Journal of Economic Dynamics & Control 50 (2015) 144–154

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

To bail-out or to bail-in? Answers from an agent-based model

Peter Klimek [a], Sebastian Poledna [a], J. Doyne Farmer [b,c], Stefan Thurner [a,c,d,*]

[a] Section for Science of Complex Systems, Medical University of Vienna, Spitalgasse 23, A-1090, Austria
[b] Institute for New Economic Thinking at the Oxford School and Mathematical Institute, Eagle House, Walton Well Rd., University of Oxford OX2 3ED, UK
[c] Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501, USA
[d] IIASA, Schlossplatz 1, A 2361 Laxenburg, Austria

ARTICLE INFO

Article history:
Received 7 March 2014
Received in revised form
14 August 2014
Accepted 15 August 2014
Available online 1 September 2014

JEL classification:
G33
G21
G38
H3
H30

Keywords:
Agent-based model
Bail-in
Bail-out
Crisis resolution

ABSTRACT

Since the beginning of the 2008 financial crisis almost half a trillion euros have been spent to financially assist EU member states in taxpayer-funded bail-outs. These crisis resolutions are often accompanied by austerity programs causing political and social friction on both domestic and international levels. The question of how to resolve failing financial institutions, and how this depends on economic preconditions, is therefore a pressing and controversial issue of vast political importance. In this work we employ an agent-based model to study the economic and financial ramifications of three highly relevant crisis resolution mechanisms. To establish the validity of the model we show that it reproduces a series of key stylized facts of the financial and real economy. The distressed institution can either be closed via a purchase & assumption transaction, it can be bailed-out using taxpayer money, or it may be bailed-in in a debt-to-equity conversion. We find that for an economy characterized by low unemployment and high productivity the optimal crisis resolution with respect to financial stability and economic productivity is to close the distressed institution. For economies in recession with high unemployment the bail-in tool provides the most efficient crisis resolution mechanism. Under no circumstances do taxpayer-funded bail-out schemes outperform bail-ins with private sector involvement.

1. Introduction

In March 2013 Cyprus became the epicenter of financial turmoil in what would become the 2012–2013 Cypriot financial crisis. The crisis gained momentum in the wake of the Greek government-debt crisis, when Cypriot banks were exposed to haircuts of up to 50% in 2011 and the state was unable to raise liquidity from the markets to support its financial sector (Stavárek, 2013). In March 2013 bonds issued by Cyprus were downgraded to Junk status, which disqualified them from being accepted as collateral at the European Central Bank (Wilson, 2012). Consequently the Cypriot government requested financial aid from the European Financial Stability Facility (EFSF) (Al Jazeera, 2013). What followed was an unprecedented, international struggle about who has to pay for the losses incurred by a national banking crisis. The EU and the International Monetary Fund (IMF) replied to Cyprus' request by proposing a €10 billion deal, including a 6.7% one-time bank deposit levy

* Corresponding author.
E-mail address: stefan.thurner@meduniwien.ac.at (S. Thurner).

http://dx.doi.org/10.1016/j.jedc.2014.08.020
0165-1889/

for deposits up to €100,000, and 9.9% for higher deposits on all national bank accounts (Stavárek, 2013). Despite being on the verge of financial collapse, large demonstrations and political upheaval led the Cypriot parliament to reject this proposal (The Guardian, 2013). The situation was finally resolved by approving a plan to restructure the second largest Cypriot bank into a bad bank and to guarantee all deposits below €100,000, but to levy all higher uninsured deposits (Stavárek, 2013).

In the case of Cyprus the EU-IMF originally proposed to resolve the banking crisis by a *bail-out*, i.e. by forcing *all* taxpayers or depositors in the country to participate in the €10 billion loan. As a result of political turmoil, this plan was altered such that only depositors at the failing bank were forced to participate in the deal. This took the form of a balance sheet restructuring, a debt-to-equity conversion. This type of crisis resolution was formally the first realization of a so-called *bail-in* (Ötker-Robe et al., 2011). The 'bail-out versus bail-in' debate, i.e. which crisis resolution outperforms the other in terms of fostering financial stability and overall economic output and growth, has been in full swing since then (Zhou et al., 2012; DeGrauwe, 2013). Proponents of bail-ins often cite the moral hazard problem of bail-outs, i.e. the incentive to take risks for systemically important financial institutions (SIFI) when others (taxpayers) will have to pay eventual losses (Zhou et al., 2012). On the other hand, bail-ins are criticized for providing a channel for contagion risks from the failing institution to its investors, as has been pointed out in the discussion surrounding the resolution of the Austrian Hypo Alpe-Adria bank (Reuters, 2013). After all, it was a debt restructuring in the Greek banking sector similar to a bail-in which triggered the crisis in Cyprus (Stavárek, 2013). It is finally also unclear under which circumstances an orderly liquidation of a troubled bank would be preferable over both, bail-outs and bail-ins (Stern and Feldman, 2004).

The Cypriot financial crisis is only one in a series of examples for a banking crisis which blurred the lines between bank bail-outs and sovereign bail-outs. For example, following the Emergency Economic Stabilization Act of 2008, the US treasury department disbursed loans of a combined volume of $204.9 billion (b) among 707 banks in the Capital Purchase Program, of which $16.7b are still outstanding (US Government Accountability Office, 2012). In Europe, the EFSF disbursed loans of €52b to Portugal €41b to Ireland in 2011 (EFSF, 2013; European Commission, 2013). The first and second Greek bail-out consisted of tranches of about €110b each. Spain received a loan of €41.4b in 2012–2013. In addition, the IMF also provided billions of loans as financial aid to European nations, €48.1b to Greece, €9.1b to Hungary, €22.5b to Ireland, €26b to Portugal, and €12.6b to Romania. As a result of the 2008 financial crisis the combined bail-out volume in EU member states totals almost half a trillion Euro (EFSF, 2013; European Commission, 2013). These bail-outs are typically accompanied by strict austerity programs causing political and social friction on both domestic and international levels. The question of how to resolve a failing SIFI is ultimately a question about maintaining financial, economic and political stability on a supranational scale. The performance of financial crisis resolution mechanisms has to be evaluated not only by ensuring financial stability, but also by how they impact the entire economy in terms of unemployment, economic growth, liquidity provision to entrepreneurs, etc.

DSGE models, by now the most popular way to study effects of policy interventions on macro-economic fluctuations, generally lack interactions between the financial sector and the real economy. There are basically three approaches to introduce financial friction or defaults in these models. First, in the collateral approach it is assumed that borrowers are required to provide a sufficient amount of collateral to guarantee that under no conditions in the future the borrower will have to default – a cash-in-advance constraint (Kiyotaki and Moore, 1997). In the second approach banks are assumed to be able to hedge credit risk such that no defaults are possible at the expense of an external financing premium (Bernanke et al., 1999). In both approaches default does not occur in equilibrium, however. In a third approach agents are allowed to choose what fraction of their outstanding debt to repay, and partially default on their obligations in return for a default penalty (Dubey et al., 2005). This approach introduces endogenous default rates at equilibrium. By studying general equilibrium (GE) models which incorporate the cash-in-advance constraint and endogenous default rates, it has been shown that capital requirements for banks effectively lead to a trade-off between financial stability and economic efficiency (Tsomocos, 2003; Goodhart et al., 2006; De Walque et al., 2010). A GE model where households take loans from both a banking system and a 'shadow banking system' was recently proposed in Goodhart et al. (2012). There it was shown that if households choose to default on their loans, this may trigger forced selling by the shadow banks and lead to a fire sale dynamics. Another influential model of bank runs and financial crises is the Diamond-Dybvig (Diamond and Dybvig, 1983) model. This model shows how self-fulfilling panic and bank runs may arise when the liabilities of a bank are more liquid than its assets. In the original Diamond-Dybvig model a bank run is only one of multiple equilibria, which makes it impossible to actually predict future bank runs. In a modified version of this model it was shown how a unique equilibrium can be obtained given that the fundamentals of the model economy are stochastic (Goldstein and Pauzner, 2005). The Diamond-Dybvig model has also been extended with a government agent that may bail-out failing banks (Wang, 2010; Keister, 2012). There it was shown that it is not the financial crises itself, but the announcement of the bail-out which may trigger a bank run (Wang, 2010). However, a commitment of the government to a no-bail-out policy may increase the vulnerability of a bank for a bank run too (Keister, 2012).

In this work we address the question of which crisis resolution mechanisms perform optimally under given economic circumstances. We focus on three highly relevant resolution mechanisms to contribute to both the 'bail-in versus bail-out', and the 'too-big-to-fail' debates. (i) The troubled financial institution or bank is *liquidated by a purchase & assumption* (P&A) operation (McGuire, 2012). (ii) The bank is *bailed-out* using taxpayer money, or (iii) the distressed bank is *bailed-in* through a debt-to-equity conversion. In particular we try to clarify which crisis resolution mechanisms minimize financial contagion risks, lead to the highest liquidity provision for the economic sector, reduce unemployment most, and lead to the highest economic output. The first, the P&A resolution mechanism, corresponds to the case where the distressed financial institution undergoes a balance sheet restructuring to wind it up in an orderly manner as a 'gone concern'. In the bail-out and bail-in cases the distressed bank continues to operate after the crisis; the balance sheets of the bank are restructured so that it can continue as a 'going concern'. This allows us to investigate whether it is beneficial to let the failing institution default or not. If the troubled bank is saved, we can inquire on a quantitative basis whether private sector involvement in the resolution plan is beneficial or not. We employ the framework of the Mark I CRISIS model developed within the CRISIS project.[1] This is an agent-based model (ABM) framework implementing a closed economy consisting of banks, firms, and households. These agents interact with each other in various markets. The CRISIS framework is especially useful for the study of different crisis resolution mechanisms since it provides a model for both the economic and the financial sector. Both sectors are modeled with fine granularity and a rich structure of inter-sector linkages, such as credit or deposit markets (Delli Gatti et al., 2008; Gaffeo et al., 2008; Delli Gatti et al., 2011). This makes it an ideal testbed to study the propagation of financial crises to the real economy and vice versa, and how this is influenced by different crisis resolution mechanisms. Within this framework and closely related models it has already been studied how systemic risk can be reduced or eliminated via a systemic risk transaction tax, or under different regulatory regimes (Thurner and Poledna, 2013; Poledna and Thurner, 2014). These works also emphasized the importance of cascading spreading of credit risk within financial or interbank networks, and how this may lead to failures of the entire financial system (Boss et al., 2005; Iori et al., 2008; Caccioli et al., 2012; Battiston et al., 2012; Thurner et al., 2012; Poledna et al., 2014). The main causal mechanism of this cascading spreading is based on balance sheet interactions of the individual economic agents. An unexpected reduction of financial inflows of one of the agents leads to a reduction of the financial outflows of the agent, which in turn leads to reductions of financial inflows of other agents, and so on. Consequently the net worth of the economic agent under consideration may decrease and trigger a fire-sale, as shown in both empirical (Calvo et al., 2008) and agent-based modeling approaches (Giansante et al., 2012). Agent-based models have indeed shown to display a great potential in studying the relations between credit money, fiscal policies (Dosi et al., 2010, 2013), and macro-economic instabilities (Raberto et al., 2012; Erlingsson et al., 2014).

In this work we address only mechanical aspects of bank defaults and resolutions. There are no agents that can adapt their behavior to the given regulatory regime. For instance, we do not include the moral hazard problem, i.e. that the knowledge of being bailed-out in financial distress induces additional risk-taking behavior by banks. We also do not address the case of mixed crisis resolution strategies, such as letting banks default partially. Each bank in the model follows the same strategy. Hence there is also no long-term growth in the model generated by the evolutionary culling of banks with bad strategies, as envisaged in Schumpeter's concept of creative destruction (Schumpeter, 1942; Klimek et al., 2012).

2. Crisis resolution mechanisms

We focus on three highly relevant crisis resolution mechanisms in their generic forms. One of them, 'purchase & assumption' provides an orderly way to close a defaulting institution. This will be compared to bail-out and bail-in resolution mechanisms, respectively, both ensuring a survival of the bank in distress. We assume that the resolution mechanisms will be enacted 'top-down' by a single resolution authority acting within a legal framework which grants the required powers to the authority. Here we provide the rationale behind each crisis resolution mechanism, their detailed model implementations follow in Section 3.

Purchase & assumption. A 'purchase & assumption' (P&A) is a resolution mechanism that allows for transferring the troubled bank's operations to other, healthy banks (McGuire, 2012; FDIC, 2003). The mechanism typically includes the withdrawal or cancelation of the troubled bank's license. Each of the other banks in the system purchases parts of the failing bank's assets and assumes its liabilities. Here we assume that the volume of the asset purchase for each bank is proportional to the value of the purchasing bank's liquid assets. Similarly, we assume that the troubled bank's liabilities are proportional to the assets taken over. Note that there exists a finance gap since the total asset values will be smaller than the combined value of the liabilities. This gap will be closed by the banks which take over the troubled banks, since they get more liabilities than assets in the procedure described above. Therefore the losses of the failing bank will effectively be paid by the other banks. The main difference between a liquidation and a P&A is that under liquidation the assets of a liquidated institution are sold over time to pay its liabilities to depositors, whereas in the P&A assets and liabilities are transferred to other banks. An advantage of a P&A is that there is no need to impose a process to pay out depositors of a failing bank. Since the deposits are transferred to a healthy institution depositors may access their accounts without delay at each stage of the resolution. Due to these reasons a P&A is typically considered more efficient than a liquidation (McGuire, 2012), and it will be used here as the standard way to close down an institution.

Bail-out. A bail-out usually describes providing funds to a financially distressed institution or country which is deemed healthy enough to survive after recapitalization (Wright, 2009). Another reason to bail out an institution may be to minimize contagion risks of the insolvency of a large and interconnected, i.e. systemically important, financial institution. We are interested in the case where the funds are not provided by a private investor, for example by buying floundering stocks of a company at firesale-prices, but by a government. In exchange the government typically receives preferred stock and therefore cash dividends over time, which are used to protect the taxpayers' money. The government effectively becomes

[1] http://www.crisis-economics.eu

the owner of the taken-over institution whose common stock equity will be canceled (i.e. shareholders lose their investment), but the claims of debtors and depositors will be protected. The use of bail-out resolution mechanisms has been highly controversial. The existence of government-sponsored safety nets may actually work as an incentive for institutions to take financial risks, since in case of failure they will be bailed out anyhow – the problem of moral hazard (Zhou et al., 2012). Another criticism involves the high costs typically involved in bail-outs (Zhou et al., 2012). In a sample of bail-outs in 40 different countries the average cost of a typical bank bail-out was estimated to be 12.8% of GDP (Wright, 2009). Especially after the 2008 financial crisis, interest in alternative and cheaper crisis resolution mechanisms which do not require taxpayer involvement surged.

Bail-in. As opposed to a bail-out, a bail-in forces the creditors of the troubled financial institutions to bear some of the financial burden (Ötker-Robe et al., 2011; Zhou et al., 2012; DeGrauwe, 2013). The claims of typically unsecured debt holders are written off in a bail-in and/or converted into equity to recapitalize the failing institution. The bail-in instrument therefore provides a private sector funded resolution mechanism as opposed to government-funded solutions like bail-outs. The legal framework for such top-down balance sheet restructuring was provided in the US by the Dodd–Frank Wall Street Reform in 2010, and in the UK under the 2009 Banking Act (FDIC, 2012). In the Eurozone there is currently no legal framework for bail-ins. The first formal realization of a bail-in took place in the Cypriot banking crisis 2012/2013. Consequently there is relatively little experience in the long-time consequences of this resolution mechanism. However, the perceived success of the Cyprus episode led the head of the Eurogroup of finance ministers, Jeroen Dijsselbloem, to state that the Cyprus deal may serve as a template for future crisis resolutions (Stavárek, 2013).

3. Agent-based model

We study the performance of the crisis resolution mechanisms using the Mark I CRISIS model. This is one of a suite of models developed within the CRISIS project on the basis of an agent-based macro-economic model (Delli Gatti et al., 2008, 2011; Gaffeo et al., 2008). The Mark I CRISIS model consists of a coupled economic and financial ABM which is *closed*, i.e. there are no in-flows and out-flows of any kind of capital. Banking crises can thus not be resolved by simply printing new money – some agents have to actually pay for the losses. A similar version of the Mark I CRISIS framework has recently been used to study the implementation of a taxation scheme for interbank transactions in order to eliminate or reduce systemic risk (Poledna and Thurner, 2014). For a more comprehensive description of the coupled economic-financial simulator see Poledna and Thurner (2014). In the following we provide an overview of the agents and their interaction mechanisms, and list the changes with respect to previous versions of the CRISIS model. The model contains three types of agents: households, banks, and firms. Agents interact on various markets. Households and firms interact on the job and consumption-good market, banks and firms interact on the credit market, banks interact on the interbank market.

Households. There are two types of household agents, namely I firm owners and J workers. Each worker j has a personal account $PA_{j,b}(t)$ at bank b and applies for a job at z different firms in one model time-step. Once hired, she/he receives a fixed income w per time-step for supplying fixed labor productivity α. The workers deposit their income at their personal account $PA_{j,b}(t)$. If a worker is unemployed, she/he receives no wages but will still consume goods. The banks where a given worker opens his/her deposit are randomly chosen in the model initialization and remain fixed throughout time (unless the bank is closed under a P&A). Each of the I firm owners owns exactly one firm, and both the firms and their owner are indexed by i. They also have a personal account $PA_{i,b}(t)$ at a randomly chosen bank b. At each time step each household – worker or firm owner – computes its consumption budget as a fixed percentage c of its personal account. It spends $cPA_{i/j,b}(t)$ on the cheapest single product it finds by comparing products from z randomly chosen firms. An alternative variant of the model where the consumption budget is based on income, and not wealth, is discussed in the supporting information. Both household types, firm owners and workers, may be subjected to a one-time bank deposit levy to provide the funds that are necessary to resolve a failing bank, see the description of the model crisis resolution mechanisms.

Firms. There are I firms, all producing a perfectly substitutable good. Each firm is owned by a single firm owner, and each firm owner always owns not more than one firm. At each time step the firms have to decide on two quantities, their expected demand $d_i(t)$, and their expected price for the produced product, $p_i(t)$. Let $\overline{p}(t)$ denote the average weighted price over all products, $\overline{p}(t) = \sum_i p_i(t) d_i(t) / \sum_i d_i(t)$. They compute the demand and price by taking into account the previous demand $d_i(t-1)$ and price $p_i(t-1)$. If the firm sold all of its goods at the previous time step, it either increases the price (if $p_i(t-1) < \overline{p}(t-1)$), or increases its expected demand if $p_i(t-1) \geq \overline{p}(t-1)$. If the demand at the previous time step was lower than expected, the firm either reduces the price (if $p_i(t-1) > \overline{p}(t-1)$), or decreases the expected demand if $p_i(t-1) \leq \overline{p}(t-1)$. Firms always change only either the price or the quantity, but not both simultaneously in one time step. In all other cases the expected demand and price do not change. Each firm computes the number of required workers to achieve the desired demand, always assuming that each worker supplies labor productivity α. If the wages for this workforce exceed the firm's current liquidity, it applies for a credit. On the credit market firms approach z randomly chosen banks and choose the credit offered at the lowest rate. If the real interest rate exceeds a threshold rate r^{max}, the firm's credit demand contracts to ϕ percent of the original loan volume. After the loan is provided, firms recompute their desired workforce and hire or fire workers in order to meet the expected demand. The newly produced goods are then sold on the consumption goods market. A firm with positive profit pays out δ percent of the profit as dividend to its owners. If a firm has negative liquidity after the consumption good market closes, the firm owner may provide the missing cash from his/her personal account. If these funds are smaller than the liquidity gap, the firm goes bankrupt. The firm owner is held liable and his/her personal account is used to partly pay off debtors (banks), which incur a capital loss in proportion to their investment. Finally, the firm owner immediately starts a new company with demand $d_i(t) = \langle d_i(t) \rangle_i$ and price $p_i(t) = \langle p_i(t) \rangle_i$ being equal to their current population average.

Banks. Banks are subject to capital requirements, their leverage must not exceed a given value λ^{max}; they have to maintain a cash reserve ratio of at least κ^{min}. Each bank b offers each firm i a loan at rate $r_{b,i}$ based on i's *financial fragility* $l_i(t)$ (the quotient of i's outstanding debt and its cash),

$$r_{b,i} = r_0(1+\epsilon)[1+\tanh(\mu l_i(t))], \tag{1}$$

where r_0 is the refinancing rate, μ is a constant, and ϵ is a random number drawn from a uniform distribution between zero and one. The nominal market interest rate $i^{(n)}(t)$ in the model is given by $i^{(n)}(t) = \sum_{i,b} r_{b,i} Lb, i / \sum_{i,b} L_{b,i}$, where $L_{b,i}$ denotes the loan volume provided from bank b to firm i at rate $r_{b,i}$. $CV(t)$ denotes the total amount of outstanding loans from all banks at a given time t. As long as the banks have enough liquidity and fulfill their capital requirements, they always grant the requested loans. If they do not have enough cash, they approach z randomly chosen other banks and try to get the missing amount from them. Banks always grant interbank loans at a rate $r^{(ib)}$ when requested, given that they have enough cash and fulfill the capital requirements. If a bank does not have enough cash and is unable to get the required funds from other banks, it does not pay out the loan. Each time step firms repay τ percent of their outstanding debt. In case the banks make a profit, they pay out δ percent of the profit as dividends. Initially there is one randomly chosen household that owns the bank and receives the dividends. If a bank's equity becomes negative it is insolvent and undergoes one of three possible crisis resolution mechanisms, (i) P&A, (ii) bail-out, and (iii) or bail-in. Through bail-outs and bail-ins other households and firms may become shareholders of the bank and receive dividends too.

The model interactions are summarized in Fig. 1A. Firms pay households wages or dividends, households consume goods produced by the firms. Both firms and households make deposits at the banks. The banks grant loans to the firms. In each time-step the model consists of the following sequence of steps.

1. Firms define their labor demand and seek loans from banks.
2. Banks raise liquidity on the interbank market to service the loans to firms.
3. Firms hire or fire workers and produce goods.
4. Workers receive wages, spend their consumption budget on goods and save the remainder.
5. Firms pay out dividends, firms with negative cash go bankrupt.
6. Banks and firms repay loans.
7. Illiquid banks seek funds on the interbank market, insolvent banks are resolved.

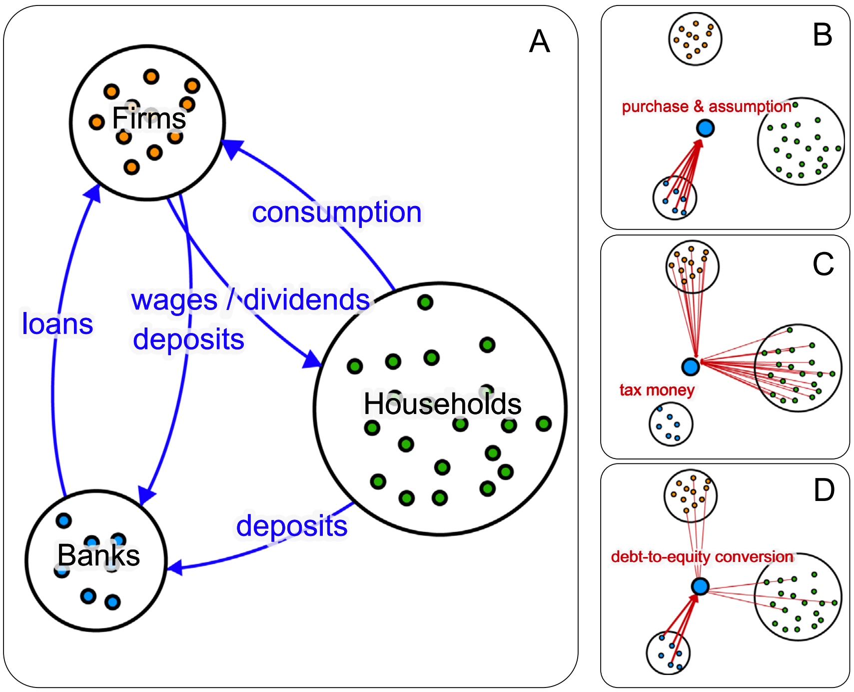

Fig. 1. (A) The three sets of agents (households, firms, and banks) and their most important interactions are shown. Firms and households interact on the consumer-goods and job market, firms and banks on the credit market. Households and firms deposit their income with banks. The flows of funds in the CRISIS macro-financial model are shown in blue. Panels (B–D) show the flows of funds taking place in crisis resolutions as red arrows. The troubled bank b is positioned in the middle of each panel. (B) Healthy banks purchase b's assets and assume its liabilities. (C) Households and firms bail out b using tax money. (D) A bail-in with a debt-to-equity conversion with b's debtors takes place. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

Crisis resolution mechanisms in the model. Bank b goes bankrupt if its equity $E_b(t)$ becomes negative by an amount of $-M_b$, $E_b(t) \equiv -M_b < 0$. The three different crisis resolution mechanisms are implemented in the following way.

- P&A The normalized weight vector w_i, $\sum_i w_i = 1$ is constructed where the index i runs over all banks with positive equities, i.e. healthy banks. The entries in w_i are proportional to the banks' equities. Each healthy bank takes over a share proportional to w_i of the resolved bank's interbank loans and firm loans. The household deposits are also transferred from the failing to the healthy banks. Each deposit is transferred to bank i with probability w_i. The flows of funds involved in the P&A are sketched in Fig. 1B.
- Bail-out The normalized weight vector w_i runs over all households and firms and has entries proportional to the households' personal accounts $PA_{j,b}(t)$ and the firms' cash $C_i(t)$. If a tax exemption for small deposits is in place we set $w_i = 0$, given that the accounts or the firm's cash is smaller than ζ max[$PA_{j,b}(t), C_i(t)$], with the tax exemption parameter $0 \le \zeta < 1$. Then a one-time bank deposit levy $w_i(M_b + m)$ is transferred from the households and firms to the bailed out bank, where m is an overhead to ensure that the bank has enough equity to resume operations after the bail-out. The previous owners of b lose their investment and firms and households receive an ownership share of w_i percent of bank b. The flows involved in a bail-out are summarized in Fig. 1C.
- Bail-in A bail-in implements a debt-to-equity conversion. We assume that the resolution authority seeks to protect depositors as far as possible. Therefore an amount $M_b + m$ from the claims from other banks are converted into bank b's equity first, where again m is an overhead to ensure that b can continue its operations after the bail-in. Only if these funds do not suffice we impose a one-time bank deposit levy following the rules specified under bail-out, but with w_i being non-zero only if the levied deposit is with bank b. In return, ownership rights are transferred to the agents which bailed in the troubled bank, with the prospect of future dividend payments. The flows of funds involved in a bail-in are shown in Fig. 1D.

Note that in these crisis resolution mechanisms banks may only buy negative capital from defaulted banks to the extend that their own net worth does not turn negative. However, since the net worth of the banks that buy negative capital decreases, these processes render them more vulnerable and may introduce systemic instabilities.

4. Results

A MatLab implementation of the Mark I CRISIS model is used and extended by the described crisis resolution mechanisms. Some of the model parameters are kept fixed, as listed in supporting table SII. To estimate the robustness of the results we are interested in two different settings (1 and 2) of the remaining parameters listed in supporting table SIII. Stock-flow consistency demands that at each time in the simulation the total value of the monetary bases of all banks is conserved (since no money is exogenously added) and that the value of aggregate assets of the banks always equals the value of their aggregate liabilities, as can be seen in the supplementary figure S1.

Fig. 2 gives an overview of the model dynamics and shows that stylized empirical facts found in real economies are reproduced (see below). Simulations were performed with parameter setting 1 and a start equity for banks of $E_b(0) = 50$. Fig. 2A shows the Output $Y(t)$, which represents the combined value of all produced goods per time step as a function of time. Results are shown for the three different crisis resolution methods (black for P&A, red for bail-out, and green for bail-in), starting with the same initial random seed. At about $t = 2000$ the first bank insolvency takes place, and the outputs start to deviate from each other. Times where at least one bank is financially distressed are highlighted by vertical lines in the respective colors. It becomes immediately apparent that details of the model dynamics are sensitive to the choice of the resolution method, and that crises occur in bursts. Time periods with a large number of bankruptcies alternate with phases of stability.

The emergent firm sizes C_i are measured as total asset value, unemployment $U(t)$ as the percentage of unemployed workers in the given time step, and inflation $\pi(t)$ is given by the change in retail price index $\pi(t) \equiv \overline{p}(t)/\overline{p}(t-1) - 1$. Values have been taken in the time period before the first banking crisis occurs. Fig. 2B–D shows the reproduction of several phenomenological laws found in real economies. Fig. 2B confirms a well known empirical Zipf law in the distribution of firm sizes (Axtell, 2001). Fig. 2C shows Okun's law (Prachowny, 1993) for the inverse relation between unemployment change $dU(t) = U(t) - U(t-1)$, and productivity change $dY(t) = Y(t) - Y(t-1)$. Finally, Fig. 2D shows the Philipp's curve (Blanchard, 2000) as an inverse relationship between unemployment U and inflation π.

A central and extensively studied feature of the real economy ABM employed in the CRISIS macro-financial model is the existence of a first order phase transition between economic states of low and high unemployment (Gualdo et al., 2013). This phase transition is closely related to the interest rates in the model and, in particular the refinancing rate r_0. The interest rates for loans offered to firms are roughly given by r_0 plus a risk-dependent markup. A discontinuity appears in the model once this rate approaches the firms' credit contraction threshold, leading to the phase transition (Gualdo et al., 2013). The first order phase transition also appears in the model when one assumes a continuous and monotonously decreasing function for the credit contraction process, instead of the step function that we currently use (Gualdo et al., 2013). The reason for this is that credit contraction introduces an asymmetry in the hiring/firing process of firms. When firms are highly indebted, they will hire workers at a slower rate which in turn shifts the steady-state of the economy (Gualdo et al., 2013).

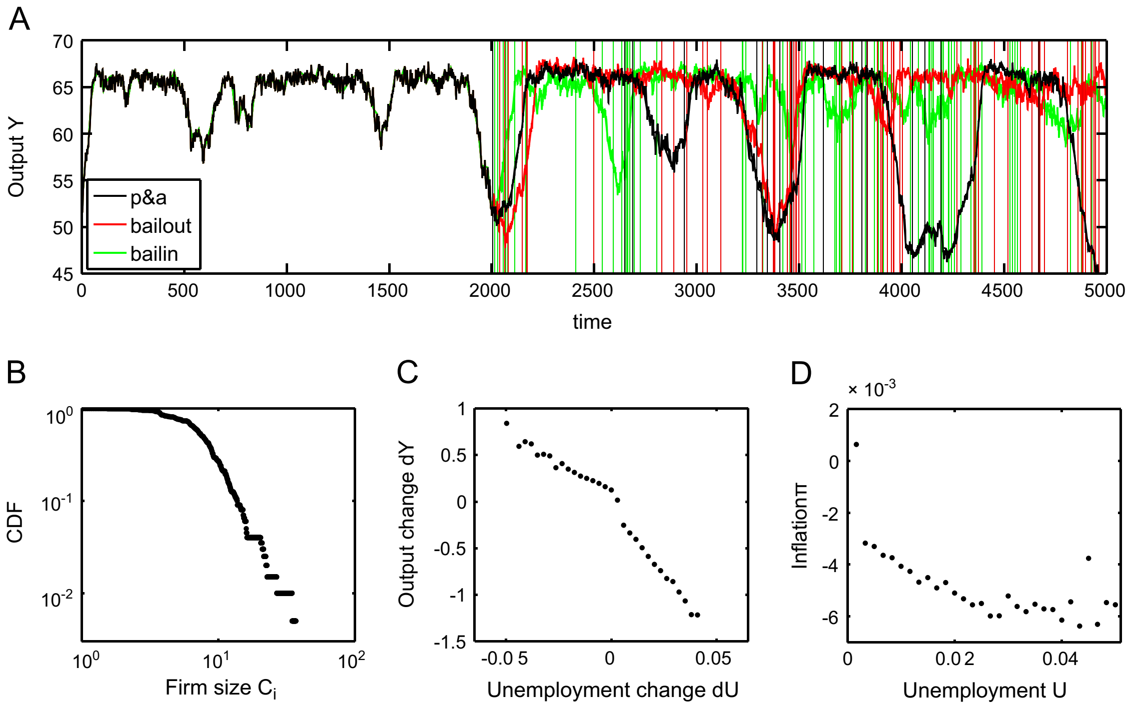

Fig. 2. (A) Output Y for a generic run of the model dynamics for the three scenarios 'purchase & assumption' ('p&a', black), 'bail-out' (red), and 'bail-in' (green). Each run starts with the same initial configuration and random number seed. Vertical lines indicate that at least one bank's equity became negative at this time. The model produces stylized empirical facts of real economies, such as the (B) firm size distribution, (C) Okun's law, and (D) Philipp's curve. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

This generic phase transition is a remarkable result, since many properties tend to be qualitatively similar within each phase. That is, small changes in parameters only lead to small effects as long as the system is prepared sufficiently far away from the phase transition. This offers a viable way out of the curse of high dimensionality and huge parameter spaces, which many complex agent-based models suffer from. It is often enough to understand the generic properties within each of the phases of the system in order to characterize its behavior. We will therefore compare the results for the different crisis resolution mechanisms in three different interest rate regimes. As already discussed, firms i receive offers for loans from bank b at real interest rates $r_{b,i}(t)$. This rate is given by r_0 and a risk-dependent markup term that depends on the financial fragilities of the firms. In the low interest rate regime firms typically receive loans at rates $r_{b,i}(t)$ that are smaller than r^{max}. In the critical regime the rates $r_{b,i}(t)$ are often very close to r^{max}. Finally, in the high interest rate regime the rates $r_{b,i}(t)$ that firms have to pay for loans are typically above r^{max}. Note that r_0 and r^{max} are external parameters. Their values, together with the financial fragilities of the firms, determine whether the model economy is likely to be in the high, low, or critical interest rate regime. In the following we keep r^{max} fixed and vary r_0 to study the model in different interest rate regimes. Results are discussed for the unemployment U, output Y, the combined outstanding credit volume of firms CV, the interest rate $i^{(n)}$, and the average negative equity in banking crises, $M = \langle M_b \rangle_{E_b(t)<0}$. Here, $\langle \cdot \rangle_{E_b(t)<0}$ denotes the average over all occurrences of a negative bank equity and hence the application of one of the crisis resolution mechanisms. Let t_f be the time-step where only one bank is left in the P&A scenario. Values have been averaged over 50 iterations and the time-span starting from the first banking crisis until $t = \min(t_f, 1000)$. We can now focus on the question of which crisis resolution mechanism shows the best performance in terms of highest economic output, lowest unemployment, and highest financial stability as measured by funds required to save distressed financial institutions. Results for U, Y, CV, $i^{(n)}$, and M for the generic cases of r_0 being below, at, or above the phase transition are shown in Fig. 3A–C, respectively, for parameter setting 1. In figure S2 the case for setting 2 is shown. Fig. 3 shows a spider plot for each interest rate regime where each crisis resolution mechanism is displayed as a patch (black for P&A, red for bail-out, green for bail-in) and the area of the patch is proportional to the values of U, Y, CV, $i^{(n)}$, and M. Results for these parameters as a function of r_0 are summarized in Fig. 3 for parameter setting 1, and for parameter setting 2 in supplementary figure S4. The findings are similar for both sets of parameters. Results for the model variant with an alternative rule to compute the consumption budget for households are shown in the supplementary figure S5. There are no qualitative differences between the two model variants. The left columns show U, Y, CV, $i^{(n)}$, and M as functions of the refinancing rate r_0 for the P&A scenario (black), bail-out (red), and bail-in (green). The right columns in figures S3 and S4 show the relative differences between the crisis resolution mechanisms. If $Z^{(c)}$ is any observable (such as U or Y) under crisis resolution mechanism $c = 1, 2, 3$, then $\Delta Z^{(c)}$ is given by $\Delta Z^{(c)} = Z^{(c)} - \langle Z^{(c)} \rangle_c$, i.e. the difference between the observed values and the values averaged over all crisis resolutions c.

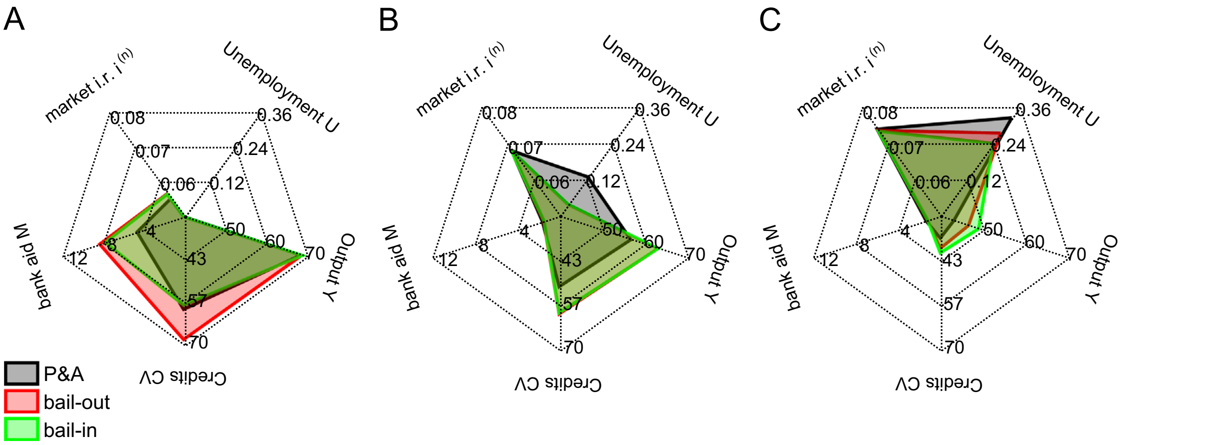

Fig. 3. The effects of the P&A scenario (black), bail-out (red) and bail-in (green) are shown for unemployment U, output Y, credit volume CV, bank aid M and market interest rate $i^{(n)}$, for parameter setting 1 and three different interest rate regimes. (A) In the low interest rate regime (r_0=0.021) there is practically zero unemployment, high economic output, and much higher costs associated with bail-outs and bail-ins as compared to the P&A case. (B) In the critical interest rate regime (r_0=0.027) the economy transitions from a healthy state of low unemployment to an unhealthy state of high unemployment and recession. This transition sets in at lower interest rates in the P&A case compared to bail-outs and bail-ins. (C) The high interest rate regime (r_0=0.03) is characterized by low economic productivity at high unemployment. The bail-in crisis resolution mechanism performs consistently better in terms of output than its alternatives. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

Table 1
Summary of main results. For each resolution mechanism and interest rate regime ($r_{b,i}$ which is basically refinancing rate r_0 plus risk dependent markups. See text.) we list the unemployment U, output Y, and total credit volume CV. The values for resolution mechanisms that lead to the lowest unemployment and highest output within the given interest regime are highlighted in bold. For the low interest regime all three resolution mechanisms perform similar, in the critical interest regime bail-outs and bail-ins both outperform the P&A case, while in the high interest rate regime the bail-in mechanism ranks highest.

	P&A	**bail-out**	**bail-in**
Low interest rates $r_{b,i}$ (low unemployment and high output)	U=**0.0007**(**1**) Y=**68.62**(**4**) CV=**59.5**(**8**)	U=**0.0000** Y=**68.93**(**4**) CV=**67.9**(**1**)	U=**0.0000** Y=**68.91**(**4**) CV=**67.2**(**1**)
Critical interest rates $r_{b,i}$ (onset of transition to high unemployment and low output)	U=0.131(4) Y=56.8(3) CV=50.8(3)	U=**0.041**(**1**) Y=**63.1**(**1**) CV=**58.9**(**1**)	U=**0.041**(**1**) Y=**63.1**(**1**) CV=**58.7**(**2**)
High interest rates $r_{b,i}$ (high unemployment, low output)	U=0.323(5) Y=43.3(3) CV=36.4(3)	U=0.274(9) Y=46.7(6) CV=39.6(4)	U=**0.249**(**8**) Y=**48.4**(**6**) CV=**40.6**(**4**)

Low interest rate regime. For both parameter settings the low interest rate regime can be prepared with $r_0 < 0.025$. Results are shown in Figs. 3A and S2A for $r_0 = 0.021$. Since r_0 is below its critical value unemployment U is practically zero under each crisis resolution mechanism and values for the output Y are identical; the economy is 'healthy'. However, the bail-out case shows a slightly higher credit volume CV than the bail-in or P&A cases. Since the firms share a higher burden of the financial losses in the bail-out case than in the other two cases, they compensate for this by requesting higher loans from the banks. The market interest rates are higher in the bail-out and bail-in case compared to the P&A scenario – suggesting higher risk-dependent markups in the interest rates offered to firms. A drastic difference can be seen in the negative equities accumulated by the banks under the three crisis resolution mechanisms. The value of M is much lower in the P&A case compared to the bail-out and bail-in scenario. This suggests that as banks become larger by purchasing and assuming assets of other banks, the risk of further financial losses in the low interest rate regime is greatly reduced. This is seen in Eq. (1), where low interests imply a low number of firm defaults which can be more effectively absorbed by larger banks.

Critical interest rate regime. The critical interest rate regime can be prepared with $0.025 < r_0 \leq 0.027$, see Figs. 3B and S2B for $r_0 = 0.027$. Here the onset of the phase transition can be observed, i.e. unemployment becomes non-zero and output decreases. In the bail-out and bail-in case this onset is at substantially higher values of r_0 than for the P&A scenario. All parameter values are nearly identical for bail-outs and bail-ins, and the output Y is higher compared to the P&A case due to the later onset of the phase transition. In this regime the households and firms still have enough wealth to bail-out (or bail-in) banks without leading to a decrease in economic activity. However, if banks default in this regime and the financial sector has to absorb these losses (as in the P&A case), this reduces the credit supply compared to the bail-out and bail-in case. Consequently, there is less economic activity and smaller output Y in the P&A case.

High interest rate regime. The high interest rate regime can be obtained with $r_0 > 0.027$ for both parameter settings, see Figs. 3C and S2C for $r_0 = 0.03$. Unemployment soars far above 20% and output drastically declines; the economy has transitioned into an 'unhealthy' state, a recession. At the point $r_0 = 0.027$ two crossovers occur. Output and unemployment for bail-in and bail-out begin to diverge, with bail-in having higher output at lower unemployment, and the nominal interest rates approaching the same value for all three resolution mechanisms. For higher values of r_0 the bail-in strategy consistently outperforms both bail-out and P&A in terms of output Y. The credit supply in the P&A case is even smaller than in the critical interest rate regime. The costs M are comparable in both scenarios. At the crossover at $r_0 = 0.027$ the financial burden on households and firms reaches a point where economic activity is impaired more in the bail-out case than in the bail-in case. In the high interest rate regime firms and households do not have enough savings to assist distressed banks without causing a substantial decline in consumption or production. Since in the bail-in case only a small set of firms and households need to absorb the financial losses, the remaining parts of the economy perform better than in the bail-out case.

5. Summary and discussion

Our main findings are summarized in Table 1. In this work we quantified the economic performance of three different crisis resolution mechanisms which played a pivotal role in the resolution of banking crises in the recent past. The main difference between these mechanisms is whether the troubled bank is closed down or not, and which sector of the economy has to bear the major burden of the financial losses inflicted by the banking crisis. Under the P&A resolution mechanism the distressed bank is closed and its assets and liabilities are purchased and assumed by healthy banks, which thereby pay for the losses. In a bail-out the financial burden is carried by the taxpayers, in the bail-in the burden is distributed among the troubled banks' debtors. We tested the performance of these resolution mechanisms within the framework of the Mark I CRISIS model, an ABM equipped with coupled economic and financial sectors (Tables 2 and 3).

The performance of the resolution mechanisms is closely related to the state of the model economy, i.e. whether market interest rates are high or low. We found that the P&A mechanism performs best in a regime where unemployment is low and economic output high, i.e. the economy is 'healthy'. While in terms of economic production there is almost no difference between the different resolution mechanisms, the orderly liquidation of the distressed bank leads to substantially smaller losses to other banks and therefore increased financial stability compared to bail-outs or bail-ins. This is because the P&A case resolution mechanism leads to larger banks which can absorb the – in the low interest rate regime – comparably small losses due to firm defaults much more effectively than banks which are drip-fed by bail-ins or bail-outs. However, in the recession regime, characterized by high unemployment and comparably low economic productivity, this does not hold. In this regime the bail-in mechanism outperforms both the P&A and the bail-out mechanism in terms of higher economic output and stability. Here the banking sector alone can no longer cope with the increasing number of firm defaults and

Table 2
Overview and description of fixed model parameter.

Symbol	Parameter	Value
B	number of banks	20
I	number of firms	100
J	number of worker	700
$E_b(0)$	banks' start equity	10
α	labor productivity	0.1
w	wage	1
z	number of applications in consumption good or credit market	2
κ^{min}	minimal cash reserve ratio	0.005
λ^{max}	maximal leverage ratio	100
τ	debt reimbursement rate	0.05
μ	interest rate coefficient	0.2
r^{max}	credit contraction threshold	0.05
$r^{(ib)}$	interbank loan interest rate	0

Table 3
Overview and description of variable model parameter.

Symbol	Parameter	Setting 1	Setting 2
δ	dividends	0.25	0.5
ϕ	credit contraction parameter	0.75	0.8
c	propensity to consume	0.85	0.8
m	crisis resolution overhead	1	0.5
ζ	tax exemption	0.0	0.05

credit supply dwindles under the P&A mechanism. In the bail-in case the financial losses are absorbed by, and confined to a smaller part of the economy, and the remaining parts of the economy perform better than in the bail-out case. In the intermediate economic state between the healthy and unhealthy, bail-outs and bail-ins lead to almost the same results and both outperform the P&A mechanism. In this case the households and firms are wealthy enough to allocate funds to troubled financial institutions without reducing productivity and consumption.

A number of questions and further research agendas immediately arise as a consequence of this work. First, it remains to be seen how the results depend on the liquidation procedure that is actually imposed. In the P&A case the number of banks decreases over time and we stop the simulation if only one bank is left. It is interesting to see what happens if we re-populate the financial sector with new banks. Another important question is whether our main findings still hold if we consider smoothing effects in the resolution schemes, such as collecting the funds required for bail-outs or bail-ins over several time-steps of the model. The evolutionary perspective of having competing banks with different strategies or even regulatory regimes also remains to be explored. Further, it would be interesting to investigate a mix of resolution mechanisms. For example, banks could be only partially liquidated only if certain conditions are met, such as the bank being small enough. How do our results depend on the choice of the economic production model? What if, instead of the Mark 1 economic model, firms are endowed with capital and labor and produce goods according to a Cobb–Douglas function or, say, the *AK* growth model? Does this impact the performance of the resolution mechanisms? Another very relevant question is how the resolution mechanisms perform if we add other, endogenous, conventional or unconventional monetary policy operations. For example, what if the central bank sets r_0 via a Taylor Rule, or intervenes with quantitative easing programs? These policy operations might introduce complex feedback mechanisms between the default probabilities of various agents and the interest rates in the model economy, and thereby influence the performance of the crisis resolution mechanisms. The results presented in this paper therefore do not necessarily have general validity, and may indeed differ for different choices of behavioral rules. It will be possible to study these and related questions in the future within the CRISIS framework, which provides a suite of economic and financial model building-blocks which can be plugged together and extended. It is also worth considering the question of whether the best banking resolution mechanism can indeed be determined by a neutral scientific investigation. Maybe this mechanism has to be the outcome of a genuine political economy debate, depending on the judgment of the social and economic actors involved.

To conclude with a summary at a very high level, the policy implications obtained within the cosmos of the Mark 1 CRISIS model are:

- It is beneficial to let distressed banks default only if the overall state of the economy is healthy enough.
- There are no economic conditions under which a taxpayer-funded bail-out outperformed the bail-in mechanism with private sector involvement.

Acknowledgments

We acknowledge financial support from FP7 projects CRISIS agreement no. 288501, LASAGNE, agreement no. 318132, and MULTIPLEX, agreement no. 317532.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jedc.2014.08.020.

References

Al Jazeera, 2013. Cyprus asks EU for financial bailout. Retrieved 16/01/2013.
Axtell, R., 2001. Zipf distribution of US firm sizes. Science 293 (5536), 1818–1820.
Battiston, S., Puliga, M., Kaushik, R., Tasca, P., Caldarelli, G., 2012. Too central to fail? Financial networks, the FED and systemic risk. Scientific Reports 2.
Bernanke, B., Gertler, M., Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. In: Tayler, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1, Elsevier, Cambridge, MA, USA.
Blanchard, O., 2000. Macroeconomics, Second ed. Prentice Hall, Upper Saddle River, NJ, USA.
Boss, M., Summer, M., Thurner, S., 2005. The network topology of the interbank market. Quant. Financ. 4, 677–684.
Caccioli, F., Boucaud, J.-P., Farmer, J., 2012. Impact-adjusted valuation and the criticality of leverage. arXiv.org:1204.0922.
Calvo, G.A., Izquierdo, A., Mejia, L.-F., 2008. Systemic sudden stops: the relevance of balance-sheet effects and financial integration. Research Department Working Papers 637, Inter-American Development Bank.
DeGrauwe, P., 2013. The new bailin doctrine: a recipe for banking crises and depression in the eurozone. CEPS Commentary, retrieved 04/04/2013.
Delli Gatti, D., Desiderio, S., Gaffeo, E., Cirillo, P., Gallegati, M., 2008. Emergent Macroeconomics: An Agent-based Approach to Business Fluctuations. New Economic Windows, Springer, Milano, Italy.
Delli Gatti, D., Desiderio, S., Gaffeo, E., Cirillo, P., Gallegati, M., 2011. Macroeconomics from the Bottom-up. Springer, Milan.
De Walque, G., Pierrard, O., Rouabah, A., 2010. Financial (in)stability, supervision and liquidity injections: a dynamic general equilibrium approach. Econ. J. 120 (549), 1234–1261.

Diamond, D.W., Dybvig, P.H., 1983. Bank runs, deposit insurance, and liquidity. J. Polit. Econ. 91 (3), 401–419.
Dosi, G., Fagiolo, G., Roventini, A., 2010. Schumpeter meeting Keynes: a policy-friendly model of endogenous growth and business cycles. J. Econ. Dyn. Control 34, 1748–1767.
Dosi, G., Fagiolo, G., Napoletano, M., Roventini, A., 2013. Income distribution, credit and fiscal policies in an agent-based Keynesian model. J. Econ. Dyn. Control 37, 1598–1625.
Dubey, P., Geanakoplos, J., Shubik, M., 2005. Default and punishment in general equilibrium. Econometrica 73 (1), 1–37.
EFSF, 2013. FAQ about European Financial Stability Facility and the new ESM, 21/01/2013 (retrieved 13/02/2014).
Erlingsson, E.J., Teglio, A., Cincotti, S., Stefansson, H., Sturluson, J.T., Raberto, M., 2014. Housing, market bubbles and business cycles in an agent-based credit economy. Economics 6, 2014–2018.
European Commission, 2013. Balance of payments—European Commission. ec.europa.eu, retrieved 13/02/2014.
Federal Deposit Insurance Corporation, 2003. Resolutions Handbook (FDIC, 2003).
Federal Deposit Insurance Corporation, Bank of England, 2012. Resolving globally active, systemically important, financial institutions (FDIC, BoE, 2012).
Gaffeo, E., Delli Gatti, D., Desiderio, S., Gallegati, M., 2008. Adaptive Microfoundations for Emergent Macroeconomics. Technical Report 0802.
Giansante, S., Chiarella, C., Sordi, S., Vercelli, A., 2012. Structural contagion and vulnerability to unexpected liquidity shortfalls. J. Econ. Behav. Organ. 83, 558–569.
Goldstein, I., Pauzner, A., 2005. Demand-deposit contracts and the probability of bank runs. J. Financ. 60 (3), 1293–1327.
Goodhart, C.A.E., Sunirand, P., Tsomocos, D.P., 2006. A model to analyse financial fragility. Econ. Theory 27, 107–142.
Goodhart, C.A.E., Kashyap, A.K., Tsomocos, D.P., Vardoulakis, A.P., 2012. Financial regulation in general equilibrium. NBER Working Paper No. 17909.
Gualdo, S., Tarzua, M., Zamponi, F., Bouchaud, J.-P., 2013. Tipping points in macroeconomic agent-based models. arXiv.org:1307.5319.
Iori, G., De Masi, G., Precup, O.V., Gabbi, G., Caldarelli, G., 2008. A network analysis of the Italian overnight money market. J. Econ. Dyn. Control 32, 259–278.
Keister, T., 2012. Bailouts and financial fragility Mimeo. Federal Reserve Bank of New York.
Kiyotaki, N., Moore, J., 1997. Credit cycles. J. Polit. Econ. 105 (2), 211–248.
Klimek, P., Hausmann, R., Thurner, S., 2012. Empirical confirmation of creative destruction from world trade data. PLOS ONE 7 (6), e38924.
McGuire, C.L., 2012. Simple Tools to Assist in the Resolution of Troubled Banks. World Bank, Washington, DC, USA.
Ötker-Robe, I., Narain, A., Ilyina, A., Surti, J., 2011. The too-important-to-fail conundrum: impossible to ignore and difficult to resolve. IMF Staff Discussion Note SDN/11/02.
Poledna, S., Thurner, S., 2014. Elimination of systemic risk in financial networks by means of a systemic risk transaction tax. arXiv.org:1401.8026v2.
Poledna, S., Thurner, S., Farmer, J., Geanakoplos, J., 2014. Leverage-induces systemic risk under Basle II and other credit risk policies. arXiv.org:1301.6114.
Prachowny, M.F.J., 1993. Okun's Law: theoretical foundations and revised estimates. Rev. Econ. Stat. 65 (2), 331–336.
Raberto, M., Teglio, A., Cincotti, S., 2012. Debt, deleveraging and business cycles, an agent-based perspective. Economics 6, 2012–2027.
Reuters, 2013. Bank bond investors should fear fast-tracked EU bail-in, retrieved 12/12/2013.
Schumpeter, J.A., 1942. Capitalism, Socialism and Democracy. Harper, NY.
Stavárek, D., 2013. Lessons learned from the 2013 banking crisis in Cyprus. Eur. Financ. Syst. 2013, 312.
Stern, G.H., Feldman, R.J., 2004. Too Big too Fail: the Hazards of Bank Bailouts. Brookings Institution Press, Washington DC, USA.
The Guardian, 2013. Cyprus eurozone bailout prompts anger as savers hand over possible 10% levy, retrieved 16/03/2013.
Thurner, S., Poledna, S., 2013. DebtRank-transparency: Controlling Systemic Risk in Financial Networks. Scientific Reports 3, 1888.
Thurner, S., Farmer, J., Geanakoplos, J., 2012. Leverage causes fat tails and clustered volatility. Quant. Financ. 12, 697–707.
Tsomocos, D.P., 2003. Equilibrium analysis, banking and financial stability. J. Math. Econ. 39, 619–655.
US Government Accountability Office, 2012. Capital Purchase Program: revenues have exceeded investments, but concerns about outstanding investments remain. GAO-12-301.
Wang, C., 2010. Bailouts and bank runs: theory and evidence from TARP. Eur. Econ. Rev. 64, 169–180.
Wilson, J., 2012. Cyprus requests eurozone bailout. Financial Times, retrieved 25/07/2012.
Wright, R.E., 2009. Bailouts: Public Money, Private Profit. Columbia University Press, New York.
Zhou, J., Rutledge, V., Bossu, W., Dobler, M., Jassaud, N., Moore, M., 2012. From bail-out to bail-in: mandatory debt restructuring of systemic financial institutions. IMF Staff Discussion Note SDN/12/03.