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the impact of basel III on financial (in)stability - an agent-based credit network approach

by Sebastian Krug, Matthias Lengnick,
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The Impact of Basel III on Financial (In)stability

– An Agent-based Credit Network Approach –

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Abstract

The Basel III accord reacts to the events of the recent financial crisis with a combination of revised micro- and new macroprudential regulatory instruments to address various dimensions of systemic risk. This approach of cumulating requirements bears the risk of individual measures negating or even conflicting with each other which might lessen their desired effects on financial stability. We provide an analysis of the impact of Basel III's main components on financial stability in a stock-flow consistent (SFC) agent-based computational economic (ACE) model. We find that the positive joint impact of the microprudential instruments is considerably larger than the sum of the individual contributions to stability, i.e. the standalone impacts are non-additive. However, except for the buffers, the macroprudential overlay's impact is either marginal or even destabilizing. Despite its simplicity, the leverage ratio performs poorly especially when associated drawbacks are explicitly taken into account. Surcharges on SIBs seem to rather contribute to financial regulations complexity than to the resilience of the system.

JEL classification: G01, G28, E40, C63

Keywords: Banking Supervision, Basel III, Liquidity Coverage Ratio, Macroprudential Regulation, Financial Instability, Agent-based Computational Economics

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1 Introduction

The recent financial crises has painfully disclosed the policy mismatch between the former regulatory framework of banking supervision, namely Basel II, and its intended objective of financial stability. The existing deficiencies predominantly concern neglected dimensions of systemic risk as well as their corresponding transmission channels [Repullo et al. (2013)]. These disregarded dimensions include liquidity and also contagion risk, both resulting from various sources [Bank of England (2011)]. The one-dimensional regulatory approach of rigidly focusing on capital adequacy requirements (CAR), in order to address mainly the solvency risk of banks, has appeared to be insufficient in terms of ensuring the resilience of the financial system. Achieving financial stability, as the necessary precondition for overall macroeconomic stability, inevitably requires the identification of the entire range of sources of systemic risk in the financial system and of the factors that are driving them [Arnold et al. (2012)].

Accordingly, the Basel Committee on Banking Supervision (BCBS) has aimed to approach the existing gaps with the Basel III accord. A growing consensus is arising that the framework passed through the indispensable development process towards a broader consideration of dimensions of systemic risk by re-orientating banking supervision to place stronger emphasis on mitigating instability in the financial system as a whole, i.e. by the invocation for macroprudential regulatory tools [Borio (2011); Hanson et al. (2011); Blanchard et al. (2010, 2013)]. The planned phasing-in of the accord starting in 2014 intends to allow banks to meet the stricter capital requirements by retained earnings and, more importantly, without downsizing their credit supply to the real economy [Basel Committee on Banking Supervision (BCBS) (2013)]. Moreover, it gives regulators as well as researchers some time to analyze the impact of the new regulatory requirements.

For instance, Arnold et al. (2012) call for further research in this area. They state that we indeed know that more capital is better since it increases banks' loss absorbency capacity, at least, for relatively low requirement levels. But they also expect that stability cannot just be seen as a monotonic function of capital. Maybe there are levels at which even stricter requirements constitute a binding constraint for supervised institutions struggling with the compliance and, perhaps, leading to negative externalities promoting rather instability instead of strengthening the financial system [van den End and Kruidhof (2013)]. Hence, the *first* question arising in this context is whether there exist optimal levels for the new multiplicity of imposed regulatory instruments taking them into account individually.

Furthermore, in the wake of a considerable regulatory reform, not merely the standalone impact of a single imposed requirement has to be put into question. As Dombret (2013), Member of the Executive Board of the Deutsche Bundesbank, stated recently:

To ensure consistency, we need to focus even more on the systemic aspects of financial regulation. Regulatory measures must build upon each other and be interlocked to set consistent incentives. Otherwise, we run the risk of individual measures conflicting with

each other. Such a lack of consistency might lessen the desired effects of the new regulations or even negate them entirely. Impact studies are an important tool in this context. To gauge the effects of new regulation, such studies should accompany all major reform projects.

With this in mind, even though every single regulatory requirement, at least up to some optimal level, may contribute to financial stability individually, it does not necessarily say all that much about their collaboration. Thus, concurrency issues have to be seriously taken into account. Considering the urgent need for immediate action during the early stage of the financial crisis in the context of the enormous complexity of the financial system and the public and political pressure on the supervisory authorities, there was probably only little time for deep investigation concerning the consistent collaboration of the proposed measures. Hence, the *second* question is whether the concurrent imposition of multiple micro- and macroprudential instruments lead to a regulatory environment in which they (perhaps partially) offset each others individual contribution to financial stability.

In this paper we apply the model proposed in Lengnick et al. (2013) to show that the strengthening and extension of the microprudential regulation contributes substantially to the resilience of the financial system. It is worth mentioning that the joint impact of its components on stability is considerably larger than the sum of the individual contributions. Hence, the newly introduced liquidity regulation can be seen as well designed complementary to an adequate capital base of banks. Furthermore, implementing a part of the capital requirement as a flexible buffer forcing banks to build up capital above the minimum requirement embodies the best possible outcome. Thus, we identify the three-dimensional combination consisting of 2 microprudential tools plus a macroprudential conservation buffer as the optimal combination, both in terms of financial stability and regulatory complexity.

Moreover, we show that the impact of the leverage ratio negatively depends on the capital base of banks, thus, serving as an additional back-up constraint. It seems that with an increasing amount of already existing constraints, adding the leverage ratio restricts banks' flexibility that it, indeed, negates a crucial part of the positive impact of the other regulatory tools.

Finally, we show that surcharges on SIBs have a quite moderate standalone and even destabilizing multi-dimensional impact on financial stability. Hence, surcharges in their current implementation merely contribute to financial regulations complexity and not to the resilience of the system.

The remainder of the paper is organized as follows: section 2 briefly reviews the recent literature on the impact of the Basel III accord. In section 3.1, we provide a brief description of the underlying model. Section 3.2 outlines the adjusted and newly introduced micro- and macroprudential components of Basel III and explains how they are implemented in the model. The subsequent analysis of section 4 includes both the standalone impact of the regulatory tools as well as simulations of simultaneously implemented requirements. Section 5 concludes.

2 Brief Review of Recent Literature

During the pre-crisis period, there has been comparatively moderate emphasis on topics concerning systemic risk. On the occasion of the recent events and the criticism of the economics profession that followed, this has changed substantially and financial instability has become one of the most important topics in economics. As a consequence, former studies in this area have gained more and more attention from the supervisory authorities seeking for guidance to appropriately regulate the fragile financial system.

Existing studies on the impact of the Basel III accord can be summarized by the fact that the impact of such a major financial reform is twofold. On the one hand, imposing stricter regulation on the financial sector implies benefits in terms of an increased resilience of the system but, on the other hand, these benefits are dearly bought by the costs of restricting financial sector activity and, thus, its supportive capacity which is associated with declining economic performance and growth. Table 1 provides an overview of recent studies on these issues. On closer examination, there are three facts which are particularly conspicuous.

- The first one is that there are only very few studies¹ concerning the impact of more than one component of the Basel III accord. The majority of studies rather just considers single components of the framework, i.e. their standalone impact.
- Second, except for Angelini et al. (2011); Kato et al. (2011), these studies show a strict separation of the analysis of micro- and macroprudential instruments. Additionally, the analysis of microprudential tools predominates, in particular, there is a strong focus on the fixed capital adequacy requirement (CAR) and the LCR. An analysis of the impact of the new macroprudential part of Basel III is missing. Therefore, the sources of systemic risk are only partially taken into account.
- The few studies which, at least partially, analyze the impact of Basel III's macroprudential overlay (i.e. Angelini et al. (2011); Derviz (2013); Georg (2011)) mainly make use of general equilibrium (GE & DSGE) frameworks. Although it is crucial especially for the analysis of macroprudential policy, the interaction and coordination among economic agents and, hence, between financial and real sector as well as within financial sector itself is completely neglected. Furthermore, the suitability of analyzing crises, i.e. out-of-equilibrium situations of the economy, with an equilibrium approach could generally be put into question [Colander et al. (2009); Teglioni et al. (2012)].

Hence, we contribute to the existing literature on financial regulation by providing an analysis of the impact of Basel III's main components (both, jointly and in isolation) on financial stability. For this purpose, we consider the *combined* impact of micro- and macroprudential instruments, thus, incorporating various sources of systemic risk. Since one cannot simply aggregate the several

¹ In particular, Barrell et al. (2010); Locarno (2011); Angelini et al. (2011); Kato et al. (2011); Giordana and Schumacher (2012).

standalone impacts of the instruments in order to avoid the fallacy of composition, we consider the interaction and coordination of economic agents as crucial for the analysis, especially for the impact of the macroprudential tools. Therefore, we choose a stock-flow consistent (SFC) agent-based computational economic (ACE) model of the financial sector as the appropriate methodology to address the described issues. To the best of our knowledge, Cincotti et al. (2012) provide the only study using an agent-based approach in this area so far using the EURACE model.

Table 1: Studies on the Impact of Basel III-Components

Authors	Analysis Framework	Analyzed Instrument(s)	Qualitative Impact of Instrument(s)
Cost/benefit-analysis of tighter financial regulation:			
Miles et al. (2012)	Empirical	CAR (<i>i</i>)	⊕
Kato et al. (2011)	Empirical	CAR/LCR/CCycB (<i>i/a</i>)	⊕
Studies on costs in terms of economic performance/growth:			
Milne (2013)	CC	LCR (<i>i</i>)	— ^b
Hartlage (2012)	CC	LCR (<i>i</i>)	— ^b
Locarno (2011)	Empirical	CAR/LCR/NSFR (<i>i</i>)	⊖
Hakura and Cosimano (2011)	Empirical	CAR (<i>i</i>)	⊖
Angelini et al. (2011)	Analytical (DSGE)	CAR/LCR/NSFR/Buffer (<i>i/a</i>)	⊖
Slovik and Cournède (2011)	Empirical	CAR (<i>i</i>)	⊖
Studies on benefits in terms of economic/financial stability:			
Derviz (2013)	Analytical (GE)	CAR (<i>a</i>)	⊖
Gideon et al. (2013)	Analytical (OCP)	NSFR (<i>i</i>)	⊕
Cincotti et al. (2012)	ACE	CCycB (<i>a</i>)	⊕
van den End and Kruidhof (2013)	Empirical (MCS)	LCR (<i>i</i>)	⊕
Balasubramanyan and VanHoose (2013)	Analytical	LCR (<i>i</i>)	⊖/⊕
Giordana and Schumacher (2012)	Empirical	CAR/LCR/NSFR (<i>i</i>)	⊕
Boissay (2011)	Analytical (GE)	LCR (<i>i</i>)	⊕ ^a
Georg (2011)	CC	Surch. on SIFI (<i>a</i>)	— ^b
Barrell et al. (2010)	Empirical	LR/LCR (<i>i</i>)	⊕
Gauthier et al. (2012)	Empirical	CAR (<i>a</i>)	⊕
Dib (2010)	Analytical (DSGE)	CAR (<i>i</i>)	⊕

^a Although the impact is positive, it just holds for relatively low levels, i.e. $LCR \approx 0.15 - 0.27$.

^b CC studies do not provide an analysis within a traditional model framework. The component's impact is rather conjectured based on logical reasoning followed by a discussion of potential alternatives. A quantitative impact cannot be determined.

Note: GE = General Equilibrium Model; DSGE = Dynamic Stochastic General Equilibrium Model; OCP = Optimal Control Problem; CC = Constructive Criticism; MCS = Monte Carlo Simulation; ACE = Agent-based Computational Model; (*i*) = Study considers microprudential tools; (*a*) = Study considers macroprudential tools; CAR = Capital Adequacy Requirement; LCR = Liquidity Coverage Ratio; NSFR = Net Stable Funding Ratio; SIFI = Systemically Important Financial Institution.

3 The Model

The resilience of the financial system cannot only be affected from outside of the system, i.e. passively through exogenous shocks, a fragile state can also emerge endogenously from its inherent structures,

i.e. the build up of systemic risk through financial sector imbalances [Blanchard et al. (2013); Boissay (2011)]. Due to this tendency towards instability, regulators are charged with the difficult task of balancing the financial sector's growth-supportive services with their capacity to expose both individual banks and the whole financial system to failure [e.g. Borio and Lowe (2002, 2004); Portes (2009); Boissay (2011)]. Being developed during the recent financial crisis, Basel III had to address several sources of systemic risk. A widely accepted taxonomy of these sources distinguishes between two main dimensions, namely the *time-varying* (TvD) and *cross-sectional* dimension (CsD) [Borio (2003); Bank of England (2011); Galati and Moessner (2012)]. The former refers to the development of risk over time relative to the systems capital and liquidity resources whereas the latter concerns the magnitude of consequences of a shock depending on the system's structural features.

Hence, a comprehensive quantitative evaluation of Basel III has to be based on a model that incorporates these various sources of systemic risk and, therefore, allows for the build up of financial sector imbalances as well as endogenous financial distress and bank failures. For our analysis, we pick the ACE-SFC model described in Lengnick, Krug and Wohltmann (2013) (LKW) since it meets all these requirements (explanation follows below).

3.1 A Short Description of the LKW Model

The LKW model is composed of a set of households/firms (representing the real sector; HH), banks (representing the financial sector; BA) and one central bank (CB). All transactions between them are accounted for in individual balance sheets (tables 2-3). HHs hold cash C^h and deposits D^h with one BA. At the same time they take loans L^h from BAs. BAs, on the other hand, hold cash C^b , reserves R^b at the CB and save² bonds S^b . They take deposits D^b from and grant credits L^b to HHs. Additionally they are engaged in interbank lending I_+^b/I_-^b . The CB holds save bonds S^{cb} that have been bought from BAs in RePo-operations. On its liabilities side there is the currency in circulation C^{cb} as well as the deposits of BAs R^{cb} .

Agents are of the zero intelligence (ZIA) [Chen (2012)] type to isolate the impact of market rules on market outcome. HHs have an individual preference for liquidity given by $C^h = q \cdot D^h$. To meet this objective, they can deposit cash at and take loans from BAs. Additionally, HHs trade with one another to account for real sector interactions which of course also result in financial sector activity.

BAs collect deposits from HHs. Doing so, they have to comply with a minimum reserve requirement imposed by the CB. Excess liquidity is lent to HHs (credits). Additionally, shortage (excess) of liquidity can be balanced through lending (borrowing) on the interbank market. BAs also have the opportunity to make use of RePo-operations offered by the CB, i.e. they sell save bonds in exchange for cash with the right of re-purchasing later.

Money is endogenously produced by agents' interactions over time via credit/lending contracts.

² The characterization as 'save' asset indicates that they are qualified for being accepted in RePo-operations with the CB.

Assets	Liabilities
Cash C^h	Loan Bank L^h
Deposits D^h	
	Equity E^h

Table 2: Balance sheet of households $h = 1, \dots, H$

Assets	Liabilities
Cash C^b	HH Deposits D^b
Reserve R^b	BA Credits I_-^b
Credits HH L^b	
BA I_+^b	
AAA Bonds S^b	Equity E^b

Table 3: Balance sheet of banks $b = 1, \dots, B$

Assets	Liabilities
AAA Bonds S^{cb}	Currency C^{cb}
	BA Deposits R^{cb}
	Equity E^{cb}

Table 4: Balance sheet of central bank

The monetary aggregates are therefore endogenously produced as a model result by an interactive process. In this sense they are endogenous.³ The model does not rely on equilibrium or rationality assumptions, therefore self-organization could possibly break down and endogenous crisis can occur (compare Lux and Westerhoff (2009); Colander et al. (2009); Kirman (2010)).

TvD in the LKW model The artificial monetary economy includes some real world financial frictions like liquidity hoarding of BAs, fire sales, unexpected excessive withdrawals and funding constraints. If the collapse of a single bank occurs, it may trigger a severe cascade of bank failures (described in section 6 of Lengnick et al. (2013)). This leads to cyclical variations in the levels of leverage and of both inter-sector (between real and financial sector) and intra-sector (among banks) financial activity over time, i.e. the model includes alternating phases of positive and negative feedback loops. This (stylized) financial cycle⁴ [Borio (2013); Drehmann et al. (2012)] represents the TvD of systemic risk within the model and, thus, replicates the typical procyclicality in the behavior of market participants [Minsky (1982)].

Real world experience shows that at some point during the upswing of the cycle, first doubts

³ This concept of endogeneity of money shall not be mixed up with that of the Post-Keynesian school (Lengnick et al.; 2013, p. 16). For more on this strand, see McLeay et al. (2014b,a).

⁴ The financial cycle is also often denoted as ‘liquidity spiral’ [Brunnermeier (2009)].

about the sustainability of the prospering development arise due to the recognition of an asset price bubble and, hence, market sentiments immediately turn from euphoria into an extreme form of risk aversion [Brunnermeier (2009); Derviz (2013)]. Asymmetric information now results in the simultaneous occurrence of additional distortions reflecting the binary character of liquidity⁵. In the model, this pattern is incorporated by the introduction of funding constraints.

Since banks perform the standard process of maturity transformation, they are increasingly exposed to maturity mismatches, i.e. time-varying *liquidity risk* [Diamond and Dybvig (1983)]. It is assumed that once a BA is in financial distress, this becomes public knowledge. As a result the BA faces additional pressure due to unexpected withdrawals by HHs, i.e. a bank run occurs [Brunnermeier et al. (2009)]. If it is publicly known that the BA is in distress it has no longer access to liquidity through the interbank market because no other BA is willing to lend it money for precautionary reasons (liquidity hoarding). As described by Leijonhufvud (2012), a bifurcated credit environment emerges endogenously in the LKW model. As a consequence, the interbank market's impact on the economy is twofold: it stabilizes during normal times but increases the probability of contagion and systemic risk during crises due to higher interconnectedness (described in section 6 of Lengnick et al. (2013)).

The described funding constraints limit credit supply to the real and financial sector and, therefore, further intensify the downturn of the financial cycle by triggering a significant increase in the rate of credit defaults. Hence, a further amplification effect of crises within the model follows from *solvency risk* associated with the balance sheet contagion channel [Bernanke and Gertler (1999)]. Figue and Page (2013) show that banks' procyclical reliance on wholesale funding through the interbank market is accompanied by a covarying interconnectedness of the banking network and, thus, also by an evolving network of financial claims covarying in density and complexity over time. Accordingly, Gorton and Metrick (2012) show that the fragility of the financial system increases with the length and opaqueness of funding chains and becomes more and more prone to spread initial shocks through cumulated *counterparty risk*. Thus, in a highly interconnected environment, even former solvent banks are affected by the distress of their peers since they have to compensate unexpected losses associated with the depreciation of a significant part of their assets [Bank of England (2011)]. This feature is also captured by the model since LKW show that if the loss absorbency capacity of affected institutions is insufficient due to underestimated capital requirements, imminent bank failures⁶ spread financial distress through large parts of the system and an entire collapse might only be avoidable by public sector interventions. As a result, the performance of individual institutions gains in importance and makes the system more sensitive to initial failures.

⁵ Boissay (2011), for instance, models the fund demand curve in a *humped-shaped* way in order to appropriately represent financial market frictions.

⁶ Even if these institutions can absorb the negative shocks for the moment, they are now put under pressure to comply with the imposed regulatory framework which also forces them to behave in a procyclical manner [Adrian and Shin (2008)].

CsD in the LKW model The CsD deals with the system’s *structural* features, i.e. its network topology of financial claims at a certain point in time. This means that for any given level of TvD, the impact of a shock might depend on the size of the emitting bank, its position within or the form of the network [Delli Gatti et al. (2010)].

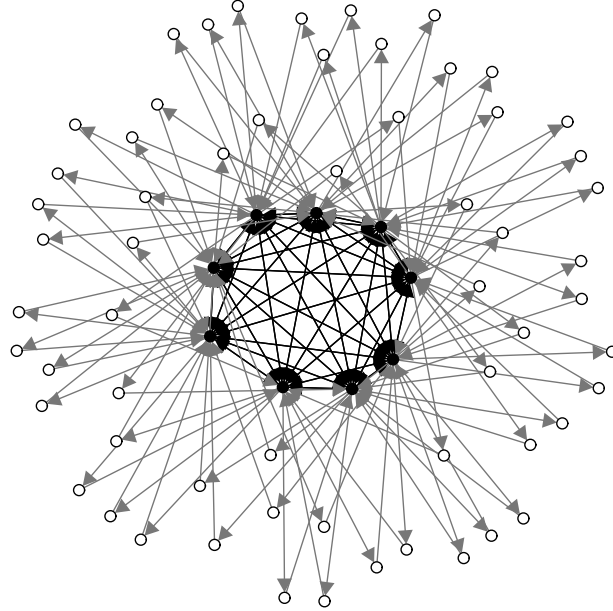


Figure 1: Example of financial network between HHs (white) and BAs (black)

All agents in the LKW model are heterogeneous in various indicators (e.g. size). They are also interconnected through financial claims as described above. Both, heterogeneity and network structure are not exogenously fixed but develop endogenously over time as a result of agents interaction (an example is given in figure 1). Therefore, the model allows to analyze how the endogenous network topology, and thus CsD, is changed under different regulatory regimes.

3.2 Addressing Sources of Systemic Risk with the Basel III Accord

Basel III strengthens the microprudential regulation by introducing a revised version of the capital adequacy standards as well as new liquidity requirements. The former includes a qualitative and quantitative tightening, whereas the latter targets banks’ funding and maturity structure. These measures aim to endow the financial sector with a more sufficient foundation of absorbing resources in order to become less prone to unexpected losses and liquidity outflows.

However, the main lesson of the recent financial crisis was that a solely microprudential view of financial regulation, i.e. ensuring the individual solvency of financial institutions, is obviously necessary but apparently not sufficient. Regarding the traditional microprudential approach of Basel II, Blanchard et al. (2013) state that

[...] it does not sufficiently take into account the interactions among financial institutions and between the financial sector and the real economy. The same bank balance sheet can have very different implications for systemic risk depending on the balance sheets (and the interconnections) of other institutions and the state of the economy as a whole. Thus, prudential regulation has to add a systemic and macro dimension to its traditional institution-based focus. Regulatory ratios must reflect risk not in isolation but in the context of the interconnections in the financial sector and must also reflect the state of the economy.

This is in line with Crockett (2000) who first mentioned the importance of an incorporated macro-prudential view into financial regulation.

Hence, a macroprudential overlay has been included in Basel III which now differs from its predecessor by placing considerable emphasis on measures aimed at mitigating procyclical behavior to smooth the financial cycle. For this reason, buffers are imposed on top of the already existing capital requirements. They are supported by a maximum leverage ratio which restricts the overall size of the banking sector. Moreover, the cross-sectional risk is addressed with capital surcharges on globally systemic important financial institutions (G-SIFIs).

In the following, we briefly describe the functioning of the analyzed components ($\hat{=}$ tools) of Basel III, in what way they intend to mitigate systemic risk and how they are implemented in the model. A list of all acronyms used throughout this section can be found on page 26.

3.2.1 Strengthening the Microprudential Regulation

Minimum Risk-based Capital Adequacy Requirement (CAR) The minimum capital requirement is defined as bank's core equity⁷ in relation to bank's total risk-weighted assets (RWA). Compared to Basel II, it has been raised by 2.5% (from 2% to 4.5%). Thus, the Core Capital Quota (CCQ) for bank i at time t is denoted by:

$$CCQ_{i,t} = \frac{\text{Core Capital}_{i,t}}{RWA_{i,t}} \geq 4.5\% \quad (1)$$

where $RWA_{i,t}$ are the assets weighted by their corresponding probability of default according to the guidelines of the BCBS. For instance, assets like cash have a zero weight, whereas retail loans have a rather high risk weight at 90% of their face value.

Due to the structural simplicity of the balance sheets underlying the LKW model, the RWA of the analysis entirely consists of either granted loans of bank i at time t or bonds. Furthermore, we do not explicitly distinguish between core and tier 1 capital⁸. By calibrating the RWA to Bankscope

⁷ In the framework itself bank's core equity is denoted as CET ratio, i.e. as ratio of common equity tier 1 and RWA. Both terms are used synonymously. See Basel Committee on Banking Supervision (BCBS) (2011a).

⁸ Other qualifying and supplementary capital is irrelevant for our analysis. Moreover, the Deutsche Bundesbank (2012) has shown in a study on the monitoring of Basel III that due to the narrowed definition of qualifying capital both

data from September 2012/2013 for SIBs and US non-SIBs, we ensure a distribution of RWA within the model which is sufficiently close to reality. This is especially important since the majority of the regulatory tools (except for the LR and the LCR) are measured relative to banks' RWA. Hence, the approach ensures that the amount of capital required by the analyzed tools do represent a reasonable measure for both banks' loss absorbency capacity and also for the impact of the tools on their stability.

Liquidity Requirements (LCR) As described in the previous section, increasing maturity transformation leads to an increased probability of maturity mismatches and, therefore, to liquidity risk. The exposure to liquidity risk alone would not lead to financial distress if the possibility to refinance and to roll over bank's debt would be always available. Unfortunately, it is not and even banks with adequate capital resources can come under severe financial distress as sources of short-term funding become inaccessible.

The second microprudential⁹ tool, i.e. the Liquidity Coverage Ratio (LCR), aims at promoting the short-term resilience of banks' liquidity risk profile [Basel Committee on Banking Supervision (BCBS) (2013)]. It requires them to hold an adequate stock of unencumbered high-quality liquid assets (HQLA¹⁰) that can be converted easily and immediately into cash, especially during times of stress in particular to avoid collective fire sales [Balasubramanyan and VanHoose (2013)]. Banks complying with the LCR are expected to meet their net liquidity outflows during a 30 calendar day stress scenario:

$$\text{LCR}_{i,t} = \frac{\text{High Quality Liquid Assets (HQLA)}_{i,t}}{\text{exp. Net Cash Outflows (of next 30 days)}_{i,t}} \geq 100\% \quad (2)$$

where the expected net cash outflows are defined by

$$\text{exp. Net Cash Outflows}_{i,t} = E[C_{i,t}^{\text{out}}] - \min \left\{ E[C_{i,t}^{\text{in}}], 0.75 \cdot E[C_{i,t}^{\text{out}}] \right\}. \quad (3)$$

This scenario assumes a combined idiosyncratic and system-wide shock that mainly results in a partial loss of retail deposits and a full loss of wholesale (i.e. interbank) funding and, hence, simulates a large part of the shocks experienced during the recent crisis.

the core capital and the tier 1 capital are yet approximately the same, at least for German banks. But even though this might change if banks have adjusted their capital structure appropriately during the implementation phase of the accord, we focus on core capital since it has the highest loss absorbing capacity. Hence, the simple structure of banks' balance sheets leads to the fact that core capital (i.e. CET1) and equity is the same since asset classes which are usually not part of banks' core of capital/CET1 (i.e. assets of inferior loss absorbency capacity) are not part of the LKW model.

⁹ Although the LCR is microprudential by nature, it has some macroprudential elements. It prohibits, at least in the short-term, from banks' procyclical behavior which amplifies the already deteriorating economic conditions and, therefore, reduces the risk of spillovers through funding chains [European Central Bank (ECB) (2013)].

¹⁰ These type of assets are characterized by low risk, the ease and certainty of valuation, a low correlation with risky assets, the listing on a developed and recognized exchange and the fact that they are traded on an active and sizable market with low volatility. In the best case, they are also central bank eligible.

In order to qualify as HQLA, assets are required to have a zero risk weight, i.e. they must be excluded from the RWA calculated for the CCQ (level 1 assets like cash, reserves and government bonds)¹¹. Furthermore, total expected cash outflows are calculated by multiplying the face value of various types of liabilities by the rates at which they are expected to run off or be withdrawn under the stress scenario. For instance, unsecured interbank loans becoming due during the 30-day period are assumed to run off with a rate of 100%, i.e. they are not rolled over, whereas retail deposits are assumed to run off by 5% or 10% depending on whether they are covered by a deposit insurance or not. Thus,

$$E[C_{i,t}^{out}] = c_{i,t}^{out} + \sum_{k=1}^n \lambda_k^l \cdot l_{i,t,k} \quad (4)$$

with $c_{i,t}^{out}$ denoting the contractual outflows of the period between t and $t + 30$ (which would occur either way, i.e. even in normal times) and λ_k^l denoting the run-off rate for liability $l_{i,t}$ of type k (with $k = 1, \dots, n$) under the assumed stress scenario [Keister and Bech (2012)].

Expected cash inflows are also considered under the stress scenario which includes defaults or the prolongation of granted loans. Inflows are calculated in a similar way to outflows except for the application on assets instead of liabilities (λ_k^a is the run-off or default rate of assets):

$$E[C_{i,t}^{in}] = c_{i,t}^{in} - \sum_{k=1}^n \lambda_k^a \cdot a_{i,t,k} \quad (5)$$

The stress scenario underlying our model constantly assumes a run-off rate for retail deposits of 10% as well as 100% for wholesale deposits, i.e. it is slightly more restrictive than the one proposed by Basel III¹². The HQLA $_{i,t}$ consist of the amount of cash plus the amount of AAA-Bonds held by bank i at time t . Its net cash outflows consist of retail and wholesale deposits with the mentioned run-off rates. Only wholesale deposits with a maturity less or equal to 500 ticks¹³ are incorporated which represents the 30-day time scale of the LCR.

It has to be mentioned that the liquidity regulation of Basel III consists of two components. Beside the LCR, it also imposes the Net Stable Funding Ratio (NSFR) on banks which intends to incentivize a more sustainable and sound maturity structure in order to reduce banks' maturity transformation by reducing the reliance on volatile short-term (wholesale) funding. Nevertheless, we think that the LCR is the more influential regulatory instrument which is also considerably more

¹¹ Assets with a (low) positive risk-weight (less or equal to 20%) also qualify as HQLA but face a deduction of 15% of their face value (level 2 assets like government or corporate bonds). Due to the simplicity of our bank balance sheet structures, we do not incorporate level 2 assets.

¹² Basel III's stress scenario proposes 3% or 5% for pre-funded secure scheme retail deposits and 10% for the unsecured rest. This means that the results may have a tendency to slightly overestimate the impact of the LCR.

¹³ 'In our setting, time necessarily comes in discrete steps. To come as close as possible to the ideal of continuous time, we scale down the length of these time steps by so much that the model becomes practically continuous. In each (infinitesimal small) time step, the agents are allowed to make decisions and act.' (Lengnick et al.; 2013, p. 8). Such a very small unit of time is called a *tick*.

present in the literature (see table 1). Moreover, the NSFR is said to provide incentives similar to those of the LCR. Therefore and with respect to the length of the paper, we do not analyze the impact of the NSFR.

3.2.2 The New Macroprudential Overlay of Basel III

Capital Conservation Buffer (CConB) Since the value of bank capital varies in a procyclical manner [Adrian and Shin (2008)], it is typically affordable for banks to comply with them during upswings. Moreover, under Basel II, there have been few incentives to hold additional capital. Hence, at the sudden event of a reversal of the financial cycle, the binding constraint of the CCQ contributes to the tense situation by forcing banks to adjust their balance sheet structure, i.e. to deleverage in order to meet the fixed CAR, thereby strongly amplifying the current trend of the cycle [van den End and Tabbae (2012)]. In order to address this procyclicality, the Basel Committee introduces a capital conservation buffer (CConB) which intends to conserve the minimum capital base of the CCQ (compare eq. (1)) by requiring banks to hold 2.5% core capital (CET1) above the regulatory minimum of 4.5% of RWA. In contrast to the strictly binding CCQ, a potential non-compliance with the CConB just leads to a payout block, i.e. the affected institution can use the additional core capital to absorb unexpected losses (e.g. due to volatile valuation of collateral) without starting a deleveraging process but is also forced to retain (a fraction of) future earnings instead of paying out dividends until the conservation buffer is restored.

Counter-Cyclical Buffer (CCycB) In addition to the CConB, Basel III comprises a second buffer, i.e. the counter-cyclical buffer (CCycB). It represents an instrument provided to the national supervisory authorities which enables them to address excessive credit growth at a national level by extending the CConB by up to 2.5% during upswings as well as suspending it during downturns of the financial cycle. In our simulation, upswings are defined as the period from the beginning of the simulation until the first bank fails.¹⁴

Leverage Ratio (LR) However, since phases of excessive credit growth are accompanied by excessive leverage, Basel III's leverage ratio (LR) addresses a related issue. This nominal, i.e. non-risk sensitive, measure supplements the risk-based CAR approach by constraining banks' leverage to prevent from massive destabilizing deleveraging processes. It is defined as follows

$$LR_{i,t} = \frac{\text{Tier 1 Capital}_{i,t}}{\text{Total Assets}_{i,t}} \geq 3\% \quad (6)$$

According to the definition of the CCQ, banks can comply with it at various levels of leverage. Therefore, the LR sets an upper limit for financing banks' total assets with debt by interlinking

¹⁴ For reasons of simplicity, we do not explicitly introduce a mechanism to recover the CCycB once it is suspended since this would require agents to form expectations which would be a renunciation from our ZIA approach.

the total assets to the held Tier 1 capital, thus, serving as a backstop measure for banks' leverage. According to the narrowed definition of regulatory capital, the Tier 1 capital almost equals the previously defined core capital of the CCQ. In the model, the LR represents the relationship between core capital and total assets.

Capital Surcharges on SIBs The increasing interconnectedness within the financial sector leads to an increased probability that shocks, originating from single banks, affect large parts of the system. In particular in situations in which single institutions, due to their considerable size, interconnectedness and complexity, represent crucial elements for the functioning of the whole payment system, failures of such systemically important banks (SIB) must necessarily be prevented through public sector interventions. In anticipating this, achieving systemic importance has become a desirable goal for banks. The associated moral hazard includes negative externalities like excessive risk-taking, reduced market discipline and competitive distortions [Brunnermeier (2009)]. While this behavior seems to be rational for banks given their economic environment in the pre-crisis period, the outcome is undesired in terms of financial stability [Basel Committee on Banking Supervision (BCBS) (2011b)].

Table 5: Surcharges on SIBs

Cluster	Score Range	Additional Capital Requirements
5 (empty)	above D ^a	3.5%
4	C - D	2.5%
3	B - C	2.0%
2	A - B	1.5%
1	Cut-off point - A	1.0%
0	<i>not systemically important</i>	–

^a The highest cluster is always empty in order to permanently provide an incentive for banks of the 4th cluster not to grow further.

Note: The size of the clusters depend on the existing set of SIBs, thus, one cannot show explicit score levels for them prior to their evaluation.

Reference: Basel Committee on Banking Supervision (BCBS) (2011b)

In response, the Basel Committee now penalizes banks' tendencies towards systemic importance. For the set of worlds' largest banks, characteristics of relative importance are measured and transformed into scores. Then surcharges of up to 2.5% of RWA depending on the scores are imposed on top of the CCQ and the buffers. Hence, surcharges provide an incentive for banks to become less important or at least prevent from becoming more important. Table 5 shows the surcharges for each cluster.

The scores for each bank are based on five indicators, i.e. size, interconnectedness, substitutability, cross-jurisdictional activity and complexity. Due to our model structure, the last two indicators cannot be incorporated into the calculation of the scores since we model a closed economy and the

bank agents are all equally complex (or rather simple). The remaining three indicators are weighted equally, thus, a bank's total score is defined as follows:

$$\text{Total Score}_{i,t} = \frac{1}{3} \sum_{k=1}^3 s_{i,t,k} \quad (\text{Score of Bank } i) \quad (7)$$

It consists of the following measures, incorporating the bank's *size* measured by its total assets relative to the size of the whole banking sector

$$s_{i,t,1} = \frac{\text{Total Assets}_{i,t}}{\sum_{j=1}^n \text{Total Assets}_{j,t}}, \quad (8)$$

its *interconnectedness* within the financial network measured by the relative amount of loans granted to other banks on the interbank market and the AAA-Bonds held at the central bank, the relative amount of funds borrowed from other banks on the interbank market as well as the individual relationship of each bank i between its borrowed funds from the interbank market and its total liabilities, i.e. the magnitude of financing through the interbank market

$$s_{i,t,2} = \frac{1}{3} \left(\frac{\text{Loans}_{i,t}^{IB} + \text{AAA-Bonds}_{i,t}^{CB}}{\sum_{j=1}^n \text{Loans}_{j,t}^{IB} + \sum_{j=1}^n \text{AAA-Bonds}_{j,t}^{CB}} + \frac{\text{Credits}_{i,t}^{IB}}{\sum_{j=1}^n \text{Credits}_{j,t}^{IB}} + \frac{\text{Credits}_{i,t}^{IB}}{\text{Credits}_{i,t}^{IB} + \text{Deposits}_{i,t}} \right). \quad (9)$$

The third indicator represents a measure of the bank's *substitutability* in the case of its failure. If the score is high, the bank is rather indispensable (at least in the short- and mid-term) due to the provided financial services and its relevance for the functioning of the payment system. The Substitutability is measured by the relative value of payments send through the payment system measured over a time span of 500 ticks

$$s_{i,t,3} = \frac{\text{Payments send}_{i,t}}{\sum_{j=1}^n \text{Payments send}_{j,t}}. \quad (10)$$

4 Sensitivity Analysis

In order to answer the proposed research questions, we analyze all $2^5 = 32$ possible impact combinations of the described set of regulatory tools of a two-level full factorial design with 5 factors ranging between the pure implementation of Basel II and its successor Basel III. The results of the computational experiments are measured in terms of financial stability meaning banks' survival rate over all 500 simulation runs (à 40.000 ticks each) of the same experiment setup. Table 6 shows the impact of all 32 regulatory regimes on banking sector stability. The following subsections provide a deeper analysis of selected results.

Table 6: Results of two-level full factorial design of the computational experiment

CAR	LCR (100%)	CCB (2.5%)	LR (3%)	Surcharges on SIB (avg.)	Avg. Impact on Stability	With LR Disincentive
2%	0%	0%	0%	No	23.7	52.6 (+28.9)
2%	0%	0%	0%	Yes	34.7 (+11.0)	
2%	0%	0%	3%	No	39.3 (+15.5)	
2%	0%	0%	3%	Yes	39.3 (+15.6)	
2%	0%	2.5%	0%	No	39.3 (+15.6)	
2%	0%	2.5%	0%	Yes	50.9 (+27.1)	
2%	0%	2.5%	3%	No	43.4 (+19.7)	
2%	0%	2.5%	3%	Yes	52.7 (+28.9)	
2%	100%	0%	0%	No	34.6 (+10.8)	
2%	100%	0%	0%	Yes	40.8 (+17.0)	
2%	100%	0%	3%	No	78.5 (+54.7)	
2%	100%	0%	3%	Yes	78.8 (+55.0)	
2%	100%	2.5%	0%	No	47.4 (+23.7)	
2%	100%	2.5%	0%	Yes	62.4 (+38.7)	
2%	100%	2.5%	3%	No	60.4 (+36.6)	
2%	100%	2.5%	3%	Yes	68.8 (+45.1)	
7%	0%	0%	0%	No	50.7 (+27.0)	
7%	0%	0%	0%	Yes	52.1 (+28.4)	
7%	0%	0%	3%	No	56.5 (+32.7)	
7%	0%	0%	3%	Yes	56.6 (+32.9)	
7%	0%	2.5%	0%	No	73.3 (+49.6)	
7%	0%	2.5%	0%	Yes	75.7 (+51.9)	
7%	0%	2.5%	3%	No	75.3 (+51.5)	75.0 (+51.3)
7%	0%	2.5%	3%	Yes	76.7 (+53.0)	
7%	100%	0%	0%	No	82.6 (+58.8)	
7%	100%	0%	0%	Yes	80.2 (+56.5)	
7%	100%	0%	3%	No	68.0 (+44.3)	
7%	100%	0%	3%	Yes	67.7 (+44.0)	
7%	100%	2.5%	0%	No	76.9 (+53.1)	
7%	100%	2.5%	0%	Yes	75.9 (+52.1)	
7%	100%	2.5%	3%	No	73.5 (+49.8)	
7%	100%	2.5%	3%	Yes	73.1 (+49.4)	

4.1 Impact of Revised Microprudential Regulation

Risk-based Capital Requirement (CCQ) First of all, we analyze in what way varying capital requirements affect the stability of the financial sector. To isolate the impact of different CCQ levels on stability, we perform the following experiment:

1. We run the model for one realization of the pseudo-random number generator and save $CCQ_i \forall i$ at the time of the first bank failure.
2. We adjust the initial endowment of equity (E_i) in order to obtain $CCQ_i = CCQ^* \forall i$, i.e. we assure that all banks comply with the current CCQ-target level CCQ^* . If all CCQ_i are sufficiently close to the target level CCQ^* , we continue with step 3, otherwise we return to step 1.
3. We perform a simulation with the same random numbers. The relative amount of banks

surviving until period 40.000 is saved as a measure of stability. Recall that steps 1 and 2 guarantee that the target CCQ^* holds.

4. Steps 1 to 3 are performed for different values of CCQ^* and 500 different realizations of the pseudo random number generator.

As a result, this proceeding yields the dashed line of figure 2(a) showing the average stability results plotted against CCQ^* . On the micro-level, a tightened capital requirement definitely associated with costs by limiting a bank's growth-supportive capacity but it has only a positive effect on the systems stability if it also contributes appropriately to total risk. Since this trade off does not hold for all banks equally, the focus should be on the allocation of required capital. Hence, it might be worthwhile to search for superior (macroprudential) ways to impose the current purely microprudential CAR. Gauthier et al. (2012) provide empirical evidence for the positive impact of a macroprudential CAR, i.e. for alternative mechanisms of consistently allocating required capital according to each banks' contribution to total risk of the banking system. Hence, in a further set of experiments, we also control for the distribution of the imposed CCQ across banks and vary it according to their size. Let $E^{aggr.}$ be the sum of equity hold by all banks. The initial endowment with save assets of each bank i in order to comply with the different capital requirements is now given by

$$E_i = E^{aggr.} \frac{size_i^\alpha}{\sum_i size_i^\alpha} \quad (\text{with } \alpha \geq 0) \quad (11)$$

where the size of a bank ($size_i$) is proxied by its total assets. This rule allows to vary the distribution of the CCQ across banks. Note that we do not change the average CCQ imposed on the banking sector and that, therefore, the aggregate amount of equity held in the system does not change. Hence, α is a measure of the unequal treatment across banks. For $\alpha = 1$ (benchmark scenario) the rule is identical to the above experiment in which all banks are treated equally, i.e. the same CCQ is imposed on all banks and their size doesn't matter (as in the case of Basel II). In the case of $\alpha = 0$, the absolute amount of equity is equal across all banks, i.e. the smaller a bank the higher the CCQ imposed on it. Furthermore, setting $\alpha = 2$ leads to a CCQ_i which is proportional to the square of bank i 's size, i.e. large banks are stricter regulated relative to small ones.

Figure 2(a) shows that in the benchmark scenario of $\alpha = 1$, banks' raised loss absorbency capacity contributes to the stability of the financial system. Interestingly, even though the contribution is almost monotonically increasing up to a CCQ of 20%, it is nonlinear and levels above 3% seem to be less efficient since a further increase in the CCQ would only lead to a moderate positive effect on stability. This can be interpreted as a threshold at which the addressed solvency risk is eliminated to a large extent.

Moreover, adjusting the distribution of the imposed CCQ in favor of relatively small (not systematically important) banks ($\alpha = 2$) improves financial stability, although, the amount of capital issued by the banking sector as a whole does not change at all and, hence, also the aggregated costs induced by the requirements stay constant. Although the gain in stability of about 10% is not as

high as in Gauthier et al. (2012)¹⁵, the α -rule shares their idea of a systemic capital requirement. Additionally, the pure size seems to be a very rough indicator for a bank's individual contribution to systemic risk and a more suitable indicator (in the context of a more complex model structure) could be defined which might lead to a higher gain. The case of $\alpha = 0$ can be seen as a robustness check as it shows that absolute capital requirements, i.e. regulating large banks less than small ones, performs worse compared to the opposite case $\alpha = 2$ for up to 15% CCQ.

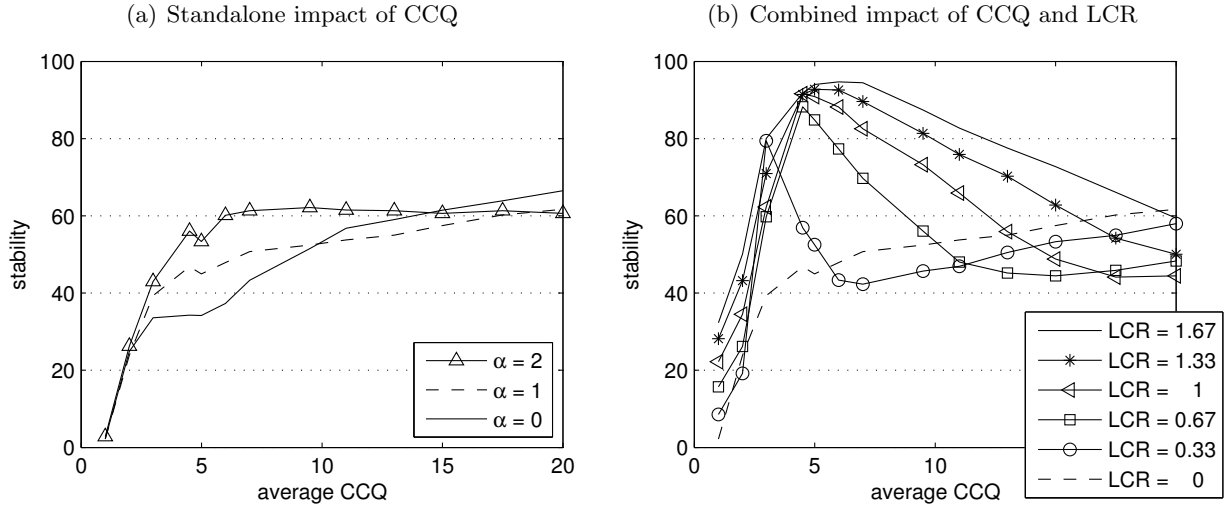


Figure 2: Impact of a strengthened loss absorbency capacity and funding structure

Liquidity Regulation Figure 2(b) shows the impact of different levels of the LCR imposed in addition to the CCQ (from now on, assume $\alpha = 1$). Based on the case of LCR=0 which is inherited from figure 2(a), we successively add stricter liquidity requirements. Even for rather low levels, the implementation of the LCR contributes significantly to the resilience of the financial sector by eliminating liquidity risk.

With a view to the standalone impact of the CCQ (LCR = 0 case), a further increase would lead to a more stable system. This would underpin the general monotonic ‘more is better’-conjecture concerning capital requirements mentioned at the beginning. However, incorporating the two-dimensional impact of the combination of both microprudential instruments *contradicts* this conjecture. For arbitrary (positive) levels of the LCR, the imposition of even higher CCQs no longer leads to monotonically improving outcomes. Instead, it now leads to hump-shaped stability paths including a backward-bending part. These results reveal the trade-off between the indented positive effect of reduced solvency risk through an increased loss absorbency capacity of banks and the negative effect of rising procyclicality associated with rising strict capital requirements. Generally,

¹⁵They find that, ‘with the same amount of overall capital in the banking system, [...] systemic capital requirements can reduce default risk of the individual bank as well as the risk of a systemic crisis by about 25%’.

the positive effect dominates for relatively low (i.e. single-digit) requirement levels since the CCQ's marginal contribution to stability by the elimination of solvency risk is relatively high. Additionally, it is still affordable for most banks to comply with it even in times of financial distress. But, as the CCQ rises, the results show that this marginal contribution eventually becomes negative since the positive effect is diminishing and the negative effect is intensifying, i.e. the rising capital requirement becomes more and more a binding constraint for banks in distress and it gets hard for them to comply with it. These countervailing effects explain the existing stability maxima depending on the combination of capital and liquidity requirements. Presupposing the prevalence of the bifurcated credit environment of Leijonhufvud (2012), the mentioned trade-off leads to additional pressure on the distressed part of the banking sector. Thus, for relatively high CCQs, further increases of the strict capital requirements rather *weakens* the resilience of the system.

Concerning the LCR, we find that any additional imposition decreases the liquidity risk of banks and, thus, initially boosts the resilience of the system up to some maximum outcome. Although there even exists a maximum outcome for low LCRs, it is rather far away from the global maximum which is in contrast to the findings of Boissay (2011) who shows within a general equilibrium framework that *only* the implementation of relatively low LCR requirements (between approx. 0.15-0.27) are efficient in terms of both preventing from financial crises and preserving the functioning of the interbank market. In our ACE model, even the outcome of the *combination* of a strict CAR of 7% and a LCR of 1 seems to be rather modest taking into account the disastrous consequences following a single bank failure or even the costs of public sector interventions to avoid it. In that case, the probability for a bank to go bankrupt or to need help from the public sector amounts to 17.44% which we would assess as high in this context.

As our results show, the imposition of capital and liquidity requirements influence each other and simply strengthening both requirements further and further may in fact decrease stability (figure 2). Therefore, a precise adjustment by the supervisory authorities is inevitable.

Figure 3 shows boxplots¹⁶ comparing the average impact of both tools as they are defined in Basel III. Adjusting only the minimum capital requirement (from 2% of Basel II to 7% of Basel III (CCQ & CConB)) would just lead to minor improvements of the average survival rate of banks (+27.01%) since solvency risk is just one dimension of risk faced by banks. Similarly, addressing solely liquidity risk by implementing the LCR and leaving the capital requirement at the low level of Basel II would not be efficient in terms of financial stability (+10.85%). Hence, strengthening the resilience of the system requires a *combined* implementation of both microprudential instruments since their positive joint impact is considerably larger than the sum of their individual contributions to stability

¹⁶ The boxplots illustrate the impact on stability by showing five moments of the distribution of bank survivals. The box represents the average survival rate over all different random seeds, plus (minus) one standard deviation. The whiskers illustrate plus (minus) two standard deviations. To remove the influence of outliers, we limit the length of whiskers to the upper 95% (lower 5%) quartiles.

We decided to use this definition because the underlying random variable can only take integer values in the range from 0 to 10. Small impacts would therefore not be visible if we plotted median and quantiles.

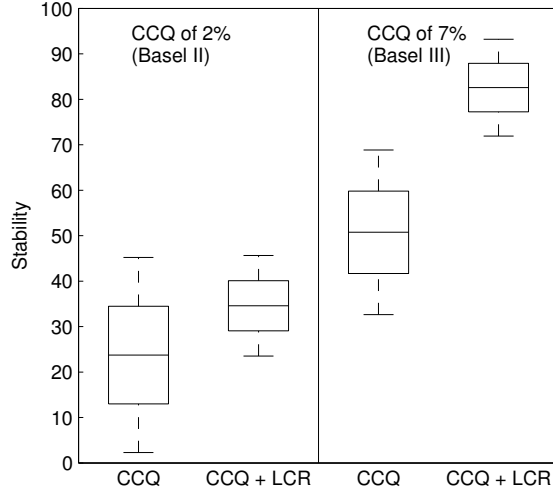


Figure 3: Impact of the strengthened microprudential regulation of Basel III

(+58.83%). This confirms the expectations of Ojo (2010) and Arnold et al. (2012) about the impact of the Basel III accord who both state that an appropriate implemented liquidity regulation ‘*would represent a huge step forward in rectifying some gaps which are inherent in Basel II*’ (see Ojo (2010), section C4).

According to that and despite the criticism regarding its element of procyclicality [Blundell-Wignall and Atkinson (2010) among others], our results underpin the strengthening of the microprudential regulation of Basel III. Especially the current magnitude of imposed strict capital requirements seems to be reasonable since the positive effect is most efficient for requirements up to 5%. Moreover, we cannot promote the criticism raised early after the announcement of the Basel III accord that liquidity management should best be left to the market as the crisis would have been primarily due to the lack of solvency and confidence. However, there is still room for further fine-tuning of the microprudential instruments in the future.¹⁷

4.2 Impact of the Macroprudential Overlay

Counter-cyclical Buffer (CCycB) The solid lines in figure 4(a) show the simulation results for the implementation of the capital buffers and of the max leverage ratio. Starting from the setup of Basel II with only 2% capital requirement, the adjustment to the new Basel III minimum requirement of 7% (CCQ+CConB) dominates its predecessor for all levels of the LR. The CCycB also requires additional core capital but now the regulators can (partly or fully) suspend the requirement and, hence, prevent from the destabilizing effect of excessive credit growth by providing desired flexibility to the financial sector when needed and, thus, relaxing tense market situations. A further increase of the minimum

¹⁷ ‘*These issues of managing liquidity are best left to the market, with supervisors focusing on solvency issues and resolution regimes to deal efficiently with insolvency when it arises.*’, Blundell-Wignall and Atkinson (2010, p. 20).

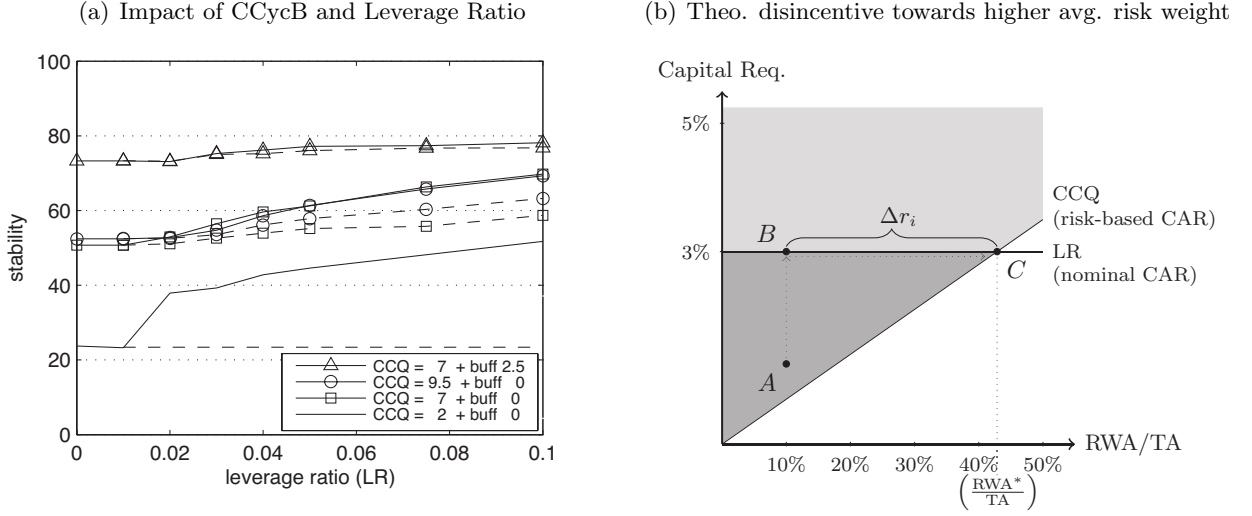


Figure 4: Impact of the Counter-cyclical Buffer and the Leverage Ratio

capital requirement above the Basel III setup of 7%, i.e. implementing the additional 2.5% core capital not as buffer but as strict requirement, would contribute to the system's resilience only marginally since the additional increase in procyclicality would neutralize the elimination remaining solvency risk. But implementing it as a buffer, i.e. maintaining the additional 2.5% during upswings¹⁸ but leaving the strict threshold at 7% during downturns, strictly dominates the setup with a pure fixed requirement since the buffer also eliminates part of the remaining solvency risk. Additionally, the buffer does not only avoid increased procyclicality, it decreases it instead. This clearly shows that not only the amount of the capital basis but also the way of its imposition represents an essential factor for the systems' stability properties which underpins the findings of Cincotti et al. (2012).

These results are also in line with Figue and Page (2013) who have used network analysis to show how poor macroeconomic conditions affect banks' possibility to roll over their debt. Furthermore, they state that supervisors could overcome a freeze of the interbank market with a considerable reduction of requirements, e.g. with a counter-cyclical capital requirement. Thus, the CCycB would strongly contribute to a recovery of lending activity between banks during times of financial distress.

Limited Bank Leverage (LR) In general, imposing a nominal, i.e. non-risk based capital requirement on banks has a positive effect on financial stability (figure 4(a)). However, the magnitude of its impact decreases with a rising capital base of the banking sector. This makes sense since it is all the more important to restrict the growth of leverage of a bad capitalized banking sector without an appropriate loss absorbency capacity compared to its well capitalized replica. This is mainly due to the fact that both the risk-based and the nominal capital requirement are complementary, i.e. they

¹⁸ Upswings have been defined as the period of time until the first bank failure (see p. 12).

restrict distinct balance sheet relationships,¹⁹ and increasing the CCQ c.p. leads to an increasing fraction of banks which simultaneously comply with the leverage ratio (they move from the dark grey in direction of the light grey area in figure 4(b)). Put differently, the leverage ratio is more binding in combination with a low CCQ since increasing the CCQ involves banks adjusting their balance sheet structures by rather issuing equity instead of debt due to the definition of regulatory capital.

Moreover, there is a current debate about the pros/cons of risk-based and nominal capital requirements and their predominance in future financial regulation. For instance, Hoenig (2013); Jarrow (2013); Hellwig (2010); Blum (2008) argue in favor of a (significantly higher) nominal CAR as main tool for bank's capital regulation while using the risk-based measure only as a backstop which would be the opposite of the Basel III proposal. On the contrary, Lautenschläger (2013) replies that a nominal CAR like the LR not only penalizes low-risk businesses (banks with low RWA) by requiring them to hold a disproportionate large amount of capital compared to their contribution to overall systemic risk, it also provides an unintended incentive for these banks to increase their RWA.²⁰

Figure 4(b) shows this disincentive from a theoretical point of view. Assuming a situation in which bank i has RWA_i of about 10% of its total assets, i.e. it represents a low-risk business. It then complies with a risk-based CAR of, say, 7% (it is a non-SIB and located in a jurisdiction without a CCycB) by holding core capital of about 1% of its total assets which slightly exceeds the minimum requirement of 0.7% (point A). Now, the introduction of the LR of 3% forces bank i to raise its core capital by 2% ($A \rightarrow B$). The bank is then confronted with the incentive to adjust its asset structure towards higher risk (RWA_i increased by Δr_i) in order to enhance its earnings/ROE while still complying with both the risk-based and nominal capital requirement in the direction of point C . Hence, from a theoretical point of view, reaching point C (and having $RWA^* > RWA_i$) is the optimal behavior for low-risk banks being hit by the introduction of a nominal capital requirement such as Basel III's leverage ratio.

To evaluate the impact of the mentioned disincentive on the performance of the LR, we conduct additional computational experiments in which banks have the possibility to shift their balance sheet structure towards higher RWA. Thus, if bank i is hit by the introduction of the LR, it increases risk weights of bank i at most by

$$\Delta r_i = \max \left\{ \frac{RWA^*}{TA} - \frac{RWA_i^{old}}{TA_i}, 0 \right\} \quad \left(\text{with } \frac{RWA^*}{TA} = \frac{LR}{CCQ_i} \right). \quad (12)$$

¹⁹ The capital requirement interlinks the risk-weighted assets with the core capital whereas the leverage ratio interlinks the total assets with the core capital. Thus, issuing (e.g. corporate) debt would affect (increase) the capital base of a bank while not affecting the RWA and, therefore, affecting the CCQ. Instead, the leverage ratio would not be affected since the total assets would increase by the amount of debt issued.

²⁰ Note that we do not cope with the question whether these 'low-risk businesses' really provide just a minor contribution to overall risk, i.e. whether the concept of Basel's RWA really has the ability to represent a bank's true contribution to risk in the financial sector. See Das and Sy (2012) on that issue. Our analysis just follows the theoretical argument of Lautenschläger (2013) here.

We assume that affected banks increase the risk weight of their save bonds from $RW_B^{old} = 0$ to a positive value RW_B^{new} such that $RWA_i^{old} \leq RWA_i^{new} \leq RWA^*$ holds. Let RWA^* be achieved with the risk weight on bonds RW_B^* . The new risk weight RW_B^{new} is given by

$$RW_B^{new} = \beta \cdot RW_B^*, \quad (13)$$

where β measures the magnitude of the disincentive effect arising due to the introduction of the LR which is set to $\beta = 0.05$.

The dashed lines in figure 4(a) represent the corresponding results with LR disincentives in place. In the case of a low capital basis (CCQ=2%), the negative impact of the LR disincentive has a large negative impact on stability leading to a complete crowding out of the former positive influence of the LR. However, a more profound capital basis prevents more and more banks from being affected by the nominal floor and its associated disincentive which dampens the magnitude of both correlating effects on stability and the crowding out occurs just in part. Thus, compared to a low capital basis, the already minor positive impact of the LR declines less but also on much lower underlying impact level [see also the last column of table 6]. Hence, our results show that, despite its simplicity, the LR has its drawbacks and the usage of a nominal floor instead of a risk-based measure as predominant tool for capital regulation might also not have the expected positive effect since its introduction would lead to an overall incentive for banks to alter their balance sheet structure towards higher risk.

Special Treatment of G-SIB/G-SIFI As shown in table 5 (see page 13), the Basel Committee categorizes all banks into five clusters. The affiliation of a considered bank to one of these clusters represents its relative importance or systemic relevance within the set of all banks. Additional to this weighted average-approach (eq. (7)), we conduct comparative computational experiments in which the single indicators (size, interconnectedness, substitutability) alone determine the total score of a bank and, therefore, also its assignment to a cluster to test whether one of them performs better in representing a banks' systemic importance than the weighted average. Figure 5(a) shows the distribution and the classification of the set of banks using solely the three indicators and also the case of using the weighted average. Approximately, 62% of all banks in all runs of the experiment are considered as *not* systemically important and no surcharges are imposed on them. On the banks assigned to the remaining clusters 1, ..., 4 (cluster 5 is empty), surcharges according to table 5 are imposed, respectively.²¹

Figure 5(b) shows the impacts of the surcharges assuming banks' compliance with Basel III's CAR of 7%. Obviously, surcharges do have a slightly positive impact on stability and determining their total score with a single indicator is not inferior to the usage of their weighted average, i.e. it seems

²¹Our cluster size is based on Deutsche Bundesbank (2012), where a classification for the largest German banks is conducted. This approach ensures that the level of surcharges imposed on banks and their relative position within the bank importance distribution coincides with reality.

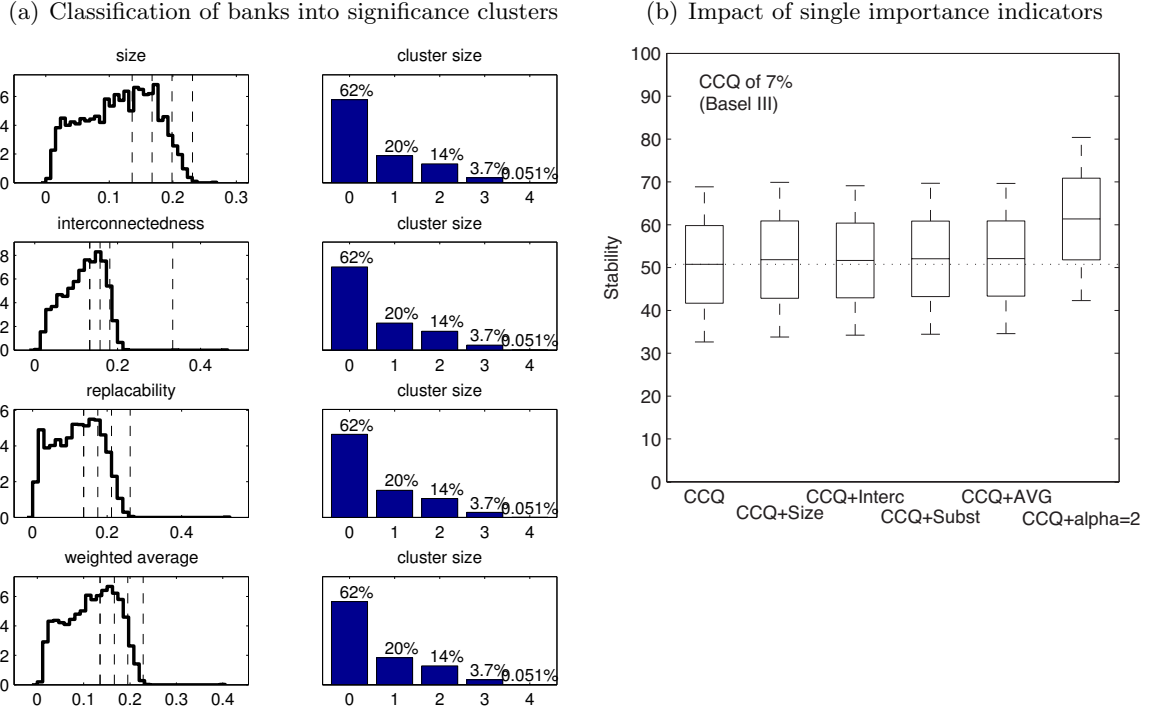


Figure 5: Impact of SIB Surcharges on Financial Stability

to be possible to get (approx.) the same outcome with a *much simpler* classification rule. Hence, the relationship between regulatory complexity and the outcome in terms of financial stability can be improved. In particular, our simple $\alpha = 2$ -rule (introduced in section 4.1) dominates Basel III's surcharges on SIBs (independent of the determination of the total scores). The crucial difference here is that the surcharges just extend the risk-based requirements for a subset of banks leaving the capital regulation of the rest unaffected whereas the α -rule alters the whole distribution of imposed requirements but does not even increase the capital requirement on average.

These results are in line with Huang et al. (2011) who use a decomposition analysis to show that banks' marginal contribution to systemic risk is almost *linear* in their probability of default but rather *exponential* in their size. Moreover, they are also in line with Plosser (2013) who argues that an adequate capital base represents the most effective preventive measure to reduce the probability of bank failures in the first place. In addition, higher levels of capital may permit regulatory or market intervention before a bank actually fails, thereby making bankruptcy or bailouts unnecessary. But, even though the Basel III accord enables regulators to assign capital surcharges on SIBs, deciding on their level is anything but trivial and the current Basel III surcharges may simply be too low.

Summarizing, the supplemental implementations of the buffers (CConB + CCycB), forcing banks to hold additional capital during upswings, represent complementary and likewise indispensable macroprudential tools since they reduce the increased procyclicality of the microprudential instru-

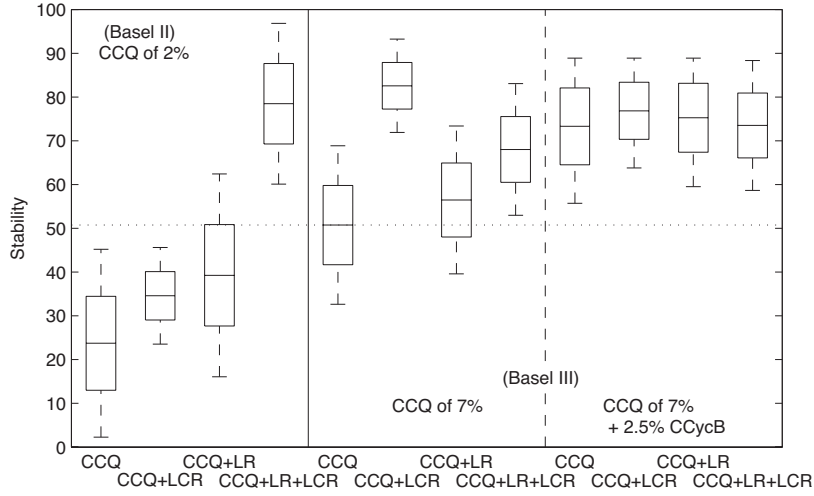


Figure 6: Comparison of regulatory tools under different CAR regimes

ments. The close connection of these instruments is clearly shown by the fact that the three-dimensional impact of the minimum requirement, the LCR and the CCycB comes very close to the best outcome of the set of experiments (+53.12% in comparison to the Basel II CAR of 2%). However, the *most effective* and also most stable combination includes just the minimum requirement and the LCR (+58.83%).

We also find that the leverage ratio has a larger standalone impact if the capital base is rather low, thus, serving as an additional back up-constraint (+15.53% in comparison to Basel II CAR of 2% and +5.74% in comparison to Basel III CAR). Considering the situation in which the above mentioned most efficient combination is imposed, the additional imposition of a nominal capital requirement would decrease the survival rate from 82.57% to 68.02%. It seems that with an increasing amount of already imposed constraints, adding the max leverage ratio restricts banks flexibility in such a way that it, indeed, negates a crucial part of the positive impact of the other regulatory tools.

Finally, we find that surcharges on SIBs have a considerable standalone impact of +10.98% at 2% CAR but only +1.36% at 7% CAR. This can be explained by the elimination of solvency risk since the surcharges extend the risk-based capital requirement. If we again consider the most efficient combination from above, its contribution is also slightly destabilizing (−2.38%).

5 Conclusion

The Basel III accord reacts to the events of the recent financial crisis with a combination of revised microprudential and macroprudential regulatory instruments in order to address various newly identified dimensions of systemic risk. This approach of cumulating requirements bears the risk of

individual measures negating or even conflicting with each other which might lessen their desired effects on financial stability.

Since one cannot simply aggregate the several standalone impacts of the instruments to avoid the *fallacy of composition*, we consider the interaction and coordination of economic agents as crucial for the analysis, especially for the impact of the macroprudential tools. Thus, we provide an analysis of the impact of Basel III's main components on financial stability in a stock-flow consistent (SFC) agent-based computational economic (ACE) model.

We find that the strengthening of the microprudential regulation contributes substantially to the resilience of the financial system. Both components are mutually dependent, i.e. addressing solely bank's solvency *or* liquidity risk leads to inferior outcomes compared to a joint imposition. Moreover, the joint impact of the microprudential instruments is considerably larger than the sum of the individual contributions to stability, i.e. the standalone impacts are not additive. Hence, the newly introduced liquidity regulation can be seen as complementary to an adequate capital base of banks. This demonstrates exemplarily that the whole is (literally) greater than the sum of its parts in the ACE SFC model.

Concerning the macroprudential overlay, the impacts are either marginal or even destabilizing except for the buffers (CConB and CCycB) which indeed represent indispensable instruments to counteract agents' procyclical behavior. Although the leverage ratio embodies a synthesis of both non-risk sensitivity and simplicity, it falls short of expectations especially when associated disincentives are explicitly taken into account. This result shows that, even though the drawbacks of the current risk-based approach are undoubted and the number of proponents of simple rules in financial regulation prosper, it is rather difficult to implement a working proposal that leads to the desired results and that this task needs careful consideration in any case.

Presupposing the simplified financial environment of the LKW model, we find that surcharges on SIBs act more as backups with minor impact on stability merely contributing to financial regulation's complexity than to the resilience of the system. Admittedly, the liquidity regulation also piles up the level of complexity but in terms of costs and benefits, it is by far superior. Concerning this matter, we identify potential for improvement. Nevertheless, our results might of course be mitigated if more complex modeling environments are used.

To sum up, Basel III's macroprudential overlay does contribute to the overall financial stability, albeit less than expected, in particular, against the background of the mere amount of instruments implemented. Regarding its intended purpose of mitigating systemic risk, strengthening the financial system against shocks and, far more important, the maintenance of its functioning in times of stress without emergency support, our results show that the overlay is fundamentally able to contribute to the achievement of these desirable goals but the fine-tuning within the framework to avoid conflicting instruments as well as the contribution to stability per 'unit of complexity' could be improved.

The close relationship of the microprudential tools and the buffers shown in our analysis is

exemplary for the successive amending structure of current financial regulation. Navigating by sight, i.e. being only able to *react* as soon as possible to recent events in a highly dynamic and complex environment [Blanchard (2013)], and the resulting *time-inconsistency* of financial regulation forces supervisors to permanently address newly discovered transmission channels of systemic risk by imposing additional constraints. As a consequence, the already overwhelming complexity of financial regulation will further increase dramatically. Thus, although the performance of the LR seems to fall short of expectations in this context, it seems to be reasonable to pursue the avenue of simple regulatory rules rather than trying to regulate an increasingly complex financial sector with even more complex rules.

Table 7: Acronyms

Acronym	Meaning
ACE	Agent-based Computational Economics
BA	Bank
BCBS	Basel Committee on Banking Supervision
CAR	Capita Adequacy Requirement
CB	Central Bank
CConB	Capital Conservation Buffer
CCQ	Core Capital Quota
CCycB	Countercyclical Buffer
CET1	Common Equity Tier 1 Capital
CsD	Cross-sectional Dimension of Systemic Risk
DSGE	Dynamic Stochastic General Equilibrium Model
ECB	European Central Bank
G-SIB/G-SIFI	Global Systemically Important Bank / Financial Institution
GE	General Equilibrium Model
HH	Household
HQLA	High-quality Liquid Assets
LCR	Liquidity Coverage Ratio
LKW	Lengnick, Krug, Wohltmann (2013)
LR	Leverage Ratio
NSFR	Net Stable Funding Ratio
ROE	Return on Equity
RWA	Risk-weighted Assets
SFC	Stock-flow Consistent
TvD	Time-varying Dimension of Systemic Risk
ZIA	Zero Intelligence Agent

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