Policy Lessons from Systemic Risk Modeling and Measurement

The SYRTO code

(Report for Work Package 8)

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This version: February 26, 2016

SYRTO

SYstemic Risk TOmography

Signals, Measurements, Transmission Channels, and Policy Interventions

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 320270.

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Six Take Aways from Systemic Risk Measurement and Modelling

The SYRTO project (SYstemic Risk TOmography) has delivered new results on the statistical modeling of systemic crisis. This report outlines the most important policy lessons. Below are six takeaways for policy makers.

I. Models give useful early warning signals of systemic crises

Crises are unpredictable, almost by definition. However, many research findings point to the fact that signals on an impending crisis are available. Financial imbalances such as high and increasing leverage of the banking system, a debt-driven boom in asset prices are consistently found to have predictive power for a banking crisis.

Some models are more elaborate and technical than others, but each has its own merit. Simple models give imprecise signals, but provide understanding of which economic forces are important. Elaborate models, such as those using machine learning techniques (data mining) are much better at predicting, but are more difficult to interpret.

One specific model, namely regression trees, seems very promising in offering good predictions. The data-driven decision tree provides a natural "menu" of questions that policy makers can ask, resulting in a systemic risk score and intuition on which economic variables are most important in the current regime.

II. Low financial stress levels are not synonymous to high financial stability

In contrast to financial imbalances, which are predictive of crises, market-based financial stress measures are not forward looking. These are measures such as volatility, or the probability of default, which only shoot up when a crisis actually occurs. They are consistent with existing notions of the timing of historical crises, but are not easily used to gauge the probability of an impending crisis.

A case in point is the 2008-2009 financial crisis. At the start of 2007, most statistical stress indicators were at their lowest, sometimes the lowest point in decades. This seems contradictory, until we realize that the safety before the crisis was actually one of the driving forces that led to the crisis: many financial products had seemingly low risk, but turned out to harbor neglected risks that drove the panic when they materialized.

An important lesson for policy makers is that, in normal times, financial stress indicators reflect the apparent calm as priced in the markets and could be misleading. Such measures need to be complemented by information on the actual behavior of banks, a topic should be high on the agenda of policy makers.

III. The challenge is to make hard decisions based on soft information.

The reigning paradigm concerning asset-price bubbles before 2008 was that of non-intervention. Having seen the fall-out of the financial crisis, the consensus view has shifted towards intervention. Some of this is reflected in formal regulations, such as counter-cyclical capital buffers and new rules on the liquidity position of banks.

Another example is the change in policy stance of regulators and governments, who want to become more pro-active in intervening in institutions to avoid new systemic crises. From the above it is clear that models provide a useful signal of potential crises, but a large margin of error remains. Moreover, different models can give different signals about whether financial stability is threatened. This creates a problem for intervening, as false alarms need to be balanced against the potential for crises missed.

One possibility to improve decision making is to invest in communication with the financial sector and the public, putting focus on the potential dangers if no action is taken. This effectively lowers the barrier to intervene and make early-warning signals more useful. It remains the tough job of the regulator to “take away the punch bowl when the party get going”, i.e., the regulator is most effective in booming markets, when the forces against intervention are strongest.

Successful intervention and interventions that were not necessary after all are almost impossible to distinguish. Therefore, a process of trial and error is inevitable, and the danger of a ‘cry wolf’ effect needs to be managed by effective communication.

IV. Manage the complexity of the financial system

Ongoing financial innovation and institutional developments have led the financial sector to resemble a complex dynamic system. Such systems have been analyzed in engineering, where it is well known that they suffer from several problems. A key one is that a single malfunction can have unpredictable effects. Large scale failures can occur in a random fashion. Intervening in the system is hard. The problems amount to the phenomenon of “normal accidents”, i.e., the occurrence of crashes in dynamic and complex systems is the norm rather than the exception.

The literature offers suggestions on how to deal with complex systems. First of all, the complexity itself might be reduced by striving for modularity, so that different parts of the financial system can easily be distinguished and have well-defined relations. Second, the monitoring of the financial system should improve by investing in data collection and analysis. Thirdly, there is a need for continuous improvement in the modeling and analysis of financial risks in the financial network. The improvements in data collection and modeling should be used to develop more sophisticated stress tests that guide policy makers on where the potential breakdowns are located.

V. There is evidence for a country-specific financial cycle

The financial crisis of 2008/2009 was preceded by at least a decade of very high credit growth. Looking back, this is suggestive of a ‘financial cycle’ with persistent growth of credit and asset prices. Such growth rates trend according to a cyclical pattern with a duration of 15 years, and are country-specific. However, due to data limitations it is too early to draw any definitive conclusions regarding the behavior of financial cycles.

The concept of the financial cycle is now firmly embedded in the approaches developed by national supervisors and the ESRB to mitigate financial instability. It should be noted, however, that macroprudential policies cannot replace monetary policy, fiscal policy and, even less, industrial policy. The knowledge of the interlinkages between financial stability, banks, and growth is too limited for attempting to use macroprudential policy for fine-tuning the credit cycles.

VI. Systemically important institutions are correctly identified

Compared to sophisticated statistical techniques, the common-sense approach to identifying systemically relevant institutions (SIFIs), by using the size, interconnectedness, leverage and liquidity is adequate. Also, simple measures based on the risk of one institution in isolation (such as value-at-risk) work surprisingly well in measuring its systemic importance. The fact that an institution such as AIG was not identified as systemically important before the crisis was due to the absence of data rather than using incorrect measures.

In that respect, the common standards for supervisory reporting developed by the European Banking Authority for EU banks, with harmonized templates and definitions, represent a major step in the right direction. Comparable, consistent and comprehensive data from supervised entities help supervisors to make informed decisions on preventative measures, on use of micro- and macro-prudential tools and to promptly react on idiosyncratic problems or system-wide build-up of systemic risks.

Preface - Background to the SYRTO Code

The financial crisis of 2008/2009 and ensuing Euro crisis of 2010/2011 have shown that new thinking on EU-wide policies for systemic risk are necessary. This report explores the challenges for governance and coordination of macro-prudential policies aimed at systemic risk.

This report is a deliverable from the SYRTO project, containing the policy implications and recommendations for the measurement and management of systemic risk. In writing the report we have drawn from a wide body of academic research on systemic risk, such as has been done under the SYRTO grant, but not limited to it.

To give focus to the report, some limitations apply. These are in the choice of topics on which the econometrics and statistical work done in SYRTO have a bearing.

The remainder of this report is as follows. Chapter 1 introduces the policy challenges regarding governance and coordination of systemic risk. The challenges are then addressed in subsequent chapters that deal with prevention, mitigation and stabilization.

Financial firms and financial markets can be triggers and transmitters of systemic risk. Chapter 2 deals with the triggers, both outside and inside financial institutions, and how to detect them early on. (The direct effect of low-probability events on financial firms). The chapter ends with recommendations on how to improve the governance and coordination of policies aimed at preventing systemic risk.

Chapter 3 deals with the transmission of systemic shocks (low probability/high impact events) through the financial system. Research finds an important role for the financial cycle, and a low-risk anomaly that can be indicative of an impending crisis. The chapter ends with recommendations on how to improve the governance and coordination of policies aimed at the transmission of systemic risk.

Chapter 4 describes the lessons learned on stabilizing the European banking sector. Assuming we can never completely prevent systemic events, we look at possibilities of limiting the damage and breaking transmission chains. The chapter ends with recommendations on how to improve the governance and coordination of policies aimed at the stabilization of the financial system after a crisis.

Chapter 5 concludes.

Appendix A contains an overview of deliverables for work package 8 “The SYRTO Code”

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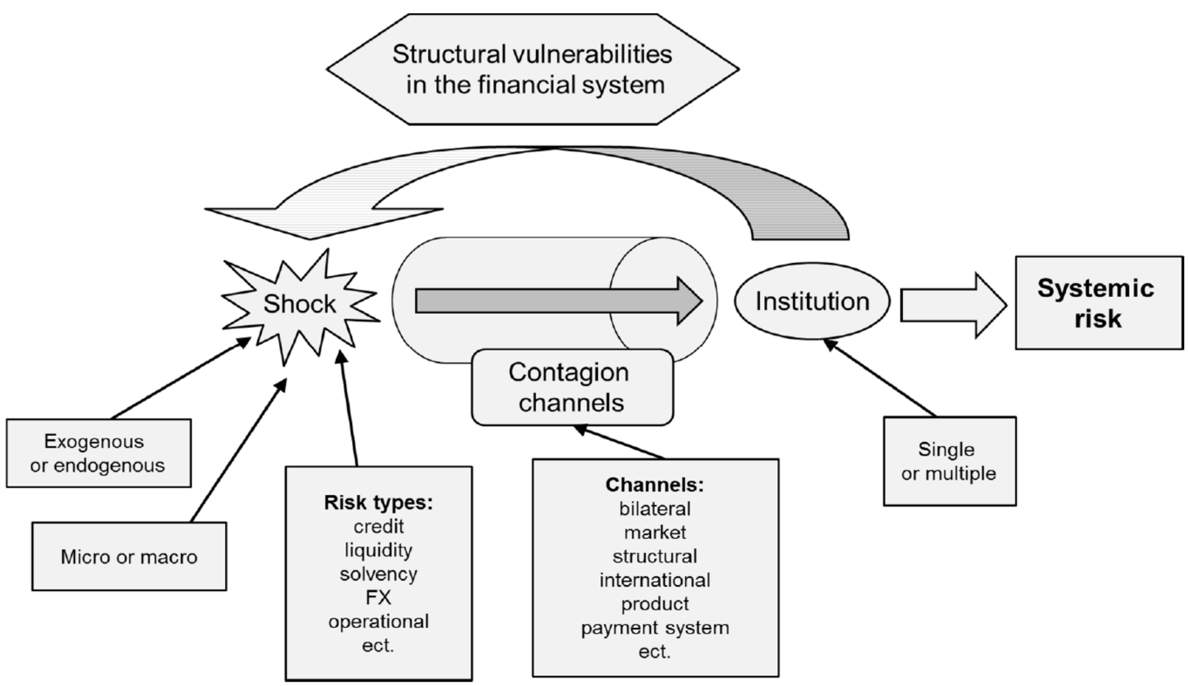
1 Introduction: The Governance and Coordination of systemic risk

The 2008/2009 financial crisis showed the shortfalls in the existing supervisory regime. New rules and regulations are presented in the perspective of how they address the earlier shortcomings in managing systemic risk. We introduce the governance and coordination issues that are addressed in the remaining chapters.

The financial crisis changed the consensus on the adequacy of traditional bank regulation, which focused on the solvency of a single institution. The basic insight is that the banking system can ‘run on itself’, because of a lack of trust between financial institutions. The old system assumed that the health of banks was adequately captured with risk-based regulation, which turned out to be false. When the losses mounted, it turned out that potential losses were severely underestimated. Moreover, it became quite hard to assess which bank was solvent and which was not. The financial position of multiple banks was threatened at the same time: a systemic crisis.

Systemic risk is the risk of the breakdown in the financial system, by the default of two or more institutions in the same time period. Systemic risks are characterized by (i) initial shocks of modest magnitude, and (ii) the transmission of those shocks between financial institutions that threatens their existence. Figure 1 visualizes the concept of systemic risk.



Source: Smaga (2014)

For the financial system we can identify two dependency chains in the “Black box” of contagion channels (the cylinder in Figure 1). First, a common shock can affect all institutions, caused by the collapse of an asset price bubble funded by debt. For example, a real estate boom and subsequent bust affects all the banks who have lent to real estate developers. This is a shock to all banks, caused by the common exposure. As such, it is a dependency chain that might not be observable *ex ante*, when regulators only focus on the health of individual banks.

The second source of dependency is contagion: a shock to just one or a few institutions spills over to other institutions and markets through the networked structure of the financial system. The classic example is in Schnabel and Shin (2004), who document an usually high contagion between the grain and sugar price during the crisis of 1763. The contagion had no fundamental reason, but was caused by the distressed selling of sugar by a bank that had speculated with grain. In that way, the two market prices started to move together, and the problem of one bank spilled over to other banks, leading to multiple bank failures. A modern-day example is the credit crisis of 2007/2008 which was initially confined to a problem in real estate and CDOs. The losses that ensued led to the selling of other assets so that comovement arose between assets that were otherwise not related, see Brunnermeier (2009).

The essence of systemic risk and the focus of this report is the dependency links and contagion between institutions in the financial system. The failure, or near-failure, of multiple banks in the 2007-2010 period have shown that new measurement techniques, policies and institutional structures are necessary to prevent or mitigate systemic risks in the futures. Below we introduce the systemic risk instruments that have been introduced after 2007, and the issues in terms of governance structures and the coordination between micro- and macro-prudential policies. Separate issues are connected to sections in the other chapters that survey the policy implications from the work on Systemic Risk Tomography (SYRTO).

1.1 Systemic risk instruments

The regulatory reform initiated by the G20 in the aftermath of the crisis is close to finalization. In the EU, the new rules on capital and liquidity represent the first defense for preventing the accumulation of systemic risk. They have incentivized banks to move towards safer business models and required more robust capital and liquidity buffers to those institutions willing to operate in riskier markets. Better capitalized banks are also better positioned for supporting lending and economic growth. There is indeed increasing evidence suggesting a positive correlation between strong capital ratios and banks capacity to sustainably lend into the real economy, see Carney (2013).

The repair process of the European banking system since 2011 has led to a major strengthening of banks' capital base. EU banks increased their common equity tier 1 (CET1) ratio between 2011 and 2014 from 9.2% to 12.1%, see European Banking Authority (2015b). While banks have further reduced exposures in certain areas or business lines, for instance, in investment banking, total asset volumes increased by about 6% as of December 2014.

New regulations have focused on the following aspects:

A. Mitigating liquidity risk

Liquidity risk has been, if not the source, the main driver of the financial crisis. The combination of poor liquidity management and a reliance on short-term funding led to multiple failures and near-failures when liquidity disappeared. Earlier regulation operated on the assumption that robust capital cushions would shield banks against major shocks.

Already in 2008, the Basel Committee published the Principles for Sound Liquidity Risk Management and Supervision. These provided guidance on the risk management and supervision of funding liquidity risk in order to foster better risk management practices. In addition, the Committee introduced two minimum standards (the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR)) for liquidity and funding, which pursue the objectives of promoting short-term resilience of a bank's liquidity positions as well as longer-term funding stability.

Stricter requirements and supervision have also been introduced on banks' funding plans. Banks are now explicitly requested to develop a funding strategy that provides effective diversification in the sources of funding. While banks should plan their funding strategy under business-as-usual circumstances, they are also required to consider contingency plans to be activated in case of emergency situations, both idiosyncratic and systemic. This mitigates the transmission of systemic shocks through the banking system that could arise from the forced liquidation of (illiquid) assets to cover a funding shortfall.

B. Higher capital ratios

Higher capital requirements have come into force, which mitigates the transmission of shocks. Contingent capital and bail-in capital serve the same purpose. Counter-cyclical capital buffers (CCB) for systemically important financial institutions (SIFIs) lean against the build-up of debt-driven asset price bubbles that are known for triggering systemic problems. The CCB can vary between 0% and 2.5% of risk-weighted assets (RWA) and is switched on by national authorities when deemed necessary.

C. Reducing asset volatility.

For US-banks, the Dodd Frank act limits proprietary trading, which reduces the vulnerability of individual banks to shocks. Ring fencing ensures that consumer banking activities are shielded from more risky banking activities. For the remaining financial market activities of banks, central clearing (CCP) for swaps and credit value adjustments (CVA) reduce the counterparty risk from derivative transactions, which limits the fall-out of a defaulting counterparty to the financial system.

D. Improving supervision and resolution

In the European context the problem of resolution was made harder by the system of national supervision for cross-border banks, which made it hard to assess solvency, liquidity and to estimate the externalities of bank failures. To improve the supervision of large European banks, the banking union has been formed. The single supervisory mechanism (SSM) and the single resolution mechanism (SRM) are designed to ensure a fair and orderly supervision process and increase the objectivity of the decision to close down a troubled bank. The SRM reduces the uncertainty and disruption in case of a looming default, mitigating the transmission of initial shocks through the financial system.

1.2 Governance structures for systemic risk

The introduction of systemic risk instruments has gone hand in hand with the development of governance structures, such as changes in the ECB's responsibility, the European Banking Union, the SSM and the SRM. The SYRTO research on systemic risk has consequences for these institutions and the governance of systemic risk.

From the early warning research (see Section 2.1) comes a clear need for a governance mechanism to set the threshold for false warnings. The early warning models produce forecasts on the probability of an impending crisis, but they come with a band of uncertainty. The uncertainty gives rise to two problems, namely that of false warnings (act, but there is no crisis) and that of missed crisis (not acting, but a crisis still occurs). Policy makers need to understand this choice and decide on thresholds for acting. In this dilemma, a clear governance structure is important. Section 4.5 outlines the policy maker's dilemma in putting a large weight on the prevention of systemic crises in the loss function.

A problem for researchers is that of the missing counterfactual[2]: successful interventions will appear in the data as "no crisis". It makes statistical inference on crisis-signals harder, and complicates the communication of an institution that is responsible for systemic risk mitigation. The public might argue that the enacted policies have been unproductive, since a crisis did not materialize and the immediate costs were quite visible. For example, higher lending standards have affected the spending power of consumers. The low volatility paradox gives rise to such problems, where a systemic risk supervisor might want to intervene right at the time when market-implied risks are at their lowest. This is described in Section 2.2, in combination with relevant research done in SYRTO.

Two international institutions that have been involved in systemic risk are the Basel Committee on Banking Supervision, and the Financial Stability Board. They have no official jurisdiction, but they have been instrumental in proposing measures to determine which institutions are

[2] This was pointed out by Charles Goodhart at the SYRTO conference held in Amsterdam, June 4-5, 2015.

systemically important. Research in SYRTO has looked at the same issue, i.e., which institutions contribute most to systemic risk, from a more econometric angle. The results largely overlap the proposed methodology, as described in Section 3.2.

Note that the effective governance of systemic risk could involve a large role for international institutions. For example, researchers from both the IMF and the BIS have warned for the problems of excessive credit growth, financial innovation and the potential for systemic risk, see for example Borio et al. (2001), Borio and White (2004), Rajan (2006). These institutions are less susceptible to national interests or industry lobbying and can act more independently. To some, this is their biggest weakness, but for systemic risk it could be exactly the right thing to have.

The effectiveness of the single resolution mechanism will become clear in the coming years. In Chapter 4, Section 4.1 describes how coordination in case of a bank default between countries could work, based on the work in Schoenmaker and Siegmann (2014). A voting mechanism based on the asset shares or loan shares of banks in each country leads to outcomes that are close to what a supranational supervisor would achieve. One implication is that decisions made by a supranational supervisor, such as the ECB in the European Banking Union, are quite close to that of an optimal voting scheme.

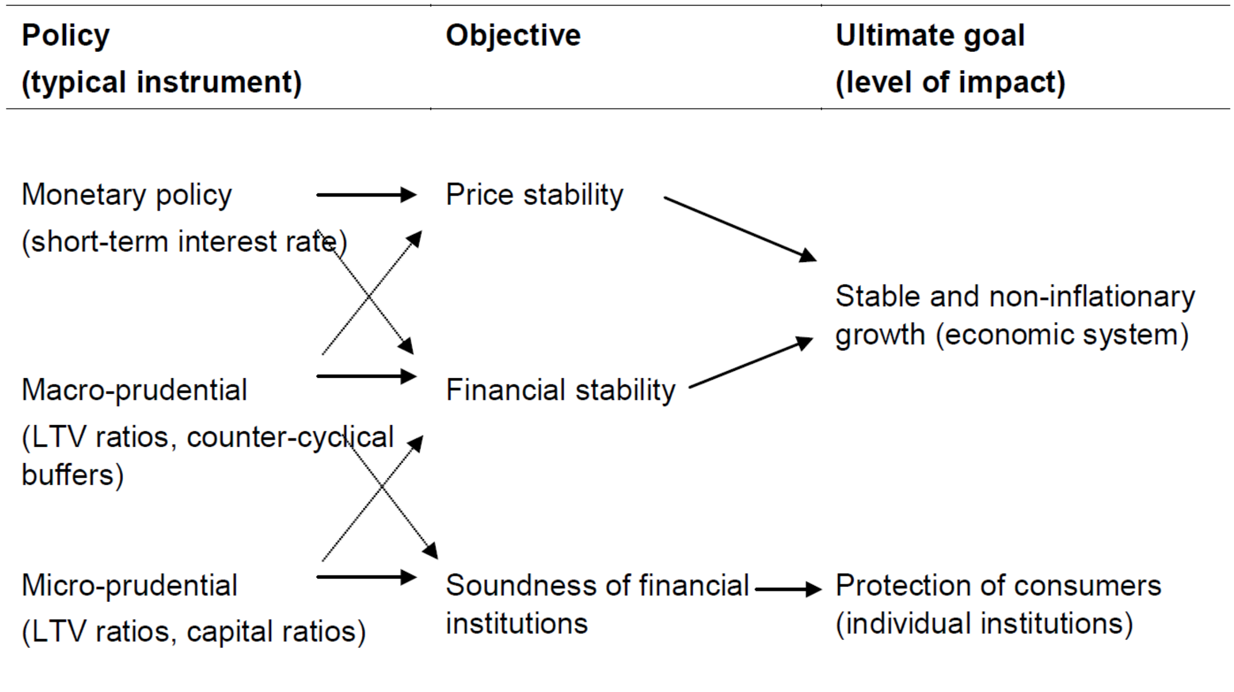
An important governance issue is the role of the ECB in stabilizing European financial markets. Section 4.3 describes the most recent research that analyzes the effectiveness of the ECB's interventions that were aimed at several aspects of the European financial market. It seems that its interventions were mostly successful, and, in terms of results, the ECB as institution serves the purposes of mitigating systemic risk well.

1.3 Coordination of macro and micro-prudential responsibilities

SYRTO research holds lessons for the best mechanisms to coordinate macro- and micro-prudential supervision.

In the traditional view, prudential supervision at the level of a single institution is enough to mitigate the potential moral hazard problems that arise from deposit insurance. As such, in the EU, national supervisors were responsible for the micro-prudential supervision tasks. The EU-passporting agreements arranged for home-country supervisors to take the lead in supervising cross-border banks.

From the perspective on systemic risk it is clear that the micro-prudential approach is not enough. The reason is that the interventions or regulations that are necessary to make the system more resilient depend on the interplay between institutions. Policymakers have dubbed this the "macroprudential" approach to supervision, where the word "macro" refers to the perspective of the system-as-a-whole. The figure below illustrates the policy framework for the financial and economic system:



Source: Schoenmaker (2013)

Macro and micro-prudential policies overlap in that they are both aimed at the stability of financial institutions. They deviate in the area where micro-prudential interests are the protection of consumers of a single bank and macro-prudential interests are the stability of the system as a whole.

On the supervisory structure, Schoenmaker (2014) recommends to assign macroprudential powers to a single body. This facilitates ownership and designates clear responsibilities. To prevent gridlock when micro and macro-prudential concerns do not coincide, it may be appropriate to define a hierarchy of objectives, where the macroprudential objective takes precedence. This could be a procedure to agree upon for the ECB and ESRB.

Micro- and macroprudential perspectives can collide in the case of low market-implied risks. We describe in Section 2.2 how low volatility can be a warning signal for systemic crises. But low volatility is a good thing from a microprudential perspective: buffers appear to be high, and risk appetite appears to be low, because the measured riskiness of the assets is low. For the interplay of the two responsibilities, it is important for microprudential supervisors to incorporate the systemic risk assessment in their appraisal of the soundness of institutions.

Also in Chapter 2, we survey systemic threats on the horizon. Each of the threats has an element of the micro vs. macro debate.

Central clearing has a positive influence on the stability of a single institution, because the uncertainty and unpredictable contagion effect caused by the default of one counterparty is mitigated, see Section 2.3.1. All transactions are cleared centrally and the default of one clearing member is borne by the default fund of the clearing, and, ultimately, the clearing members. However, in the case of a large systemic event, there is a risk that the system-wide impact is larger than in the de-centralized setup. For the effective interplay microprudential and macroprudential responsibilities, it is therefore of key importance that the size of the default fund reflects macroprudential concerns.

Contingent convertibles (Section 2.3.3) contribute to the loss-absorbing capital for a bank and are admitted by microprudential supervisors to fulfill capital requirements. However, their widespread use could lead to new channels of contagion. Micro and macroprudential supervisors will need to coordinate on mitigating potential channels for systemic risks to propagate through the system by subsequent triggers of contingent convertible bonds.

In the mitigation of systemic risk (Chapter 3), the interplay between micro- and macroprudential authorities becomes a concern in terms of the financial cycle. The research in SYRTO finds that a financial cycle can be identified as a separate cyclical component in time series of credit growth and house prices. However, the cycle is different per country and per asset class. This creates the need for information sharing between country-level experts and a macroprudential supervisor. The guidelines from the ESRB incorporate this intuition, by proposing countercyclical capital buffers in capital regulations for banks, which are switched on and off on a country-by-country basis.

Coordination between micro- and macroprudential tasks is important for stabilization (Chapter 4), in the areas of stress-testing, complexity and the policy maker’s loss function. In stress-testing (Section 4.4), microprudential supervisors need to coordinate with macroprudential authorities on the appropriate stress scenarios that not only stress a single institution, but include system-wide shocks and take potential channels of contagion into account. Done properly, stress tests are a good crisis management tool that benefits stabilization.

The complexity of the financial system (Section 4.7) might not always be clear from the microprudential view. The complexity of financial products and business practices of banks deserves specific attention from the microprudential supervisor. The complexity of interactions and causality chains should be on the radar of the macroprudential supervisor. The coordination between the two types of supervisors is necessary to obtain a comprehensive assessment of where the largest downside risks related to complexity are.

The policy maker’s loss function (Section 4.8) defines the trade-off between missed crises and false warnings. These are the typical type-I and type-II errors in statistical inference and, in the policy space, pose a specific challenge to the communication and interventions of the supervisor and regulator. At the one end is a missed crisis, which is obviously of great concern. But at the other end is the fall-out from too many false warning. Systemic risk instruments will be used frequently, and an actual crisis will seldom materialize. This could hurt the reputation of regulators. This is both a matter for the governance of systemic risk in general, as for the coordination between micro- and macroprudential responsibilities.

2 Prevention

Limiting the probability of systemic crises is a first step at mitigating systemic risk. Effective governance depends on the quality of early-warning models, and takes into account that a period of low volatility could be misleading. Moreover, future systemic risk triggers might be quite different than what we have observed in the past.

2.1 The accuracy of early-warning models for systemic risk

Although the severity and length of the financial crisis has been surprising, the fact that a large downward correction to asset prices and bank profits was coming, was largely predictable in the months leading up to the financial crisis. Such signals could be identified from a credit-fueled real estate boom in the US and several European countries, with large lending exposures by an overleveraged banking system. These are the typical indicators found in early-warning models as well, and several indicators signal stress in the system 2-3 months ahead.

Box 1 outlines the approaches that are taken for early warning models.

Box 1: Types of models for early warning of systemic risk

There are roughly three approaches for early warning models of systemic risk and we describe them below. A more detailed overview, describing 23 systemic risk models in use, is in Blancher et al. (2013).

Threshold models

Warning models for crises originated with the IMF in the seminar work of Kaminsky et al. (1998), who built a prediction model for currency crisis using intuitive indicators that were usually involved in the occurrence of a crisis. For example, exports, deviations of the real exchange rate from a trend, etcetera. Indicators are giving a 'warning signal' whenever their value exceeds a threshold level, e.g., the 95% highest or lowest level for that variable in the past. Combining the signals leads to a prediction of a crisis, 24 months in the future.

The approach of using threshold-exceedances as signals implies that a lot variability in, for example, the exchange rate, is not directly related to the crisis probability and can be seen as 'noise'. This explains the name of "Noise-to-Signal (NSR) approach" that is sometimes used.

Berg and Pattillo (1999) and Berg et al. (2005) show that the Kaminksy et al. model has some success in predicting actual crises in a dataset of 16 developing countries and works well compared to private sector models that were developed at roughly the same time.

In a similar vein, threshold models for systemic risk use macroeconomic and financial balance-sheet time series data that produce signals whenever the variable exceeds a threshold. The sum of the signals is the warning indicator. Borio and Drehmann (2009a) show that it works well in predicting banking system distress, including that of the United States in 2007/2008.

Arsov et al. (2013) examine the performance of threshold models where the signals come from several financial measures for the tail risk and interconnectedness of financial institutions, market volatility, liquidity risk etc.

In its flagship report (European Systemic Risk Board (2014)), the ESRB proposes to use “key indicators books” of systemic risks, including stress test results and estimates of the financial cycle. Ideally, each indicator carries a threshold level beyond which it signals a need for action (it ‘flashes red’). It observes the challenge to find thresholds that match policy makers’ preferences for missed crises vis-à-vis false positives.

Logit models

Standard techniques use a logit model, predicting crisis (yes or no) from a set of data. The logit model is a standard statistical approach to handle dependent data (that what needs to be explained) that only takes value 0 or 1. Such as a country experiencing a crisis in a certain period, or not. The benefit of using such a model is that a large set of input variables can be used to obtain coefficient estimates for the importance of variables. Statistical inference tells the user whether a certain variable significantly affects the outcome or not. The straightforward inference and interpretation of the logit models makes it the standard approach for testing the predictive value of novel and creative variables for crisis. See for example Billio et al. (2015a), who develop a systemic complexity measure (entropy) as an early warning signal and use the logit specification to test whether it can predict banking crises.

Data mining techniques

The most novel techniques use models from machine learning, such as used for image recognition, autonomous vehicles, handwriting and speech recognition. Such techniques start from a large test set that consists of correctly classified cases (e.g., cancer), and find patterns in the data (e.g., MRI scans) upon which predictions in a validation set are generated.

The machine learning algorithms such as regression trees and cragging aim at finding partitions of the data where a small set of variables explains the occurrence or absence of a crisis. The results are promising, giving better predictions than traditional logit-regression models, see Savona and Vezzoli (2015), Savona (2014), Manasse et al. (2013). The resulting tree-structure (a partition of the data in several regimes) can be interpreted as showing the ‘states of the world’ for which different relationships are relevant.

Insofar machine-learning algorithms lead to decision trees, it has intuitive advantages to threshold or logit models: depending on the type of country and economic situation, different dynamics could be indicators for a systemic crisis. For example, the resulting tree in Manasse et al. (2013) identifies two different regimes in which banking crises occur in emerging markets: a “Latin American type”, resulting from the combination of a (past) credit boom, a flight from domestic assets, and high levels of interest rates on deposits; and an “Asian type”, which is characterized by an investment boom financed by banks' foreign debt. For regulators and policy makers, the output from such machine learning algorithms can clearly complement economic analysis.

Not all machine-learning algorithms lead to directly interpretable results, and some of the best algorithms result in a 'black box' predictor. This is a major drawback of some approaches and requires constant attention from the modeler, i.e., the balance between interpretation and performance.

The ECB's MARS working group (see Alessi et al. (2015)) has performed a comparison ("horse race") of different prediction models to evaluate which ones work best in predicting banking crises. Their approach is not free from biases, as the models are estimated in sample, and the participating authors use slightly different datasets. The results are nonetheless insightful for the range of performance accuracy that can be achieved.

1-3 years horizon	Missed crises (%)	False alarms (%)
Baltussen et al.	12	31
Bush et al.	38	36
Antunes et al.	40	4.65
Neudorfer, Sigmund	8.9	2.3
Kauko	79.3	1.44
Behn et al.	5.6	24.7
Babecký et al.	5.6	34.8
Joy et al.	3.2	12.8
Alessi, Detken	38	4

Table 1: Crisis prediction performance

Source: Table adapted from Alessi et al. (2015). Based on 4-12 quarters-ahead prediction. The studies have slight differences in the exact sample data that is used for calibration and prediction.

Table 1 shows that the best algorithms miss banking crises only in 3.2% (Joy et al.) or 5.6% (Behn et al. and Babecký et al.) of cases. That corresponds to a forecasting accuracy of 96.8% and 94.4%, respectively. This seems a phenomenal performance, but comes with a number of caveats and lessons for policy makers.

First, the best predictors also raise false alarms in between 13% and 35% of cases, one to three years prior to a crisis. These are considerable percentages and lead to challenges for policy makers: the occurrence of false alarms can undermine the credibility of the supervisory institutions, which can hurt their effectiveness in implementing measures aimed at mitigating the fall-out of a crisis. We discuss this in more detail in Section 4.8, on the policy maker's loss function. The loss function weighs missed crisis against false alarms and is one of the parameters in the model of Alessi and Detken (2011).

Second, the outcomes of Table 1 are in-sample, which means that the predictions are made using a model that is estimated on the same sample. As such, it can be seen as an exercise in finding out which variables are most correlated with crises *in the past*. The nuanced interpretation of the horse-race is that, looking back, 95% of banking crises had a warning signal in advance.

Clearly, one would like to know if models estimated on past data could also predict future crises. Statistically, such tests would be carried out by using a test sample for the estimation of the model, and a validation dataset to check the performance beyond the initial test set. For example, banks are obliged by the regulator to perform such tests when making their risk models. The IMF has surveyed the performance of its EWS for currency crises in the same way. However, the statistical procedure is no guarantee that the model with work in the actual future (starting today, so to say).

Given the general limitations of using historical data to predict the future there is still an important lessons to learn, which is that there is room to actively oppose "this time is different" thinking. As Reinhart and Rogoff (2009) have shown, many crises follow similar patterns. But the fact that countries and times are different is quite easily used to defend a position that action is not necessary, because the historical patterns are not valid for the present situation. Pushing back to such thinking by pointing to empirical evidence should be part of a skeptical approach to "new era thinking" (Shiller (2015)) where overly indebted banks or inflated asset prices are taken for granted. The resilience of the financial system would increase if it least the lessons of the past are incorporated in its functioning.

Third, when interpreting early warning model outcomes, we should take the history bias into account: Several factors to the financial crisis were unique and not likely to be repeated in the same way. For example, the persistent decline in the long-term interest rate over the past thirty years was unexpected and played a large role in the building up of financial imbalances that partly led to the financial crisis, see Council of Economic Advisers (2015). Moreover, an early-warning model is estimated based on crisis data where crises actually happened. The early warning signals associated with crises that were averted because of adequate action show up as ‘false signals’.

Finally, the potential for spotting crises suggest that trends matter. Financial and banking crises are unlike seismic activity, where only the general frequency and magnitude are known. In the financial system, imbalances build up over time and can be spotted. New risks might not be in an early-warning model, but the models do teach us that there is time to spot trends that could lead to economic disaster. In Section 2.3 we offer some suggestions of where new systemic risks could lie, which might not be captured in the current early-warning model.

The above holds an important lesson for the governance of systemic risk: In developing governance structures, one should take into account the potential for false warnings. If the macroprudential supervisor is the central bank, its authority might be questioned if too many interventions are perceived as unnecessary, ex post. This requires good communication. Or, the macroprudential and monetary roles of the ECB need to be clearly distinguished. We further discuss this in Section 4.8.

2.2 Using market-implied volatility as a warning signal

> "Uniform succession or coexistence has been a cause of our expecting the same succession or coexistence on the next occasion" - Bertrand Russell

At the height of the financial crisis of 2008/2009, it appeared that we experienced a 'Minsky moment', after Hyman Minsky, who claimed that financial bubbles are inevitable in a modern economy. Given that investments have inherently uncertain cash flows, he postulated a theory whereby initially sound investments led to overinvestment in booming sectors, resulting in speculative investing that becomes disconnected from economic fundamentals, see Minsky and Kaufman (2008).

In Minsky's frame, the speculative phase builds on the recent profitability of sectoral investments or technology, which has seen good growth and low risk. Such patterns lead to an inflow of money from investors who perceive the trend to continue for quite some time in the future. However, the historical record also influences the supply side, where projects of lower quality than the original investments are sold to investors as being similar in growth prospects. On a small scale, such effects were visible in the IT bubble of 2000: riding on the back of successful tech IPOs, new companies came to the market with much less earnings potential. They resembled initially profitable ventures, but turned out to be hugely speculative.

Given the generality and timescale at which Minsky's theory plays out, formal testing is hard. But the idea is tantalizing: could it be that a period with good growth and low volatility creates the conditions for speculative finance and a subsequent crash? It could be that the period before 2007 was exactly that. Box 2 reviews the phenomenon that many systemic risk indicators were at their *lowest* right before the onset of the financial crisis.

Box 2: Empirical evidence for the low volatility paradox

We give three examples of measures that aim to capture systemic stress and are at their lowest point just before or during the 2007/2008 credit crisis.

Banking stability index

Schwaab et al. (2011) compute several indicators of financial distress, one of which is the banking stability index. It measures the expected number of bank defaults, given one default. It is also used by Hartmann et al. (2005) and Segoviano and Goodhart (2009). Schwaab et al. compute it from the common variation in expected default frequencies of financial firms as provided by Moody's KMV CreditEdge. Moody's compute expected default frequencies (EDF) from bank equity values and balance sheet data.

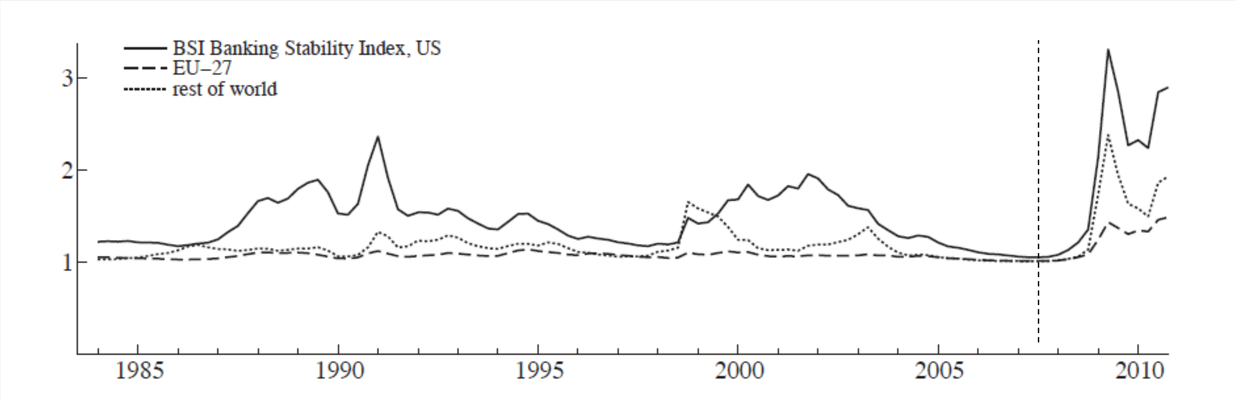


Figure 2: Banking stability index

Source: Schwaab, Koopman, Lucas (2011). This figure shows the expected number of financial defaults over a one year horizon conditional on at least on default occurring. Financial firms comprise banks and financial non-banks. The dashed vertical line is mid-2007.

From the graph we see that the banking stability index for the US has never been as low as in mid-2007. The rise in the measures for all three areas after 2008 illustrates the stress in the banking system for that period. The apparent stability of banks right before the crisis follows from the low volatility in their equity returns, which is one of the important inputs for computing EDFs.

Financial system variance

Billio et al. (2012) perform a principal component analysis of the monthly standardized returns of individual hedge funds, broker/dealers, banks, and insurers over January 1994 to December 2008. Figure 3 shows the system variance from the GARCH(1,1)-model estimated for the first principal component.

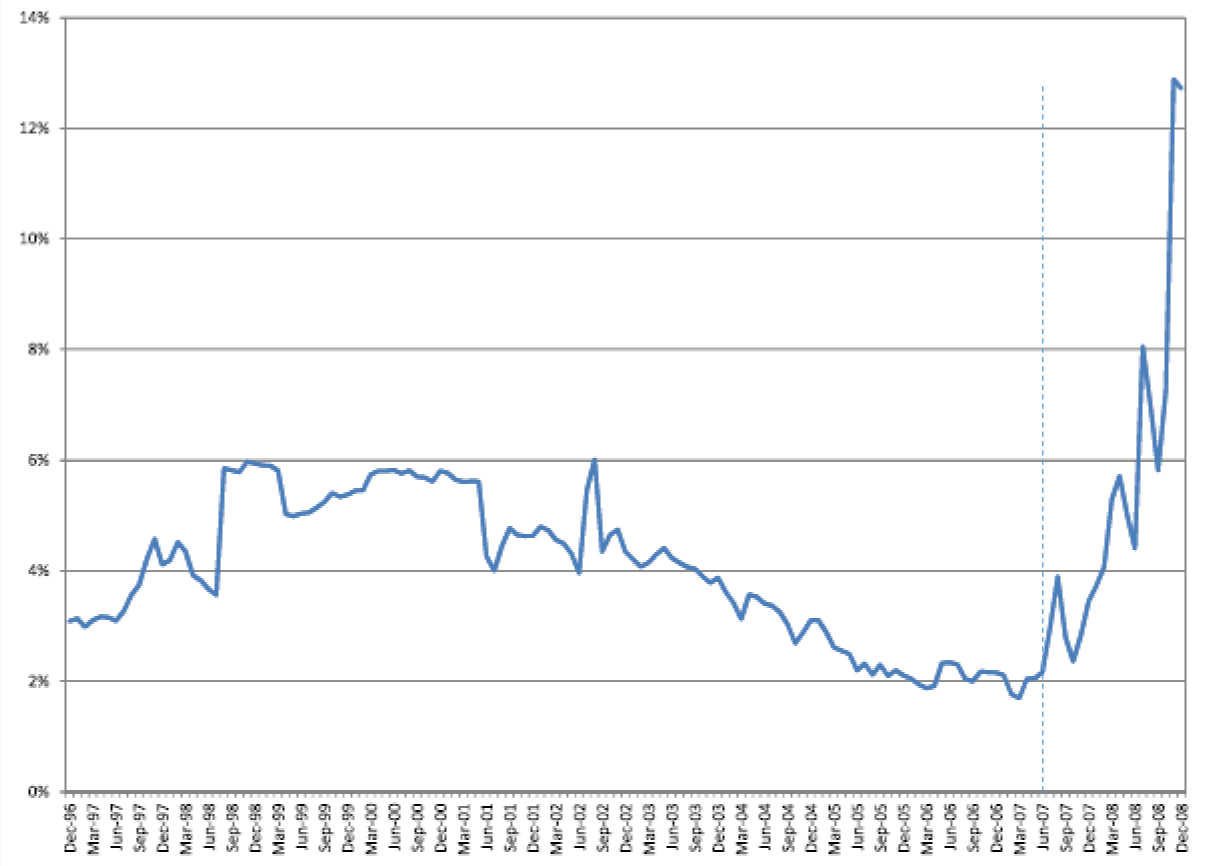


Figure 3: Financial system variance

Source: Billio, Getmansky, Lo and Pelizzon (2012). The figure shows the system variance from the GARCH(1,1)-model estimated for the first principal component. The dashed vertical line is at June 2007.

The almost continuously descending line of financial system variance from 2002 to 2007 fits in the framework of Adrian and Shin (2010), who describe a simple model of leverage financial institutions under risk-based regulation. The risk-based aspect implies that capital is proportional to historical risk, which leads to feedback loops in trading: an initial increase in asset prices improves the balance sheet of an institution. If the increase is repeated, perceived risk seems to be small. The improved balance sheet and decrease in risk (for example, VaR) lead to buy pressure in the asset. This becomes a self-sustaining loop. In a sense, the risk-based regulation in Basel I and II seems to invite this behavior, so that a "Minsky moment" becomes inevitable.

Downside macroeconomic risks

Giglio et al. (2015) compute 23 measures to infer downside macroeconomic risks. Figure 4 is from their paper, showing 6 out of 23 measures: default spread, DCI[3], market leverage,

[3] DCI is the Dynamic Causality Index (DCI) from Billio et al. (2012) which counts the number of significant Granger-causal relationships among bank equity returns.

volatility, TED spread and a turbulence[4] measure. Measures are scaled by their variance for comparability. At the point where the financial crisis started (Oct. 2008) the measures are not at their highest level. Rather, some are at the lowest point in decades.

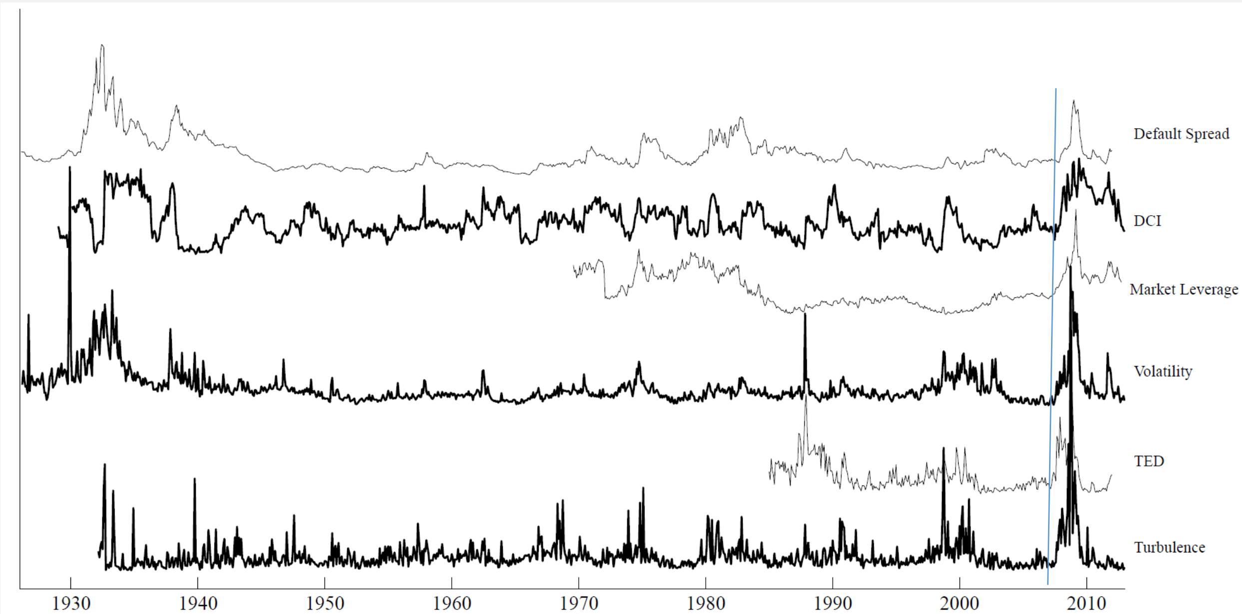


Figure 4: Systemic risk measures

Source: Giglio, Kelly and Pruitt (2015).The figure shows the default spread, dynamic correlation index, market leverage, volatility, TED spread and turbulence over time. The vertical line is at June 2007.

As shown in Box 2, early warning signals for the global financial crisis as developed and analyzed in the SYRTO research find that (i) a buildup of risk in the system was visible in the increased complexity and low-priced risk, (ii) estimates for systemic failure are mostly at their lowest point right before the start of the crisis, i.e., in 2006 or 2007.

The financial crisis has given renewed interest in the flaws of macroeconomic models. Particularly, the absence of a financial sector with frictions. Brunnermeier and Sannikov (2012) and Boissay et al. (2014) describe the "volatility paradox" whereby which *systemic* risks are highest when *measured* risks (such as, for example, the U.S. VIX) are particularly low. For example, in Boissay et al. (2014), a stochastic growth model with a financial sector can have a banking crisis that typically results from an unusually long sequence of small, temporary productivity shocks. Borio and Drehmann (2009b) call this the “paradox of financial stability".

It is possible that the low-risk anomaly was a one-off event. Market participants might have learned from the financial crisis, and are pricing in systemic risks. If so, stability measures based on market data might become more informative value in the future. Such an effect was seen in

[4] The Kritzman and Li (2010) turbulence measure of excess volatility for financial institutions, defined as the realized squared returns divided by their historical volatility.

option prices after the stock market crash of October 19, 1987 (Black Wednesday). There is evidence that after 1987, put options started to display a sharp volatility "smile" for the first time, see Benzoni et al. (2011). The arrival of a large shock leads to new beliefs among market participants who update their estimate of the likelihood of market crashes. Similarly, it could well be possible that eyes have been opened on the systemic vulnerabilities of the financial system, and market prices have been reflecting those risks ever since.

The evidence of the low-risk anomaly points to a fruitful line of research, which is to consider the difference between fundamental-based and market-based measures of risk as an indicator of systemic problems. For example, Schwaab et al. (2014) find that the unexplained part of realized defaults was at its minimum in 2006. The low defaults could be sustained by increasing asset prices and the availability of credit, a similar effect as the one at work in the US housing market prior to 2006. Thus, an exceptionally low default rate is indicative of an impending crisis. López-Salido et al. (2015) find evidence that elevated credit-market sentiment is predictive of a decline in economic activity, two years ahead.

From a systems perspective, the exceptional financial market stability and underpricing of risk in the period 2003-2007 can be viewed as a period of increasing complexity and tight coupling of a dynamic complex system. In Section 4.7 we discuss this way of looking at the financial system and the consequences for policies aimed at stabilization.

The low-volatility paradox holds a lesson for the coordination of micro and macroprudential supervision. From the microprudential perspective, low recent volatility translates implies low risks and low capital requirements. However, based on the evidence above, the macro-risks could be at their highest, and action might be warranted. In essence, risk-based regulation has the potential to stimulate feedback loops of asset purchases and declines in perceived riskiness, which is ultimately de-stabilizing. This problem of risk-based regulation being dependent on recent volatility is well-known and outlined in for example Danıelsson et al. (2004).

One solution to mitigate procyclicality is to have a countercyclical capital buffer that moves with the credit cycle, and is higher for systemically important institutions. The higher capital in good times reduces credit growth while at the same time providing a larger buffer to absorb losses in bad times. An issue remains whether the mechanism of the countercyclical capital buffer is strong enough to counter the cyclical behavior of risk appetite.

2.3 Systemic risk triggers on the horizon

We discuss some potential future triggers of systemic risks that appear in the literature. None of them will trigger a crisis for sure, but it should stimulate our thinking about where dangers lie.

2.3.1 Central clearing counterparties

Central clearing counterparties (CCCPs) have been introduced on banks to mitigate counterparty risks and to make the trading in former over-the-counter (OTC) derivative contracts more transparent and standardized. Duffie et al. (2015) finds that CCCPs have led to an increase in collateral, which seems a good thing.

A potential source of systemic risk is the risk that the CCCP itself collapses, if one of the participants suffers a large shock. Borovkova and El Mouttalibi (2014) simulate several network structures of participants in a CCCP that could arise in practice, and find that this risk is real for some configurations of the network. In addition, a CCCP might run risks if many participants perform similar trades. This risk of "crowded trade" could be a new systemic risk, see Menkveld (2015).

A related issue is the question whether a liquidity squeeze might be caused by implementation of Credit Value Adjustments (CVA) in derivative contracts, as introduced in Basel III. With a CVA, the net position of a derivative contract needs to be pledged as margin with the CCP. When the counterparty defaults, the collateral is sufficient to cover the loss. But this transforms counterparty (credit) risk into the liquidity risk of having to provide margin at the worst possible time, see Economist (2015). I.e., a bank might find itself at the negative end of a trade and have enough capital but not enough liquidity to post margin. In effect, this creates the potential for a liquidity crisis, just like the one observed during the 2008/2009 financial crisis. The short-term funding problems of special purpose vehicles now become short-term funding problems of the credit value adjustment.

2.3.2 Contingent convertible bonds

Given the increased capital requirements, banks have been issuing near-capital, such as contingent convertible bonds, see Flannery (2010). These are debt securities that convert to equity when a specific trigger is reached. The trigger can be a certain level of capital, or a share price. Regulators accept these instruments as part of the loss-absorbing financing of banks, see Avdjiev et al. (2013). McDonald (2013) reviews the aspects of designing contingent convertibles, like the choice of trigger and susceptibility to manipulation. For example, there are opportunities for a bank to trigger the conversion of CoCos opportunistically, see Berg and Kaserer (2014).

Although CoCos provide extra loss-absorption of banks, systemic risks could be actually be increasing through their use by banks. First, contagion in the banking sector is increased if banks hold CoCos of other banks on their books. We cannot find hard evidence that banks are having them, but it could well be the case and deserves regulatory attention.

Second, Chan and Wijnbergen (2014) argue that CoCo conversion gives a negative signal about bank assets. If these assets have features in common across banks, this could trigger a reduction in trust in other banks as well. In this way, CoCos can lead to new channels of contagion.

Third, Koziol and Lawrenz (2012) argue that the extra protection provided by CoCos could lead to risk-shifting behavior by the banks' managers, increasing the risks for the banking system as a whole.

The use of CoCos by banks requires coordination between micro- and macroprudential supervision. Microprudential supervision might need to treat the contingent capital with caution. Stress tests should include a second-round effect of CoCos being triggered, i.e., the feedback loop of the triggering of the CoCo of one bank to other banks. Macroprudential supervision should monitor the use of CoCos in the financial system and work through stress scenarios using bank data and actual trigger points. In the same light, having good, i.e., complete, timely and accurate) data on CoCos is key. Having data from multiple banks will make it possible for the supervisor to run simulations for the whole system, to assess systemic risks.

On the upside, De Spiegeleer et al. (2015) show how CoCo prices can be used to derive implied volatilities for banks' Common Equity Tier 1 (CET1) ratio. The outcomes can be used to infer market-implied probabilities of the CET1 dropping below a certain level. And they can provide information on the severity of stress scenarios, relative to the scenarios of the ECB. In this way, CoCos can contribute to a finer picture of market estimates of stress and default risk of financial institutions.

Note that systemic problems are not limited to contingent capital, but also appear for the normal unsecured funding. As explained by Hanson et al. (2011), the debt overhang problem and the externalities associated with excess reliance on short-term funding have been drivers of systemic risk. The new regulations on higher-quality capital and improved liquidity aim to deal with this problem.

2.3.3 Systemic risk in non-bank sectors

The financial crisis started in and transmitted through the banking sector. One non-bank institution that played a significant role, however, was an American insurer, AIG. It had developed a large financial insurance business, and turned out to be the counterparty to many CDS contracts. Its systemic relevance was recognized by the US treasury, who bailed out AIG with $182 bln. of capital.

As documented by Koijen and Yogo (2013), many insurers resort to "shadow insurance" to decrease capital requirements. Using some regulatory loopholes, insurance companies transfer insurance risks to related entities that have to hold less capital. This increases the profitability of the insurer (in terms of return-on-equity), but it increases the risks of the insurer in a non-transparent way. This could pose a new systemic risk.

Another systemic vulnerability posed by the insurance sector functions through the asset channel. Insurers are active in many asset markets, their own financial performance could impact asset prices and have a knock-on effect with other institutions, see Schwarcz and Schwarcz (2014). Insurers and banks have many crossholdings of each other’s securities and the failure of an insurer can pose a systemic trigger to the system as a whole.

Finally, a negative shock to insurers could translate into significantly lower payments to insured customers. This does not necessarily lead to multiple failures of financial institutions, but it does pose a risk that starts in the financial system and ends up with grave real economic consequences.

3 Mitigation

In this chapter we trace the challenges that arise from the need to limit the transmission of systemic shocks. We start with the financial cycle, which might explain the occurrence of systemic problems over time. Then, we look at the evidence on how to determine which institutions are systemically vulnerable.

3.1 Managing the financial cycle

Given the tides and seasons, it is quite natural to observe cycles in other areas of our existence. In economic life, this has led to the development of theories for the 'business cycle', the fluctuation of real economic growth which seems to follow a cycle of approximately seven years. Other cycles have been proposed in the past, such as the Kuznets infrastructural cycle (20 years) or the Kondratiev technological cycle (50 years), but they have gone out of fashion. However, since the financial crisis a new cycle has gained attention from researchers and policy makers: the financial cycle.

Systemic shock transmissions depend on the state of the financial system. If leverage is high, institutions are more vulnerable. A strong growth in house prices might lead to overvaluations. These considerations are summarized in the notion of the 'financial cycle'. The financial cycle represents the up- and downswings in the financial system in terms of credit and asset prices.

Econometric work on the financial cycle in the US finds that house prices, credit and credit-to-GDP share a similar type of cycle, with a length of around 15 years, twice that of the typical business cycle average (7/8 years), see Box 3.

Box 3: Financial cycles across countries and measures

The financial cycle captures systematic patterns in the financial system such as credit growth and asset prices. The essence of cyclical behavior is that highs and lows occur with a regulator frequency, and the speed of change is highest in the intermediate (average) state. For most economic variables, such behavior is not observed, as they are either (i) random walks, moving freely up and down, such as stock prices, or (ii) mean-reverting, so that the direction of change is always in the direction of the equilibrium state, such as inflation or interest rates.

An important consequence of economic cyclical behavior is that there is no stable point: the system always moves from a high to a low. Detecting whether such a cycle exists in the financial system is therefore quite important, with the ultimate goal of finding means to control or dampen it.

There is evidence of a systematic link between house prices, credit and real economic growth, see Igan et al. (2009) that peaked just before the onset of the financial crisis. However, it is not clear whether the cycles of house prices and credit are identical. Also, cycles might be different per country. Both questions are important for policy makers who might want to apply macroprudential instruments based on the state of the financial cycle.

The paper by Galati et al. (2015) analyzes the characteristics of financial cycles using a multivariate model-based filter. It tests whether cycles in house prices and credit are similar, per country. Figure 5 below is from their paper and gives a graphical representation of their results.

From the figure, we observe that cycles differ per country. The paper suggests that, due to data limitations, it is too early to draw any definitive conclusions regarding the behavior of financial cycles. For example, for the United States they find that the financial cycle is quite pronounced in the last 20 years, but less so in earlier periods. Given all recent changes in financial markets, these features may very well change again.

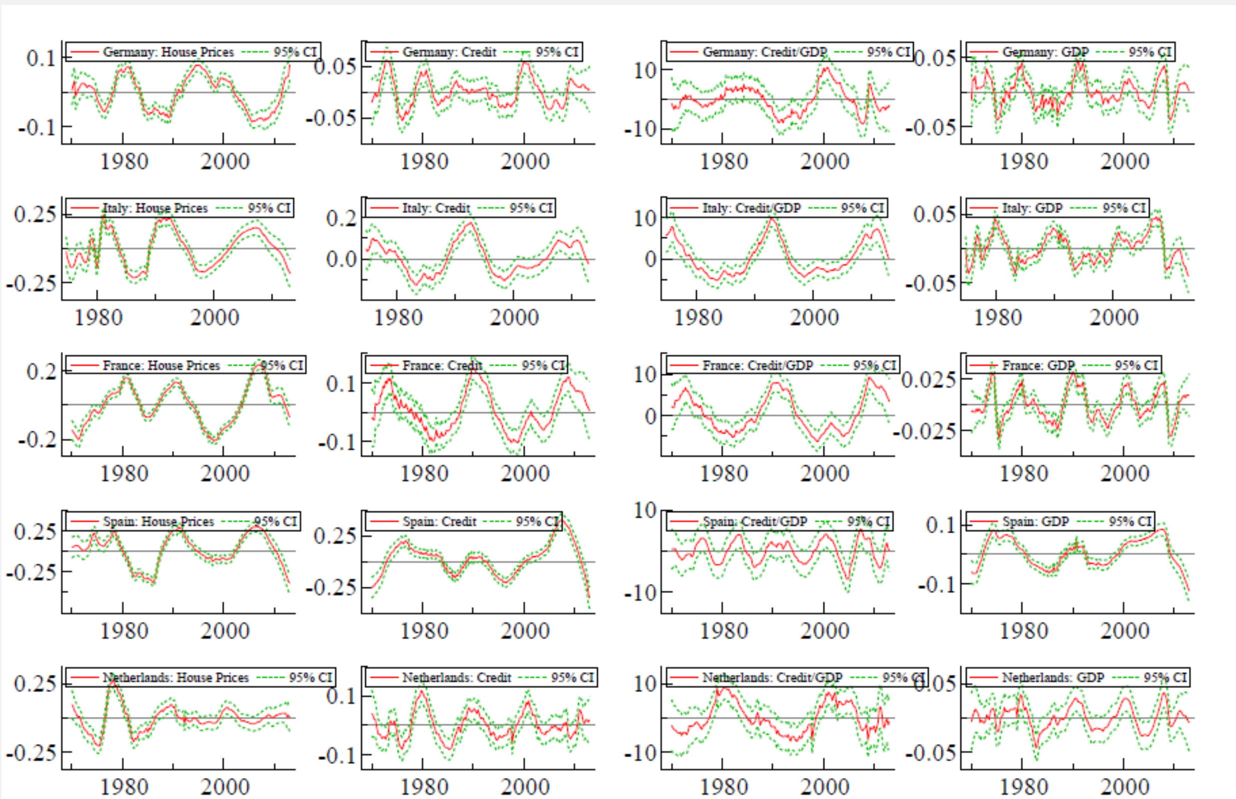


Figure 5: Univariate cycle estimates of Germany, Italy, France, Spain and The Netherlands
Source: Galati, Hindrayanto, Koopman, Vlekke (2015). The figures show the cyclical component over time for house prices, credit, credit-to-GDP, and GDP, respectively per column. The countries are in rows.

Schüler et al. (2015) find similar cycles and significant differences across countries, but with more similarities between the business cycle and the financial cycle.

In its current form, the financial cycle was first proposed by Borio et al. (2001), who hypothesized that the large swings in the state of the financial sector might follow a cyclical pattern. Given the increased importance of the financial sector (a larger share of GDP), the financial system might be contributing to the amplitude of the economic up- and down-swings.

The UK evidence suggests that the swings in the financial sector have become larger over time, see Figure 6. Between 1920 and 1970, banks' equity return is low on average, with low volatility. After 1970, both the average and the volatility are high.

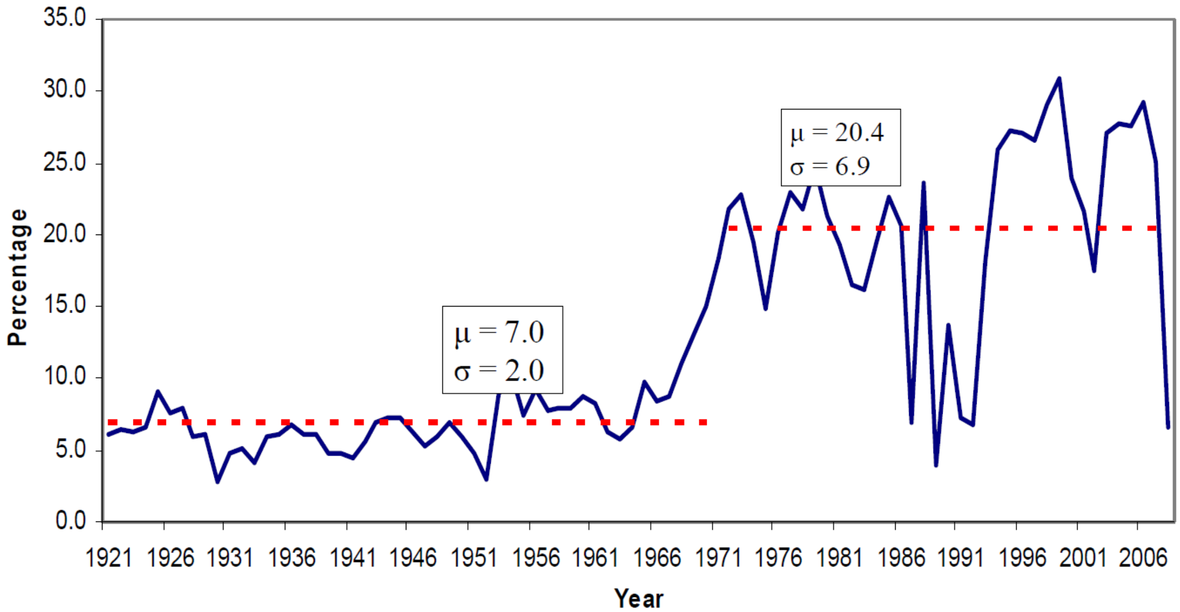


Figure 6: Return on equity in UK finance 1921-2008

Source: Haldane and Alessandri (2009). The figure shows the average return on equity in the UK banking sector over time. The means are shown in dashed lines, separately for the period 1921-1970 and 1971-2008. The mean and standard deviation per period are shown in the graph.

The research into financial cycles has developed up to the point that it has been translated into concrete policy actions by the ESRB, see European Systemic Risk Board (2014). It recommends monitoring credit growth rates and asset price appreciations and applying suitable macroprudential instruments when the cyclical component is rising (too) fast.

Based on evidence for the United States, Elliott et al. (2013) suggests that macroprudential policy can be effective in limiting consumer debt. However, the evidence in Box 3 shows different country-specific patterns. This leads to three implications for policy.

First, there could be a rational, fundamental reason for asset price appreciations that are permanent. In the econometrics of detecting a cycle, this is the long-run growth term. For example, house prices that have been appreciating for fundamental reasons (foreign investors, increase in female labor market participation) are not expected to reverse, as in a cyclical pattern. Thus, Schwarcz (2014) suggests that using financial cycle-theory for macroprudential policy might fail because of the difficulties of identifying bubbles before they burst. This is the classic dilemma that has faced central bankers before, in the situation of rapidly increasing stock prices or real estate prices.

Second, financial cycles are not similar per country. This creates a problem for regulators in the Euro area who would want to intervene with Euro-wide measures. Instead, regulators could measure country-specific cycles and work with predefined rules that are applied based on the state of the financial cycle. Moreover, we cannot expect macroprudential policies to replace monetary, fiscal policy, or industrial policy. The knowledge of the interlinkages between financial stability, banks, and growth is too limited for attempting to use macroprudential policy for fine-tuning the credit cycles, see Lopes and Quagliariello (2014).

Third, macroprudential policies could increase the risk in the shadow banking sector, i.e., the part of the financial system that is not regulated in the same way as banks (hedge funds, private equity firms, etc.), see Schwarcz (2012) and Schwarcz (2013). Unregulated institutions might take up the risks that become too expensive for banks to carry on their books, because of capital requirements. But the overall risk in the financial systems remains unchanged, with potential systemic consequences.

The existence of shadow banking suggests that effective governance of systemic risk needs an assessment of risks that accumulate outside the regulated institutions. A requirement of providing data to a central supervisor would improve the systemic oversight, without having to cast an ever increasing net of regulation, i.e., on institutions that are currently not regulated. Focusing on transparency could be a sensible choice given the cost-benefit trade-off of outright regulation.

3.2 Identifying systemically important institutions

> In hindsight, I think there have been some systemic situations prior to this one that were not classified as such. The failure of IndyMac pointed the focus to the next weakest institution, which was WaMu, and its failure pointed to Wachovia, and now we're looking at Citi and I wonder who's next. I hope that all of the regulators, all of us, including Treasury and the Fed, are looking at these situations in a balanced manner, and I fear there has been some selective creativity exercised in the determination of what is systemic and what's not and what's possible for the government to do and what's not.
>
> John Reich, director of the Office of Thrift Supervision (OTS), Nov. 23, 2008, as quoted in Financial Crisis Inquiry Commission (2011).

The financial system exists of institutions, of which some are more important than others. One approach to improve financial stability is to identify systemically important institutions. These are institutions for which shocks have a wider impact on the system and on the economy. If they can be identified early on and made more resilient, the whole system benefits.

The literature distinguishes between institutions that are most vulnerable to systemic shocks and those that are contributing the most to systemic risk. For the policy orientation of this paper, we focus on the latter, i.e., contributions to systemic risk.

Starting in 2008, the policy approach has been to consider institutions that are particularly large, interconnected or leveraged. The Basel Committee on Banking Supervision (2014) provides the methodology for determining globally systemically important institutions (G-SIBS), see Figure 7.

Indicators and their weights — Table 1

Category	Indicator	Line item	Indicator weight
Size	Total exposures[1]	2o	1/5 = 20%
Interconnectedness	Intra-financial system assets	3f	1/15= 6.$\bar{6}$%
	Intra-financial system liabilities	4g	1/15= 6.$\bar{6}$%
	Securities outstanding	5i	1/15= 6.$\bar{6}$%
Substitutability/financial institution infrastructure	Payment activity	6n	1/15= 6.$\bar{6}$%
	Assets under custody	7a	1/15= 6.$\bar{6}$%
	Underwritten transactions in debt and equity markets	8c	1/15= 6.$\bar{6}$%
Complexity	Notional amount of OTC derivatives	9c	1/15= 6.$\bar{6}$%
	Trading and AFS securities	10f	1/15= 6.$\bar{6}$%
	Level 3 assets	11a	1/15= 6.$\bar{6}$%
Cross-jurisdictional activity	Cross-jurisdictional claims	12c	1/10= 10%
	Cross-jurisdictional liabilities	13d	1/10= 10%

Figure 7: Indicators and weights for determining G-SIBS.

Source: Basel Committee on Banking Supervision (2014). The table gives the weight for each factor that is to be used in computing the overall systemic importance of an institution.

The approach is based on indicators (see Figure 7) that each contribute to a total risk score. The score determines the amount of extra capital that an institution on the G-SIB list needs to hold.

The first category, size, obtains the largest weight (20%) in the G-SIB score. This seems sensible, as research shows that size is one of the most dominant predictors of systemic risk impact. For example, Drehmann and Tarashev (2011) find that bank size approximates three model-based measures of banks' systemic importance. Moreover, Benoit et al. (2015) find that the systemic risk orderings of institutions obtained from risk based measures such as SRISK and ΔCoVaR, are very well approximated by simpler measures such as Beta and Value-at-Risk. Nucera et al. (2015) find that beta times market value leads to the most stable ranking of financial institutions, before and in the crisis.

From the econometric research, interconnectedness is found to be contributing to systemic risk, as more the most central institutions, i.e., those with the most links to other institutions, have the largest effect on the whole system, see Billio et al. (2012), Bianchi et al. (2014), Hautsch et al. (2015), Blasques et al. (2014) and De Bruyckere (2015).

4 Stabilization

The stabilization of the European banking system has required change and innovations in institutions, regulation, supervision and crisis management capabilities. We review the evidence on what contributes to financial stability and the open questions that remain.

4.1 Fiscal fragilities coordination

As a response to the financial and Euro-crisis, countries in the Euro-area have implemented austerity measures to prevent government finances from running out of control. The implementations of the fiscal measures and reforms have been advocated by the ECB and are implied by the agreements in the Stability and Growth Pact (SGP). This is effectively a coordination of fiscal policy with a common goal of debt sustainability. It remains a question, however, to what extent the coordinated fiscal discipline has increased the stability of the Euro area.

Manasse (2015) argues that the fiscal measures have made budget deficits more similar across countries, but at the costs of divergent unemployment and growth numbers. The reason is that prices and wages are inflexible: austerity measures and do not result in lower wages, but in higher unemployment. Moreover, the extent of the rise of unemployment is stronger for countries that had an inflexible labor market to begin with, see Manasse and Baldini (2013). So, the countries with initial labor market distortions are hit harder by fiscal consolidation than others. This leads to a divergence in the development of unemployment in the Euro zone, which can lead to an erosion of support for the Euro. Billio et al. (2015b) finds similar results, in terms of the sensitivity of growth to the US economy, which is markedly different per country.

One source of debt dispersion, the recapitalization of banks, is removed with the introduction of the banking union, see the other subsections below. With Euro-wide supervision and coordination of bailouts, the heavy and dispersed burden of dealing with failing banks has become a common responsibility and stability is enhanced, see Goodhart (2014). This is a start to mitigate fiscal fragilities.

Addressing divergence in unemployment is hard, but a few solutions are offered. The solution advocated by Manasse is to introduce a simpler mechanism that stimulated countries to enact structural reforms. A corrective arm sets final targets for consolidation in the short term that are understandable to voters and have the largest external effects on the other Euro countries. The preventive arm of the mechanism monitors budget deficits as early warning indicators of solvency problems, see Manasse (2014).

Others propose a Euro-wide unemployment insurance scheme to limit shocks caused by the single monetary policy, see Dullien and Fichtner (2013), Pisani-Ferry et al. (2013). However, such a scheme might not be politically feasible, given the sensitivity of tax collecting on a European level. A more realistic approach would be to focus on limiting labor market distortions, decreasing the gap between insiders and outsiders and reducing youth unemployment, see Kirkegaard (2014). This form of coordination could lead to more convergence in unemployment in the Euro area and mitigate the fiscal fragilities in the Euro area.

4.2 Liquidity Support for European Banks

One measure of the healthiness of the banking is the extent to which banks use the deposit facility of the ECB. Before October 2008, this facility was virtually unused, as the deposit rate is always lower than the lending rate, so users of this facility are putting their money there at a loss. The use of the deposit facility signals banks' unwillingness to lend money to other banks and thus becomes a measure of aggregate trust in the banking system, by banks themselves. Figure 8 below shows the use of the deposit facility from January 2007 until August 30, 2015.

To alleviate stress in the banking sector, the ECB applied an unorthodox monetary instrument, Long-term Refinancing Operations (LTRO). This had the effect of injecting liquidity in the banking system, with the expectation that banks would start functioning normally. Figure 8 below shows the evolution of the ECB's balance sheet since January 2007.

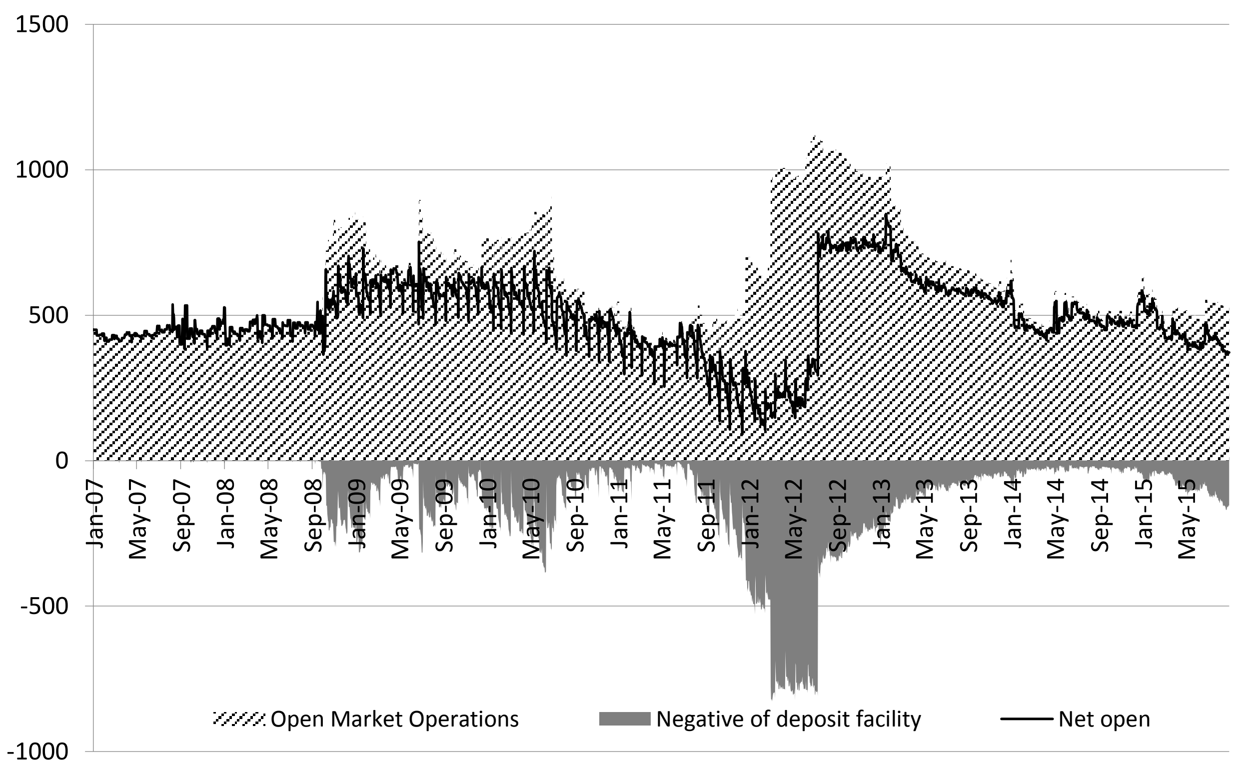


Figure 8: Lending operations of the ECB (bln €)

The dashed upper area shows the amount of open market purchases by the ECB. The dark area shows the use of the deposit facility by banks (negative, for readability). The solid line is the net open position.

The downward spikes (in dark grey) show the extent to which the deposit facility is used. The largest use is in 2012, with a large increase on March 1, 2012, when the ECB lent €1019 bln to banks via its LTRO operation. A marked drop in the use of the deposit facility is on July 11, 2012, from 808 bln to 325 bln. This is the day after the ECB decreased the deposit rate from 0.25% to 0%.

ECB interventions might have had some drawbacks as well: at least some banks in GIPIS countries have used LTRO-financing to buy bonds of their home countries, profiting from a “carry trade”, see Acharya and Steffen (2015). This implies that regulatory arbitrage was at work (through the zero risk weight for sovereign bonds), and banks were increasing systemic risk by strengthening their ties to their home country.

4.3 Stabilizing the Sovereign Bond Market

The need to intervene in the sovereign bond market during the European crisis was clear: (i) the ECB’s monetary policy was not effective in mitigating deflation and stimulating growth, (ii) countries were at risk of paying excessive interest rates due to market expectations of continuing crisis or default.

Two programs were aimed at sovereign bonds: the Securities Market Program (SMP) and the Outright Monetary Transactions (OMT). The literature suggests that these programs were successful: both yields and volatility of yields declined, see Ghysels et al. (2014) who analyze the effectiveness of the Securities Market Programme (SMP). Krishnamurthy et al. (2014) find that the direct purchase of bonds through the SMP and OMT had a significant impact on sovereign bond yields, while the effects of LTRO are small.

The introduction of the ECB's LTRO program, having the objective of providing short-term liquidity to banks, shows that the channel from bank bailout to sovereign risk (described by Acharya et al. (2014a) can be reversed: offering liquidity to banks may improve the market liquidity of sovereign bonds and also indirectly reduce sovereign risk, see Eser and Schwaab (2015), Breckenfelder and Schwaab (2015).

Pelizzon et al. (2013) find that, in Italy, once credit spreads got below 500bps, liquidity of the sovereign bond market improved markedly. Given that 500bps is close to the investment grade bonds, investor risk appetite matters for the effectiveness of ECB actions. Moreover, after the ECB interventions, the link between credit risk and liquidity disappears.

It turns out that fears about inflation, as articulated by Eggertsson and Woodford (2003) were not vindicated. They suggested that a commitment to higher future inflation would be effective in avoiding deflation. This is in line with conventional wisdom before 2007, as a former central banker said “if you had asked me whether expanding the monetary base times 100 (US) or times 10 (EU) would not be enough to prevent deflation, I would not have believed it”.

At the same time, the exact channels through which QE work, are not clear. As former Fed president Ben Bernanke quipped (Financial Times, Oct. 13, 2014): "the problem with QE is that it works in practice, but it doesn’t work in theory".

The banking crisis led to a situation of recession and excess debt, which obviates the need for government intervention, see Eggertsson and Krugman (2012). However, given the complex political situation of coordinating fiscal policies in the EU, Europe's struggle is more strenuous than that of the US.

4.4 Stress-testing the banking sector

Timothy Geithner describes at length the struggle of the US Treasury to get the banking stress test right, see Geithner (2014). Ultimately, the test worked: the results were close to private-sector estimates, banks with a projected capital shortfall raised new equity, and the transparency put new confidence in the market. This was needed for the European banking sector as well, as the feeble state of European banks put a drag on growth, see Lucchetta et al. (2015).

The European stress tests needed a number of iterations before it had any beneficial effects. For example, as described in Acharya et al. (2014b), the extent of capitalization that came out of the July 2011 EBA stress test seemed far too low and, for this reason, has been followed by the EU-wide recapitalization exercise. Moreover, the exercise was criticized since it failed to identify some vulnerable banks. Notwithstanding this caveat the results of the 2011 EU-wide stress test were perceived as a key crisis management tool and generated significant debate, not only about the test themselves but also about the role of stress testing in crisis management, see Haben and Quagliariello (2015). Against this background, the outcome of the stress test should be interpreted in the context of two key deliverables beyond the simple quantification of the capital shortfall. First, the pre-emptive actions triggered by the announcement of the stress test, with about 50 billion raised by banks in the first 4 month of 2011. Second, the transparency of results, with full disclosure of specific elements that investors were concerned about, including actual data on sovereign holdings and the basic components of capital.

Regarding the first: In October 2014, the ECB published the results of its Comprehensive Assessment of Europe's 130 largest banks. It consisted of an asset quality review (AQR) and the EU-wide stress test coordinated by the EBA. The goal of assessment was to provide transparency about the health of the banking system before taking over supervisory responsibilities for major banks in the Euro area. Breckenfelder and Schwaab (2015) find that the link between banks and sovereigns became weaker in stressed countries. The additional bank risk is borne by sovereigns in stronger countries. This could imply that that non-stressed countries were also affect by the comprehensive assessment because markets view them as providing guarantees for banks in stressed countries.

4.5 Coordination of Bank bailouts

One of potential benefits of the Euro area is cross-border banking. Such activities stimulate trade, facilitate competition in financial services and increase the diversification of banks' earnings. However, the domestic orientation of the financial safety net is a barrier to cross-border banking, as national authorities have limited incentives to bail out an international bank. This hampers financial stability.

The problems of resolution and burden sharing are resulting from the increased cross-border activities of European banks, see De Haan et al. (2014). Initially seen as a following naturally from the single markets perspective of the EU, it becomes a problem when each country follows its own procedures and interest when banks get into trouble. Countries might be tempted to take a resolution decision solely based on the social welfare in their own country, disregarding the direct and indirect effects (contagion) of a bank failure. Moreover, regulatory forbearance might be stronger in a national context, see Morrison and White (2013).

Schoenmaker and Siegmann (2014) analyze the potential for different bailout schemes in achieving efficient resolutions of bank failures. Simulating bank defaults in a multi-country setting, they find that voting schemes with voting weights relative to asset shares can achieve similar efficiency is the resolution outcomes under a supranational authority. This suggests that cooperation between countries, with or without a central authority, does not have to lead to large conflicts of interests.

Béranger and Scialom (2015) point out that some problems remain in the European bank resolution mechanism, i.e., the SSM and the SRM. First, deposit insurance schemes are not the same across countries. This leads to a cost-benefit trade-off that is different for each country, and makes agreements around recapitalizations harder. Second, it remains difficult to separate subsidiaries for large and complex banks, complicating the allocating of costs and benefits per country. Finally, "living wills" are not fully developed yet, so that estimating the liquidation value of a bank is hard. This is an impediment to the orderly liquidation of a bank and to the computation of the costs and benefits to recapitalization.

Note that capital and liquidity are not easily transferrable from one country to another, leading to potential bias in assessing adequate capitalization per country, see Cerutti and Schmieder (2014).

4.6 Perceptions of the European economy

A further stabilization of the European banking sector will depend on the prospects for growth and the confidence in these prospects that drives consumption and investment decisions of households and firms. Sentiment about growth is measured in Manisera and Zuccolotto (2013), who estimate a nonlinear Combination of Uniform and shifted Binomial (CUB) Model on survey data. Carpita et al. (2015) estimate the impact of macroeconomic news on the feelings of the general public about the economic situation. Carpita and Ciavolino (2015) study the public opinion in the European Union on four socio-economic aspects and how these perceptions could be related to the future Gross Domestic Product.

4.7 Acknowledging the complexity of the financial system

> We are talking about a law of systems development which is: every system always operates at its capacity. As soon as there is some improvement, some new technology, we stretch it…
> Larry Hirschhorn (quoted in Woods (2002) as the Law of Stretched Systems)

Until recently, the textbook treatment of financial system considered a system consisting of basic building blocks that channel funds from lenders/investors (those with excess funds) to borrowers/entrepreneurs. This could be through direct finance (stocks & bonds) or through financial intermediation (banking, private equity, insurers). Such a description of the financial system makes it look like the running of the postal system: letters go from sender to receiver through a chain of functions, and problems with one letter do not spillover do other letters. See Figure 9.

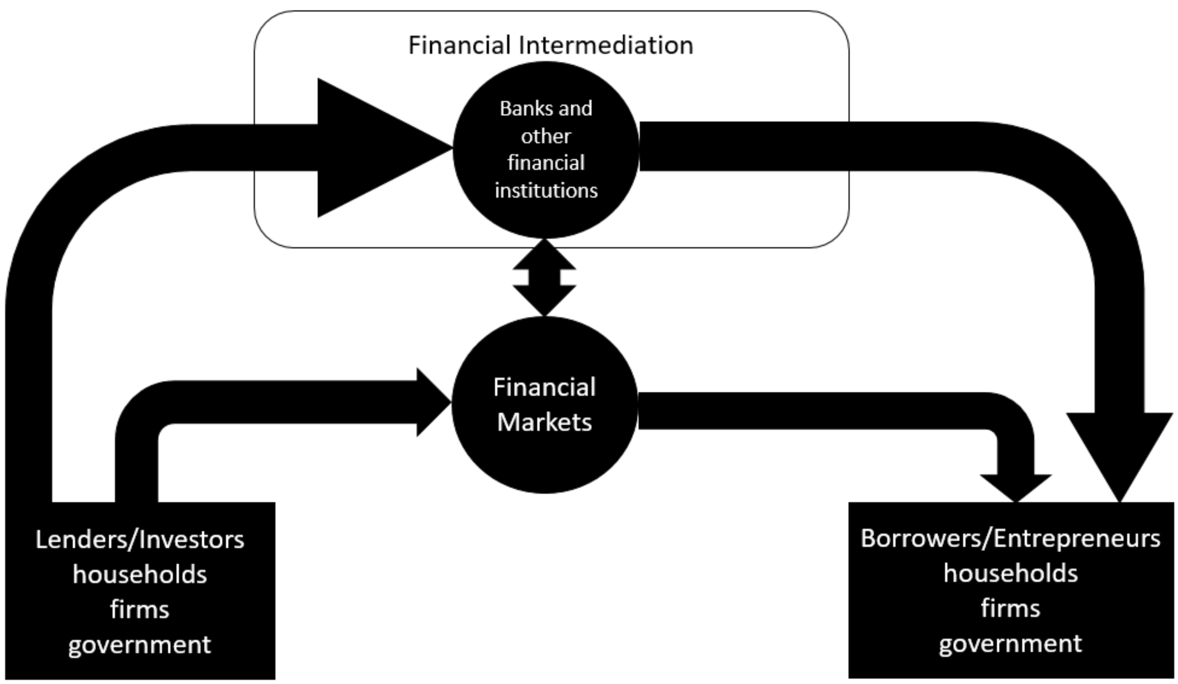


Figure 9: The financial system in the abstract

In principle, this is the way that the financial system *could* work, except that in practice, it is much more complex. The financial system consists of a network of interlocking obligations, between parties up and down the credit chain, and between institutions across the system. In systems theory, this would be called 'dynamically complex'. Banks interact with each other and with other institutions in the system, which blurs the simple credit path from savers to borrowers.

Moreover, the use of derivatives and risk management techniques makes it practically impossible to see and monitor the interactions between all parties in the system. The parallel with engineering is already there from the phrase "financial engineering" that is used for the work of pricing and trading derivatives. A typical complex structure is that of the CDO, as illustrated for one notorious case in Figure 10.

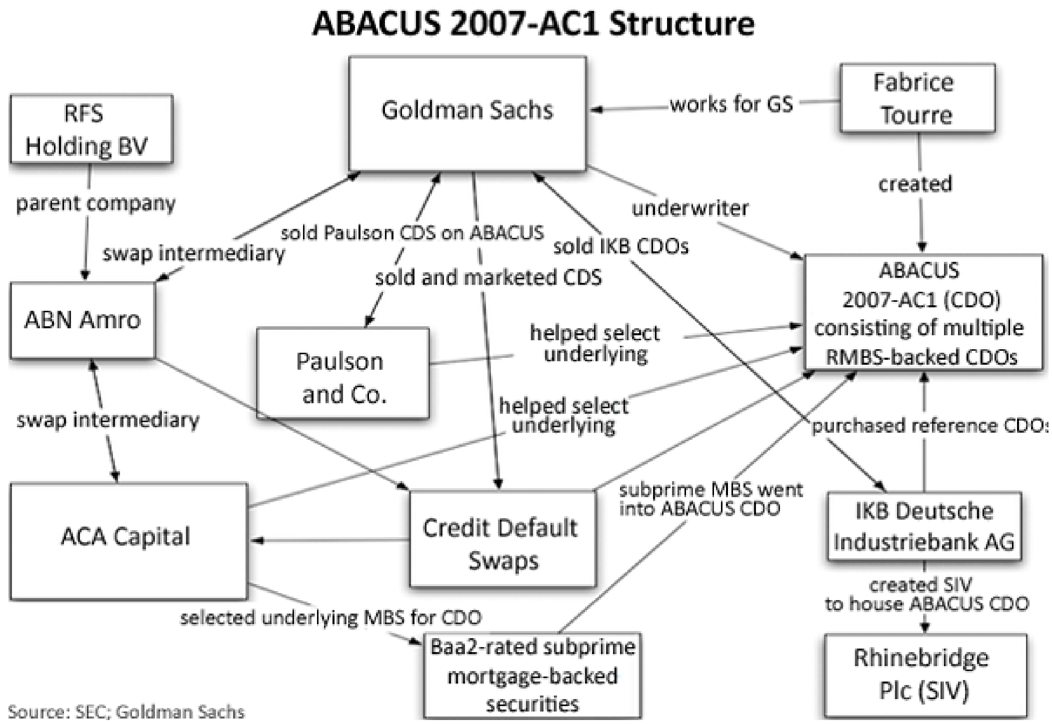


Figure 10: A small piece of the "real" financial system

Source: businessinsider.com. The figure shows the Goldman Sachs Abacus CDO structure as presented in the lawsuit of the SEC.

Theoretical models on the efficiency of CDOs (i.e., the efficiency stemming from the fact that the tranches of the CDO could cater to investors with different risk appetites), missed an important point. The real structure of a CDO was complex, geared towards regulatory arbitrage, opaque for most investors, and with a risk profile that was not well understood, see Coval et al. (2009). Also, the method of rating securities by credit rating agencies was designed for single-name bonds and not for CDOs. As the rating system was stretched, structured finance started operating very near the edge of safety for investors.

Figure 10 is an example of complexity in a transaction, involving many parties. Another form of complexity is in the financial institution itself. For example, the complexity of the risk models used by banks, the exposures and relations to its counterparties, and the composition of different activities in a bank.

Khandani and Lo (2007) describe the convergence of quantitative strategies by hedge funds and the simultaneous collapse of these strategies in August 2007. It illustrates how the joint application of mathematical strategies can formulaically trigger massive sell-offs, without parties having the time or opportunity to exercise judgment. This tight coupling of financial markets is a serious risk factor.

Bank complexity is a specific concern in Europe because of the prevailing ‘bank bias’. Where the US is more market-based, Europe is more bank-based. Before the crisis, this seemed to be just a matter of taste, cultural tradition, or legal system, see Demirgüç-Kunt and Maksimovic (2002). However, Langfield and Pagano (2015) find that bank bias (the deviation of the bank asset to GDP-ratio from the average) is directly related to systemic problems: countries with a larger bank bias are hurt more economically in a crisis.

4.7.1 Modeling of complexity

Several papers have brought the ideas of complexity theory to the financial system, such as Mauboussin (2002), Markose (2005), Schwarcz (2009), Haldane and May (2011). Complexity theory is the science of studying Complex Adaptive Systems, as they appear in biology, crowd control and engineering. The increasing complexity of the financial system and the financial crisis of 2008/2009 have brought the theory to the forefront of our thinking about systemic risk.

In normal times, the financial system is loosely coupled: orderly legal procedures are followed in case of a problem or failure regarding an institution or a transaction. However, in some instances the system becomes tightly coupled: the interactions between different parts of the system become fast and unpredictable. The failure of a single component can trigger a cascade of events that ultimately leads to a crash. The mechanism of contagion can take place through pre-set triggers defined debt covenants and fast trading. The speed of transactions that is defining the liquidity and ease-of-use of the financial system in good times becomes the source of its problems in bad times.

A first lesson from resilience engineering, see Dekker et al. (2008), is that the resilience of complex systems can be improved by first accepting that “real” systems are different from “imagined” systems. Real systems are usually stretched to the edge of safety and are used for purposes for which they might not have been designed. As a consequence, apparent stability can sometimes lead to loss of resilience and increased systemic fragility: because everybody takes stability as given, it pays off in the short term to take stability for granted and underinvest in safety measures. If then a shock happens, the resulting damage is larger than when stability is not taken as given. This is related to the low-volatility paradox documented in Section 2.2.

Another feature of a dynamic complex system that is relevant for the financial sector is the custom-to-failure cycle, as pointed out by Schwarcz and Chang (2012). Reliance on heuristics to manage risk can lead to heuristics-based customs with both banks and regulators. With continuing innovation and complexity of financial institutions and markets, the custom becomes out of touch with reality, creating the possibility of a crash. A combination of dynamic complexity and tight coupling leads to "normal accidents", i.e., the occurrence of system-wide failures becomes inevitable and "normal".

4.7.2 Policy actions: Regulation of Complexity and Margin of Safety

A number of suggestions come from systems theory that could be used by regulators and supervisors in the financial sector. Patterson et al. (2007) propose collaborative cross-checking of a system or procedure by people with different perspective to enhance safety and spot problem. Nemeth et al. (2011) stress the importance of a qualified cadre of operators (the people that actually run the system) and social capital.

Haldane (2012) suggests that regulators should aim for simple rules that facilitate understanding, communication and provide the correct incentives for all actors. In addition, as suggested by Tett (2015), banks and regulators would increase their understanding of the financial world by actively seeking not to work in silos, for example, by creating cross-disciplinary teams that cooperate across existing silos of bank activities and/or regulatory focus.

One way to tackle complexity is to regulate the complexity of the financial sector directly. As a start, we could measure the complexity of the control structure of financial institutions, see Lumsdaine et al. (2015). Their approach results in new insights, such as the fact that institutions designated as systemically important (SIFIs) are not necessarily more complex as other institutions. Also, insurance companies seem to be more complex than other institutions in their control hierarchy. A concrete policy action is to levy a regulatory 'complexity fine', as a part of the countercyclical capital buffer for SIFIs.

Policy makers could aim to increase the 'modularity' of the financial system, as advocated by Schwarcz (2009). Schwarcz proposes a form of modularity in terms of providing liquidity (shutting off a malfunctioning part of the system by providing it with ample liquidity). However, this idea could be taken further by enhancing the modular structure of the financial system itself. The essential benefit of increased modularity is that we reduce the chance that a failure in one part of the system will systemically trigger a failure in another part. In practice, this could be obtained by increasing the importance of market-based finance relative to bank-based finance. However, in the European context, changing or limiting the role of banks In Europe, can only happen if access to other sources of external finance improve, i.e., a better access of small and medium enterprises (SMEs) to the bond market.

The direct regulation of complexity is a challenge taken up by the Basel Committee (BCBS) and the European Banking Authority (EBA). The Basel Committee has proposed guidelines for Simple, Transparent and Comparable ("STC") securitizations, see Basel Committee on Banking Supervision (2015). The EBA has published a report on qualifying securitizations, see European Banking Authority (2015a). These initiatives should improve the information given to investors and aid supervisors in assessing the quality and safety of securitized investment products.

A “warm up” period for novel securities or funding structures would help to improve stability. As an example, consider Figure 11 below. It shows the price of CDO indices from 2007 to 2009. Initially, prices were stable or flat, at 100 cents on the dollar for the two most senior tranches. Banks were allowed to place low risk weights on these securities. However, once the crisis starts, prices crashed and the apparent safety of these instruments turns out to be false.

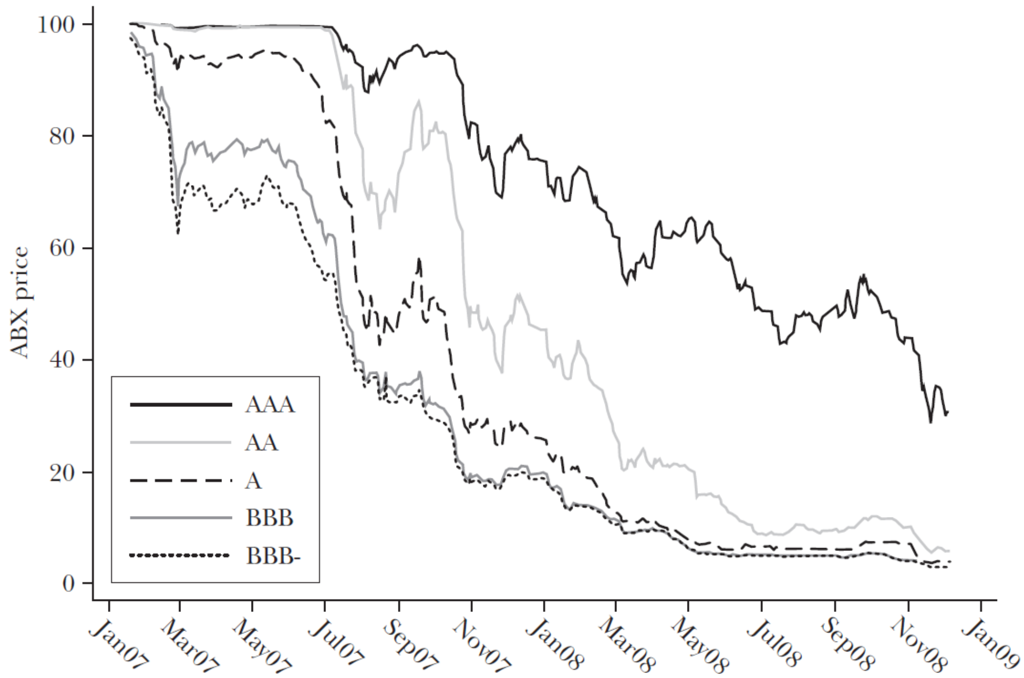


Figure 11 : CDO prices 2007-2009

Source: Brunnermeier (2009). The figure shows the price of Mortgage Credit Default Swap ABX indices. The ABX 7-1 series initiated in January 2007.

Looking back, there would have been all the reason to limit CDO issuance to the extent that their performance in a cyclical downturn was not well established. This would have given banks and their supervisors the time to learn about the risk profile of CDOs. Limiting the use of new structures is related to the margin of safety suggested by Schwarcz (2014), who quotes the principle as defined by Sunstein (2002): “Regulation should include a margin of safety, limiting activities below the level at which adverse effects have not been found or predicted”.

An example in the current day is the use of contingent convertible bonds (CoCos) by banks, as described in Section 2.3.2. The extent to which they appear on a bank’s balance sheet as funding or as assets might be limited to first suffering a cyclical downturn before a further expansion of their use by banks is allowed. In this way, markets, bankers and regulators can learn about the risk factors inherent in them.

Note that new regulatory policies can be counter-productive and destabilizing, see Haldane (2012). A similar argument is made by Brunnermeier et al. (2009): simply increasing the quantity of information to investors does not resolve the problem, as everyone is limited in their understanding of reality, be it through natural limits of understanding, or through a lack of time or money to investigate. New initiatives should be aimed at improving supervisory access to data, combined with the right set of tools to interpret and monitor the state of the financial system.

4.8 The policy maker's loss function

In its flagship report (European Systemic Risk Board (2014)), the ESRB proposes to use “key indicators books” of systemic risks, including stress test results and estimates of the financial cycle. Ideally, each indicator carries a threshold level beyond which it signals a need for action (it ‘flashes red’). It observes the challenge to find thresholds that match policy makers’ preferences for missed crisis versus false warnings. Missed crisis is what every policy maker wants to avoid. But too many false warnings undermine the credibility of the same policy maker. Moreover, it could be a cause for political deadlock, as the gains and losses of intervention and crisis prevention are not evenly spread: a country with a small financial sector will be mostly concerned with the prevention of a crisis that hurts the real economy. However, prevention measures might directly hurt the real economy of a country with a large financial sector. Also, today's gains are certain, while future losses are uncertain/unknown unknowns

In general, enacting preventive measures that limit financial innovation and growth requires enormous discipline and faith. There is the case of Chinese regulators being sidelined in 2014/2015, during the stock market boom that ended in collapse. There have been banks who got rid of critical CROs before 2007. Insightful in the case of bubbles is the failure of George Soros’ Tiger fund, in March 2000. As documented by Brunnermeier and Nagel (2004), it was one of the few hedge funds that bet against the IT-bubble, but closed down because most investors withdrew their money. Likewise, optimal regulation leads to painful choices, which could be described as “taking away the punchbowl while the party gets going”[5].

The fact that some crises are not prevented in the first place results from the difficulty of identifying successfully prevented crises as well as the institutional inertia that prevents direct and far-reaching interventions. The inertia cannot be blamed to a single institution or institutional failure, but is the natural result of conflicting interests in the wake of an impending problem of unknown size. See Fu and Li (2014), who describe the problems of an institutional status quo bias.

During the SYRTO conference in June 2015, Charles Goodhart (LSE) suggested that the problem for a policy maker is that we only see events where central bankers *have* acted. How about when they considered acting but didn't do it? With access to the archives of central banks, we would learn a lot from the comparison of successful and unsuccessful interventions.

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[5] The quote is from William McChesney Martin, a former Chairman of the US Federal Reserve, who uses it as an analogy for the basic responsibility of a central bank, see Martin (1955).

Relevant for using Early-Warning Signals is the following: the effectiveness of early warning models increases if the policy maker is willing to incur false alarms. By communicating what’s at stake, and by using even false alarms to improve the resilience of the financial sector, there will be benefits for the EU at large.

5 Conclusion

Many of the research results and questions in this report have been driven by the problems that arose in the financial crisis of 2008 and 2009, and with the understanding that manias and market crashes can never be prevented completely. However, some useful avenues have been discovered in preventing, mitigating and stabilizing systemic risk.

On prevention, the early-warning systems capture informative signals on an impending crisis. Hopefully, this report contributes to our understanding of the usefulness of these models, including stress tests, and help regulators to take more decisive action when danger looms.

On mitigation, the empirical research finds that the financial cycle is real, which implies that, in normal and quiet times, there is a natural tendency for credit growth and asset prices to move away from equilibrium. Moreover, very low measured financial stress coupled with a high point in the cycle signals a high systemic vulnerability.

Sound regulation is also an important mitigant of systemic risk. Stricter rules on banks' capital and liquidity delivered a more robust banking sector and contributed to the repair of EU banks. Further research on systemic risk can contribute to impact assessments as well as to monitoring the consequences for the regulatory reforms and better calibrating rules.

On stabilization, empirical research has shown how unorthodox policies of the ECB were apparently effective in stabilizing the Euro crisis. To improve stability of the system, research from related fields such as engineering shows how a complex dynamic system can be made more resilient. This holds useful lessons for the governance of systemic risk and the coordination between micro-and macroprudential regulators.

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Appendix: Overview of deliverables for Work package 8

D8.1 Working papers/scientific publications on policy-monetary-regulatory implications of system risk

- Arakelian, V., P. Dellaportas, R. Savona, M. Vezzoli (2015), European Sovereign Systemic Risk Zones, *SYRTO Working paper n. 13/2015*.
- Lucchetta, M., A. Paradiso, R. Savona (2015), Oil Price Shocks, Financial Frictions and TFP Dynamics, *SYRTO Working paper n. 19/2015*.
- Mattson, R.S., P. de Peretti (2014) Investigating the Role of Real Divisia Money in Persistence-Robust Econometric Models, *SYRTO Working paper n. 4/2014.*
- Mattson, R.S., P. de Peretti (2014) Defining Money Using Stochastic Semi-Nonparametric Tests for Weak Separability: An Empirical Study on US Data, *SYRTO Working paper n. 6/2014.*
- Pelizzon, L., M.G. Subrahmanyam, D. Tomio and J. Uno (2014), Limits to Arbitrage in Sovereign Bonds Price and Liquidity Discovery in High-Frequency Quote-Driven Markets, *SYRTO Working paper n. 7/2014*.
- Pelizzon, L., M.G. Subrahmanyam, D. Tomio and J. Uno (2014), Sovereign Credit Risk, Liquidity, and ECB Intervention: Deus ex Machina?, *SYRTO Working paper n. 8/2014*.

D8.2 Technical reports on Monetary Integration Satisfaction and Policy Intervention Satisfaction measurement

- Carpita, M., E. Ciavolino, and M. Nitti (2015), On the Prediction of the Economic Public Opinions in Europe, *working paper, University of Brescia.*
- Carpita, M. and E. Ciavolino (2015), MEM and SEM in the GME framework: Statistical Modelling of Perception and Satisfaction, *SYRTO Working paper n. 26/2015.*
- Manisera, M. and P. Zuccolotto (2015), Nonlinear CUB models, *SYRTO Working paper n. 14/2013.*

D8.3 SYRTO Code

- The SYRTO Code, with the major results and policy implications from the other work pacakges in SYRTO is contained in this document.