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 microprudential and new macroprudential regulatory instruments in order 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. 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 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 not additive. However, except for the capital conservation buffer which represents an indispensable instrument to counteract agents' procyclical behavior, the macroprudential overlay's impact is either marginal or even negative. Especially, surcharges on SIBs rather contribute to financial regulations complexity than to the resilience of the system.

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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 mentioned issues with Basel III, the latest version of its global regulatory framework on banking supervision. To fill existing gaps, the framework passed through the indispensable development process towards a broader consideration of dimensions of systemic risk. Thus, beside the narrowing of the definition of capital and the adjustment of its requirement, the microprudential regulation is extended by liquidity requirements, e.g. the Liquidity Coverage Ratio (LCR), to improve banks' liquidity risk profile. Furthermore, a growing consensus is arising that one essential advancement of the reform agenda is to reorientate banking supervision to place stronger emphasis on mitigating instability in the financial system as a whole, i.e. the invocation for macroprudential regulatory tools [Borio (2011); Hanson et al. (2011); Blanchard et al. (2010, 2013)]. Beside the mitigation of systemic risk, their purpose includes the strengthening of the financial system against shocks and the maintenance of its functioning in times of stress without emergency support from central banks and governments. The Basel Committee has addressed these facts by also introducing e.g. capital buffers, a maximum leverage ratio and capital surcharges on (global) systemically important banks or financial institutions (G-SIBs or G-SIFIs respectively).

The implementation of the new instruments will be phased in from 2013 onwards over an extended transition period, and will all be fully applicable from 2019 onwards. This phasing-in 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 [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 (2012)]. 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 in order to reveal conflicting regulatory measures resulting in a potential impairment of regulation. 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 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. This demonstrates exemplary that the whole is indeed greater than the sum of its parts if interaction among agents is taken into account. 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 fixed minimum requirement during good times comes extremely close to 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. Based on the situation in which the above mentioned best working combination is imposed, an additional imposition of a leverage ratio would significantly increase banks' probability of default. 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 impact on financial stability. If we again consider the most efficient combination as a benchmark, its contribution is at best marginal. 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 and in section 3 we provide a brief overview of the so far identified sources of systemic risk and of their amplification channels emphasizing the neglected parts of the pre-crisis regulatory framework, i.e. Basel II. Section 4 outlines both the adjusted and newly introduced micro- and macroprudential components of Basel III. It follows a brief description of the underlying model which is based on Lengnick et al. (2013). The subsequent analysis of section 5 includes both the standalone impact of the adjusted and new regulatory instruments as well as simulations of simultaneously implemented requirements. Section 6 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 studies[1] 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.

[1] In particular, Locarno (2011); Angelini et al. (2011); Giordana and Schumacher (2012).

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

Authors	Analysis Framework	Analyzed Instrument(s)	Qualitative Impact of Instrument(s)
Studies on costs in terms of economic performance/growth:			
Milne (2013)	CC	LCR (i)	–[b]
Hartlage (2012)	CC	LCR (i)	–[b]
Locarno (2011)	Empirical	CAR/LCR/NSFR (i)	$\ominus$
Hakura and Cosimano (2011)	Empirical	CAR (i)	$\ominus$
Angelini et al. (2011)	Analytical (DSGE)	CAR/LCR/NSFR/Buffer (i/a)	$\ominus$
Cournède and Slovik (2011)	Empirical	CAR (i)	$\ominus$
Studies on benefits in terms of economic/financial stability:			
Derviz (2013)	Analytical (GE)	CAR (a)	$\ominus$
Hlatshwayo (2013)	Analytical (OCP)	NSFR (i)	$\oplus$
van den End and Kruidhof (2012)	Empirical (MCS)	LCR (i)	$\oplus$
VanHoose and Balasubramanyan (2012)	Analytical	LCR (i)	$\ominus$/$\oplus$
Giordana and Schumacher (2012)	Empirical	CAR/LCR/NSFR (i)	$\oplus$
Boissay (2011)	Analytical (GE)	LCR (i)	$\oplus$[a]
Georg (2011)	CC	Surch. on SIFI (a)	–[b]
Dib (2010)	Analytical (DSGE)	CAR (i)	$\oplus$

[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; (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

- Second, except for Angelini 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 [Teglio 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 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, there are no studies using an agent-based approach in this area so far.

3 A Taxonomy of Currently Identified Sources of Systemic Risk

The resilience of the financial system cannot only be affected from outside of the system, i.e. passively by exogenous shocks originating from the real economy. The build up of stability risks in terms of financial imbalances are referred to as *systemic risks* since they emerge *endogenously*, i.e. from its inherent structures. Due to this tendency towards instability, supervisory authorities 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)].

What economic crises have typically in common is that they are the result of a complex interconnection of causes. In the case of the recent financial crisis, the supervisory authorities' task was to address several new interconnected sources of systemic risk. This entails the difficulty of blurred boundaries which impedes a clear and sharp identification of individual transmission channels and, therefore, also their addressing. However, there is a widely accepted current taxonomy of these sources. It distinguishes between *two* main dimensions of systemic risk [Borio (2003); Bank of England (2011); Galati and Moessner (2012)], namely *time-varying* and *cross-sectional* risk. The former refers to the development of risk over time relative to the systems capital and liquidity resources whereas the latter concerns the potential consequences of a shock depending on structural features of the system.

3.1 The Time-varying Dimension of Systemic Risk

The time-varying dimension of systemic risk refers to the procyclical behavior of financial market participants causing the so-called financial cycle[2] which is characterized by varying levels of leverage and financial sector activity over time [Borio (2012); Drehmann et al. (2012)]. During the upward phase, the procyclicality, i.e. positive feedback loops caused by herding, myopia, declining risk aver-

[2] The financial cycle is also often denoted as "liquidity spiral" [Brunnermeier (2009)].

sion and the systemic underestimation of risk, implies a gradual build up of indebtedness, exposures to risk and improvements of the overall market sentiment [Brunnermeier (2009); Derviz (2013)]. In the following, we briefly describe the transmission channels underlying the build up of such financial sector imbalances.

Solvency Risk Usually, at the peak of the financial cycle first doubts about the sustainability of the previous development arise and the market sentiment immediately turns from euphoria into an extreme form of risk aversion.The resulting price corrections are accompanied by substantial impairments of assets and lead to negative feedback loops on the real economy associated with the lack of liquidity and the deterioration of financing conditions. The turnaround in market sentiment and economic conditions is now further amplified by a significant increase in the rate of credit defaults. Thus, banks face a higher *solvency risk* since they have to compensate unexpected losses associated with the depreciation of a significant part of their assets [Bank of England (2011)]. If the loss absorbency capacity of affected institutions is insufficient due to underestimated capital requirements, imminent bank failures will trigger financial distress and a collapse might probably only be avoidable by government bail outs.

Liquidity Risk But not only the real sector's leverage varies during the financial cycle. In the wake of its growing indebtedness, banks are also forced to show a collective tendency to excessively expose themselves to risk [Boissay (2011)] which comes along as part of their maturity transformation. If banks increasingly transform the maturities of their assets and liabilities, they face an increased probability of maturity mismatches and, therefore, an increased *liquidity risk*. The exposure to this time-varying but permanent risk of liquidity shortages is due to the fact that the pay off of banks' assets and the (to some extent unpredictable) withdrawals of their on-demand liabilities occur far apart in time [Diamond and Dybvig (1983)]. In order to bridge these shortages, they are frequently forced to refinance or to roll over their short-term debt which, in turn, requires the permanent and durable access to sources of short-term funding. Especially in phases of high-level maturity transformation, even very small distortions in the availability of these funding sources can exacerbate or yet cause severe effects on the financial sector. The tricky part is the simultaneous occurrence of several of these distortions immediately after a turnaround in market sentiment where banks are highly (procyclical) reliant on short-term funding. Now, the reality of unpredictable deposit maturities catches up with the banking sector and the combination of risk aversion and asymmetric information leads to substantial unexpected liquidity outflows[3] [Brunnermeier et al. (2009)].

This emphasizes the central role assigned to a functioning interbank market since the flexible provision of overnight wholesale deposits during this tense situation is essential for the survival of banks. Unfortunately, not only retail banking customers have serious doubts about the solvency

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

of banks, the same holds for banks among themselves leading to excessively restrained interbank lending. On the one hand, this is likewise due to uncertainty about the potential counterparties' solvency, on the other hand, institutions with surplus liquidity are themselves highly vulnerable to liquidity shortages. The resulting liquidity hoarding behavior for precautionary reasons leads to *Leijonhufvud*'s bifurcated credit environment [Leijonhufvud (2012)]. Such a volatile, i.e. extremely short-term and unstable funding structure forces banks to alternatively sell off their assets, even at huge discounts, in order to meet unexpected excessive withdrawals. The subsequent excess supply associated with significant price drops deteriorates market liquidity and once highly liquid assets suddenly turned illiquid.

Contagion Risk These price adjustments even negatively affect the balance sheet positions and the solvency of banks which are not forced to participate in fire sales[4]. So even without suffering from liquidity shortages, these institutions are now put under pressure to comply with the imposed regulatory framework. The described funding constraints again limit credit supply to the real and financial sector and further amplify the downturn of the financial cycle in a highly procyclical manner. Furthermore, the procyclical reliance on short-term funding is accompanied by likewise time-varying (interbank) lending activity and, thus, interconnectedness of the banking network [Fique and Page (2013)]. The arising complex network of contracts, i.e. chains of intra-financial sector claims, contribute to systemic risk through an increased potential for *contagion*. With longer, larger and more opaque funding chains the system becomes more and more prone to spread initial shocks through cumulated *counterparty risk* [Gorton and Metrick (2012)]. As a result, the performance of individual institutions gains in importance and makes the system more sensitive to initial failures.

3.2 The Cross-sectional Dimension of Systemic Risk

The transmission and spread of a shock originating from a bank highly depends on its relative importance within the financial network. The distress or failure of several relative unimportant banks might not lead to severe effects since only a moderate part of the system is affected by the shocks. But in the case of the failure of a bank which is sufficiently large and interconnected, the extent and impact of the shock might be also large enough to result in an entire collapse. Thus, in contrast to the time-varying dimension of systemic risk, the cross-sectional dimension deals with the *structural* features of the financial system. For any given level of time-varying risk at a certain point in time, the degree of the systemic impact caused by a shock highly depends on the system's structure and topology. This can be, for instance, the distribution or concentration of risk at a point in time within the network, co-varying risks in overall balance sheets (i.e. common risk factors), the existence of systemically important financial institutions (SIFIs) and the general opacity and complexity of banks and their interconnections [Galati and Moessner (2012)].

[4] Regular impairment test within the scope of fair value and mark-to-market accounting lead to melting capital in terms of depreciated asset values.

Concentration of Risk A network with a high concentration of risk is less resilient than one in which risk is more evenly distributed. The same holds for the provision of financial services. Especially in the situation in which a small number of systemically important institutions like, for instance, AIG[5] during the recent crisis, play a key role within the network, irresistible spillover effects can be triggered from these important nodes.

Opacity and Complexity of the Financial Network Furthermore, systemic effects also depend on the potentially insufficient transparency of financial networks (its opacity) and its complexity in terms of the difficulty to collect reliable information about its structure. Rising opacity and complexity of exposures and interconnections support the build up of funding chains and also make the resolution of single institutions more difficult. Additionally, behaviors like the focusing on off-balance sheet positions and shadow banking activities contribute to a dense web of exposures impeding an easy revelation of existing counterparty risks.

In order to address these cross-sectional issues, an adequate regulatory framework should include tools affecting the market structure, whereas the time-varying dimension primarily motivates tools which affect the balance sheet structure of financial institutions. In what way the revised regulatory framework of the Basel Committee attempts to meet the expectations is discussed in the following section.

4 Addressing Sources of Systemic Risk with the Basel III Accord

In order to address the time-varying dimension of systemic risk, 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*

[5] The American International Group (AIG), one of the largest insurance companies of the world, has become the focus of the recent debate about concentrated risk since it massively issued Credit Default Swaps (CDS) and, thus, became a systemically important node within the financial network. The US government was forced to nationalize AIG to avoid a bankruptcy cascade.

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."

In line with Crockett (2000), who first mentioned the importance of an incorporated macroprudential view into financial regulation, the distinction between both views can be best illustrated in terms of their differing objectives. A purely microprudential regulation aims at limiting the probability of failures of individual institutions, i.e. limiting *idiosyncratic* risk, to protect depositors. However, the macroprudential view's objective is rather to limit the costs to the economy associated with financial distress, i.e. limit *systemic risk*, by limiting the build up of aggregate imbalances.

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 which also address time-varying risk. 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).

4.1 Strengthening the Microprudential Regulation

In the following, we briefly describe the functioning of the analyzed components of Basel III and in way they intend to mitigate systemic risk.

Minimum Risk-based Capital Adequacy Requirements (CAR) The minimum capital requirement is defined as bank's core equity[6] in relation to bank's total risk-weighted assets (RWA). Thus, the Core Capital Quota (CCQ) for bank i at time t is denoted by:

$$\mathrm{CCQ}_{i,t} = \frac{\text{Core Capital}_{i,t}}{\mathrm{RWA}_{i,t}} \geq 4.5\% \tag{1}$$

where $\mathrm{RWA}_{i,t}$ 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 loans typically have a risk weight at 100% of their face value. Compared to Basel II, the minimum requirement has been raised by 2.5% (from 2% to 4.5%). But banks' capital base has not only been found to fall short, it has also been recognized that the definition of the term "regulatory capital", i.e. capital that qualifies to meet the requirements, has been far too wide. Large parts of the former

[6] 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 BCBS (2011a).

capital resources have ex post been either identified to be unable to absorb losses or turned illiquid during times of distress. A significant narrowing of regulatory capital was the consequence, thus, incorporating only components of banks' capital with a high loss absorbency capacity. The newly introduced term of the core equity base, mainly consisting of common shares and retained earnings, leads to a more restricting capital requirement and, therefore, intends to increase banks' resilience against unexpected losses and to reduce solvency risk.

Liquidity Requirements (LCR) As described in the previous chapter, 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 microprudential[7] tool, i.e. the Liquidity Coverage Ratio (LCR), aims at promoting the short-term resilience of banks' liquidity risk profile [BCBS (2013)]. It requires them to hold an adequate stock of unencumbered high-quality liquid assets (HQLA[8]) that can be converted easily and immediately into cash, especially during times of stress in order to bridge potential maturity mismatches and to avoid collective fire sales [VanHoose and Balasubramanyan (2012)]. Banks complying with the LCR are expected to meet their liquidity outflows during a 30 calendar day liquidity stress scenario. 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.

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

where the expected net cash outflows are defined by

$$\text{Exp. Net Cash Outflows}_{i,t} = E[C^{out}_{i,t}] - \min\left\{E[C^{in}_{i,t}],\ \ 0.75 \cdot E[C^{out}_{i,t}]\right\}. \tag{3}$$

In order to qualify as HQLA, assets are required to have a risk-weight of 0%, i.e. they must be excluded from the RWA calculated for the CCQ (level 1 assets like cash, reserves and government bonds)[9]. Furthermore, total expected cash outflows are calculated by multiplying the face value of

[7] 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 [ECB (2013)].

[8] 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.

[9] 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.

various types of liabilities by the rates at which they are expected to run off or be withdrawn in 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,

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

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 $k = 1, \ldots, n$) 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):

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

Above all, the LCR is intended to improve the banking sectors ability to absorb negative liquidity shocks like excessive withdrawals arising from a downturn of the financial cycle. It has to be mentioned that the liquidity regulation of Basel III consists of two components. Beside the LCR, it 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 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.

4.2 The New Macroprudential Overlay of Basel III

The new macroprudential overlay of the Basel III accord consists of the following components:

Addressing Time-varying Risk (CCB & LR) In order to address the procyclicality in the behavior of financial institutions, the Basel Committee introduces a capital conservation buffer (CCB) which requires banks to hold core capital (CET1) above the regulatory minimum of 4.5% of RWA. As the name suggests, it is intended to act as buffer to conserve the minimum requirement of the CCQ (compare (1)). In contrast to the strictly binding CCQ of 4.5%, a potential non-compliance with the CCB just leads to a payout block, i.e. the affected institution can use the additional core capital to overcome temporary distress (e.g. due to volatile valuation of collateral) but is also forced to retain future earnings instead to payout dividends until the conservation buffer is restored. Therefore, the buffer addresses in particular the procyclicality of standard CAR (i.e. the CCQ). Since the value of bank capital varies in a procyclical manner, it is typically affordable for financial institutions to (often only just) comply with them during upswings. Moreover, there have been few incentives to hold additional capital prior to the recent financial crisis. At the sudden event of a reversal of the financial cycle, the binding constraint of the CCQ contributes to the tense situation by putting additional pressure on most banks. Holding only the minimum amount of capital leads to a situation in which they are often forced to act in order to meet the fixed CAR. The resulting collective behavior strongly amplifies the current trend of the cycle [van den End and Tabbae (2012)].

In addition to the CCB, Basel III comprises a second buffer, i.e. the counter-cyclical buffer. Both are functionally identical. The only difference is that the latter is controlled by the national central banks while the CCB is controlled on an international level by the BCBS. Since we model a closed economy, our analysis includes only the CCB.

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

$$\mathrm{LR}_{i,t} = \frac{\text{Tier 1 Capital}_{i,t}}{\text{Total Assets}_{i,t}} \geq 3\% \tag{6}$$

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 the total assets to the held Tier 1 capital[10], thus serving as a backstop measure for banks' leverage.

Addressing Cross-sectional Risk 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. Otherwise, an irreplaceable part of the financial system threatens to disappear (TBTF-problem). In anticipating this, becoming systemically important is 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 [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 trans-

[10] According to the new definition of regulatory capital, the Tier 1 capital almost equals the previously defined core capital of the CCQ.

Table 2. 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	*not systemically important*	–

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

formed into scores. Then surcharges of up to 2.5% depending on the scores are imposed on top of the CCQ and the CCB requirement. Hence, surcharges provide an incentive for banks to become less important or at least prevent from becoming more important. Furthermore, the probability of failures is reduced due to an increased loss absorbency capacity of SIBs. 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. Table 2 shows the surcharges for each cluster.

5 Sensitivity Analysis

A comprehensive quantitative evaluation of Basel III has to be based on models that allow for endogenous bank failures and systemic risk. Since Basel III addresses various dimensions of systemic risk (i.e. time-varying and cross-sectional), the model also has to be able to create all these dimensions endogenously. For our sensitivity analysis, we pick the agent-based computational (ACE) model described in Lengnick, Krug and Wohltmann (2013) (LKW model) since it fulfills all these requirements.

The LKW model is composed of a large set of households/firms and banks. All transactions are accounted for in the agents' individual balance sheets within a stock-flow-consistent (SFC) framework. Agents are of the zero intelligence (ZIA) [Chen (2012)] type to isolate the impact of market rules on market outcome. Households hold cash, draw loans from banks and place deposits. Banks collect deposits from households and lend them to others. Since deposits can be withdrawn at any time but loans can not, banks perform the standard process of maturity transformation, i.e. they are subject to liquidity risk.

Money is endogenously produced by agents' interactions via credit/lending contracts that span a complex network of financial claims. Although the model does not rely on equilibrium or rationality assumptions, it has been shown that, most of the time, the economy operates close to the unique equilibrium. However, from time to time a collapse of single banks might occur which can trigger a severe cascade of bank failures. The model also introduces an interbank market that allows banks to create credit/lending relations with other banks. It has been shown by LKW that the interbank market has a twofold impact on the economy: it stabilizes during normal times but increases the probability of contagion and systemic risk during crises. Additionally, banks are able to obtain liquidity from the central bank via RePo operations.

The LKW model is well suited for a sensitivity analysis of the several regulatory tools of Basel III because it captures the time-varying dimension of systemic risk through maturity transformation/mismatch and liquidity risk. Moreover, the complex interrelations of balance sheets through credit/lending contracts result in a network of claims which gives rise to cross-sectional systemic risk.

In order to answer the proposed research questions, we analyze all $2^5 = 32$ possible impact combinations of the described set of regulatory tools 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[11] ranging from 0% to 100% under a two-level full factorial design with 5 factors including both the standalone impacts of a potential implementation of the individual tools as well as any combination of their collective implementation. The following subsections provide a deeper analysis of selected results.

5.1 Impact of Revised Microprudential Regulation

(Core) Capital Adequacy Requirement First of all, we want to analyze in what way varying capital requirements affect the stability of the financial sector. Due to the structural simplicity of the balance sheets underlying the LKW model, the risk-weighted assets (RWA) of the analysis entirely consists of the granted loans of bank i at time t. Furthermore, we do not explicitly distinguish between core and tier 1 capital[12]. Thus, the CCQ in our model is given by:

$$\mathrm{CCQ}_{i,t} = \frac{\text{Core Capital}_{i,t}}{\text{Loans}_{i,t}} \tag{7}$$

To isolate the impact of different CCQ levels on stability, we perform the following experiment:

[11] Financial stability here means banks' survival rate over all 500 simulation runs (á 40.000 ticks) of the same experiment setup (each consisting of 9 banks). Table 3 (see page 25) shows how many of the 4.500 banks of an experiment have survived until the end of a simulation run.

[12] Also 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 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 hast the highest loss absorbing capacity.

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.

Figure 1 shows the average stability results plotted against CCQ^*. In the described experiment (benchmark scenario of figure 1) in which the same CCQ is imposed on all banks (as in the case of Basel III), banks' raised loss absorbency capacity contributes to the stability of the financial system. Interestingly, even though the contribution is monotonically increasing up to a CCQ of 13%, it is nonlinear and levels above 7% seem to be less efficient since a further increase in the CCQ would only lead to a marginal positive effect on stability. This can be interpreted as a threshold at which the addressed solvency risk is eliminated to a large extent.

Beside the positive effect on stability, the increased capital requirements also burdens the banking sector with increased costs which might affect its supportive capacity in a negative way. Hence, it might be worthwhile to search for alternative or superior ways to implement the fixed CAR than it is done in the Basel III accord. 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

$$E_i = E^{aggr.} \frac{size_i^{\alpha}}{\sum_i size_i^{\alpha}} \qquad (\text{with } \alpha \geq 0) \tag{8}$$

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.

Thus, figure 1 shows that adjusting the distribution of the imposed CCQ in favor of relatively small (not systemically important) banks leads to an improved outcome in terms of financial stability, although, the amount of capital issued by the banking sector as a whole does not change at all and, thus, also the aggregated costs induced by the requirements stay constant. But, as figure 1 also shows, an $\alpha \geq 1$ does not strictly dominate[13] Basel II's uniform distribution of CARs. If the unequal treatment associated with the imposition of stricter requirements on larger banks reaches excessive levels (e.g. $\alpha = 5$), the outcome is inferior to lower values of α. A value of $\alpha = 10$ is even worse than the case of the reversed inequality, i.e. a stricter regulation of small relative to large banks.

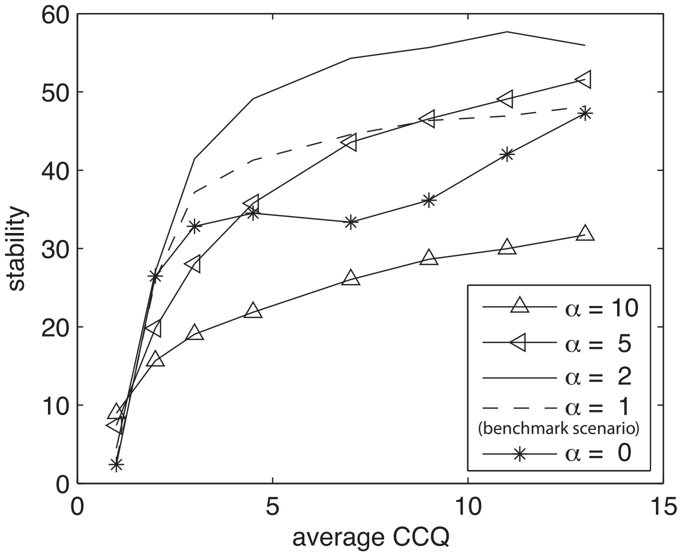

Figure 1: Impact of varying Core Capital Quotas (CCQ) on Financial Stability

Liquidity Regulation We have explicitly modeled the liquidity risk in the banking sector which enables us to measure the impact of the LCR on its stability. The stress scenario underlying our model constantly assumes a run-off rate for retail deposits of 10% as well as 100% for wholesale deposits. Thus, it is more restrictive than the one proposed by Basel III since the 10% for retail deposits represents the upper bound[14]. The High Quality Liquid Assets ($\text{HQLA}_{i,t}$) consist of the amount of cash plus the amount of AAA-Bonds held by bank i at time t. Its net cash outflows consists of retail and wholesale deposits with the mentioned run-off rates. Only wholesale deposits with a maturity less or equal than 500 ticks[15] are incorporated which represents the 30-day time scale of the LCR. Figure 2 shows the impact of different levels of the LCR imposed in addition to

[13] Dominance of $\alpha = 2$ above $\alpha = 1$ means that for all given CCQ requirements $\alpha = 2$ yields higher stability results.
[14] Basel III's stress scenario proposes 3% or 5% for pre-funded secure scheme retail deposits and 10% for unsecured rest. This means that the results may have a tendency to underestimate the impact of the LCR.
[15] Ticks correspond to a very small time step as in the LKW model.

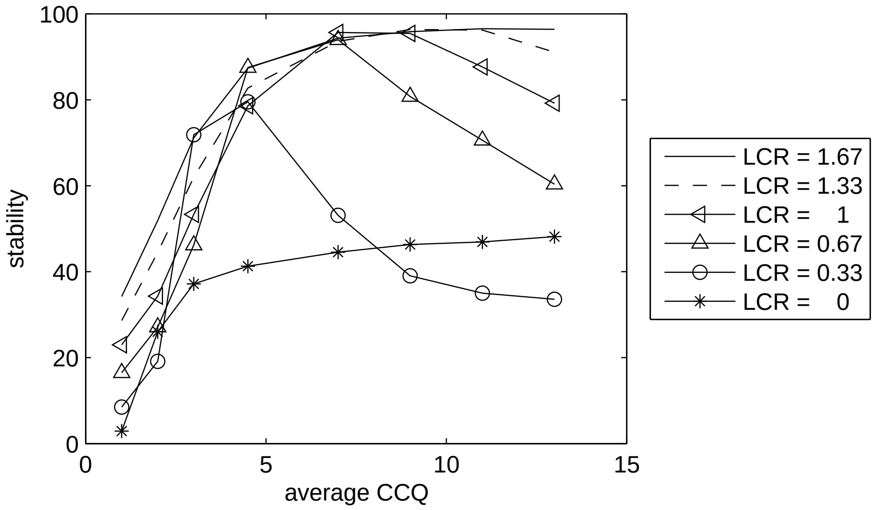

Figure 2: Impact of varying CCQs and Liquidity Coverage Ratios (LCR) on Financial Stability

the CCQ. Based on the case of LCR $= 0$ which is inherited from figure 1[16], 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. The implementation phase of Basel III will start with a LCR of 60% which seems to be a good initial point, even though the results would invoke stricter requirements in the near future.

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 a monotonically improved outcome. 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, the positive effect dominates for relatively low (i.e. single-digit) capital requirements 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 becomes negative and, therefore, the impact of an increased loss absorbency capacity gradually declines until the solvency risk is largely eliminated. This diminishing positive effect is confronted with the negative effect of an intensifying procyclicality since the rising capital requirement becomes more and more a binding constraint for banks in financial distress and it gets hard for them to comply with it. These countervailing effects

[16] From now on, assume $\alpha = 1$.

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 capital requirements rather *weakens* the resilience of the financial system instead of strengthening it.

Any given additional imposition of the LCR 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. $15\% - 27\%$) 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 4.5% and a LCR of 1 seems to be rather modest taking into account the disastrous consequences following a single bank failure or the costs of public sector interventions. In that case, the probability for a bank to go bankrupt or to need help from the public sector amounts to 21.4% which we would assess as high in this context.

Obviously, the imposition of banks' capital and liquidity requirements, i.e. the instruments addressing banks' solvency and liquidity risk, influence each other which requires precise adjustment by the supervisory authorities. Imposing both requirements but adjusting only one of them may lead to suboptimal and unintended results. Despite the criticism of both microprudential instruments regarding their 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 on the resilience of the financial system by preventing bank failures dominates for single-digit requirements. However, there is still room for further fine-tuning of the microprudential instruments in the future. Taken as a whole, we cannot promote the early criticism of Blundell-Wignall and Atkinson (2010) who argue 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[17].

Figure 3 shows boxplots[18] of the average impact of both the capital and liquidity requirement. Adjusting only the minimum capital requirement from the 2% of Basel II to 4.5% of Basel III would just lead to minor improvements of the outcome. In line with that finding, also addressing only 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. Hence, strengthening the resilience of the

[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).

[18] The boxplots illustrate the impact on stability by showing five moments of the distribution of bank survivals: the average survival rate over all different random seeds, plus/minus one standard deviation and plus/minus two standard deviations. We decided to follow this definition because the usual way of showing median and quantiles for our discrete variable with only ten possible realizations would often suggest equal impacts of different treatments.

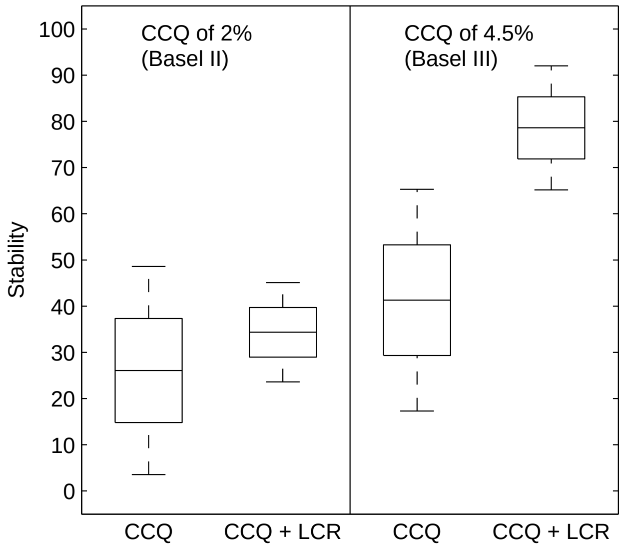

Figure 3: Impact of the strengthened microprudential regulation of Basel III

system requires a *combined* implementation of both microprudential instruments since the positive joint impact of the microprudential instruments is considerably larger than the sum of the individual contributions to stability. This confirms the expectations of Ojo (2010) and Arnold et al. (2012) about the impact of the Basel III accord which both state that an appropriate implemented liquidity regulation "*would represent a huge step forward in rectifying some gaps which are inherent in Basel II.*"

5.2 Impact of the Macroprudential Overlay

Capital Conservation Buffer and Limited Bank Leverage In the previous section, we showed that an increase in the loss absorbency capacity of banks with a strict capital requirement yet contributes to the system's stability as long as it does not become a too binding constraint due to increased procyclicality. The idea of the CCB is to eliminate the amplifying effect of a strict and, thus, procyclical requirement by forcing banks to hold an amount of capital above the strict minimum requirement during good times that can be reduced during bad times.

Figure 4 shows the simulation results for the implementation of the CCB and of the max leverage ratio. Starting from the setup of Basel II with only 2% capital requirement, the adjustment to the Basel III capital requirement of 4.5% dominates its predecessor (solid line located strictly above dashed line). Generalized to different settings of the LR, that is what we already know from the previous section. The CCB amounts to 2.5% of additional required core capital that can be reduced down to the rigid threshold during times of distress and, hence, its countercyclical character directly addresses the procyclicality of the microprudential instruments. A further increase of the minimum capital requirement above the Basel III setup of 4.5%, i.e. implementing the additional 2.5% core

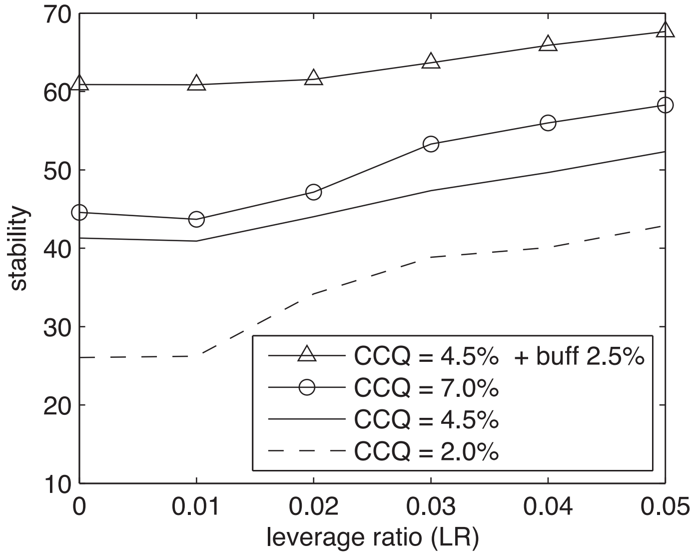

Figure 4: Impact of the Capital Conservation Buffer (CCB) and the Leverage Ratio on Financial Instability

capital not as buffer but as strict requirement would indeed eliminate a part of the remaining solvency risk (circles located above solid line). Unfortunately, the elimination is dearly bought at the cost of increased procyclicality which is why the outcome in terms of stability has only slightly improved. Implementing it as a buffer, i.e. maintaining the additional 2.5% during good times[19] but leaving the strict threshold at 4.5% during bad times, strictly dominates the setup with the pure fixed requirement since the buffer also eliminates a part of the remaining solvency risk but, additionally, it 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.

These results are in line with Fique 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 conservation buffer would strongly contribute to a recovery of lending activity between banks during times of financial distress.

Furthermore, imposing a maximum leverage ratio on banks has a positive effect on the resilience of the system. 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, although both the minimum capital

[19] In our simulation, good times are defined as ticks from the beginning of the simulation until the first bank fails.

and the maximum leverage requirement are complementary, i.e. they restrict distinct balance sheet relationships[20], an increasing CCQ leads to the simultaneous compliance with the leverage ratio. Put differently, the leverage ratio is more binding in combination with a low CCQ since increasing the CCQ involves banks adjusting their balance sheets structures by rather issuing equity instead of debt due to the definition of regulatory capital. Hence, presupposing the compliance with the CCQ of Basel III, the additional imposition of the leverage ratio might rather contribute to the increase in complexity of the regulatory framework than to the resilience of the financial system.

Special Treatment of G-SIB/G-SIFI As shown in table 2 (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. The importance is measured by a score based on five indicators, i.e. size, interconnectedness, substitutability, cross-jurisdictional activity as well as the complexity of the bank. 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:

$$\text{Total Score}_{i,t} = \frac{1}{3}\sum_{k=1}^{3} s_{i,t,k} \qquad \text{(Score of Bank } i\text{)} \tag{9}$$

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

$$s_{i,t,1} = \frac{\text{Total Assets}_{i,t}}{\sum_{j=1}^{n} \text{Total Assets}_{j,t}}, \tag{10}$$

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

$$s_{i,t,2} = \frac{1}{3}\left(\frac{\text{Loans}^{IB}_{i,t} + \text{AAA-Bonds}^{CB}_{i,t}}{\sum_{j=1}^{n}\text{Loans}^{IB}_{j,t} + \sum_{j=1}^{n}\text{AAA-Bonds}^{CB}_{j,t}} + \frac{\text{Credits}^{IB}_{i,t}}{\sum_{j=1}^{n}\text{Credits}^{IB}_{j,t}} + \frac{\text{Credits}^{IB}_{i,t}}{\text{Credits}^{IB}_{i,t} + \text{Deposits}_{i,t}}\right). \tag{11}$$

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

[20] 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.

(a) Classification of banks into significance clusters (b) Impact of single importance indicators

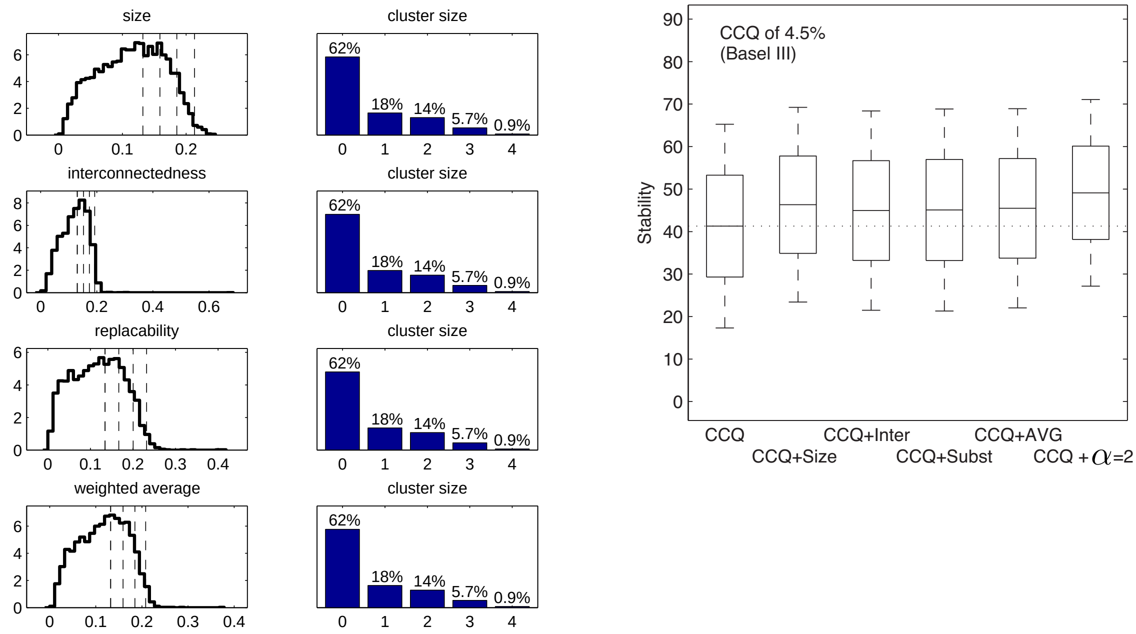

Figure 5: Impact of SIB Surcharges on Financial Stability

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

$$s_{i,t,3} = \frac{\text{Payments send}_{i,t}}{\sum_{j=1}^{n} \text{Payments send}_{j,t}} \tag{12}$$

Additional to the weighted average-approach of the Basel Committee, we conduct comparative computational experiments in which the single indicators 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 2 are imposed, respectively[21].

Figure 5(b) shows the impacts of the surcharges assuming banks' compliance with Basel III's CAR of 4.5%. Obviously, surcharges do have a positive, although, not substantial impact on the resilience of the financial system. Furthermore, imposing surcharges on important banks and determining their

[21] Our cluster size is based on Deutsche Bundesbank (2012), where a classification for the largest german banks is conducted.

total score with a single indicator is not inferior to the usage of their weighted average, i.e. it seems to be possible to get (approx.) the same outcome with a much simpler rule for the classification. In particular, our simple rule regarding the power law distribution of capital requirements among banks introduced in section 5.1 dominates the combination of Basel III's fixed CAR and surcharges on SIBs (independent of the determination of the total scores). This result is 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. Hence, the relationship between Basel III's regulatory complexity and the outcome in terms of financial stability can be improved.

Moreover, our results 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. Also Haldane (2013) emphasizes as well that surcharges on SIBs are indeed helpful since they eliminate some additional solvency and contagion risk but they are not sufficient to solve the TBTF-problem. This means that in reality, we are in a situation in which the SIBs already exist and the macroprudential overlay of Basel III yet does not provide an incentive scheme which is strong enough to force these too big banks to shrink themselves to a desired sustainable and supportive size. We actually go one step further by showing that even in a system in which all banks start from scratch, i.e. from a non-systemic important state, surcharges on SIBs are not sufficient to prevent their emergence.

6 Conclusion

To conclude, 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 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 not additive. However, except for the capital conservation buffer (CCB) which indeed represents an indispensable instrument to counteract agents' procyclical behavior, the macroprudential overlay's impact is either marginal or

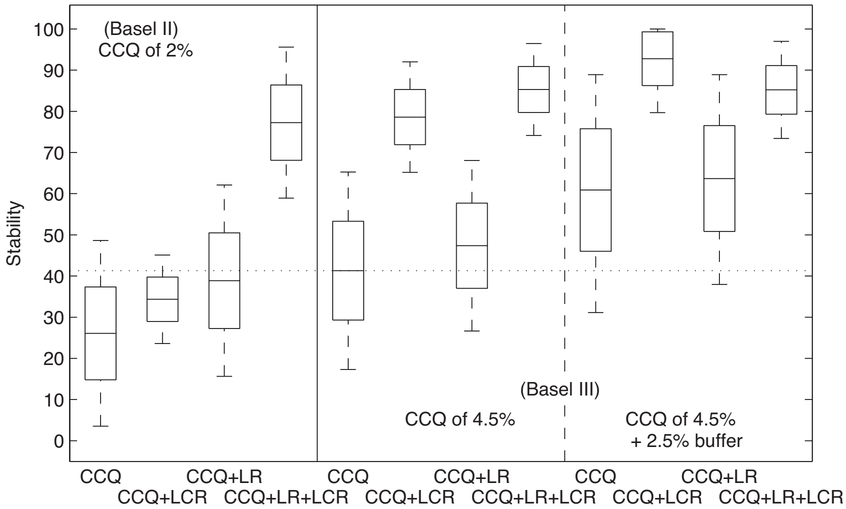

Figure 6: Comparison of regulatory tools under different CAR regimes

even negative. Especially, surcharges on SIBs rather contribute to financial regulations complexity than to the resilience of the system.

Non-additivity of Standalone Impacts We find that the strengthening of the microprudential regulation contributes substantially to the resilience of the financial system. However, both components are mutually dependent, i.e. addressing solely bank's solvency *or* liquidity risk leads to inferior outcomes in terms of financial stability compared to a joint imposition. Hence, the newly introduced liquidity regulation can be seen as complementary to an adequate capital base of banks. In this context, particular mention should be made of the fact that their joint impact increases the average survival rate of banks by +52.5% whereas their standalone impact (+15.2% for the CAR and +8.2% for the LCR) is quite moderate (see figure 6 or table 3). This demonstrates exemplary that the whole is indeed greater than the sum of its parts if interaction among agents is taken into account.

CCB Counteracts Procyclicality Furthermore, the supplemental implementation of the capital conservation buffer (CCB), forcing banks to hold capital above the fixed minimum requirement during good times, represents a complementary and likewise indispensable macroprudential tool since it reduces the increased procyclicality of the microprudential instruments (CCB has a standalone impact of +14,4%). The close connection of these instruments is clearly shown by the fact that the three-dimensional impact of the revised CAR, the LCR and the CCB comes extremely close to the best outcome of the set of experiments (+66.7%). However, it is definitely the *most effective* combination since the additional effort to be made to identify SIBs drastically increases the complexity of the imposed regulation.

Table 3. 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
2%	0%	0%	0%	No	26.1
2%	0%	0%	0%	Yes	35.9 (+9.8)
2%	0%	0%	3%	No	38.9 (+12.8)
2%	0%	0%	3%	Yes	38.8 (+12.7)
2%	0%	2.5%	0%	No	40.5 (+14.4)
2%	0%	2.5%	0%	Yes	52.1 (+26.0)
2%	0%	2.5%	3%	No	43.8 (+17.7)
2%	0%	2.5%	3%	Yes	52.1 (+26.0)
2%	100%	0%	0%	No	34.3 (+8.2)
2%	100%	0%	0%	Yes	41.3 (+15.2)
2%	100%	0%	3%	No	77.2 (+51.1)
2%	100%	0%	3%	Yes	76.7 (+50.6)
2%	100%	2.5%	0%	No	47.2 (+21.1)
2%	100%	2.5%	0%	Yes	63.7 (+37.6)
2%	100%	2.5%	3%	No	59.5 (+33.4)
2%	100%	2.5%	3%	Yes	70.6 (+44.5)
4.5%	0%	0%	0%	No	41.3 (+15.2)
4.5%	0%	0%	0%	Yes	45.5 (+19.4)
4.5%	0%	0%	3%	No	47.4 (+21.3)
4.5%	0%	0%	3%	Yes	47.7 (+21.6)
4.5%	0%	2.5%	0%	No	60.9 (+34.8)
4.5%	0%	2.5%	0%	Yes	65.8 (+39.7)
4.5%	0%	2.5%	3%	No	63.7 (+37.6)
4.5%	0%	2.5%	3%	Yes	65.8 (+39.7)
4.5%	100%	0%	0%	No	78.6 (+52.5)
4.5%	100%	0%	0%	Yes	83.0 (+56.9)
4.5%	100%	0%	3%	No	85.3 (+59.2)
4.5%	100%	0%	3%	Yes	85.5 (+59.4)
4.5%	100%	2.5%	0%	No	92.8 (+66.7)
4.5%	100%	2.5%	0%	Yes	92.9 (+66.8)
4.5%	100%	2.5%	3%	No	85.2 (+59.1)
4.5%	100%	2.5%	3%	Yes	85.3 (+59.2)

Cumulating Constraints Weakens System Stability 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 (+12.8% with Basel II CAR of 2% compared to +6,1% with Basel III CAR). Considering the situation in which the above mentioned most efficient combination is imposed, i.e. not just an increased CAR but also the LCR and the CCB, the additional imposition of a max leverage ratio would decrease the survival rate from 92.8% to 85.2%. 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.

Surcharges Are Inefficient Finally, we find that surcharges on SIBs have a considerable standalone impact of +9,8% at 2% CAR and +4.2% at 4.5% CAR. This can be explained by the elimination of solvency risk since the surcharges extend the CAR. If we again consider the most efficient combination from above, its contribution is only marginal (+0.1%). Hence, surcharges in their current implementation rather act as backups with minor impact on financial stability and merely contribute to financial regulations complexity than to the resilience of the system. To sum up, Basel III's macroprudential overlay does contribute to the overall financial stability, albeit far less than expected. But, especially when considering 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 cast doubt on whether these desirable goals can be achieved with the current macroprudential overlay of the accord.

Concerning future research in this area, it seems to be worthwhile to not longer disregard the primary objective of financial regulation, i.e. ending the era of navigating by sight [Blanchard (2013)]. The close relationship of the microprudential tools and the capital conservation buffer 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, and the resulting *time-inconsistency* of financial regulation forces supervisors to permanently address new 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, it seems to be reasonable to follow the invocation of Haldane and Madouros (2012) and rather try to develop simple rules than trying to regulate an increasingly complex financial sector with even more complex rules. Such a simple rule would probably be more macroprudential than Basel III's current overlay.

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