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The Limits to Credit Growth: Mitigation Policies and Macroprudential Regulations to Foster Macrofinancial Stability and Sustainable Debt*

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Abstract

We study an economy with a high degree of financialization in which (non-financial) firms need loans from commercial banks to finance production, service debt, and make long-term investments. Along the business cycle, the economy follows Minskyan dynamics with firms traversing various stages of financial fragility, i.e. hedge, speculative and Ponzi finance (cf., Minsky, 1978, 1986). In the speculative finance stage, cash flows are insufficient to finance debt repayments, and banks are willing to provide roll-over credits in order to prevent a default on the debt. In the Ponzi finance stage, banks are still willing to keep firms alive through "extend and pretend" loans, also known as zombie-lending (Caballero et al., 2008). This lending behavior may cause credit bubbles with increasing leverage ratios. Empirical evidence suggests that recessions following such leveraging booms are more severe and can be associated to higher economic costs (Jordà et al., 2011; Schularick and Taylor, 2012).

We therefore study policy measures that might mitigate the severity and intensity of the economic losses ensuing from such severe downturns. We investigate micro- and macro-prudential regulations aimed at: (i) the prevention and mitigation of credit bubbles, (ii) ensuring macro-financial stability, and (iii) limiting the ability of banks to create unsustainable debt. Our results show that the use of non-risk-weighted capital ratios have slightly positive effects, while cutting-off funding to all financially unsound firms (speculative and Ponzi) has very strong positive effects. However, merely cutting-off funds to Ponzi financed firms has hardly any effect at all.

Key words: Financialization; Macroprudential regulation; Full Reserve Banking; Full Equity Finance.

JEL Classification: C63, E03, G01, G28

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Supplementary material

All code for reproducing the results of this paper is available upon request, and can also be downloaded from our website.[1] To run the model, and to perform policy simulations, you require the ETACE Virtual Appliance, which can also be downloaded from our website.[2]

1 Introduction

The social function of banking and finance is to provide credit that supports economic development and productive activities. This is how Schumpeter saw the role of the banking sector, and the notion is also at the core of Minsky's argument in favour of community development banks (Minsky et al., 1992). The reason is rather simple: in developed economies, most jobs are provided by small and medium-sized enterprises (SMEs). According to data from the World Bank Enterprise Surveys reported in Demirguc-Kunt et al. (2015), the median contribution of SMEs to total employment amounts to 66 percent in EU countries, 55 percent in the UK, and 50 percent in the US.

Schumpeter's theory of credit and development distinguishes between a 'primary wave' of credit to finance innovations and a 'secondary wave' of credit to finance consumption, over-investment and speculation (Bezemer, 2014). In Minsky's proposal for Community Development Banks (CDBs), credit should be supportive of local enterprises, that are small-scale, and do not require loans in the order of millions, but rather in the order of thousands of dollars or euros.

The main theme of this paper is the key role of productive versus unproductive credit for financial stability, and could therefore be labelled as "Schumpeter meeting Minsky". This distinction between productive versus unproductive credit also played an important role in the Japanese Banking Crisis (Werner, 2003, 2005).

In this paper we consider various proposals to improve the financial stability of the banking system, with a particular focus on mitigation policies and macroprudential regulations that aim to reduce the large overall economic costs of severe downturns. We test for the efficacy of such proposals by computational experiments, using a stock-flow consistent agent-based model (SFC-ABM), that has already been successfully applied in a previous analysis (van der Hoog and Dawid, 2015). This follow-up paper could therefore be seen as a robustness analysis of those earlier results.

We consider a financially fragile economy with a high degree of financialization in which (non-financial) firms need loans from commercial banks to produce a final consumption good, to service their debt, and to make long-term investments. Along the business cycle, the economy follows Minskyan dynamics with firms traversing various stages of financial fragility, i.e. hedge, speculative and Ponzi finance (cf., Minsky, 1978, 1986). In the speculative finance stage, cash flows are insufficient to finance debt repayments, and banks are willing to provide roll-over credits in order to prevent a default on the debt. In the Ponzi finance stage, banks are still willing to keep firms alive through "extend and pretend" loans, also known as zombie-lending (Caballero et al., 2008). This lending behavior may cause credit bubbles with increasing leverage ratios. Empirical evidence suggests that recessions following such leveraging booms are typically more severe and can be associated to higher economic costs than other recessions (Jordà et al., 2011; Schularick and Taylor, 2012).

We therefore study policy measures that might mitigate the severity and intensity of the economic losses ensuing from such severe downturns. We investigate micro- and macro-prudential regulations aimed at: (i) the prevention and mitigation of credit bubbles, (ii) ensuring macro-financial stability, and (iii) limiting the ability of banks to create unsustainable debt. Our results show that the use of non-risk-weighted capital ratios have slightly positive effects, while cutting-off funding to all financially unsound firms (speculative and Ponzi) has very strong positive effects. However, merely cutting-off funds to Ponzi financed firms has hardly any effect at all.

The contributions of the paper are the following. We consider several theoretical hypotheses about the credit cycle, and test them using a computational model of a finite-state, discrete-time, random dynamical system with memory (see Section 2 on methodology). Second, we analyse the *synthetic* data that is generated by the simulation model using methods similar to those used for analysing *empirical* data (e.g., Claessens et al., 2011). And third, we perform scenario testing to verify or contradict the theoretical hypotheses from the first step and generate new hypotheses, which can then again be tested.

Our previous analysis shows that an increase in the capital adequacy ratios does not in and of itself improve the financial stability of the banking system. This goes against the common wisdom in the debate about how to reform credit market regulations, in which the main proposals (i.e., Basel III) are for the most part geared towards strengthening the capital requirements.

Our results also run counter to the long-standing view that, with regard to asset price bubbles, it would be better to deal with the aftermath of the bust, rather than trying to prevent a bubble from occurring in the first place. This is related to the belief that it is difficult to detect beforehand whether a boom is 'healthy' or 'unhealthy', and that it would be much more costly to incur the economic costs of restraining the unfettered growth in credit rather than "cleaning up the mess after the crash" (Dell'Ariccia et al., 2014).

We find however that the amplitudes of severe downturns following leveraged booms are so costly, that it seems worthwhile to sacrifice some economic growth on the short run and to restrain credit growth in order to prevent the worst downturns from causing large economic losses.[3]

In our model, a strengthening of the liquidity requirement does help to generically improve the stability of the system, and to significantly reduce the economic loss in output during severe downturns. We use empirical measures of the economic loss, namely the amplitude and cumulative loss of output during the recessions, that are based on empirical studies (Claessens et al., 2011; Jordà et al., 2011; Schularick and Taylor, 2012). According to these measures, the strengthening of the capital ratio requirement leads to an increase in the amplitude of the most severe downturns, while a strengthening of the central bank reserve (liquidity) requirement leads to a decrease in the amplitude of recessions.

To explain these results we have shown that two mechanisms play an important role, namely a *credit-congestion* effect and a *Zombie-lending* effect.

Firstly, the credit-congestion effect occurs on the credit market when the liquidity regulations are lax. If banks have lots of excess liquidity, they tend to use this liquidity to fund both healthy and unhealthy firms. The unhealthy firms are financially unsound and require large sums of liquidity to satisfy their financial commitments. The banks are willing to fund such financially fragile and risky firms because of the higher returns on their investments. It is not clear whether such pure rent-seeking behavior on the part of the banks serves any societal benefits (Cochrane, 2014; Zingales, 2015).

This leads to a congestion effect on the credit market, since the risky firms lay claim to the largest part of the banks' excess liquidity, whereas the smaller, more financially sound firms are left pining for the funds. Unable to secure funding, some of these smaller firms go out of business and enter into illiquidity bankruptcy as a result. This congestion effect could be resolved by strengthening the liquidity requirement. That is, by cutting off funding to the unsound firms at an earlier stage in order to prevent the financially sound firms from entering into illiquidity bankruptcies. This is exactly the result we observe in the model, namely that if the liquidity requirement is tightened considerably – in our model, by requiring the banks' cash and central bank reserves to consists of up to 30 to 50 percent of deposits – this results in the illiquidities of healthy firms to be replaced by insolvencies. We interpret this as a positive result, in the sense that the illiquidities implied an inefficient allocation of credit.

Secondly, the Zombie-lending effect appears in relation to lax capital requirements. This is caused by banks that are allowed to fund large, unsound firms that need new loans to roll-over their existing debt obligations, thereby running up their leverage ratios. If such speculative or Ponzi financed firms would be cut-off from funds at an earlier stage and not be kept on artificial life-support by the banks they would turn out to be dead already. Hence the term Zombie-firms. The banks keep them alive by providing funds at ever-increasing interest rates, until the debt process becomes truly unsustainable. This is precisely what happened during the Japanese banking crisis of the 1990s, when the banks supported many already insolvent firms, in order not to face the fact that they should have already written-off the bad debt at a much earlier stage (see Werner, 2003, 2005; Miyajima and Yafeh, 2007; Caballero et al., 2008 for in-depth analyses, and Section 1.1 below for a brief overview).

Such highly fragile and risky firms account for a large proportion of the banks' risk exposure. If there are no strict limits on banks' leverage ratios, then those firms will keep growing their unsustainable debt volume. But eventually they will become insolvent, possibly resulting in financial contagion effects due to the large amounts of bad debt that result. If such firms would not be allowed to build up such a large amount of debt, the financial contagion could be contained.

However, in our previous analysis (van der Hoog and Dawid, 2015) we show that an increase in the capital adequacy ratio does not by and of itself make the financial system more stable, and that the amplitude of the severe downturns may in fact increase for increasing levels of the capital requirement. The reason for this somewhat counter-intuitive result is that in the absence of strict liquidity requirements there will be repeated episodes of credit bubbles. Therefore, a generic result of our analysis seems to be that a more restrictive regulation on the supply of liquidity to firms that are already highly leveraged is a necessary requirement for preventing credit bubbles from occurring again and again.

1.1 The Japanese Banking Crisis and Zombie Firms

Recent studies of the Japanese banking crisis have attempted to characterize which type of firms are sensitive to changes in the availability of bank credit. Our baseline scenario fits the story of zombie firms that were being supported by banks during the banking crisis in Japan during the 1990s (e.g. Miyajima and Yafeh, 2007; Caballero et al., 2008). One empirical finding is that firms that are sensitive to credit crunches have high levels of leverage, high bank debt, and low profits. These are usually small firms since those are the ones that have more limited access to financial (i.e. bond) markets.

Another class of firms that are sensitive to credit crunches are so called 'zombie' firms. These are unproductive firms that are "artificially kept alive" by the banks. The group of zombie firms consists of relatively large firms, with relatively low performance and whose leverage increased consistently during the 1990s.

The process underlying the 'zombie-lending' mechanism is the following. The bank decides to artificially keep alive such poorly performing firms in order to avoid further losses to its own balance sheet. It does so by rolling over the debt of the zombie firm. Even though it is conjectural whether such zombie firms really existed and whether evidence for this can be found in the empirical data of the Japanese banking crisis, the mechanism that banks could support such firms for their own survival is a feasible explanation for sluggish growth and a highly leveraged real sector, also in our simulation model.

The continued financing of otherwise insolvent firms by rolling-over their debt and taking on more leverage causes two problems. First, it prevents a deleveraging and subsequent restructuring of the financially unsound firms. Second, the unhealthy and highly risky borrowers cause a *congestion* on the credit, goods and labour markets. On the credit market, they take out liquidity that cannot be used to fund smaller, more productive firms that are financially healthier. This inefficient allocation of funds prevents the small firms from growing. Also, the unsound firms maintain a large capital stock by investments that are purely debt financed, whereas the healthy firms do not invest since they are facing distorted competition on the product market from the zombie firms that are producing with "unfairly obtained" capital ("unfair" in the sense that it resulted from uncritical risk-assessments by the banks). On the labour market the unhealthy firms are hoarding productive workers that could otherwise be hired by the healthy firms.

There is ample anecdotal evidence that a similar phenomenon as in Japan's 1990s is currently at work in China and is a prime cause of the stagnating growth of the Chinese economy. Schuman (2015) describes how Chinese cement factories do not file for bankruptcy, in order to prevent having to pay severance payments to their idle employees. These employees are often highly qualified engineers who do not want to quit their job out of a fear of losing their claims to unemployment benefits and severance pay. These highly skilled people cannot be hired by other firms. Thus, the small and more productive firms are thwarted from getting a highly qualified workforce, from investing and augmenting their capital stock, and from getting loans from the banks. Hence they remain small, and cannot hire the workers they need to produce and get the economy to grow again.

For the banks to be able to prop up the zombie firms a sufficient amount of liquidity is needed. If the monetary policy of the Central Bank is to act as a lender of last resort and therefore to adopt a fully accommodating monetary policy, it will provide the banks with all the liquidity required, and as a consequence the outcome described above would be possible. At least, it would be consistent with the observation that: (i) more loans are allocated to the financially weakest firms; (ii) these firms have to pay higher interest rates and so generate bank profits; and (iii) by propping up such fragile firms a credit crunch is avoided, preventing an early deleveraging. The zombie firms are kept on artificial life support indefinitely by rolling-over their debts. As a result, both the real sector and the banking sector turn out to be more fragile, i.e., the average equity-asset ratios are lower in both sectors, since a deleveraging recession, either gradual or sudden, has not taken place.

2 Methodology

2.1 Simulation methodology

From a mathematical point of view, an agent-based model (ABM) is a non-linear stochastic process. In most cases, and for all practical purposes, ABMs can be represented by finite-order Markov processes. However, some caveats should be kept in mind.

Ordinary Markov Chains (first-order Markov processes) possess the Markov property, i.e. they are memoryless, which implies that the transition probability from the current state to the next state only depends on the current state and not on the sequence of states preceding it. This means that history does not matter, and we can start from any state as the initial state and the dynamics will evolve from that state in exactly the same way as when we would have a history that ended in that "initial" state and we would continue from there.

However, most agent-based models are history-dependent and the dynamics may show path-dependencies (or hysteresis, a memory property). In such cases the state transitions do in fact depend on history and therefore such processes do not satisfy the Markov property. A way to deal with such history-dependency mathematically is by using N^{th}-order Markov processes, i.e. a process in which the transition probabilities depend on the past N states.

The simplest Markov process is the first-order process, where only the current state determines the future, implying it is memoryless. This can be trivially generalized to higher-order Markov processes to include memory in the process by simply increasing the state space and treating the past N states as a "super-state", concatenating it to the current state to obtain the current super-state. Thus, the property of "memoryless-ness" can be recovered by expanding the definition of the current state to mean the current values of all state variables and a memory of the history of all state variables, up to a certain finite length.

Therefore, from a computational point of view, agent-based models can be seen as finite-state, discrete-time, random dynamical systems with memory. Such processes can be rigorously analysed by formal computational methods using finite state machines (FSMs, see Holcombe, 1988; Kehris et al., 2000). A requirement to apply such methods is that the implementation of the ABM itself is based on a formal, mathematical model of computation (see Holcombe and Ipate, 1998 and Ipate, 2004 for details).

The simulation framework that we use to implement our agent-based model is called *Flexible Large-scale Agent Modelling Environment* (FLAME[4]) and it uses precisely such a formal model of computation, where agents are modelled as Communicating Stream X-Machines (CSXM, see Balanescu et al., 1999). CSX-Machines are similar to finite-state machines, however, CSX-Machines differ in that they have the addition of memory so that transitions between states can depend on the memory of previous variables, and state transitions can also induce a modification of this memory. For a general overview of FLAME and formal definitions, see Coakley et al. (2006). For comparisons to other (agent-based) simulation platforms, see Coakley et al. (2012).

2.2 Data analysis methodology

The algorithm used to obtain the results for this paper is based on well-established methods from the empirical literature to study macroeconomic time series data and business cycle dating. The classic reference to business cycle dating algorithms is the original Bry-Boschan (BB) algorithm developed by Bry and Boschan (1971), and the quarterly Bry-Boschan (BBQ) algorithm proposed by Harding and Pagan (2002).[5]

We adopt a similar methodology to time series data analysis as in Claessens et al. (2011). The only difference is that we use *synthetic* data generated by our simulation model, while they use empirical data. We provide more details in Appendix A.[6]

The analysis is based on the detection of peak and through dates in the time series of output (total units of a homogeneous consumption good), followed by a conversion into recession and expansion periods according to the standard definitions.

In the U.S., the NBER defines an economic recession as: "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." (National Bureau of Economic Research, 2007) In the EU, however, recessions are defined as: "two consecutive quarters of negative economic growth, as measured by the seasonal adjusted quarter-on-quarter figures for real GDP." (HM Treasury, 2010)

In our business cycle dating algorithm, we do not refer to real GDP (since it requires a deflator). Instead we use the quarter-on-quarter growth rates of the actual units of output that have been produced in one quarter. Since we are interested in the effects of severe downturns, we would like to measure the amplitudes of recessions. In order to detect such amplitudes, a recession has to be a well-defined statistical object, and an algorithm is needed to detect when a recession starts and when it ends. For the business cycle we use the term expansion to indicate an increase, and recession for a decrease in output. For the credit (financial) cycle the corresponding terms are upturn for an increase, and downturn for a decrease in the total private sector debt, measured in terms of the total firm credit volume.

This results in the following definitions:

- A recession starts at the beginning of the first quarter of two consecutive quarters that show a negative growth rate of output (i.e., at a peak in the time series).
- A recession ends, and a recovery starts, at the beginning of the first quarter of two consecutive quarters that show a positive growth rate of output, following a recession (i.e., at a through in the time series).
- A recovery ends as soon as the level of output is reached at which the preceding recession started.
- An expansion starts at the same time as a recovery starts (i.e., at a through in the time series).
- An expansion ends at the same time as a recession starts (i.e., at a peak in the time series).

After having determined all start and end dates of recessions, recoveries and expansions across a time series, we collect all such statistical objects across an ensemble of Monte Carlo replications. That is, for each parameter setting we perform multiple runs of the simulation model with different seeds for the random number generator.[7] This ensemble of all start and end dates is fed into the recession analysis algorithm for further analysis. It thus contains the distribution of all recessions, recoveries and expansions, across all Monte Carlo replications, and for multiple parameter settings.

As in Claessens et al. (2011), we proceed by computing various statistical measures along each recession, recovery and expansion: the amplitude (depth), duration (time), slope (amplitude per unit of time), and an aggregated approximation of the leverage ratio of firms (total firm debt divided by total firm equity). For the recessions we also measure the cumulative economic costs of foregone production (the total units not produced during the recession, measured from the level of output at the start of the recession), measured along the entire duration of the recession. Effectively, this is computed as the discrete integral above the graph of the time series.

In the end, a statistical analysis of these measurements can now be made. We show box plots of the distributions of the amplitudes of all recessions in the ensemble (per parameter setting), and of the cumulative costs of recessions, for the various policies we consider. This allows us to judge the economic costs involved when comparing various proposals for micro- and macroprudential regulations.

3 Model summary

Since this paper is primarily focussed on macroprudential regulation of the banking sector and the credit market, and due to space constraints, we do not want to burden the text with a full model description. This section therefore provides a quick overview of the essential model ingredients that are directly relevant for the analysis. Please note that we re-use material that was previously developed in van der Hoog and Dawid (2015). For more extensive specifications of the other markets, i.e., the labour-, consumption goods-, and investment goods markets, detailed model descriptions can be found in Dawid et al. (2011, 2012).

3.1 Firm sequence of activities

Each firm proceeds through the following sequence of economic activities:

1. On the firm's idiosyncratic activation day the firm starts its production cycle with production planning. The production plan consists of planned output based on historical observations and the results of market research. Based on the production plan the firm determines its planned input demand for capital and labour.

2. Financial management of the firm. The firm computes the costs of production and the costs for financing its commitments. If the internal resources are insufficient the firm tries to finance externally by requesting credit.

3. Credit market with direct firm bank linkages opens. The banks provide credit by servicing the loan request on a first come first serve basis. The bank decides on the credit conditions for the applying firm (interest rate and amount of credit provided) depending on the firm's financial situation. If the credit request is refused, or not fully accepted, the firm has to reduce its planned production quantity.

4. Bankruptcy of two types could occur. If the firm is credit constrained to such extent that it is not able to pay the financial commitments it becomes illiquid and illiquidity bankruptcy is declared. If at the end of the production cycle revenues are so low that the firm has negative net worth, the firm is insolvent and insolvency bankruptcy is declared. In both cases it goes out of business, stops all productive activities and all employees loose their jobs. The firm writes off a fraction of its debt with all banks with which it has a loan and stays idle for a certain period before it becomes active again.

5. Capital goods market opens. Depending on the amount of financing secured by the firm, it makes physical capital investments. This consists of a vintage choice where the productivity of the capital stock is updated if new vintages are installed.

6. A decentralized labour market opens where firms with open vacancies are matched to unemployed households. The matching is based on the firm's wage offer and on the employee's skill level and reservation wage.

7. Production takes place on the firm's activation day. After production is completed, the output is distributed to local malls. Firms offer goods at posted prices with price revisions occurring once a year.

8. At the end of the production cycle the firm computes its revenues, and updates its income statement and balance sheet. It pays taxes, dividends, interests and debt installments. It checks if net worth is negative and if so, declares bankruptcy. Otherwise it continues with the next production cycle.

3.2 Financial management

The realized profit of a consumption goods producer equals the sales revenues plus interest received on bank deposits minus the production costs (fixed and variable costs). Hence, $\pi_{i,t}$ is determined at the end of month t as:

$$\begin{aligned}\pi_{i,t} &= R_{i,t} + r^b M_{i,t} - (C^{Fix}_{i,t} + C^{Var}_{i,t}) \\ &= R_{i,t} + r^b M_{i,t} - \left(\sum_{l=1}^{T^L} \frac{p^{inv}_{t-l} \cdot I_{t-l}}{T^L} + \sum_{l=0}^{T^L} r^b_{i,t-l} L^b_{i,t-l} \right) - \left(W_{i,t} + \frac{p^{inv}_t \cdot I_t}{T^L} \right). \end{aligned} \quad (1)$$

The fixed costs are the fixed capital expenditures over the previous periods $(t - T^L, ..., t - 1)$ and the interest due on loan contracts over the periods $(t - T^L, ..., t)$ including the loan obtained at the start of this period t. Here T^L represents the length of a loan period (typically multiple months, $T^L = 18$). The variable costs consist of the wage bill $W_{i,t}$ and the fraction of total investments that are accounted for in the current month. If profits are positive, the firm pays taxes and dividends according to the rates τ and d, respectively.

3.3 Dividend payout policy

Define average net earnings (after-tax profits) over the last n months as $\langle \pi_i \rangle_n = \frac{1}{n} \sum_{s=0}^{n-1} \pi_{i,t-s}$. The monthly dividend payout is based on the average net earnings over the previous 4 months, using the dividend rate d ($d = 70$ percent):

$$Div_{i,t} = d \cdot \langle \pi_i \rangle_4. \quad (2)$$

3.4 Firm credit demand

The total liquidity needs to finance the next production cycle consist of the planned production costs, i.e. the new wage bill and planned investments. Besides expenses related to production, the firm also needs to finance the financial commitments that are carried over from the previous production cycle, such as taxes and dividends on profits, debt installments and interest payments. The total expenditures that need to be financed at the start of the new production period $t + 1$ are as follows:

$$E_{i,t+1} = W_{i,t+1} + p^{inv}_{i,t+1} \cdot I_{i,t+1} + \tau \max[0, \pi_{i,t}] + Div_{i,t} \quad (3)$$

$$+ \sum_{l=0}^{T^L} \frac{L_{i,t-l}}{T^L} + \sum_{l=0}^{T^L} r^b_{i,t-l} \cdot L_{i,t-l}. \quad (4)$$

The last two terms represent debt installments and interest payments on old loan contracts for the previous periods $(t - T^L, ..., t)$ that now need to be serviced. Note that by using this formulation, we allow the firm to obtain a new loan to pay for its taxes and dividends of the previous period. Note also that dividends are paid out of after-tax firm profits, as is usual in the tax code. The demand for bank loans is the remaining part of the total liquidity needs that cannot be financed internally from the payment account (all variables below are determined at the start of period $t + 1$):

$$L_{i,t+1} = \max[0, E_{i,t+1} - M_{i,t+1}]. \quad (5)$$

Firms shop around for credit conditions (the interest rates are variable, the debt repayment period is fixed to 18 months) and request the same amount of credit from a random subset of banks (by default, we let a firm select 2 out of 20 banks at random). Given the credit conditions, the firm then selects the bank with the lowest interest rate offer. Thus, this generates an endogenous network of random credit relationships between banks and firms with some persistence due to the long debt repayment period.

3.5 Debt deleveraging and restructuring

Debt deleveraging is modelled by re-scaling the total debt. To make it easier for re-entering firms to obtain new loans we should improve their debt-equity ratio and lower their risk of default. This makes it more likely for a bank to accept any future loan requests from such a debt-restructured firm.

In case of an insolvency, the new target debt D^* is set lower than total assets A. The debt rescaling parameter φ is assumed to be constant across all firms and over time:

$$D^* = \varphi A \quad \text{with} \quad 0 \leq \varphi \leq 1\,. \tag{6}$$

After debt restructuring, the equity of the restructured firm is now positive, $E^* = (1-\varphi)A > 0$. The debt/equity-ratio after rescaling is given by the constant: $D^*/E^* = \varphi/(1-\varphi)$.

In case of illiquidity, the firm does not need to renegotiate its debt per se, since D is already lower then A and equity is still positive. However, since the firm is unable to pay its financial commitments it should raise new funds. It could do so either on the credit market or in the stock market by means of issuing new shares, but since we have precluded firms from issuing new shares (for reasons of simplicity) we also allow illiquid firms to write down part of their debt. In contrast to insolvent firms, illiquid firms do not rescale their debt as a fraction of assets, but as a fraction of the original debt:

$$D^* = \varphi D \quad \text{with} \quad 0 \leq \varphi \leq 1\,, \tag{7}$$

with new equity given by $E^* = A-\varphi D > E$ and a new debt/equity-ratio $D^*/E^* = \varphi D/(A-\varphi D)$. Since setting a lower value for the debt/equity-ratio improves the firm's chances of getting new loans in the future, the debt rescaling parameter φ must be set to low values $\varphi \leq 0.5$ to ensure that $D^*/E^* \ll D/E$.

3.6 Banking sector

3.6.1 Bank accounting

Bank reserves fluctuate with deposits and withdrawals, interest payments, and finally also with taxes and dividends. The net profits (or losses) after taxes and dividends are added to the reserves and held at the Central Bank. Profits π_t^b at the end of month t are determined by:

$$\pi_t^b = \sum\nolimits_i r_i^b L_{it}^b - r^b(\sum\nolimits_h M_{ht}^b + \sum\nolimits_i M_{it}^b) + r^{ECB}(M_t^b - D_t^b), \tag{8}$$

$$M_{t+1}^b = M_t^b + \Delta M_{ht}^b + \Delta M_{it}^b + (1-\tau)\max[0,\pi_t^b] - d^b(1-\tau)\max[0,\pi_t^b]. \tag{9}$$

The bank's profits consist of the margin between interests on loans and interests on deposits, plus (minus) any interest paid by (to) the Central Bank on overnight reserves (reserve debt). In case of positive profits, the bank pays taxes and dividends at rates τ and d^b, resp. The net mutations of the demand deposit accounts are given by $\Delta M_{h,t}^b = M_{h,t}^b - M_{h,t-1}^b$ and $\Delta M_{it}^b = M_{i,t}^b - M_{i,t-1}^b$, resp.

3.6.2 Bank credit supply and risk-taking behaviour

The bank's ability to provide credit is restricted by a Capital Adequacy Requirement (CAR) and the Reserve Requirement Ratio (RRR). The bank's risk-taking behaviour depends on its current level of exposure to default risk and the capital requirement.

Firms select banks at random in each production period, so the credit market can be viewed as a random matching process. The bank records several characteristics of the applying firms: total debt, size of credit requested, firm equity, and additional risk exposure. These attributes enter into the risk assessment of the bank and the loan conditions offered to the firm, consisting of size and interest rate for the loan. The firm then selects the bank with the lowest interest rate offer.

On a daily basis, the banks rank their stream of credit requests in ascending order of risk exposure. The least risky credit request of the current day is considered first, but different firms have different activation days during the month, so each new day sees new firms requesting loans to the same bank. If a healthy, financially sound firm requests a loan one day after an unhealthy, financially unsound firm has already obtained a loan with a large risk exposure, the healthy firm may see itself credit rationed due to limits on the banks' risk exposure.

3.6.3 Probability of Default

The firm's probability of default (PD) depends on the creditworthiness of the firm, measured by the debt-to-equity ratio (including the new debt). Following the internal risk-based (IRB) approach of the Basel Accords, there is a minimum risk-weight that sets a floor-level for the probability of default at 3 basis points (0.03 percent). We assume a bank associates the following PD to a loan of size L_{it}:

$$PD_{it} = \max\left\{ 3 \times 10^{-4}\, ,\, 1 - e^{-\nu(D_{it}+L_{it})/E_{it}} \right\}. \tag{10}$$

The rule is parametrized by a parameter ν ($\nu = 0.1$) that weights the impact of the debt-to-equity ratio on the probability of default.

3.6.4 Credit risk

We assume there is no collateral for debt, hence debt is unsecured and the expected loss given default (or LGD) is one hundred percent of the loan. Due to this assumption, the credit risk or Exposure at Default (EAD) of the loan is simply the probability of default times the value of the loan:

$$EAD^b_{it} = PD_{it} \cdot L_{it}. \tag{11}$$

The total risk exposure of the bank is now simply the sum of risk-weighted assets across the entire loan portfolio:

$$RWA^b_t = \sum_{i=1}^{F} \sum_{k=0}^{K(i)} PD_{kt} \cdot L_{kt}, \tag{12}$$

where the index i runs over all firms, and index $k = 0, ..., K(i)$ over loans of firm i with bank b.

3.6.5 Interest rate rule

The interest rate offered to a firm is an increasing function of the credit risk reflecting the risk premium that the bank charges to more risky, less financially sound firms. The credit risk posed by firm i enters into the loan conditions as a mark up on the Central Bank base interest rate. The weight of the credit risk in the interest rate can be calibrated by a behavioural parameter λ^B that is the same across all banks ($\lambda^B = 3$). Furthermore, the time-varying operating costs are captured by a random variable ϵ^b_t, which is uniformly distributed on the unit interval.[8]

$$r_{it}^b = r^{ECB}\left(1 + \lambda^B \cdot PD_{it} + \epsilon_t^b\right), \quad \text{where} \quad \epsilon_t^b \sim U[0,1]. \tag{13}$$

3.6.6 Capital Adequacy Requirement

Each bank is required to satisfy a minimal capital adequacy ratio, implying that banks have to observe a limited exposure to default risk. That is, bank equity (core capital) must be greater or equal to a fraction κ of the value of its risk-weighted assets. This assumption is based on Basel II/III capital requirements, where κ is between 4 and 10.5 percent. The bank's total exposure to credit risk is restricted by $\alpha := \kappa^{-1}$ times the equity of the bank:

$$E_t^b \geq \kappa \cdot RWA_t^b \qquad \text{i.e.} \qquad RWA_t^b \leq \alpha \cdot E_t^b \tag{14}$$

Here E_t^b is bank equity (core capital), RWA_t^b is the value of risk-weighted assets, κ is the capital adequacy ratio, and $\alpha := \kappa^{-1}$ is the maximum leverage in terms of equity to risk-weighted assets. If the constraint is violated the bank stops providing new loans. Pre-existing loans are still administered, firms continue to pay interest and debt installments, and the demand deposits of account holders continue to be serviced. From this we derive a credit risk exposure "budget" V^b that is still available to fund firms:

$$V_t^b := \alpha \cdot E_t^b - RWA_t^b. \tag{15}$$

The supply of credit risk in the current period is restricted to this exposure budget V^b. Firm i receives its full credit whenever the bank's total credit risk exposure remains below this limit and is fully rationed when the loan would exceed the risk limit. In terms of the exposure budget V^b the credit offer reads:[9]

$$\bar{\ell}_{it}^b = \begin{cases} L_{it} & \text{if } PD_{it} \cdot L_{it} \leq V_t^b \\ 0 & \text{if } PD_{it} \cdot L_{it} > V_t^b. \end{cases} \tag{16}$$

Bank risk exposure is positively correlated to the capital adequacy ratio α. Higher α means more risk is allowed, hence banks have at their disposal a greater budget of excess risk exposure and will tend to give out more risky loans.

3.6.7 Reserve Requirement

The banks must observe a minimum Reserve Requirement Ratio (RRR), that is, reserves must exceed a fraction $0 \leq \beta \leq 1$ of total deposits of households and firms:

$$M_t^b \geq \beta \cdot Dep_t^b, \quad \text{where} \quad Dep_t^b = M_{ht}^b + M_{it}^b. \tag{17}$$

From this an excess liquidity "budget" of the bank is derived as:

$$W_t^b := M_t^b - \beta \cdot Dep_t^b \geq 0. \tag{18}$$

If the excess liquidity budget is sufficient to provide a firm with its requested credit, then it is serviced in full. Otherwise it is *partially* credit rationed such that the bank attains its minimum reserve requirement. In case of partial rationing, the granted loan size is given by:[10]

$$\ell_{i,t}^b = \begin{cases} \bar{\ell}_{i,t}^b & \text{if } W_t^b \geq \bar{\ell}_{i,t}^b \\ \phi \cdot \bar{\ell}_{i,t}^b & \text{if } 0 \leq W_t^b \leq \bar{\ell}_{i,t}^b \\ 0 & \text{if } W_t^b < 0. \end{cases} \tag{19}$$

Here $\bar{\ell}^b_{i,t}$ is the constrained credit demand resulting from applying the CAR-constraint in (16). The fraction ϕ is such that the new reserves (incl. the granted loan) exactly exhausts the RRR constraint:

$$\{\phi : (M^b_t - \phi \cdot \bar{\ell}^b_{i,t}) - \beta \cdot Dep^b_t = 0\} \Leftrightarrow \phi = \frac{M^b_t - \beta \cdot Dep^b_t}{\bar{\ell}^b_{i,t}} = \frac{W^b_t}{\bar{\ell}^b_{i,t}}.$$

4 Macroprudential regulation and mitigation policies

The main objective of macroprudential policy and regulation is to limit the risks of system-wide crises and, when they do occur, to mitigate the negative effects of such crises. Hence macroprudential policies usually aim at smoothing the financial- and credit cycles, in order to stem the negative externalities of the financial system. Following Dell'Ariccia et al. (2014, p.352), macroprudential policies can broadly be grouped into three categories:

1. Capital and liquidity requirements:
   - conservation and counter-cyclical buffers.
   - dynamic loan-loss provisions.
2. Asset concentration and credit growth limits:
   - credit quotas to impose limits on the volume of credit.
   - speed limits on credit expansion.
   - limits on sectoral concentration of loan portfolios, to prevent overly concentrated exposures.
3. Loan eligibility criteria:
   - credit rationing of certain sectors/firms to improve the quality of borrowers.
   - loan-to-value ratios (LTV), to prevent large loans as a fraction of asset value.
   - debt-to-income limits (DTI), to prevent low-income debtors from obtaining large new loans.

We have already analysed the effectiveness of policy measures from Category I (capital and liquidity requirements) in an earlier analysis (van der Hoog and Dawid, 2015). In this paper, we will test policy measures in Category III, namely loan eligibility criteria. In particular, we will test whether credit rationing of certain firms by cutting-off funds to the most hihgly leveraged firms leads to an improvement in the quality of borrowers, and thereby to an improvement of the stability of the economic system at the macro-level. This policy can be seen as a micro-prudential policy, since it is aimed towards specific firms, but at the same time it could also be viewed as a macro-prudential policy since it has its focus on improving the stability at the macro-level.

4.1 The Admati & Hellwig proposals

In their highly acclaimed book Admati and Hellwig (2013) propose several measures to increase the equity capital in banks, which should increase the stability of the financial system. Below we consider some of these proposals, including some of our own, in the context of our model.

We first consider the effects of each regulation in isolation and then their combined effects. The results are shown in Figure 1, which shows 7 box plots corresponding to the regulations denoted below by A-G respectively.

Regulation A. Default regulation
The default regulation is to impose a capital ratio of 12.5% and a reserve ratio of 10%. The capital adequacy ratio is based on the risk-weighted assets.

Regulation B. Banning bank dividend payouts
A ban on bank dividend payouts would improve the banks' equity, due to retained dividends, so it would be easier to satisfy higher capital ratios. But it is also evident that such a ban does not completely resolve the issue of credit bubbles since it does not address the problem that banks might be funding highly leveraged firms, for example to roll-over their interest payments (speculative finance) or to refinance old debt contracts (Ponzi finance). Higher capital ratios do make the banks more robust, and downturns are less severe as a result. Also the cumulative losses are significantly reduced.

Regulation C. Using non-risk-weighted capital ratios
The second measure is to use total assets instead of risk-weighted assets (RWA) for the equity capital ratios. Basing credit regulations on risk-weighted assets makes them prone to manipulation. If banks are allowed to use their own internal risk models they can fine-tune the risk-weights in order to satisfy any capital requirements, a practice which is generally known as "Risk Management Optimization".

Further regulation on the precise measurements of these risk-weights only makes it more complex, and more prone to further manipulation. Therefore, the easiest way to simplify the regulation is to get rid of the risk-weights altogether, and to use non-risk-weighted, total assets in the capital ratios instead. This regulation has a less significant effect on the amplitude of downturns, but it does decrease the cumulative loss significantly.

Regulation D. Cut-off all funding to financially unsound firms, both speculative and Ponzi.
This alleviates two problems at once: the liquidity congestion effect and the Zombie-lending effect. The liquidity congestion effect is caused by unhealthy firms accounting for a large proportion of the excess liquidity budgets in the banks, crowding out the healthy firms. The Zombie-lending effect is the risk-counterpart to this, where the unsound firms account for a large proportion of the excess risk exposure budgets, thwarting the non-risky businesses from getting funding. By cutting off funding to both speculative and Ponzi financed firms, the hedge financed firms should be able to obtain funding more easily.

The results in Fig. 1 show that this regulation has a highly significant *positive* effect on the amplitude of downturns and also in terms of the cumulative loss. This appears to be the most effective measure to prevent severe downturns.

Regulation E. Cut-off all funding to Ponzi firms only
If the previous measure is found to be overly restrictive, it can be adjusted to only affect the Ponzi firms.

This regulation has some *positive* effect on the amplitude, but not on the cumulative loss, indicating that the average duration of recessions is prolonged by this measure.

Regulation F (=BCD). Banning bank dividends, Using non-risk-weighted capital ratios, and Cut-off all funding to financially unsound firms

This regulation has a significant *positive* effect on both the amplitude and cumulative loss, very similar to that of scenario D. That is, cutting off funding to all financially unsound firms has contributed most to this joint effect.

Regulation G (=BCE). Banning bank dividends, Using non-risk-weighted capital ratios, and Cut off all funding to Ponzi firms
The joint effect of this regulation is a significant *positive* effect on the amplitude, but no significant effect on the cumulative loss. The positive effects of scenarios B and C are counteracted by the effect of scenario E, i.e. the cut-off of funding to the Ponzi firms.

Summarizing, the banning of bank dividends (regulation B) and the use of non-risk-weighted capital ratios (regulation C) have slight positive effects, whereas cutting-off funds to all financially unsound firms (regulation D) has very strong positive effects. On the other hand, cutting-off funds to only the Ponzi financed firms (regulation E) has hardly any effects. Combinations of these policy measures do not have any additional benefits in terms of further reducing either the amplitude of recessions or their cumulative losses. Hence, we conclude that Regulation D is the most successful policy to prevent severe downturns.

[ADD FIGURE 1: "Admati and Hellwig proposals" ABOUT HERE]

4.2 Effect of regulating bank dividends

In contrast to the drastic measure of banning bank dividends altogether, we might also consider the effect of gradually increasing the bank dividend rate from 0 to 90 percent, in steps of 10 percentage points. Figure 2 illustrates the results of this sensitivity analysis. It becomes clear that a lower dividend rate does improve the situation somewhat, but there is no clear relationship between the dividend rate and the amplitude or cumulative loss due to recessions.

[ADD FIGURE 2: "Bank dividends" ABOUT HERE]

4.3 The full reserve banking proposal: Chicago Plan for Monetary Reform

Finding a solution to the problem of financial stability requires some "out of the box thinking". Below we brainstorm about some unorthodox proposals that might not function in all situations, but that might prove useful as thought experiments for the development of more attainable solutions.

The Full Reserve Banking proposal, i.e., the Chicago Plan of 100% reserve banking (Douglas et al., 1939), also known in the German-speaking world as "Vollgeld System", implies a full separation of the monetary system into two subsystems, one for deposit-taking and transactions- and payment related activities, and another subsystem for pure credit-creation and lending activities.

Institutionally, it would separate the banks into two classes: (i) deposit-taking institutions that offer services for making payments, and (ii) credit-creating companies that provide credit services and true financial intermediation between investors and entrepreneurs. This type of company would be completely funded by equity investors (Klein, 2013).

The regulatory ingredients of such a system are as follows:

1. Full Reserve Banking (FRB): A 100% central bank reserve ratio (Douglas et al., 1939): all deposits are fully covered by central bank reserves. There are no bank runs, no need for deposit insurance, and it ensures the payment system continues to function, no matter what happens in the debt system.

2. Full Equity Finance (FEF): A 100% equity capital ratio (Cochrane, 2014): all bank loans are covered by a 100% equity funds, and we use total assets instead of risk-weighted assets. This simplifies the regulatory structure enormously, it abolishes the need for risk-weights and complicated discussions on how to measure them, and there is no longer the possibility of default due to credit risks, even though defaults due to market risk are still possible. All credit risks are covered, so the debt system for investments continues to function, even if debtors would default. The banks can issue new loans only if at the same time they find the capital to fund them. This funding might come from investors different than the bank itself, which would turn the bank into a true financial intermediary between investors and entrepreneurs, not between depositors and borrowers as it is usually presented in textbooks. The investors are professionals who know full-well the risks involved in investing into risky business activities. Depositor holders on the other hand are not so well-informed and may not have detailed knowledge of the risks involved. The bank would offer investment accounts and customers can decide how much they would want to invest and in what businesses. The argument that in such a scenario the banks cannot make profits since investors are lending directly to businesses is invalid (Dow et al., 2015). Banks can still make a profit by raising a fee on both sides for their services rendered as intermediaries, i.e., for making the assessment of the credit worthiness of the business or for the monitoring the risk of default.

This proposal implies a complete separation between money and credit (see Phillips, 1992a,b and Laina, 2015b, including the comments in Laina, 2015a), and yields a super-stable system in our simulations. It also implies a separation between activities related to the payment system and investment activities. The demand deposits in deposit-taking institutions are fully covered by cash and central bank reserves while investment institutions are 100% equity financed (not leveraged on the volume of deposits). This implies the latter do not need a bailout. Note however that the above statement does not imply that all cash and central bank reserves are only reserved for covering the demand deposits. The banks could very well have reserves in excess of their demand deposits, and these excess reserves could be used to fund new loans to firms, or can be lend out to other banks on the interbank market. They might also serve as collateral, or simply be redeemed at the central bank for cash. The excess reserves are thus simply another asset on the balance sheet of the bank.

In this system, an additional requirement could be imposed that credit creation is reserved for financing new investments for productive activities only, and not for financing purely financial activities, even though the distinction is sometimes hard to make if for example a firm decides to invest in financial instruments in order to insure against uncertain future losses.

The loans have to be redeemed at a positive interest rate, which provides a means for the banks to generate profits. Of course, the investors that have put up the funds for the investments will receive part of these interests, but the bank could raise a fee on both the borrowing enterprise and the investor, for its service rendered in bringing the two parties together, and for making risk assessments and monitoring the loan over the course of the debt repayment period. Even though the creation of new loans creates deposits (since the firm will make use of the funds to make real transactions) all loans should be fully covered by equity capital.

Banks are no longer 'banks' but rather 'financial companies' that produce financial products and services. The credit-creation companies are free to create new credits, but are restrained to secure the funds from investors prior to making the investment. The company is also free to decide on using its own funds and expose itself to all the risks. This could be implemented by the company borrowing central bank reserves from the central bank or from other financial companies in the interbank market. Or, it could secure the funds elsewhere with a promise to repay. Alternatively, the company could also sell some of its assets. In short, there is a plethora of options such a financial company would have to fund new credit-creation, without having to endanger the savings of depositors.

The extent to which financial companies can create new credit could in principle be subject to limitations by the central bank by imposing credit quota's (see Ryan-Collins et al., 2014 for examples). This implies that if a company would require additional liquidity to create new credit, the central bank is not fully accommodating. Although this limits the possibility of credit bubbles, no system of regulation and control can ever entirely prevent this from happening. A misallocation of credit by foolish investments by financial companies into non-productive activities still remains a possibility, and it depends to a large extent on the incentive structure whether this occurs, and whether the system will be financially stable.

4.4 The system without any reserves

As an alternative to the system with full-reserve banking and a full equity capital coverage, we also consider the case of a system without any reserve requirements (parameters $\alpha = 1.0, \beta = 0$). This, in order to reflect the situation in Canada, Sweden, and Australia where this is in fact the case.

This implies there is still a separation between base money and credit money, and banks have to fully fund new credit from their own equity capital, or from new equity by venture capitalists. But the savings of demand deposit holders are no longer secure. One could think of a centralized deposit insurance scheme to cover losses due to bank bankruptcies. However, due to the fact that there is now a 100% capital ratio (and we use total assets instead of risk-weighted assets in the capital ratio), the bank is no longer susceptible to insolvency due to credit risk, but it could still become insolvent due to other sources of risk.

5 Results

To test the above regulations, out of all possible regulatory settings A to G we choose the best-case scenario yielding the lowest cumulative costs to the economy.[11] This best-case scenario is the combination of regulation C: using a non-risk-weighted total capital ratio, together with regulation D: full credit rationing of all financially unsound firms (both speculative and Ponzi firms). Under this best-case scenario we now impose, in addition, two new regulations:

- Regulation H: 100% total capital ratio and 100% central bank reserve ratio ($\alpha = 1.0, \beta = 1$). This is our "Limits to Credit Growth" economy, with strict liquidity restrictions on the credit growth rate.

- Regulation I: 100% total capital ratio and 0% central bank reserve ratio ($\alpha = 1.0, \beta = 0$). This is our "highly financialized" economy, without any restrictions on the credit growth rate.

For Regulation H, the consequences for the economy are shown in Figure 3(a). The system turns out to be ultra stable without any credit bubbles appearing. This illustrates the previous result from van der Hoog and Dawid (2015) that liquidity constraints work much better to induce financial stability by limiting the credit creating abilities of the banks. The average annualized growth rates of selected macro variables are reported in Table 1, column 2.

The results for Regulation I are reported in Figure 3(b) which show that the 0% reserve banking system is highly unstable, and severe recessions may occur as a consequence of the absence of limits to credit creation. The annual growth rates are reported in Table 1, column 3.

We will now investigate the difference between the "Limits to Credit Growth" economy and the "highly financialized" economy in more detail, by considering the macroeconomic context of these effects.

[ADD FIGURE 3: "Full reserve banking" ABOUT HERE]

5.1 Real effects

The real effects of Regulations H and I are shown in Figures 4-5. From Fig. 5 we observe that, even in case of full equity funding, it is still possible to generate financial instability through credit bubbles. This makes clear that a higher capital adequacy ratio does not automatically imply a more stable banking system. The credit bubbles are caused by banks' indiscriminate lending and access to liquidity, being reinforced by the Central Bank's accommodating monetary policy.

The consequences of financialization under Regulation I are clearly visible:

- After a steep credit bubble (b) the economy collapses with a steep decline in output (d) and over 50% unemployment (f).
- This leads to a quick deleveraging and a write-off of debt (b).
- The large amount of unemployed causes a sovereign debt crisis, due to large payments of unemployment benefits (g).
- The government is able to achieve a primary surplus only once the economy recovers again (g, around period 200), but not during the slump.
- Without structural reforms of the economy, however, the real economy enters into a double-dip recession with another crash, slightly less deep, but of longer duration (d).
- The second crash wipes out a lot of productive firms, which become insolvent.
- The long run state of the economy is one in which only a handful of banks survive and a few remaining firms. In other words, there is a high level of concentration in both the banking sector and the private sector. The long run economic outlook consists of debt-fuelled growth in both the private and public sectors (b,c), with an approximate long-run unemployment rate of 18 percent.

[INSERT TABLE 1 ABOUT HERE]

Table 1 shows the average long-run growth rates of the macrovariables (the growth rates are averaged across all runs). In the end, if we compare the highly financialized economy under Regulation I with the growth rates under the "Limits to Credit Growth" regulation H, we observe that:

- the technological productivity frontier grows with 1.44% per annum in both scenarios (by construction);
- the capital goods price grows with 3.51% p.a., which is lower than under H (4.65%);
- total output grows with 1.45% on average, which is somewhat lower than under H (1.70%);
- the long run unemployment rate is 14.63%, a bit higher than under H (14.08%);
- the average growth rate of private sector debt is −0.72%, which is due to the deleveraging taking place during the strong recessions, while under H the private sector debt increases on average by 1.48% per annum;
- average growth of the public sector debt is 68.09% per year, which is much higher than under H (27.34%);
- asset market price inflation is 29.90%, which is double the rate under H (13.17%).

[ADD FIGURE 4 ABOUT HERE]

[ADD FIGURE 5 ABOUT HERE]

6 Conclusions

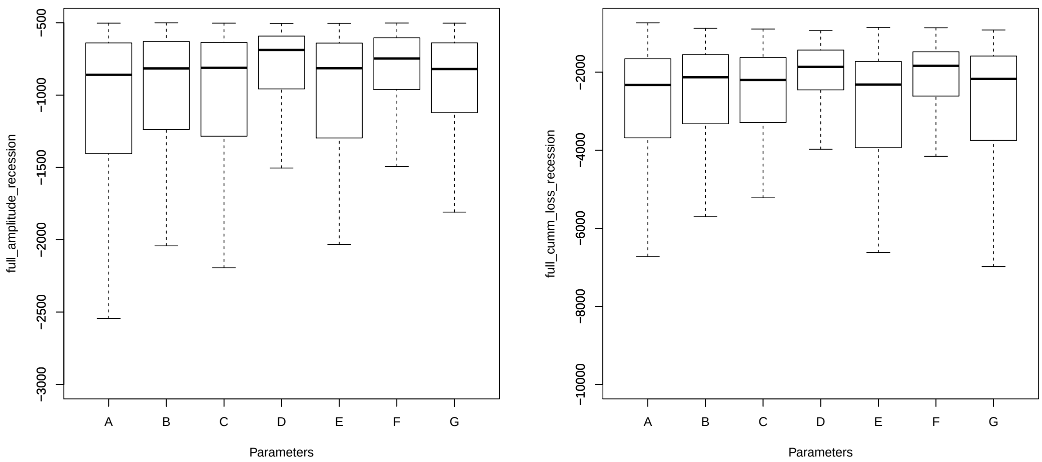
The current policy debates about Basel III on CCyB and CConsB (counter-cyclical buffers and capital conservation buffers) do not restrict the banks' ability to lend. It only makes the equity constraint more restrictive. However, as Admati and Hellwig (2013) have forcefully argued, higher capital buffers make banks more solid, so they can actually lend out more, on the long run, because they will be more stable. Our findings point into a similar direction: equity and liquidity constraints work differently, because equity constraints do not discriminate between the borrowing firms. This is so because the constraint is primarily based on the lender's balance sheet and not on the borrower's balance sheet. The firm's balance sheet data only enters through the price, i.e. through the interest rate that depends on the credit default probability. Instead, the liquidity constraint does discriminate between the borrowers, with larger credit request more likely to be rationed.

Exactly this is the main point of this paper: Credit policy should distinguish between productive versus non-productive credit. To support financial stability, credit growth should be cut off from those firms that are speculative or Ponzi financed, which are unproductive, and that use credit for purely financial purposes, be it to roll-over pre-existing debts or to invest in new financial assets. Credit should not be cut off from financially healthy and productive firms, which require the funds to produce.

The argument that "the pro-cyclicality of credit is at the root of financial and macro instability" is too simplistic. It is not the *quantity* of credit that matters, but the *quality* of credit. Credit should be channelled to those processes that are economically productive, and should be cut off from the unproductive ones. It is part of the social role of banks to figure out to which firms credit should best be channelled, and to assess the credit worthiness of the debtors. Afterwards they need to monitor the profitability of the firm and its ability to repay the loan. If the borrower cannot repay, it should not indiscriminately receive a novel "extend and pretend" loan to roll-over the old debt, which leads to a shift in Minsky states from hedge, to speculative, to Ponzi finance.

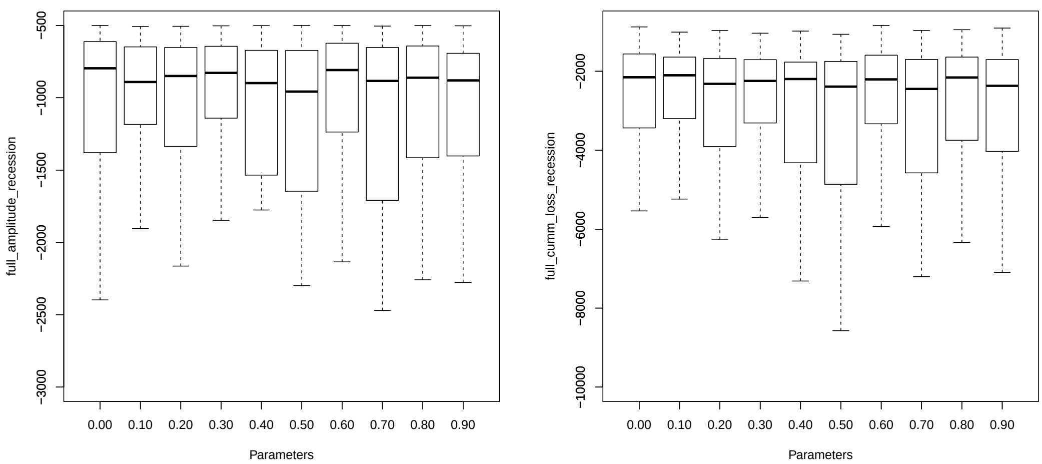
As long as the credit policy remains geared towards regulating the quantity, e.g., through aggregate credit growth targets, or credit quotas per bank, and not towards the quality of the borrowers, the policy is ill-adapted to deal with the specifics of each potential borrower. On the other hand, a focus on the quality of credit requires a detailed look at each credit request, and to assess whether the debtor is using the credit for sufficiently productive purposes to warrant the credit request.

By channelling productive credit to financially sound firms, the banks can once again perform their social function of supporting economic development, as emphasized by the literature on financial deepening. This is at the same time a micro-prudential and a macro-prudential policy since it works both at the micro-level but considers the effect at the macro-scale. It could result in Schumpeterian dynamics of creative destruction and competition between productive versus unproductive firms, but now with a Minskyan flavour, by dealing with financial fragility as well.



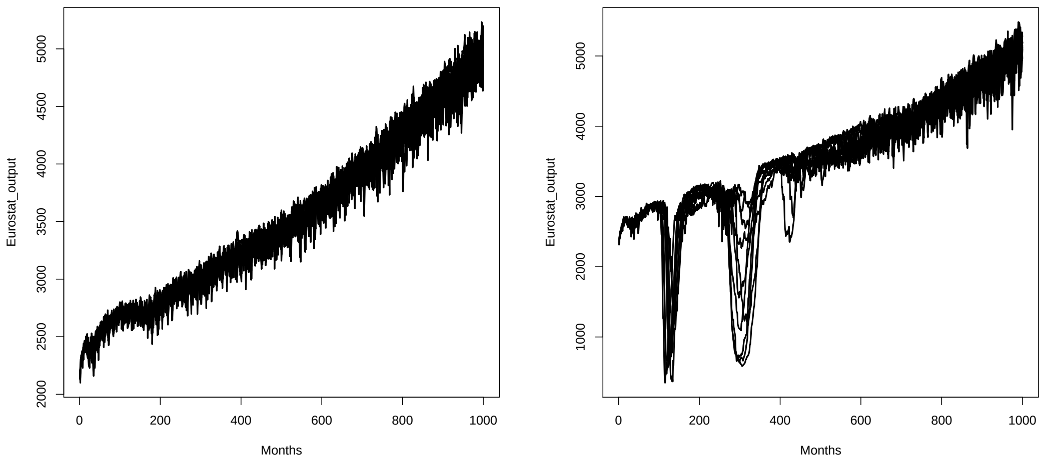
(a) (b)

Figure 1: Box plots for the analysis of the "Admati and Hellwig proposals". In terms of (a) amplitude of recessions (b) cumulative loss of output during recessions.



(a) (b)

Figure 2: Box plots for a parameter sensitivity analysis wrt. bank dividends, varying in the range $d^b = 0, ..., 0.90$. In terms of (a) amplitude of recessions (b) cumulative loss of output during recessions.



(a) Regulation H (b) Regulation I

Figure 3: Output levels for two regulations, for an ensemble of 10 runs. (a) Regulation H with 100% equity capital funding ratio and 100% central bank reserve ratio ($\alpha = 1.0$, $\beta = 1.0$). (b) Regulation I with 100% equity capital funding ratio and 0% central bank reserve ratio ($\alpha = 1.0$, $\beta = 0$). Both regulations are considered under the best-case scenario: non-risk-weighted capital ratio (regulation C) and full credit rationing of unsound firms (regulation D). Under the default parameter settings ($\alpha = 8.0$, $\beta = 0.10$) this best-case scenario yields the lowest cumulative costs to the economy. The plots illustrate that (a) full reserve banking is very stable, while (b) zero percent reserve banking is highly unstable.

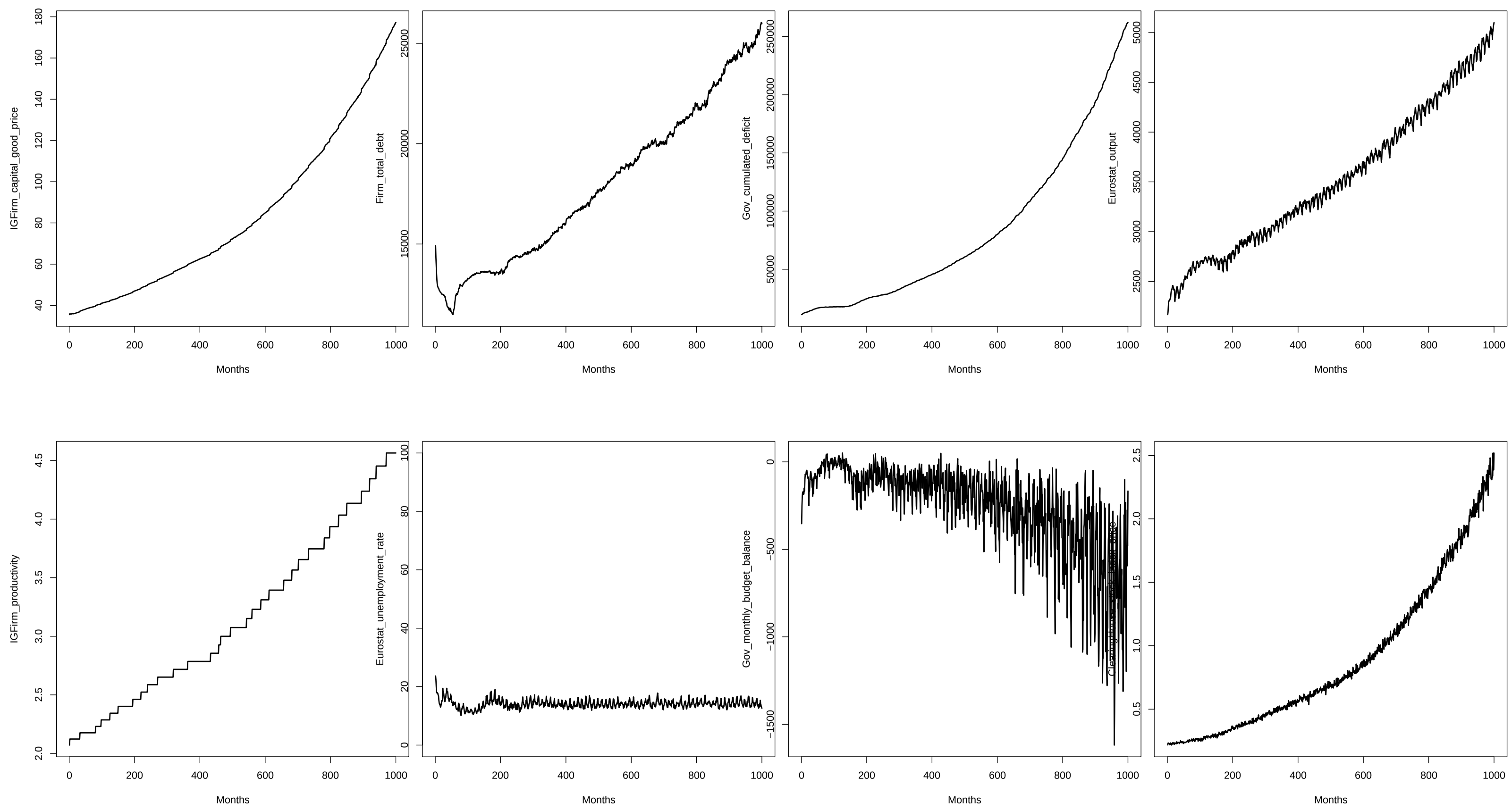
Table 1: Long-run growth rates.

Variable	Reg. H (Fig.4)	Reg. I (Fig.5)
technological productivity	1.44	1.44
capital goods price	4.65	3.51
total output	1.70	1.45
unemployment rate	14.08	14.63
private sector debt	1.48	-0.72
public sector debt	27.34	68.09
stock market index	13.17	29.90

Annualized growth rates in percentage, averaged across all runs, for periods $1 - 1000$.

Scenario: 100% capital funding ratio and 100% reserve requirement ($\alpha = 1$, $\beta = 1$)

(a) Capital goods price (b) Firm total debt (c) Gov. total debt (d) Firm total output

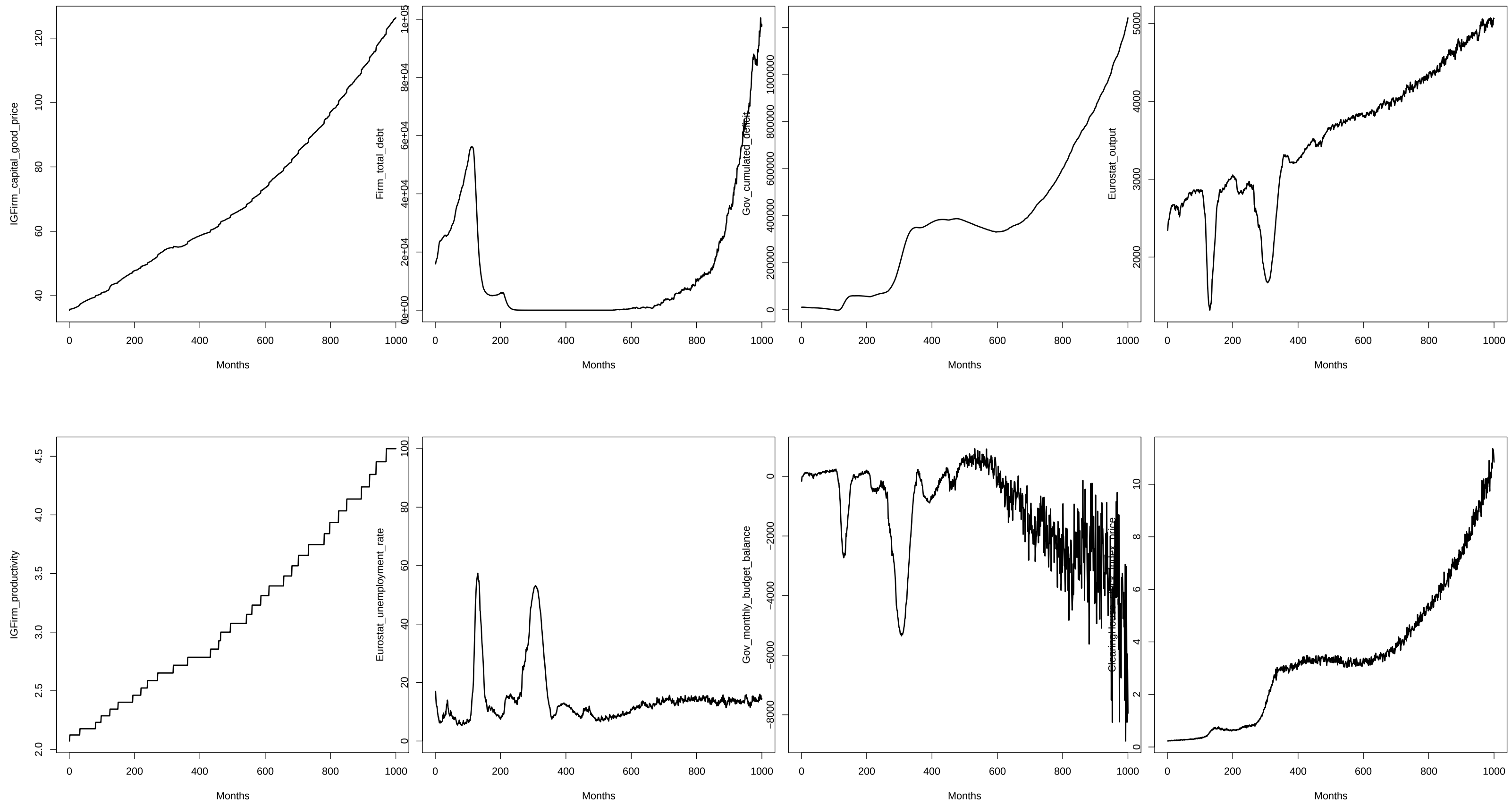


(e) Technological frontier (f) Unemployment rate (g) Gov. monthly budget deficit (h) Stock market index

Figure 4: Real effects of Regulation H (stable case). The "stock market index" is an index of all 81 firms, and 20 banks.

Scenario: 100% capital funding ratio and 0% reserve requirement ($\alpha = 1$, $\beta = 0$)

(a) Capital goods price (b) Firm total debt (c) Gov. total debt (d) Firm total output



(e) Technological frontier (f) Unemployment rate (g) Gov. monthly budget deficit (h) Stock market index

Figure 5: Real effects of Regulation I (unstable case): 0% reserve requirements and 100% capital funding ratio. The "Stock market index" is an index of all 81 firms, and 20 banks.

A Appendix: Business Cycle Dating Algorithm and Recession Analysis

The algorithm that was used to obtain the results for this paper is based on well-established methods from the empirical literature to study macroeconomic time series data. A classic reference to business cycle dating algorithms is the original BB algorithm developed by Bry and Boschan (1971). A quarterly Bry-Boschan algorithm, known as the BBQ-algorithm, was proposed by Harding and Pagan (2002). We adopt a similar methodology to time series data analysis as in Claessens et al. (2011). The only difference is that we use *synthetic* data generated by our simulation model, while they use empirical data.[12]

A.1 Terminology and Definitions

The meaning of the statistics are the same as in Claessens et al. (2011). The definitions can either be based on the time series of units of output produced, or on the actual sales levels. In our time series analysis, we have used the output-based definitions.[13]

- The determination of peaks and throughs is based on output [or sales] (in units).
- Duration of a recession is the number of quarters between peak and through.
- Duration for recoveries is the time it takes to attain the level of the previous peak (in quarters).
- The statistics "amplitude" and "slope" are based on output [or sales] (in units).
- The amplitude for a recession is the decline in output [or sales] during the peak to through decline.
- The amplitude of recoveries is the change in output [or sales] from the through level to the level reached in the first four quarters of an expansion.
- Cumulative loss is the combination of duration and amplitude and measures the cost of recessions as the foregone output that was not produced (it is calculated as an integral above the output curve).
- The slope of recession is the amplitude divided by duration. The slope of a recovery is the amplitude from the through to the period when sales reach the level of the last peak, divided by duration.

The following definitions are taken from Claessens et al. (2011, p.10-12):

Peaks and troughs A peak in a timeseries y_t occurs at time t if there are 2 periods of increase before, and 2 periods of decrease after t:

$$(y_t - y_{t-2} > 0, y_t - y_{t-1} > 0) \text{ and } (y_{t+2} - y_t < 0, y_{t+1} - y_t < 0) \tag{20}$$

A trough in a timeseries y_t occurs at time t if there are 2 periods of decrease before, and 2 periods of increase after t:

$$(y_t - y_{t-2} < 0, y_t - y_{t-1} < 0) \text{ and } (y_{t+2} - y_t > 0, y_{t+1} - y_t > 0)) \tag{21}$$

Recession A recession/downturn is the period between a peak a trough.

Expansion An expansion/upturn is the period between a trough and a peak.

Recovery A recovery is the early part of the expansion phase, defined as the time it takes for output to rebound from the trough to the peak level before the recession.

Duration of recession The duration of a recession/downturn is the number of quarters, k, between a peak (y_0) and the next trough (y_k) of a variable.

Duration of recovery The duration of a recovery/upturn is the number of quarters (r) it takes for a variable to reach its previous peak level after the trough: $\{r > k : y_r \geq y_0\}$.

Amplitude for recession The amplitude of a recession/downturn A_c, measures the change in y_t from a peak (y_0) to the next trough (y_k): $A_c = y_k - y_0$

Amplitude for recovery The amplitude of a recovery/upturn, A_u, measures the change in y_t from a trough to the level reached in the first four quarters of an expansion (y_{k+4}): $A_u = y_{k+4} - y_k$.

Slope for recession The slope of a recession/downturn is the ratio of the amplitude to the duration of the recession/downturn: $S_c = A_c/D_c$.

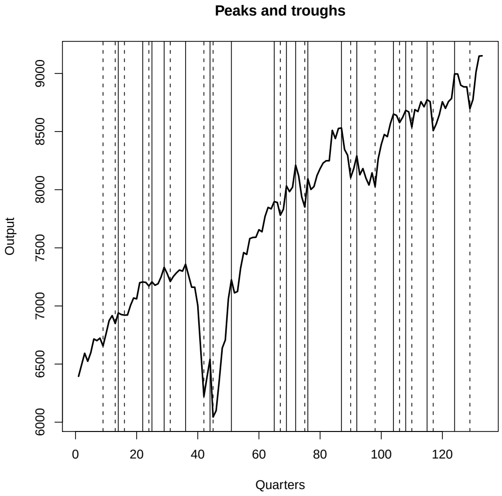
Slope for recovery The slope of a recovery/upturn is the ratio of the change of a variable from the trough to the quarter at which it attains its last peak divided by the duration: $S_r = (y_r - y_0)/D_u$.

Cumulative loss for recession The cumulative loss for a recession with duration k combines the duration and amplitude as a measure for the overall costs of recession: $F^c = \sum_{j=1}^{k}(y_j - y_0) - A^c/2$, where y_0 is the level of output at the start of the recession, and y_j are the successive terms during the recession.

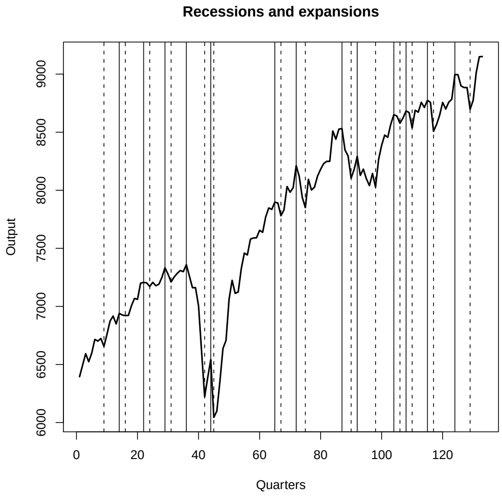
A.2 Detecting peaks and troughs

Fig.6 shows the detection of peaks and troughs in the time series of output for the business cycle (Panel a) and for the time series of total debt for the financial cycle (Panel c). Fig.6 (Panel b) shows expansions and recessions from peak to trough for the business cycle. This plot does not coincide exactly with the peaks and troughs detected in Fig.6 (a) due to the fact that sometimes two peaks can follow each other without having a through in the middle. This is because the through does not necessarily signal a recession, since it might be too short. In such cases the event is censored, i.e. removed from the plot. Fig.6 (c-d) provides the same type of analysis for the credit cycle. Here the solid lines coincide with peaks in the credit cycle, i.e. with the start of a downturn. Dotted lines indicate throughs in the credit cycle, i.e. the start of an upturn or recovery.

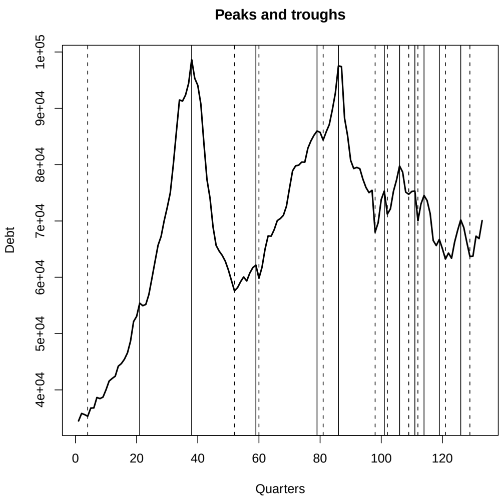
(a) Business cycle, peaks and throughs



(b) Business cycle, recessions and expansions



(c) Credit cycle, peaks and throughs



(d) Credit cycle, upturns and downturns

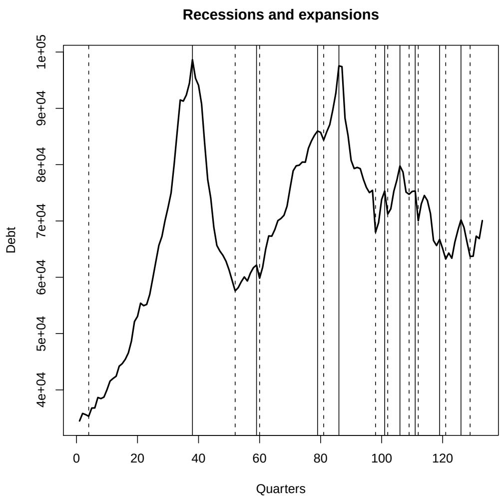


Figure 6: Peaks and troughs for the business cycle and the financial cycle, for 500 months (167 quarters). Solid lines: peaks, or start of a recession; dotted lines: troughs, or start of an expansion. (a-c) Detection of peaks and throughs. (b-d) Recessions and expansions (for the business cycle), and upturns and downturns (for the financial cycle).

Notes

[1]Code is available from: http://pub.uni-bielefeld.de/publication/2723277.

[2]ETACE Virtual Appliance: http://www.wiwi.uni-bielefeld.de/lehrbereiche/vwl/etace/Eurace_Unibi/Virtual_Appliance.

[3]These losses can be measured in various ways, from output not produced during the downturn, the additional number of unemployed, or total sales foregone.

[4]See the FLAME website http://www.flame.ac.uk/ for downloads.

[5]For this paper, we have implemented our own version of the BBQ algorithm in R.

[6]The code for the recession analysis is included in the source code that is available from our website.

[7]The typical number of replications is 50 runs per parameter setting. The random number seeds are themselves randomly drawn from a uniform distribution, and then stored.

[8]A similar specification for the interest rate rule can be found in Delli Gatti et al. (2011, p. 67). The difference with our specification is that we use the probability of default, while they use the leverage ratio.

[9]An alternative behavioural rule for the bank that we have tested is "partial rationing": when the credit risk exceeds the risk exposure budget V^b, then firm i only receives a proportion of its request, up to the constraint. This rule implies that banks always exhaust their available risk budget and does not result in a viable economy. It leads to more credit rationing rather than less, since firms coming to the bank after a very risky firm has already secured a loan will not be able to receive any loans, because the bank has already exhausted its risk budget.

[10]Note that here we use "partial rationing" for the RRR, while for the CAR we use "full rationing".

[11]Note that Regulations A to G were all considered for the default parameter setting $\alpha = 8.0$ and $\beta = 0.10$.

[12]The code for the recession analysis is included in the source code that is available from our website.

[13]The results are robust against using the output levels or actual sales. The consumption goods producing firms adjust their output based on forward-looking estimation of demand, by so called market research. Planned output therefore is a function of the actual sales over a previous history. If inventories are accumulating, the firm reduces its output, and if there are decreasing inventories, or no inventories at all, the output is increased (if production capacity allows). There can be excess production capacity, implying that the capacity utilization rate is below 100 percent.

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