Macroprudential Banking Regulation: Does One Size Fit All?

Doris Neuberger[1]
University of Rostock, Germany
Email: doris.neuberger@uni-rostock.de

Roger Rissi
Lucerne University of Applied Sciences and Arts, Switzerland
Email: roger.rissi@hslu.ch

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ABSTRACT

The macroprudential regulatory framework of Basel III imposes the same minimum capital and liquidity requirements on all banks around the world to ensure global competitiveness of banks. Using an agent-based model of the financial system, we find that this is not a robust framework to achieve (inter)national financial stability, because efficient regulation has to embrace the economic structure and behaviour of financial market participants, which differ from country to country. Market-based financial systems do not profit from capital and liquidity regulations, but from a ban on proprietary trading (Volcker rule). In homogeneous or bank-based financial systems, the most effective regulatory policy to ensure financial stability depends on the stability measure used. Irrespective of financial system architecture, direct restrictions of banks' investment portfolios are more effective than indirect restrictions through capital, leverage and liquidity regulations. Applying the model to the Swiss financial system, we find that increasing regulatory complexity excessively has destabilizing effects. These results highlight for the first time a necessary change in the regulatory paradigm to ensure the effectiveness and efficiency of financial regulations with regards to fostering the resilience of the financial system.

JEL classification: C63, G01, G11, G21, G28

Keywords: financial stability, systemic risk, financial system, banking regulation, agent-based model

[1] Corresponding author: Doris Neuberger, University of Rostock, Department of Economics, Ulmenstr. 69, D-18057 Rostock, Germany; e-mail: doris.neuberger@uni-rostock.de; phone: +49 (0)381 498 4346, fax: +49 (0)381 498 4341.

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1. INTRODUCTION

One important lesson of the global financial crisis is that microprudential banking regulation aimed at preventing the costly failure of individual financial institutions does not suffice to ensure financial stability. The Basel II microprudential capital requirements even had destabilizing effects by increasing pro-cyclical lending and regulatory arbitrage. Therefore, the 'field of vision' is a system-wide or macroprudential oversight, which aims at limiting systemic financial risk, controlling 'the social costs associated with excessive balance-sheet shrinkage on the part of multiple financial institutions hit with a common shock' (Hanson et al., 2011, p. 5). As a complement to microprudential regulation, macroprudential regulation takes into account general equilibrium effects and interactions with other types of public policy that have an impact on systemic financial stability (IMF, 2011; for a literature review see Galati and Moessner, 2012). The Basel III regulatory framework (BCBS, 2010)[2] combines micro- and macro-prudential policies by more stringent and counter-cyclical capital requirements and the introduction of a leverage ratio, liquidity requirements and a too-big-to-fail (TBTF) surcharge on systemically important financial institutions.

To ensure global competitiveness of banks the Basel III regulatory framework imposes the same minimum standards for all internationally active banks around the world. It will be implemented in Europe by a 'single rule book' regulation, which imposes the same rules on all banks in the EU. However, more stringent regulations at the national level might be necessary to adapt to national circumstances. Regulatory policies beyond Basel III have been implemented or are being discussed in individual countries, such as a ban on proprietary trading by banks in the U.S. (Volcker rule), higher capital requirements in the U.K. (ICB, 2011) or credit-concentration limits for banks in Switzerland (SIF, 2010). The question whether the one-size-fits-all approach of Basel III is appropriate to achieve (inter-)national financial stability has not been tackled in the scientific literature yet. We expect that the effects of regulatory policies on financial stability and the real economy will depend on the role of banks and the behaviour of financial market participants in the economy, which differ from country to country. Bank-based financial systems like those of Germany and Japan are likely to have other stability properties and therefore may need regulations other than market-based financial systems such as the United States and the United Kingdom.[3] The literature on financial-system architecture has compared bank-based and market-based financial systems with regard to the performance of their main functions of capital allocation and risk sharing (Allen and Gale, 1995, 1999, 2000; Boot and Thakor, 1997; Beck and Levine, 2002; Levine, 2002; Deidda and Fattouh, 2008), but not with regard to systemic risk.

The most promising approach to examine systemic financial risk and policies to deal with it are agent-based models (ABMs), which use a bottom-up approach of learning adaptive heterogeneous agents (Bezemer, 2011; Bouchaud, 2008; Economist, 2010; Farmer and Foley, 2009; Lux and Westerhoff, 2009; Thurner, 2011). While general equilibrium models can only explain minor fluctuations around a predetermined state of equilibrium, ABMs do not require a steady-state and can explain the fact that externalities arising from synchronised behaviour or interbank contagion may catapult minor fluctuations into widespread market failure (Thurner, 2011). By running repeated simulations, ABM allow agents to change their behaviour based on their interactions with other agents. The influence of financial market behaviour and regulations on the collective outcome of the system can be examined by changing the decision rules or implementing regulatory constraints. Because of nonlinear feedback effects, individual risk regulation may create extreme or systemic risks (Thurner, 2011; Thurner et al., 2012). The main

2 It was adopted by the Basel Committee on Banking Supervision and G20 in December 2010 and was approved by the EU in June 2013 in conjunction with the Capital Requirements Directive.

3 For a cross-country comparison of financial systems see Beck and Demirgüc-Kunt (2009).

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advantage of ABMs is that they can help to understand the system when the data does not exist or is inadequate (Thurner, 2011).

Agent-based models have been applied to analyze the influence of either the behaviour of financial market investors (Harras and Somette, 2011; Kaizoji, 2003, 2004; Kluger and McBride, 2011; LeBaron, 2012; Takahashi and Terano, 2003; Thurner, 2011; Thurner et al., 2012) or banking market structure and regulation (Geanakoplos et al., 2012; Georg, 2011; Webber and Willison, 2011; Westerhoff, 2008) on systemic risk. Thus far, no comparison of bank-based and market-based financial systems with respect to systemic risk and the effectiveness of banking regulations in a single model has been conducted in the literature. This paper closes this gap by analyzing for the first time the influence of both financial system architecture and the behaviour of financial market participants on financial stability and the effectiveness of macro-prudential policies (capital requirements, leverage ratio, TBTF surcharge, liquidity requirements, credit concentration limits, Volcker rule) within an ABM. It goes beyond previous studies on financial stability by examining for the first time the influence of regulatory policies on structural, functional and worst-case stability, measured by a variety of indicators. It finds that the one-size-fits-all approach along the lines of the Basel framework cannot accommodate the complexity of the financial system and is therefore not a robust framework for financial stability. By explicitly modelling different financial system architectures (various degrees of bank- and market-based financing) and investment patterns, our analyses show that these factors crucially impact the effectiveness and efficiency of financial regulations. Neglecting these distinguishing characteristics may result in regulatory failure. Calibrating the model with data of the Swiss financial system, we find that the optimal regulation varies with the corresponding dimension of stability, and that simple regulatory standards seem to dominate the optimal regulatory regime.

The paper is organized as follows. Section 2 reviews the theoretical literature which yields hypotheses about the influence of financial system architecture, behaviour of financial market participants and banking regulations on financial stability. Section 3 describes the model, and Section 4 explains the parameterization and measurements used. After a presentation and discussion of the general results in Section 5, the model is applied to the Swiss financial system in Section 6. Section 7 draws conclusions.

2. HYPOTHESES

A vast literature on comparative financial systems studies the question whether bank-based or market-based financial systems are better for promoting welfare or economic growth (Allen and Gale, 1995, 1999, 2000; Boot and Thakor, 1997; Beck and Levine, 2002; Levine, 2002; Deidda and Fattouh, 2008). While bank-based systems seem to have a comparative advantage in mobilizing capital, acquiring information, monitoring firms, and managing inter-temporal and liquidity risk, market-based systems seem to have a comparative advantage in allocating capital, aggregating diffuse information signals, and providing cross-sectional risk-sharing (for reviews see Levine, 2002; Beck and Levine, 2002). This literature compares financial systems with respect to the performance of their main functions, but not with respect to financial stability. Microeconomic theories of financial intermediation show that the provision of liquidity services by banks involves the risk of bank runs and contagious bank failures or panics (Diamond and Dybvig, 1983; Donaldson, 1992; Aghion et al., 2000). Therefore, unregulated bank-based financial systems are inherently unstable. Recent research on systemic risk has identified three main causes for systemic crises: (1) contagion among banks contagion arising from the interconnectedness of banks through the interbank loan market, (2) widespread financial imbalances that build up over time and then unravel abruptly, with adverse effects on both intermediaries and markets, (3) negative common shocks that affect intermediaries and markets at the same time due to

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common asset holdings (Bandt et al., 2010). While systemic risk through interbank contagion is caused by a counterparty externality, systemic risk through common shocks arises from a correlation externality (Georg, 2011). Counterparty externality depends on the topology of the interbank network (Nier et al., 2007; Iori et al., 2006; Thurner et al., 2003) and increases with the size of the banking sector in the economy[4]. Therefore, we expect that unregulated market-based financial systems are more stable than unregulated bank-based financial systems (hypothesis H1).

Financial systems may not only differ with respect to the role of banks versus markets, but also with respect to the behaviour of banks and other investors in the economy. The literature on financial markets with heterogeneous agents usually differentiates between three types of traders that can be observed in practice: fundamentalists who expect that the asset price will return to its fundamental value, chartists who base their decisions on an analysis of past price-trends, and noise traders who decide on the basis of noisy information (Kaizoji, 2003). If fundamental analysts prevail, the market prices of securities fully reflect all available information and passively follow real shocks of the economy. In this case financial markets are information efficient (Fama, 1970) and the real bills doctrine holds (Glasner, 1992; Selgin, 1989). If, however, chart or noise traders prevail, financial markets may develop an own dynamic, driven by financial or monetary innovations or inefficient portfolio selection. Within agent-based models for stock markets it has been shown that speculative bubbles are caused by random positive news and the heterogeneity of traders' strategies and are amplified by adaptive behaviour, where fundamentalists are driven out of the market by chart or noise traders (Harras and Somette, 2011; Kaizoji, 2003). Therefore, we expect that unregulated financial systems dominated by fundamental analysts are more stable than unregulated financial systems with other behavioural configurations (hypothesis H2).

So far we have considered financial systems without state interventions. Our first hypothesis that systemic risk increases with the role of banks in the economy implies that macroprudential financial regulation should focus on banks. Theories of financial intermediation explain two main justifications for regulating banks, the inability of depositors to monitor banks and the risk of a systemic crisis stemming from contagious bank runs (for a review see Santos, 2001). Banks may be insulated from runs by deposit insurance (Diamond and Dybvig, 1983). However, deposit insurance as well as agency conflicts between shareholders and managers create incentives for banks to increase the risk of their assets or their leverage. These risk-shifting incentives can be reduced by regulating bank capital (Kashyap et al., 2009; Santos, 2001). Moreover, bank capital has a loss-absorbing function. When losses have occurred, binding regulatory capital requirements reduce the probability and size of de-leveraging by asset sales, preventing systemic repercussions on asset prices and other institutions (Admati et al., 2011). Using a network model that considers contagion effects through network and asset fire-sale externalities, Gauthier et al. (2012) show that macro-prudential capital requirements reduce the default probabilities of individual banks as well as the probability of a systemic crisis. Therefore, we expect that higher capital regulations increase financial stability in all financial systems (hypothesis H3).

As a response to the global financial crisis, the Basel III regulatory framework imposes more stringent (risk-based) capital requirements in all countries. In addition, it introduces a TBTF capital surcharge on systemically important financial institutions, a (risk-independent) leverage ratio, and minimum liquidity requirements. The leverage ratio is to act as a 'backstop', mitigating the regulatory uncertainties from risk-based approaches and helping to offset banks' potential capital savings of understating their risks (Blum, 2008). Two minimum liquidity ratios aim to reduce the risk of bank runs resulting from banks' liquidity transformation.[5] These macro-prudential policies are expected to be complementary to each other and to the micro-prudential capital regulations of Basel II. Therefore, we expect that a combination of capital requirements, a too-big-to-fail

[4] For empirical evidence on the effects of contagion through interbank linkages see e.g. Elsinger et al. (2006), Upper and Worms (2004), Degryse and Nguyen (2007), Furfine (2003).

[5] For a review of the Basel III/CRD IV measures and the related literature see Rissi et al. (2011).

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surcharge, a leverage ratio and minimum liquidity requirements increases financial stability in all financial systems (hypothesis H4).

The Basel III capital, leverage and liquidity requirements may have only an indirect influence on banks' risk taking behaviour by regulating asset-liability ratios. Direct restrictions of banks' investment portfolios by concentration limits or restriction of proprietary trading may be more effective than these indirect measures. Concentration limits aim to reduce bank failure probability by mitigating the bulk risk in a bank's investment portfolio.[6] Therefore, we expect that concentration limits of banks' counterparty risks increase financial stability in all financial systems (hypothesis H5).

A ban on or partial restriction of proprietary trading by banks (Volcker rule[7]) limits directly socially inefficient risk taking. Therefore, we expect that Volcker rules (restrictions of proprietary trading by banks) increase financial stability in all financial systems (hypothesis H6).

The Basel III regulatory framework rests on the implicit assumption that it fits to all financial systems. Therefore our last hypothesis is that the optimal mix of regulations does not depend on financial system architecture (hypothesis H7).

3. THE MODEL

Interpreting the financial system as complex, social, adaptive and interacting system (see Outkin et al., 2008), we apply an agent-based model to provide for emergent phenomena resulting from interactions of micro-rules executed by heterogeneous BDI-agents (see Rao and Georgeff, 1991 for a detailed explanation of the *Belief-Desire-Intention*-pattern of behaviour). Following the principle of parsimonious modelling, the behavioural rules are set as simple as possible, based on broadly supported theories. The agents in our model are commercial banks, non-financial firms and private investors.

3.1. Banks and regulatory measures

In what follows, we focus on commercial banks which are grouped by size according to their total assets and market share. In particular, we focus on three categories: big, medium and small, which are subdivided into banks granting fixed-rate and -term loans to companies of the real sector, with proprietary trading activities in stocks and bonds. Banks are risk averse and modelled as leveraged investment portfolios (see Baltensperger, 1980), trying to maximise the expected end of period utility (myopic portfolio optimisation) of their profit ($E\{U(\pi)\}$) (see Kent and Thompson, 2008, p. 101):

$$E\{U(\pi)\} = E(\pi) - \frac{1}{2}\beta\sigma_\pi^2 \quad (1)$$

where π is the profit function, σ_π^2 the variance of the end-of-period profit and β ($0 \leq \beta \leq 10$) the risk- aversion coefficient of the bank, with:

$$E(\pi) = \sum_{i=1}^{6} E(r_i) \cdot V_j \text{ and } \sigma_\pi^2 = V^T \cdot \Sigma \cdot V \quad (2)$$

[6] While there are various concentration and large-exposure limitations in national regulatory regimes, an explicit rule is missing in the current Basel framework, However large exposures are taken into account under Pillar 2, and further possibilities, including a Pillar 1 capital charge on large exposures are currently under review.

[7] The U.S. Dodd-Frank Act prohibits commercial banks from proprietary securities trading and restricts their ability to own hedge funds and private equity firms that engage in such trading. This is commonly known as the Volcker rule.

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$E(r_{i\ resp.\ j})$ represents the expected return on asset *i* and liability *j*, respectively. $V_{i\ resp.\ j}$ stands for the current market value of position *i* and *j*. Σ is the variance-covariance-matrix of the returns of the assets and liabilities. At the beginning of every period, the bank estimates the expected return, the variance and the covariance of every balance sheet position according to the following behavioural equations.

The bank will form its expectations in line with one of the two following adaptive price building schemes (see Kaizoji, 2004):

Fundamental analysis: $p^f_{t+1} = p_t + \upsilon \cdot (p^* - p_t),$
Technical analysis: $p^c_{t+1} = p^c_t + \mu \cdot (p_t - p^c_t)$

with: p_{t+1} expected price for period t+1, n and m are the error correction coefficients defined per asset class, p^* the fundamental/intrinsic value, p^c the chart-technical price obtained from history, and p_t the observable market price as of time *t*. The bank will switch between these two behavioural patterns depending on the performance of these strategies evaluated in a back-testing of the two updating schemes for the past periods.

Estimates of variances (h_t), covariances ($h_{12,t}$) and correlations ($r_{12,t}$) of returns for time period *t* are updated according to an exponentially weighted moving average with decay factor l:

$$h_t = \lambda \cdot h_{t-1} + (1 - \lambda) \cdot r^2_{t-1} \tag{3}$$

$$h_{12,t} = \lambda \cdot h_{12,t-1} + (1 - \lambda) \cdot r_{1,t-1} \cdot r_{2,t-1} \tag{4}$$

$$\rho_{12,t} = \frac{h_{12,t}}{\sqrt{h_{1,t} \cdot h_{2,t}}} \tag{5}$$

with subscripts *1* and *2* indicating asset/liability *1* and *2*, and r_{t-1} being the realised return for period t–1.

The simplified balance sheet of a bank consists of the following assets and liabilities, respectively:

(i) Non-interest-bearing minimum reserve account held at the central bank defined as a percentage of the deposits.

(ii) Money market investments which serve as a financial cushion. These positions can be liquidated at their market price at any time. The size of these positions will be determined by regulatory minimum requirements for liquidity which enter the optimisation procedure as a constraint.

(iii) Interbank loans granted to other financial institutions in the interbank market: the risk-adjusted pricing of these loans takes into account the funding costs of the granting bank as well as the expected and unexpected loss derived from the rating of the counterparty in accordance to guidelines of the Basel framework. Loans are potentially only granted to banks for which there is an existing business relationship (network structure). The extent to which loans are granted or withdrawn is the result of the beginning-of-period optimisation procedure: the constrained maximisation of equation (1) will lead to target weights for each balance sheet position. A comparison to the current exposures leads to the strategy pursued during the respective period, e.g. loan enquiries will only be approved if the position increase coincides with the strategy for the respective rating category.

(iv) Loans to commercial companies: the risk-adjusted pricing as well as the position taking adhere to the same principles as listed above for the interbank loans.

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(v) Bonds and stocks (trading book position): banks can invest in corporate bonds and stocks within their proprietary trading activities. These positions have to be backed by equity capital according to the Basel requirements. The changes in the positions are determined by the result of the optimisation procedure: buy and/or sell (market) orders are submitted to market makers.

(vi) Deposits: private households/investors deposit and withdraw money from their accounts consistent with their preferences. The interest rate on deposits is determined by supply and demand in a fully competitive market for deposits. Thus, the size of this position can only be influenced by the individual bank with regards to the amount of deposits desired as part of the aggregate demand for deposits. The actual amount as well as the interest rate to be paid cannot be actively controlled by the individual bank.

(vii) Interbank loans received from other financial institutions in the interbank market: the risk-adjusted pricing as well as the position taking adhere to the same principles as listed above for the interbank loans granted.

(viii) Bonds and stocks as funding sources: each bank can issue and repurchase its own bonds and stocks at current market prices to optimise the capital structure. Once more, the target positions are the result of the overall constrained portfolio optimisation.

The maximisation of (1) has to comply with the following regulatory restrictions (the degree of enforcement of the respective constraint depends on the specific hypothesis tested, see section 2):

(i) Minimum equity capital requirements: in accordance to the Basel framework, the risk-weighted assets are calculated and need to be underpinned by equity capital.[8] Depending on the hypothesis tested, the bank needs to hold additional equity capital (TBTF-capital surcharge) due to (a) the size of its total assets, and/or (b) its market share.

(ii) Leverage restriction (Leverage Ratio): defines the minimum amount of equity capital to be held as a percentage of the non-risk-weighted total assets.

(iii) Restrictions on proprietary trading (generalised Volcker Rule): maximum of risk-weighted assets in the trading book in relation to available equity capital. The percentage can range from 0% (strict enforcement of the Volcker Rule) to 200% (merely a limitation of proprietary trading as opposed to a strict abandonment).

(iv) Minimum reserve requirement: percentage of deposits and interbank loans used for funding purposes to be held at the central bank.

(v) Minimum liquidity requirement: liquid assets (minimum reserve account and money market investments) as a percentage of deposits held.

(vi) Concentration limits to mitigate bulk risk in the bank's investment portfolio: the regulatory enforced diversification is specified as (a) a maximum percentage for an individual position with regards to the available equity capital, and (b) a maximum percentage of all bulk risk positions in relation to the equity capital.

Other constraints are the budget restriction for the balance sheet and a maximum growth rate of total assets per period (20%) to ensure realistic balance sheet growth.

In case of a default – due to illiquidity (insufficient cash to settle pending payments) or insolvency (value of assets drops below the amount of debt to be repaid) – a bank is liquidated at the end of the corresponding period and the money paid out in sequence to: depositors, creditors in the interbank market, bond holders.

[8] We do not distinguish between tier 1, 2 and 3, as empirical evidence shows that the "quality of equity" is irrelevant from the perspective of fostering financial stability. See Rissi et al. (2011).

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3.2. Interbank and deposit market

The interbank as well as the deposit market is characterised by pure competition. Therefore, an individual bank is a price-taker and is deciding only with respect to the transaction volume. Demand and supply will lead to an equilibrium interest rate which forms the base funding rate in this market, incremented by counterparty-specific expected and unexpected loss components resulting in the final rate charge by one bank to another. The dynamics of the interest rate are given by the following adaptive interest-rate building process[9]

$$r_{t+1} - r_t = \theta \cdot x_t \tag{6}$$

with $r_{t+1} - r_t$ the change in the equilibrium rate from period t to t+1, θ the error correction factor and x_t the excess demand (positive) or excess supply (negative) of interbank money.

The general mechanics for the deposit market are similar, with one difference being the adaptive interest rate process:

$$r_{t+1} - r_t = \theta \cdot n \cdot \left[(1-\chi) \cdot x_t^c + \chi \cdot x_t^n \right] \tag{7}$$

where $r_{t+1} - r_t$ the change in the market deposit rate from period t to t+1, q the error correction factor, n the total number of market participants, χ the percentage of noise traders in the population of participating agents and x_t denoting the excess demand (positive) or excess supply (negative) for deposits. The superscripts c and n refer to the two investor types: chartists and noise traders. The lower bound for the deposit rate is set to zero. The rationale for this difference in the rate-building process is that there are three types of private investors (see section 3.4) which are bundled into two for the deposit market (the fundamentalists are added to the group of chartists in order to avoid having to model forecasts for the deposit rate based on fundamental economic data).

3.3. Capital markets

The capital market consists of a set of independent market makers whose sole function is to set the market clearing price and to match transactions between market participants. They do not pursue any other objective; in particular they do not trade on their own account. There is a separate market maker for every stock and bond, i.e. the market makers are similar to specialists at the New York Stock Exchange. These market makers accept only market orders, and all financial assets are assumed to be perfectly divisible. In case of an excess demand or supply, a short-side-rule is applied which will lead to partial fills of the submitted orders. The market maker has perfect knowledge of the composition of the orders submitted with regards to the trader type (fundamentalist, chartist, noise trader) and will adjust the market price at the end of every period according to the following adaptive price building process (see Kaizoji, 2004):

$$p_{t+1} - p_t = \theta \cdot n \cdot \left[(1-\kappa-\chi) \cdot x_t^f + \kappa \cdot x_t^c + \chi \cdot x_t^n \right] \tag{8}$$

with $p_{t+1} - p_t$ the change in the market price, θ the error correction factor, n the total number of market participants, κ and χ the percentage of chartists and noise traders in the population of participating agents respectively and x_t denoting the excess demand (positive) or excess supply (negative) for the respective financial instrument. The superscripts f, c and n refer to the three

[9] Our interest rate building processes on interbank and deposit markets are modelled in analogy to the price- building process on capital markets assumed by Kaizoji (2004), see equation (8) below.

investor types: fundamentalists, chartists and noise traders. The lower bound for the price of a financial asset is set to zero.

Additionally issued bonds and stocks (bond and stock repurchases) are treated like sell (buy) orders, with the only difference that the number of outstanding financial instruments changes accordingly.

3.4. Private investors

Private investors – grouped into the three categories: fundamentalists, chartists and noise traders – maximise their end-of-period wealth (myopic portfolio optimisation) according to the following logarithmic utility function Y (see Lengwiler, 2004 for the rationale of using a logarithmic utility function):

$$\Psi[y] = k_0 + k_1 \cdot \ln[y] \tag{9}$$

where y is the total assets at the end of a period and k_0 and k_1 are constants used to calibrate the utility function. The consumption aspect is not modelled explicitly, but taken into account in a rudimentary way by the requirement of a minimum cash balance to be held (assumed to be used for consumption purposes).

In a way similar to the process described for banks (see section 3.1), every private investor is solving for the mean-variance-optimal portfolio, maximising above utility function using estimates of the expected return – the variance and the covariance of every balance sheet position according to the following behavioural equations:

Fundamental analysis: $p^f_{t+1} = p_t + \upsilon \cdot (p^* - p_t)$

Technical analysis: $p^c_{t+1} = p^c_t + \mu \cdot (p_t - p^c_t)$

Noise traders: $p^n_{t+1} = p_t + \zeta \cdot \varepsilon \cdot p_t.$

with: p_{t+1} expected price for period t+1, v, μ and ζ are the error correction coefficients defined per asset class, p^* the fundamental/intrinsic value, p^c the chart-technical price, and p_t the observable market price as of time t. ε is an investor specific standard normal error term drawn at the beginning of every period. A private investor will stick to the strategy assigned at the start of the simulation. For the updating scheme of the variances, covariances and correlations, refer to section 3.1.

The balance sheet of private investors is as follows: a minimum cash reserve of 3% needs to be held at any point in time. Deposits are held at designated banks: the size of this position is the result of the optimisation process and is mainly determined by the relative attractiveness of deposits as measured by the interest rate paid, relative to other investment opportunities. Long and short positions in bonds and stocks of banks as well as non-financial firms are taken only with designated counterparties. Changes and, therefore, buy and/or sell (market) orders submitted to market makers are indicated by a comparison of the target and actual position. Loans are directly granted to non-financial firms (crowd-funding): requests from non-financial companies for loans are authorised if this is in accordance to the target weights coming from the optimisation procedure. Potential loans are only granted to designated companies (network structure). Private investors are fully equity-financed and go bankrupt if this equity capital falls below zero, or due to an exogenous event with a probability in line with the rating of the investor.

The constrained optimisation procedure takes the following restrictions into account: (i) a minimum cash balance of 3% of total assets, (ii) a maximum change in total assets of 20% from one period to the next, and (iii) the budget restriction.

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3.5. Non-financial firms

The objective of non-financial firms is to maximise shareholders' value by realising real investments with uncertain cash flows. These investments are generated at the beginning of every period by an exogenous shock (innovation rate), are tailored to the company-specific characteristics in terms of size of the project and financing requirements, and are allocated to the corresponding company. After checking a project for its economic soundness (positive net present value), the company will seek the cheapest funding source for worthwhile investment projects. The projects can be financed either via internally available cash, bank loans, issuance of bonds or stocks, crowd funding or a mix of all of these. A company will create a pecking order of all potential funding sources according to the relative interest costs and try to fund the project according to this list of priorities. If it cannot get enough funds from these sources, the investment is abandoned. Existing projects change in value from period to period due to an exogenous shock, which can be interpreted as changed market conditions impacting the profitability and, therefore, economic viability. The asset dynamics of existing projects follow a geometric Brownian motion, with a company-specific trend and standard deviation calibrated to the rating of the company. The new value of the real assets added to the other balance sheet positions results in the total market value of assets. If the latter falls below the face value of the debt, the company is insolvent and enters the liquidation procedure (see Merton, 1974). In case of survival, the new intrinsic value of debt and equity is determined in accordance to Black and Scholes' interpretation of equity as a call option on the assets of a company. These are the intrinsic values on which fundamental investors base their investment decisions. To summarise, the financial system is exposed to two exogenous shocks: (a) the new projects allocated to non-financial companies according to the innovation rate, and (b) changes in market values of existing projects. All other dynamics are determined endogenously. The pecking order in case of liquidation of a non-financial company is as follows: bank loans, loans from other firms, bonds, loans from private investors.

The generic balance sheet structure for non-financial firms is modelled as follows: cash and money market investments are used to manage temporary excess liquidity. Direct loans to other designated firms are provided outside the banking system. The present value of existing real investments is exposed to changes in value. Loans from designated banks are used to fund investment projects. Interest rates are risk-adjusted to the rating of the non-financial ones. Direct loans from designated firms and loans from private investors (crowd-funding) happen outside the banking system in direct negotiations between the respective counterparties. Bonds and stocks are issued on the capital market. These positions are held by banks and private investors.

4. PARAMETERISATION AND MEASUREMENTS

In this section we describe the parameterisation of the model and the measures of financial stability used.

4.1. Parameterisation

To ensure robustness of the results as well as realistic realisations of the evolution of endogenous variables (e.g. volatility of stock prices and interest rates), pre-tests were run to determine adequate parameterisation. These tests included sets of different numbers of periods per simulation path, numbers of simulations, parameters for the price anticipation functions, and risk-aversion coefficients. As a result of these pre-tests, the parameterisation presented in Table 1 has been chosen.

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Table 1
Parameters used

Parameter set:	**Details:**	
Capital market:	Market makers for bonds of non-financials	Error correction coefficient: 0.0002; start-volatility: 7%
	Market makers for stocks of non-financials	Error correction coefficient: 0.0007; start-volatility: 20%
	Market makers for bonds of banks	Error correction coefficient: 0.0002; start-volatility: 5%
	Market makers for stocks of banks	Error correction coefficient: 0.0007; start-volatility: 30%
Interbank-, crowd-funding, corporate loan and deposit market	Error correction coefficient: 0.00054; start-interest-rate: 5%; start-volatility: 1%	
Intra-firm loan market	Error correction coefficient: 0.0019; start-interest-rate: 5%; start-volatility: 1%	
Investors[a)]	Fundamentalists	Error correction coefficient: 0.5
	Chartists	Error correction coefficient: 0.5
	Noise-traders	Error correction coefficient: 0.5
Network structure	Investors (max. number of designated relationships)	Deposits: 5 Bonds of banks: 10 Stocks of banks: 10 Bonds of non-financials: 10 Stocks of non-financials: 10 Crowd-funding: 5
	Non-financials (max. number of designated relationships)	Bank loans: 10[b)] Intra-non-financial-loans: 5
	Banks (max. number of designated relationships)	Interbank loans: 14 Bonds of non-financials: 20 Stocks of non-financials: 20
Real investments of non-financials	Innovation rate: 40% Expected present value of project as percentage of total assets: 5% Standard deviation of present value of projects: 3% Expected initial investment as percentage of the project's present value: 50% Standard deviation of initial investment requirement: 20%	
Risk weights for capital requirements[c)]	Positions in the trading book: 1.0 Banking book positions (non-financials): AAA: 0.2; AA: 0.2; A: 0.5; BBB: 1; BB: 1; B: 1.5; worse than B: 1.5 Banking book positions (banks): AAA: 0.2; AA: 0.2; A: 0.5; BBB: 0.5; BB: 1; B: 1; worse than B: 1.5	
Other parameters	Risk free interest rate: 3% Loss given default (ex ante): 70% Decay-factor for volatility and correlation updates: 0.97 Max. change in total assets per period: 20%	

Legend:
a) The same error correction coefficients for investors are used by Kaizoji (2003, 2004).
b) Empirical evidence shows that the average number of bank relationships of non-financial firms varies between 1.4 and 16.4 across countries. In a cross section of 20 European countries the average firm uses between five and six banks (Ongena and Smith, 2000).
c) In accordance to the Basel framework.

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4.2. Measures of financial stability

There are many different definitions of financial stability (see Cihak, 2006 for an overview). For our analyses we use the following: stability of a financial system is characterised by its ability to fulfill requirements which can be assigned to one of the subsequent three target complexes: (i) structural stability: resilience of the financial system with respect to structural key indicators (e.g. number of banks, variability of balance sheet positions and key financial ratios, default rate); (ii) functional stability: resilience with respect to the ability of the financial system to perform its key function of capital allocation; (iii) worst-case-stability: the ability of the system to perpetuate its capital allocation function and capability of system components and protagonists to survive in situations of financial crises (categorisation adapted from Brinkmann, 2007). In order to test the hypotheses in section 2 we implement(ed) the quantitative measures presented in Table 2 to capture the dimensions of stability we have discussed in a comparative static analysis.

Table 2
Stability measures used

Target Complex / Subdimension		Measure(s):
Structural stability	Stability of market structure	Herfindahl-/Gini-coefficients of balance sheet positions
	Stability of capital structure	Market capitalisation of banks and non-financial firms, debt-equity ratio, regulatory capital ratio[a)], liquidity[b)]
	Operational stability	Profit-and-loss-distribution of banks and non-financial firms, systemic loss[c)] distribution
	Risk profile	Default rate of banks, non-financial firms and private households by category
Functional Stability	Transaction stability	Loan and trading volume and their volatilities, rates, credit intermediation ratio[d)], market intermediation ratio[e)]
	Efficiency of capital allocation	Ratio of realised projects to all projects, ratio of unrealised projects due to financing gap to all projects, intermediation gap[f)], non-performing loans
Worst-case-stability		95%-expected-shortfall of systemic loss, 95%-default-rate[g)], 95%-value-at-risk

Legend:
a) Regulatory capital ratio = required equity capital / available equity capital.
b) Liquidity = (minimum reserve requirements + money market positions) / (deposits + interbank loans).
c) Systemic loss = losses on non-performing loans + losses on stocks and bonds + losses from crowd-funding.
d) Credit intermediation ratio = loans granted by banks / total financing volume of non-financial firms.
e) Market intermediation ratio = (stocks + bonds) / total financing volume of non-financial firms.
f) Intermediation gap = (present value of all positive NPV-projects – present value of all realised positive NPV-projects) / present value of all positive NPV-projects.
g) Default rate with a 95% confidence level.

In addition, we have implemented indicators of the real sector to be able to assess the impact of the proposed regulations on macroeconomic development/growth. This allows us to link the agent-based model to downstream theories of economic cycles in a consistent and coherent way. Since the present paper focuses on financial stability these results are not presented in what follows.

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5. RESULTS AND DISCUSSION

The hypotheses in section 2 are evaluated using a two-sided standard normal test statistic for the differences of means of the samples and two-sided F-tests for the differences of sample variances, respectively.[10]

Table 3 summarizes the results concerning H1. It shows that the stability of different financial systems depends on the behaviour of banks and private investors. In the case of homogeneous behaviour (100% fundamentalists or 100% chartists) market-based financial systems are significantly more stable than bank-based financial systems in all dimensions except structural stability measured by banking market concentration. In the case of other behavioural patterns (banks: 100% chartists, private investors: 100% noise traders; banks: 50% fundamentalists, 50% chartists, private investors: 33% fundamentalists, 33% chartists, 33% noise traders) the market structure of the banking system is not significantly more stable or, even, less stable in a bank-based system than in a market-based system. Irrespective of investment behaviour, market-based systems show higher functional stability (measured by the intermediation gap and the ratio of realized projects) and higher worst-case stability than bank-based systems.[11] Thus, H1 cannot be rejected.

Table 3
Results for hypothesis H1: Unregulated market-based financial systems (M) are more stable than unregulated bank-based financial systems (B).

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**	**S4[d)]**
Structural stability	Concentration of banking sector	B < M	B < M	B = M	B > M
	Systemic loss	B > M	B > M	B > M	B > M
	Default rate of banks	B > M	B > M	B > M	B > M
Functional Stability	Intermediation gap	B > M	B > M	B > M	B > M
	Credit intermediation ratio	B = M	B > M	B < M	B < M
	NPL	B > M	B > M	B > M	B > M
Worst-case-stability	95% ES	B > M	B > M	B > M	B > M
	95% default rate of banks	B > M	B > M	B < M	B > M

Legend:
[a)] S1: banking sector: 100% fundamentalists; private investors: 100% fundamentalists.
[b)] S2: banking sector: 100% chartists; private investors: 100% chartists.
[c)] S3: banking sector: 100% chartists; private investors: 100% noise traders.
[d)] S4: banking sector: 50% fundamentalists, 50% chartists; private investors: 33% fundamentalists, 33% chartists and 33% noise traders.
A measure x of an unregulated bank-based financial system (B) is statistically significantly bigger (>) or smaller (<) compared to the measure x of an unregulated market-based financial system (M) with a confidence level of at least 90%. An equals sign (=) represents a statistically not significantly different measure x.

Table 4 presents the results concerning different behavioural patterns within the same financial architecture. It shows that in a homogeneous financial system (33% bank finance, 33% market finance, 33% crowd funding) structural and functional stability are lower if the investment behaviour is dominated by fundamentalists compared to other behavioural patterns. Thus, the fact that fundamentalists immediately react to a divergence of the market price from its intrinsic value has a destabilizing effect in normal times. Only worst-case stability, measured by expected shortfall of the systemic loss is higher, if fundamentalists dominate, than if there are 100%

[10] The simulation results and test statistics are available upon request.

[11] Moreover, we found that unregulated market-based financial systems have a higher growth trend, lower economic fluctuations through monetary impulses and lower depreciation rates (not reported in Table 3).

chartists or heterogeneous behavioural patterns. Thus, parallel behaviour of financial market participants is destabilizing in normal times, but stabilizing in stress situations. The most stable behavioural configuration along all stability measures is reached if banks behave as pure chartists and private investors behave as invariably as noise traders.

For other financial architectures we find the following results (not presented). In a financial system with 50% bank and 50% market finance worst-case stability is always lower if fundamentalists prevail than if there are other behavioural configurations. The results for structural and functional stability are mixed. Bank-based financial systems dominated by fundamentalists are in almost all cases structurally and functionally less stable but, in worst-case situations, more stable than if other behavioural patterns prevail. Market-based financial systems dominated by fundamentalists are less stable in all dimensions of stability other than market-based financial systems with other behavioural patterns.

Table 4

Results for hypothesis H2: Unregulated financial systems dominated by fundamental analysts (F) are more stable than unregulated financial systems with other behavioural configurations (A)

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**
Structural stability	Concentration of banking sector	F > A	F > A	F > A
	Systemic loss	F > A	F > A	F > A
	Default rate of banks	F > A	F > A	F > A
Functional Stability	Intermediation gap	F > A	F > A	F > A
	Credit intermediation ratio	F < A	F < A	F < A
	NPL	F > A	F > A	F > A
Worst-case-stability	95% ES	F < A	F > A	F < A
	95% default rate of banks	F > A	F > A	F > A

Legend:

[a)] S1: F: 100% fundamentalists; A: banking sector: 100% chartists; private investors: 100% chartists.

[b)] S2: F: 100% fundamentalists; A: banking sector: 100% chartists; private investors: 100% noise traders.

[c)] S3: F: 100% fundamentalists; A: banking sector: 50% fundamentalists, 50% chartists; private investors: 33% fundamentalists, 33% chartists, 33% noise traders.

A measure x of a homogeneous financial system dominated by fundamentalists (F) is statistically significantly bigger (>) or smaller (<) compared to the measure x of a homogeneous financial system with the corresponding alternative behavioural pattern (A) with a confidence level of at least 90%. An equals sign (=) represents a measure x which is not significantly different.

Therefore, H2 has to be rejected. The immediate reaction of fundamental analysts to a divergence of the market price from its intrinsic value is desirable from the viewpoint of information efficiency, but has destabilizing effects by immediately transmitting real shocks to financial markets and banks. Chart-technical strategies and noise traders are smoothing out these shocks over time and thus have a shock-absorbing function. However, noise traders cause market prices to deviate from their fundamental value. Therefore, there is a conflict between the stability of the financial system and the efficient market hypothesis.

Table 5 summarizes the results concerning H3. It shows that in a market-based financial system the introduction of an 8% minimum capital ratio has no effect on structural stability and even has destabilizing effects on functional stability (measured by non-performing loans) and worst-case stability. In a homogeneous financial system the capital regulation reduces structural stability (increasing systemic loss) and worst-case stability (increasing expected shortfall of systemic loss). Only non-performing loans are reduced, implying higher functional stability. Thus, in normal times, capital requirements reduce credit losses through a more conservative lending by banks. In a bank-based financial system, the capital regulation reduces systemic loss, non-performing loans and the expected shortfall of systemic loss. These stabilizing effects can

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be explained by the loss-absorbing function of equity capital in times of crisis. However, the propagation of a crisis in the banking sector cannot be prevented by this regulatory measure.

An increase of the minimum capital ratio from 8% to 13%[12] has the following effects (not presented): in homogeneous and market-based financial systems worst-case stability declines and functional stability, measured by non-performing loans, rises. In a market-based financial system structural stability in the banking sector rises, while in a homogeneous financial system the effects on structural stability are ambiguous. In a bank-based financial system worst-case stability (measured both by expected shortfall of systemic loss and default rate of banks) and structural stability (measured by systemic loss) rise. Only functional stability declines through a rise in non-performing loans in normal times.

Table 5

Results for hypothesis H3: Higher capital regulations increase financial stability in all financial systems

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**
Structural stability	Concentration of banking sector	8% = U	8% = U	8% = U
	Systemic loss	8% > U	8% < U	8% = U
	Default rate of banks	8% = U	8% = U	8% = U
Functional Stability	Intermediation gap	8% = U	8% = U	8% = U
	Credit intermediation ratio	8% = U	8% = U	8% = U
	NPL	8% < U	8% < U	8% > U
Worst-case-stability	95% ES	8% > U	8% < U	8% > U
	95% default rate of banks	8% = U	8% > U	8% > U

Legend:
a) S1: homogeneous financial system: 33% bank finance, 33% market finance, 33% crowd funding.
b) S2: bank-based financial system: 80% bank finance, 20% market finance.
c) S3: market-based financial system: 20% bank finance, 80% market finance.
A measure *x* of a financial system with 8% capital regulation (8%) is bigger (>) or smaller to a statistically significant degree, compared to an otherwise identical but unregulated financial system (U) with a confidence level of at least 90%. An equals sign (=) represents a measure *x* which is not significantly different statistically.

The marginal benefits of increasing capital requirements from 13% to 19%[13] depend, moreover, on the financial system architecture. In a homogeneous financial system the additional capital requirements reduce the systemic loss and default rate of banks significantly. Also functional stability (lower non-performing loans) and worst-case stability rise. In a bank-based financial system the additional capital requirements reduce operational stability through higher systemic loss. The effects on functional and worst-case stability are ambiguous: the intermediation gap and the expected shortfall of systemic loss are reduced, but non-performing loans and the default rate of banks in times of stress rise. In a market-based financial system the additional capital requirements reduce both the systemic loss and the default rate of banks. Functional stability, measured by non-performing loans, and worst-case stability also rise.

Thus, we do not find a systematic relationship between capital requirements and financial stability. The effects of capital regulations depend on the dimension of financial stability and the architecture of the financial systems. H3 has to be rejected. Our findings are consistent with the mixed results of empirical studies on the effectiveness of bank capital requirements. For the U.S., Shrieves and Dahl (1992) found a positive influence of bank capital on bank asset risk, but Jacques and Nigro (1997) found a negative one. For Switzerland, Rime (2001) found no

12 As required by Basel III from big, systematically relevant banks from 2019 onwards (minimum total capital 8% + conservation buffer 2.5% + SIFI surcharge 2.5%).

13 As required from the big, systemically relevant banks in Switzerland.

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significant impact of capital regulations on bank portfolio risk, while Bichsel and Blum (2004) found a positive relationship between changes in capital and asset risk. For cross-sections of 107 countries (Barth et al., 2004) and the EU-27 (Rissi et al., 2011), no robust relationships between bank capital requirements and financial stability, measured by non-performing loans or bank fragility, could be found.

Further tightening of regulations in our model (adding consecutively a 3% leverage ratio, TBTF capital regulations, Volcker's rule and concentration limits), we cannot confirm a strictly monotonically increasing positive effect on financial stability as measured by our indicators. On the contrary, stricter regulatory regimes can lead to regulatory failure: we provide evidence that an unregulated system is more stable with regards to structural, functional and worst-case-stability compared to a system with the following banking regulations simultaneously enforced: 8% capital regulation, minimum liquidity requirements, 3% leverage ratio, TBTF-capital regulation, Volcker rule and concentration limits.

Moreover, we examined whether the Basel III regulatory measures, i.e. introduction of a leverage ratio and minimum liquidity requirements in addition to capital requirements (13% minimum equity ratio and a potential TBTF surcharge) – increase stability. The results are summarized in Table 6.

Table 6

Results for hypothesis H4: A combination of capital requirements, a too-big-to-fail surcharge, a leverage ratio and minimum liquidity requirements increases financial stability in all financial systems

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**
Structural stability	Concentration of banking sector	R2 < R1	R2 = R1	R2 > R1
	Systemic loss	R2 < R1	R2 = R1	R2 = R1
	Default rate of banks	R2 < R1	R2 = R1	R2 = R1
Functional Stability	Intermediation gap	R2 = R1	R2 = R1	R2 = R1
	Credit intermediation ratio	R2 > R1	R2 = R1	R2 = R1
	NPL	R2 < R1	R2 = R1	R2 < R1
Worst-case-stability	95% ES	R2 > R1	R2 < R1	R2 < R1
	95% default rate of banks	R2 < R1	R2 = R1	R2 > R1

Legend:

a) S1: homogeneous financial system: 33% bank finance, 33% market finance, 33% crowd funding.

b) S2: bank-based financial system: 80% bank finance, 20% market finance.

c) S3: market-based financial system: 20% bank finance, 80% market finance.

A measure x of a financial system with 13% capital regulation, too-big-to-fail surcharge, a 3% leverage ratio and minimum liquidity requirements (R2) is statistically significantly bigger (>) or smaller (<) compared to an otherwise identical financial system (R1) with 13% capital regulation and a too-big-to-fail surcharge only – with a confidence level of at least 90%. An equals sign (=) represents a measure x which is not significantly different statistically.

In a homogeneous financial system the additional leverage ratio and liquidity requirements significantly improve structural stability. Also financing efficiency rises through a decline in non-performing loans. However, worst-case stability measured by the expected shortfall of systemic losses declines. In a bank-based financial system the additional regulatory measures do not improve financial stability in normal times. However, worst-case stability rises through a higher loss-absorbing capacity. In a market-based financial system the additional regulatory measures reduce structural stability measured by banking market concentration and worst-case stability measured by the 95% default rate of banks. Financing efficiency and worst-case stability measured by the expected shortfall of systemic losses rise.

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For the addition of single measures to a minimum capital ratio of 13% (not presented) we found that the introduction of a leverage ratio in a bank-based financial system increases functional stability, but is ineffective in all other stability dimensions. In market-based financial systems, structural and functional stability rise. Size-dependent TBTF capital surcharges have destabilizing effects in a bank-based financial system. In a market-based financial system they increase structural and functional stability, but reduce worst-case stability. Irrespective of financial system architecture, liquidity requirements cannot prevent the propagation of a banking crisis, because they do not restrict investment behavior. Similar to capital requirements, they mainly have a loss-absorbing function, which can increase worst-case stability in times of stress. The exact effects depend on financial system architecture and range from stabilizing to destabilizing. Therefore, one size does not fit all and so H4 has to be rejected.

Table 7 shows that concentration limits of banks' counterparty risks help to stabilize mainly bank-based financial systems, whereas they have mostly destabilizing effects in homogeneous and market-based financial systems. In a bank-based financial system structural stability measured by concentration and systemic loss, financing efficiency measured by non-performing loans, and worst-case stability rise. In a homogeneous financial system non-performing loans decline, but systemic loss and expected shortfall of systemic loss rise. In a market-based financial system only structural stability measured by the concentration of the banking sector rises, whereas structural stability measured by systemic loss and the default rate of banks, functional stability measured by non-performing loans, and worst-case stability decline.

Table 7
Results for hypothesis H5: Concentration limits of banks' counterparty risks increase financial stability in all financial systems

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**
Structural stability	Concentration of banking sector	B = U	B < U	B < U
	Systemic loss	B > U	B < U	B > U
	Default rate of banks	B = U	B = U	B > U
Functional Stability	Intermediation gap	B = U	B = U	B = U
	Credit intermediation ratio	B = U	B = U	B = U
	NPL	B < U	B < U	B > U
Worst-case-stability	95% ES	B > U	B < U	B > U
	95% default rate of banks	B = U	B < U	B > U

Legend:
a) S1: homogeneous financial system: 33% bank finance, 33% market finance, 33% crowd funding.
b) S2: bank-based financial system: 80% bank finance, 20% market finance.
c) S3: market-based financial system: 20% bank finance, 80% market finance.
A measure x of a financial system with bulk risk regulations (B) is statistically significantly bigger (>) or smaller (<) compared to an otherwise identical but unregulated financial system (U) with a confidence level of at least 90%. An equals sign (=) represents a measure *x* which is not significantly different statistically.

Comparing the efficiency of concentration limits and 13% capital requirements (not presented), we find that in a homogeneous financial system concentration limits are more effective than capital requirements in reducing systemic loss and worst-case instability, while the reverse holds in a bank-based financial system. In a market-based financial system concentration limits tend to be less efficient than capital requirements because they reduce structural stability in the banking sector as well as functional and worst-case stability. Hence, H5 has to be rejected.

Table 8 shows the results for hypothesis H6 in the case of a strict enforcement of the Volcker rule. In both a homogeneous and a market-based unregulated financial system the introduction of a ban on proprietary trading has significant stabilizing effects with regard to all stability

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dimensions. If the same regulation is introduced into an unregulated bank-based financial system, stability rises in four dimensions (lower systemic loss, default rate of banks, non-performing loans, intermediation gap), but declines in two dimensions (higher non-performing loans, 95% default rate of banks). Therefore, H6 cannot be rejected.

Table 8
Results for hypothesis H6: Volcker rules (restrictions of proprietary trading by banks) increase financial stability in all financial systems

Target Complex / Measure		**S1**[a)]	**S2**[b)]	**S3**[c)]
Structural stability	Concentration of banking sector	V < U	V = U	V < U
	Systemic loss	V < U	V < U	V < U
	Default rate of banks	V < U	V < U	V < U
Functional Stability	Intermediation gap	V = U	V < U	V = U
	Credit intermediation ratio	V = U	V = U	V > U
	NPL	V < U	V > U	V < U
Worst-case-stability	95% ES	V < U	V < U	V < U
	95% default rate of banks	V < U	V > U	V < U

Legend:
[a)] S1: homogeneous financial system: 33% bank finance, 33% market finance, 33% crowd funding.
[b)] S2: bank-based financial system: 80% bank finance, 20% market finance.
[c)] S3: market-based financial system: 20% bank finance, 80% market finance.
A measure *x* of a financial system with the Volcker rule enforced (V) is statistically significantly bigger (>) or smaller (<) compared to an otherwise identical but unregulated financial system (U) with a confidence level of at least 90%. An equals sign (=) represents a measure *x* which is not significantly different statistically.

Comparing the efficiency of a ban on proprietary trading and 13% capital requirements (not presented), we find that both in a homogeneous and a market-based financial system the ban on proprietary trading is more efficient than the capital regulation with respect to all stability dimensions. In a bank-based financial system the effects of the Volcker rule relative to capital regulation range from stabilizing (structural stability), to ambiguous (functional stability) and on to destabilizing (worst-case stability). The results are similar for a comparison of the efficiency of a ban on proprietary trading and a mix of regulatory measures comprising 13% capital requirements, TBTF surcharges, liquidity requirements and a leverage ratio.

For the marginal benefits of a ban on proprietary trading compared to a restriction of it to a maximum of 200% of equity capital, we find that in a homogeneous financial system structural stability rises, while the effects on functional and worst-case stability are ambiguous. In a bank-based financial system, a ban on proprietary trading is less efficient than a restriction of it with regard to structural and worst-case stability. With regard to functional stability the results are ambiguous. In a market-based financial system a ban on proprietary trading is more efficient than a restriction of it with respect to all stability dimensions.

Table 9 shows the most effective (ineffective) regulation in each type of financial system. In all financial systems, the most effective measures are a ban on or a restriction of proprietary trading, which prevent or reduce destabilizing feed-back effects between capital markets and banks. In a market-based financial system the most effective regulation is the ban on proprietary trading with respect to all stability dimensions, while in homogeneous and bank-based financial systems either a ban or a restriction of proprietary trading is optimal, depending on the stability measure used. Therefore, H7 has to be rejected.

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Table 9
Results for hypothesis H7: The optimal mix of regulations does not depend on financial system architecture

Target Complex / Measure		S1[a)]	S2[b)]	S3[c)]
Structural stability	Concentration of banking sector	R6 (R8)	R7 (R5)	R6 (R7)
	Systemic loss	R6 (R8)	R7 (R5)	R6 (R7)
	Default rate of banks	R6 (R8)	R7 (R5)	R6 (R7)
Functional Stability	Intermediation gap	R7 (13%)	R5 (R6)	R6 (R7)
	Credit intermediation ratio	R6 (R8)	R7 (R5)	R6 (R7)
	NPL	R6 (R8)	R7 (R5)	R6 (R7)
Worst-case-stability	95% ES	R7 (13%)	19% (R6)	R6 (R7)
	95% default rate of banks	R6 (R8)	R7 (R5)	R6 (R7)

Legend:
a) S1: homogeneous financial system: 33% bank finance, 33% market finance, 33% crowd funding.
b) S2: bank-based financial system: 80% bank finance, 20% market finance.
c) S3: market-based financial system: 20% bank finance, 80% market finance.
U: unregulated financial system; 8%: 8% capital regulation only; 13%: 13% capital regulation only; 19%: 19% capital regulation only; R1: 8% capital regulation and minimum liquidity requirements; R2: 8% capital regulation and minimum liquidity requirements and 3% leverage ratio; R3: R2 and too-big-to-fail surcharge; R4: R3 and (risk-weighted) proprietary trading positions limited to 200% of equity capital; R5: R4 and bulk risk regulations; R6: Volcker rule only; R7: (risk-weighted) proprietary trading positions limited to 200% of equity capital only; R8: minimum liquidity requirements only.
X (Y) in the above table indicates the most effective regulation X and the most ineffective regulation Y.

6. APPLICATION TO THE SWISS FINANCIAL SYSTEM

The model in section 3 has been calibrated to the Swiss financial system to evaluate the impact of the various regulations on the resilience of the Swiss banking system. Table 10 lists the key macro-economic data used for the calibration.

Table 10
Structure of the Swiss financial system

Macroeconomic variable	Amounts in billion CHF	%
Total financing volume of non-financials	1,347.7	100
thereof:		
Banking system (total)	**692.7**	**51.4**
thereof:		
Loans to non-financials	405.4	58.5
Financing via capital market (stocks)	264.1	38.1
Financing via capital market (bonds)	23.1	3.3
Capital market (total)	**595.5**	**44.2**
thereof:		
Stock market	555.1	93.0
Bond market	40.3	7.0
Crowd-funding (total)	**59.4**	**4.4**
thereof:		
Private investors	42.6	71.6
Firms	16.8	28.4

Legend: Own calculations based on SECO (2011), Beck and Demirgüc-Kunt (2009) and SNB (2010a). Note that the private mortgage sector has been excluded.

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The banking sector is modelled by representing the actual balance sheets of the major 27 universal banks (including United Bank of Switzerland, Credit Suisse Group, Raiffeisen Group and the 24 cantonal banks): refer to Table A.1 in the appendix for a detailed description of the balance sheet structure. Companies of the real sector are grouped by their relative size into big, medium and small firms. The simplified balance sheets of non-financials consist primarily of liquid assets and the present value of their real investments on the asset side, and the major funding sources – such as bank loans, bonds and stocks issued – on the liability side of the balance sheet: see Table A.2 in the appendix for more details. Private households are uniformly segregated into the investor categories fundamentalists, chartists and noise traders and are also described by their balance sheet positions: refer to Table A.3 in the appendix for a detailed description of the balance sheet structure.

Applying the calibrated model, we find the following results for the Swiss financial system: Table 11 summarises the major findings:

Table 11
Results for the Swiss financial system

Target Complex / Measure		**S1[a)]**	**S2[b)]**	**S3[c)]**	**S4[d)]**
Structural stability	Concentration of banking sector	8% = U	8% = 13%	R = 8%	13%
	Systemic loss	8% < U	8% > 13%	R > 8%	R2
	Default rate of banks	8% = U	8% = 13%	R = 8%	R2
Functional Stability	Intermediation gap	8% = U	8% = 13%	R = 8%	13%
	Credit intermediation ratio	8% = U	8% = 13%	R = 8%	R1
	NPL	8% = U	8% = 13%	R < 8%	R1
Worst-case-stability	95% ES	8% < U	8% > 13%	R > 8%	8%
	95% default rate of banks	8% = U	8% < 13%	R < 8%	R1,R2

Legend:
a) S1: 8% capital regulation (8%) versus unregulated (U)
b) S2: 13% capital regulation (13%) versus 8% capital regulation (8%)
c) S3: 8% capital regulation + minimum liquidity requirements (R) versus 8% capital regulation (8%)
d) S4: optimal, i.e. most effective regulation for respective dimension, where: R1 = 8% capital regulation + minimum liquidity requirements + 3% leverage ratio; R2 = R1 + TBTF-capital regulation.
A measure x of a regulated financial system (e.g. 8% capital regulation) is statistically significantly bigger (>) or smaller (<) compared to the measure x of an alternatively regulated financial system (e.g. unregulated) with a confidence level of at least 90%. An equals sign (=) represents a measure x which is not significantly different statistically.

Introducing an 8% capital regulation in the previously (and hypothetically) unregulated Swiss banking sector does not have a statistically significant impact on functional stability whereas the structural (as measured by systemic loss) and worst-case-stability (as measured by 95% expected shortfall) increase statistically significantly, at least at the 90% confidence level.

A further increase of the capital requirements from 8% to 13% has destabilising effects on structural as well as worst-case-stability. Although the 95% default rate is decreasing, the 95% expected shortfall increases significantly and over-compensates the reduction in bank defaults.

Combining the 8% capital regulation with minimum liquidity requirements will destabilise the system with regards to structural and worst-case-stability. This is due to the fact that the additional regulatory requirement leads to a synchronisation of bank behaviour: in stress situations the banks have to liquidate assets to be compliant with the liquidity rules, increasing the systemic loss in a crisis. Therefore, the minimum liquidity requirements tested are an inefficient means to mitigate contagion in a financial crisis, although we observe a statistically significant reduction in the 95% default rate in the banking sector. The only stability-increasing effect is an improvement in the

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efficiency of indirect lending during normal market conditions by reducing the losses coming from non-performing loans.

Further tightening of regulations in our model (adding consecutively a 3% leverage ratio, TBTF capital regulations, Volcker's rule and concentration limits), we cannot confirm a strictly monotonically increasing positive effect on financial stability as measured by our indicators. On the contrary, stricter regulatory regimes can lead to regulatory failure.

Our model indicates the most effective regulations for every stability dimension as a by-product (see Table 11). We observe two important facts: (a) the most effective and, in that respect, optimal regulation varies with the corresponding dimension of stability, and (b) simple regulatory standards seem to dominate the optimal regulatory regime. For none of the stability dimension and policy mixes analysed do we find that excessively increasing regulatory complexity is associated with higher financial stability.

7. CONCLUSIONS

This paper uses an agent-based model of a financial system to examine the influence of financial-system architecture and behaviour on financial stability and the effectiveness of different macroprudential banking regulations that aim to reduce systemic risk.

The main findings are: (a) financial stability is not strictly monotonically increasing with respect to the level of equity capital in the system; (b) liquidity requirements do not reduce the probability of contagion effects, but merely increase the loss-absorbing amount of capital in the system; (c) unregulated financial systems show market failure; (d) too restrictive regulations result in regulatory failure; (e) effective regulations are simple and target the asset side of a bank's balance sheet, therefore efficiently restricting the decision-making process for the investment portfolio. Our analyses also reveal two important trade-offs being inherent in the Basel framework: (a) market efficiency versus stability of the financial system: fundamentalists ensure a certain degree of market efficiency, whereas noise traders and chartists provide – from the perspective of financial stability – a shock-absorption function by trading on old/stale information; (b) level playing field / one-size-fits-all versus stability of the financial system: uniform, homogeneous (international) regulations to achieve a level playing field – a prerequisite for equality of competition – jeopardize financial stability as differences in the financial architecture are not taken into account. It has been shown that the latter is crucial to foster financial resilience. A one-size-fits-all approach, along the lines of the Basel framework, cannot accommodate the complexity of the financial system and is therefore not a robust framework for financial stability. From 1988 until the beginning of the financial crisis 2007/08, fostering resilience has clearly been neglected in favour of the level playing field. Since 2008, the focal point of regulatory attention has shifted to financial stability. International banking regulators are at a crossroads.

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APPENDIX

Table A.1
Structure of the banking sector

Parameter	Big banks	Medium-size banks	Small banks
Number	2	1	24
Market share	87%	2%	11%
Balance sheet structure (in % of total assets)			
Assets:			
Cash (incl. minimum reserve requirements)	5%	6%	5%
Money market positions and other liquid assets	10%	0%	3%
Loans to other banks	25%	27%	21%
Loans to non-financials	36%	32%	36%
Trading book positions	24%	35%	35%
Liabilities:			
Deposits	48%	68%	67%
Loans from banks	27%	8%	11%
Bonds	20%	18%	17%
Equity	5%	6%	5%

Legend: Own calculations based on SNB (2010b). Note that the private mortgage sector has been excluded.

Table A.2
Structure of the non-financial sector

Parameter	
Market share of big companies	70%
Market share of medium companies	25%
Market share of small companies	5%
Balance sheet structure:	
Cash and money market positions	23%
Other liquid assets	23%
Loans to non-financials	1%
Real investments	53%
Loans from banks	30%
Loans from firms	1%
Loans from private investors	3%
Bonds held by banks	2%
Bonds held by private investors	3%
Stocks held by banks	20%
Stocks held by private investors	41%

Legend: Own calculations based on SECO (2009).

Table A.3
Balance sheet structure of private investors

Parameter	
Market share of fundamentalists	33%
Market share of chartists	33%
Market share of noise traders	33%
Balance sheet structure:	
Liquid assets	27%
Deposits	27%
Bonds of non-financials	2%
Stocks of non-financials	27%
Bonds of banks	11%
Stocks of banks	3%
Loans to non-financials	3%

Legend: Own calculations based on SNB (2010c).

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