C - D)$	23.9	28.1	19.1
CL-Rat. [in %]	4.8	3.6	6.0
Fixed MCRs			
Gross capital C	0.51	0.51	0.51
Dividend yield D/C	0.18	0.21	0.15
Net capital $C - D$	0.41	0.40	0.43
Loans L	3.4	3.4	3.4
Leverage $L/(C - D)$	8.2	8.4	7.9
CL-Rat. [in %]	12.2	11.9	12.6
Risk-sens. MCRs			
Gross capital C	0.52	0.52	0.52
Dividend yield D/C	0.18	0.22	0.13
Net capital $C - D$	0.43	0.40	0.45
Loans L	3.4	3.4	3.4
Leverage $L/(C - D)$	8.0	8.4	7.5
CL-Rat. [in %]	12.6	11.9	13.3
C-Rat. [in %]	13.1	14.1	12.0

Table 4: Loans, Dividends and Capital-Loan Ratios conditional on good and bad stage for constant interest rate $\kappa = 643bp$ and transition matrix Ω_P (persistence scenario)

	Avg	**Avg ($\cdot$ | good state)**	**Avg ($\cdot$ | bad state)**
Constant interest rate			
Unrestr.			
Gross capital C	0.17	0.17	0.17
Dividend yield D/C	0.34	0.43	0.24
Net capital $C - D$	0.11	0.09	0.12
Loans L	3.0	3.0	3.0
Leverage $L/(C - D)$	30.6	32.5	28.3
CL-Rat. [in %]	3.6	3.1	4.0
Fixed MCRs			
Gross capital C	0.37	0.39	0.34
Dividend yield D/C	0.14	0.07	0.21
Net capital $C - D$	0.31	0.36	0.25
Loans L	2.6	3.2	1.9
Leverage $L/(C - D)$	8.3	8.9	7.6
CL-Rat. [in %]	12.2	11.2	13.2
Risk-sens. MCRs			
Gross capital C	0.31	0.33	0.28
Dividend yield D/C	0.12	0.04	0.22
Net capital $C - D$	0.26	0.31	0.19
Loans L	2.1	2.8	1.4
Leverage $L/(C - D)$	8.1	9.0	7.0
CL-Rat. [in %]	12.7	11.1	14.3
C-Rat. [in %]	13.1	13.1	13.0

Table 5: Loans, Dividends and Capital-Loan Ratios conditional on good and bad stage for constant interest rate $\kappa = 709bp$ and transition matrix Ω_R (reversion scenario)

	Avg	**Avg ($\cdot$ | good state)**	**Avg ($\cdot$ | bad state)**
Constant interest rate			
Unrestr.			
Gross capital C	0.24	0.24	0.23
Dividend yield D/C	0.33	0.34	0.33
Net capital $C - D$	0.16	0.16	0.15
Loans L	3.1	3.1	3.1
Leverage $L/(C - D)$	21.3	21.2	21.3
CL-Rat. [in %]	5.0	5.1	4.9
Fixed MCRs			
Gross capital C	0.51	0.51	0.51
Dividend yield D/C	0.19	0.20	0.18
Net capital $C - D$	0.41	0.41	0.41
Loans L	3.4	3.4	3.4
Leverage $L/(C - D)$	8.3	8.3	8.3
CL-Rat. [in %]	12.1	12.1	12.0
Risk-sens. MCRs			
Gross capital C	0.53	0.53	0.52
Dividend yield D/C	0.19	0.19	0.18
Net capital $C - D$	0.43	0.43	0.43
Loans L	3.4	3.4	3.4
Leverage $L/(C - D)$	8.0	8.0	8.0
CL-Rat. [in %]	12.6	12.6	12.5
C-Rat. [in %]	13.0	13.7	11.0

Table 6: Loans, Dividends and Capital-Loan Ratios conditional on good and bad stage for constant interest rate $\kappa = 643bp$ and transition matrix Ω_R (reversion scenario)

	Avg	**Avg (· | good state)**	**Avg (· | bad state)**
Constant interest rate			
Unrestr.			
Gross capital C	0.17	0.17	0.17
Dividend yield D/C	0.33	0.34	0.31
Net capital $C - D$	0.11	0.11	0.11
Loans L	3.0	3.0	3.0
Leverage $L/(C - D)$	29.0	27.4	32.8
CL-Rat. [in %]	3.8	3.8	3.7
Fixed MCRs			
Gross capital C	0.48	0.48	0.47
Dividend yield D/C	0.16	0.16	0.15
Net capital $C - D$	0.40	0.40	0.40
Loans L	3.4	3.4	3.4
Leverage $L/(C - D)$	8.4	8.4	8.4
CL-Rat. [in %]	11.9	11.9	11.8
Risk-sens. MCRs			
Gross capital C	0.33	0.33	0.33
Dividend yield D/C	0.11	0.11	0.10
Net capital $C - D$	0.28	0.28	0.28
Loans L	2.3	2.3	2.3
Leverage $L/(C - D)$	8.2	8.2	8.2
CL-Rat. [in %]	12.3	12.3	12.3
C-Rat. [in %]	12.7	13.5	10.8

Table 7: Volatilities and correlations

Persistence Scenario				
	$\kappa = 691bp$		$\kappa = 643bp$	
	Fixed MCRs	**Risk-sens. MCRs**	**Fixed MCRs**	**Risk-sens. Basel MCRs**
σ (C-Rat.) [in %]	0.4	1.1	1.2	1.0
σ (L/(C-D))	0.27	0.45	0.78	1.09
σ (L)	0.04	0.04	0.69	0.83
σ (L) / E (L)	0.01	0.01	0.27	0.39
ρ (C, MRC) [in %]	28.5	7.3	94.5	90.1
Reversion scenario				
	$\kappa = 709bp$		$\kappa = 643bp$	
	Fixed MCRs	**Risk-sens. MCRs**	**Fixed MCRs**	**Risk-sens. Basel MCRs**
σ (C-Rat.) [in %]	0.1	1.3	0.1	1.7
σ (L/(C-D))	0.10	0.11	0.05	0.58
σ (L)	0.02	0.02	0.06	0.80
σ (L) / E (L)	0.01	0.01	0.02	0.35
ρ (C, MRC) [in %]	25.9	-10.9	30.1	92.0

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