EUROPEAN CENTRAL BANK

EUROSYSTEM

REPORT ON THE FIRST TWO YEARS OF THE MACRO-PRUDENTIAL RESEARCH NETWORK

REPORT ON THE MACRO-PRUDENTIAL RESEARCH (MARS) NETWORK AFTER TWO YEARS

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Executive Summary

In the spring of 2010 the General Council of the European Central Bank (ECB) approved the establishment of the Macro-prudential Research Network (MaRs) with the objective of developing core conceptual frameworks, models and/or tools that would provide research support in order to improve macro-prudential supervision in the European Union (EU). MaRs was set up for an initial period of two years, during which time it has followed three work streams:

- macro-financial models linking financial stability and the performance of the economy – work stream 1 (WS1);
- early warning systems and systemic risk indicators – work stream 2 (WS2); and
- assessing contagion risks – work stream 3 (WS3).

This report summarises the results of this work and progress made by the network after two years. It provides an overview of the activities of the network, reviews the findings of each of the three work streams, focusing in particular on the research questions asked by the General Council at the start of the network, and concludes with an overall assessment and a plan for the remaining work to be conducted before the network is closed at the end of 2013.

General progress of MaRs

MaRs has produced 81 papers so far (40 in WS1, 28 in WS2 and 13 in WS3), out of a work programme of 126 individual research projects.[1] Of the papers, 39 have been published or have been accepted for publication/are forthcoming in the ECB Working Paper Series with a "MaRs" stamp on the cover page and nine papers have been published in academic journals, including a few top ones (such as the Journal of Financial Economics, the Economic Journal and Economic Policy). Of course, progress has also been made on many projects for which no draft paper is available so far, but the results reported below are drawn from papers for which at least a draft is available.

[1] This excludes the 15 projects under the special initiative on sovereign contagion risk, for which 10 papers are available so far.

MaRs also pursues two joint cross-country projects involving many central banks of the EU: one on developing a "canonical model" for assessing macro-prudential regulatory policies under WS1 and another on establishing a database on financial crises in EU countries under WS2. In response to recent developments, WS3 also added a special initiative on research assessing sovereign contagion risks in Europe.

In addition to internal meetings and workshops of the different work streams and their sub-teams, MaRs has held two public conferences at the ECB in October 2011 and October 2012. In both cases, the best research from all three work streams was presented, along with external papers from academia and non-EU authorities addressing MaRs research questions.

MaRs continues to operate with a light management structure in which representatives of the ECB, euro area and non-euro area national central banks (NCBs) of the EU participate, involving a chair and two coordinators for each work stream. Professor Xavier Freixas (Universitat Pompeu Fabra) was joined in 2012 by a second consultant, Professor Hans Degryse (Katholieke Universiteit Leuven).

Work stream 1: Macro-financial models linking financial stability and the performance of the economy

A large part of this work stream was intended to provide relatively fundamental research during the initial two years, without immediately delivering operational policy tools. Its main objectives are to develop theoretical and empirical frameworks that integrate realistic characterisations of widespread financial instability into models of the aggregate economy, allow the analysis of transmission channels between financial instability and macroeconomic variables, explain the recent crisis and assess policies addressing systemic risks. In pursuing these objectives, WS1 also provides some foundations for systemic risk research in general and for the analysis conducted under WS2.

WS1 has produced several new theoretical and empirical frameworks on how widespread financial instability can be integrated into aggregate models. These directly address one of the main weaknesses of contemporaneous economics laid bare by the crisis. Paradoxically, five years into the crisis the academic economics community has made very few decisive enough efforts in this direction, which underlines the importance of the MaRs agenda.

Theoretical results highlight the fundamental importance of bank defaults, the design of bankruptcy rules, fire sales and non-linearities in characterising financial instability. Most papers focus on the endogenous build-up and unravelling of widespread imbalances, on aggregate shocks or on interactions between the two as relevant forms of systemic risk. On the asset side, imbalances are captured by the banking system's exposure to asset price bubbles; on the liability side, they are captured by banks assuming wholesale financing that contributes to the build-up of aggregate liquidity. The research shows key non-linearities that emerge as a consequence of switches between multiple self-fulfilling equilibria and of the effects of occasionally binding constraints. One novel empirical approach applied to European data suggests that at times of severe systemic

financial instability (captured by a new composite indicator also presented in the context of WS2) regime changes make the macroeconomy behave fundamentally differently from its behaviour in tranquil times. This applies in particular to the impact of financial stress on growth, with the transition being highly non-linear. It provides one explanation of why the recession caused by the financial crisis has been so severely underestimated by most analyses and forecasts. Some of these models have the potential to lead to analytical tools that could be used for early warning, forecasting or scenario analysis in the future.

Theoretical and empirical MaRs research illustrates the transmission of financial instability to the real economy through constraints on credit supply, credit demand and the disturbing effect of the breakdown of risk-sharing on the consumption plans of households. Empirically identifying credit supply and demand effects and their relative importance remains, however, a challenge. Whereas several empirical MaRs papers find that asset price shocks contribute to business cycle fluctuations, a number of other MaRs papers suggest that recessions are significantly more severe if bank credit plays an important role in a crisis.

Combining moral hazard between banks and their depositors with a costly state verification problem between entrepreneurs and banks in a dynamic stochastic general equilibrium (DSGE) model proves to be helpful in understanding the sources of the leverage cycle. Macroeconomic fluctuations are better captured, because this approach allows firm and bank leverage to reinforce each other. Other DSGE research illustrates how shadow banking associated with securitisation amplifies the leverage cycle. A general equilibrium model of household borrowing illustrates how optimism about future house valuations increases household leverage, demand for houses and real estate prices. If expectations are dashed, the result is over-borrowing, so households have to de-leverage and the boom is followed by a bust.

A growing number of theoretical MaRs papers assess the effectiveness of various regulatory policy instruments used for macro-prudential purposes. This would not have been possible without the major developments in integrating widespread financial instability into aggregate models referred to above. The instruments considered so far include loan-to-value (LTV) ratios, bank capital requirements, leverage caps, liquidity ratios, dynamic loan-loss provisions, limits on foreign currency lending or currency mismatches and margin requirements on repos. Using primarily theoretical approaches, most of these instruments are found to be effective, at least to some extent, although occasionally unintended side effects occur. Approaches to refining some instruments (e.g. making LTV ratios time-varying or removing risk-weighting in capital requirements) are also discussed. One original and well-designed sequence of papers concludes that the multitude of market imperfections that contribute to systemic risk would have to be countered with a multitude of regulatory instruments. In particular, controlling for fire-sale risk is critical to improving overall economic performance. However, not all strategies of controlling for this risk are equally effective and indiscriminate combinations of different regulations can also easily become counter-productive. Regarding the interactions between monetary policy and macro-prudential policy (captured by time-varying LTV ratios or capital ratios), an estimated DSGE approach finds that a combination of an independent macro-prudential

policy leaning against credit bubbles and a monetary policy focusing on inflation is the best response to asset price or credit supply shocks in order to maintain price stability. Another theoretical project allowing for boom-bust cycles in housing and credit points out, however, that a welfare comparison of an extended interest rate rule and counter-cyclical LTV ratios leads to ambiguous results, as lenders and borrowers are affected in opposite ways.

The joint cross-country project of WS1 involving ten NCBs developing a "canonical model" for assessing macro-prudential regulatory policies has made significant progress. The final model planned by the team features heterogeneous banks, households and firms, which can default in equilibrium, an interbank market with a central bank, various financial frictions and externalities (including fire sales) associated with business and mortgage loan defaults. Capital and liquidity requirements, dividend restrictions, LTV ratios and loan-to-income ratios for mortgages, leverage ratios and certain taxes or levies can be considered as regulatory instruments in this framework. The team is currently completing the first prototype of the model. The next steps are its coding and calibration, before the first simulation exercises on the effects of macro-prudential policies can be executed. Again, there seem to exist at present only very few comparable efforts by other authorities or academia that feature strong representations of widespread financial instability and are therefore adequate for assessing macro-prudential regulatory instruments. It would be desirable to see more efforts of this kind being undertaken in academia, for example.

Work stream 2: Early warning systems and systemic risk indicators

WS2 was designed to conduct relatively practical research, which could be of more immediate use for macro-prudential oversight in the EU. The research questions were aimed at improving indicators of current systemic stress and identifying key early warning indicators for systemic financial instability and widespread imbalances, both for the EU as a whole and at individual country level.

Various measures of the current level of systemic instability have been proposed in WS2, ranging from the application of well-established methodologies (such as principal components) to European data to new developments. In particular, a composite indicator has been developed covering stress in the main financial markets and intermediaries. In order to make the indicator systemic, these components are aggregated, taking their dependence into account, with their weights linked to their relation to the real economy. Also, distance-to-default indicators have been proposed to measure the probability of multiple bank failures. It remains an issue whether such systemic risk indicators bring us closer to measuring instability or have value as early warning tools.

A joint cross-country project has provided an homogeneous basis for assessing the performance of systemic stress and early-warning indicators for banking, currency and fiscal crises. A database of various types of crises in EU countries has been completed and has been made available to interested researchers.

WS2 researchers have developed new methodologies for selecting early-warning indicators (such as applications of Bayesian model averaging) and their optimal time lags, implemented existing methods with European data, used new data sources and designed new visual representations of the results of tools (such as self-organising maps). The results suggest that the following indicators should be included in the domestic part of an early warning system: deviations of credit-to-GDP ratios and (real) house prices from trend, credit growth, loan growth and customer deposits; term and credit spreads, intra-financial credit and credit risk conditions; equity valuations, stock returns and real equity growth; bank efficiency scores, contagion effects (see also WS3) and leverage; asset price misalignments related to market sentiment; terms of trade and current account deficit; and measures of fiscal vulnerability. WS2 research also emphasises that attention should be paid to global variables, in particular global credit volume and global credit growth, global GDP growth, global leverage, real equity growth and equity valuations, as well as commodity prices. One novel, model-based early warning indicator of systemic stress is based on the decoupling of financial firms' credit risk conditions from the macroeconomic and financial variables that usually explain them.

Detecting imbalances in asset prices or credit developments is perhaps one of the most challenging fields of WS2. The results caution against excessive reliance on simple statistical de-trending or filtering methods to detect imbalances. New developments to detect excessive credit and leverage include the construction of a structural life-cycle model and a regime switching model. In the area of equity bubbles, factors contributing to mispricing highlighted by WS2 researchers include market sentiment and the intensity of herding behaviour.

Some of the analytical tools improved or developed have featured in official publications or already feed into regular macro-prudential surveillance or ad-hoc briefings. At the same time, systematic comparative performance assessments of different systemic stress indicators and different early warning indicators have not yet been conducted in this work stream and only limited progress has been made so far in deriving the main features of an optimal overall early warning system.

Work stream 3: Assessing contagion risks

The intended main focus of this work stream was to assess the scope for cross-border bank contagion across EU countries, complementing previous research on contagion risk within EU countries. The work also looked at spillovers across different types of financial intermediary, feedback effects which amplify contagion and the distinction between the unravelling of imbalances and contagion.

As the literature has highlighted the role of interbank markets in transmitting financial instability, some WS3 projects have focused on money market interlinkages and structures. The projects provide further evidence of tiering in this market, in which some banks distribute liquidity. Moreover, due to the presence of both unsecured and collateralised transactions, the distribution of losses from interbank exposures is strongly

bimodal (most losses are either very small or very large). This stands in contrast to the usual assumption that loss given default (LGD) averages about 40%, and adds an element of fragility to the interbank system.

Other projects address the area of contagion more directly. A possible benchmark definition of contagion is that contagion exists when instability in a specific financial intermediary or market is transmitted to one or several other intermediaries or markets, notably when this transmission is not caused by common factors or fundamentals and/or is of particular strength ("extreme"). One MaRs WS3 project is developing a new methodology to disentangle short-term contagion phenomena from long-term market integration. Another has adopted a novel approach to how to complete the network of bilateral interbank exposures through stochastic simulations when precise data are not available. Moreover, it illustrates how fire sales of assets can amplify the extent of interbank contagion, which also turns out to be highly non-linear. A third project provides a global empirical study of spillovers in connection with regional banking fragility, defined as bank stock indices of several countries in a given region simultaneously showing low returns. This fragility in general is reduced if banks in a given region hold more liquid assets or capital. In Europe, regional banking fragility is reduced when banks jointly hold more liquid assets. Moreover, the greater degree of capitalisation of European banks reduces cross-regional spillovers into Europe stemming from Asia and Latin America. Finally, WS3 research made further progress in applying the network approach at the macro level, using the harmonised financial accounts for euro area countries. For example, it is shown that the transmission of a credit shock is highly dependent on the specific empirical properties of the cross-country, cross-sector network.

Against the background of the crisis in Europe, WS3 decided to add a special initiative on sovereign contagion research. The data used in the various projects are sovereign bond yield spreads, sovereign credit default swap (CDS) spreads and bank equity returns. The methodologies applied are dynamic factor models, multivariate frequency decompositions, co-integration analyses, forecasting error variance decompositions, dynamic copulas and an event study. Most papers (but not all) find evidence of contagion since the onset of the sovereign debt crisis in late 2009. Two dissenting papers argue that fundamentals and risk aversion suffice to explain sovereign yield increases and that bad news about a country's economy may be confounded with news about a lack of commitment by other countries to support the country (a different trigger of contagion).

Overall assessment and continuation of MaRs

Overall, MaRs has made significant progress over the last two years, in terms of both individual and cross-country projects, addressing most of the research questions asked by the General Council. Participating central banks would find it desirable, however, to see the wider economics community, in particular academic research and teaching, taking up more decisively some of the main directions pursued in MaRs – notably aggregate frameworks incorporating widespread financial instability and their use for the assessment of macro-prudential regulatory instruments. At the same time some of the important MaRs cross-country

projects are not yet completed and the translation of fundamental research into analytical tools supporting policy-making could be pushed forward in some areas.

Against this background, MaRs will continue to operate until the end of 2013. During this time the focus of the work should be on joint cross-country projects, MaRs research questions for which a broader basis of answers and a greater robustness of results would be desirable and analytical tools designed to support macro-prudential policy-making:

- WS1 will focus in particular on the completion of various versions of the canonical model for assessing macro-prudential regulatory policies, their programme infrastructure and coding, their calibration and their first use in a set of regulatory policy simulations as well as on the implementation of a number of analytical tools from the other newly available macroeconomic models incorporating widespread financial instability and their preparation for regular use;
- WS2 will conduct comparative performance assessments of different systemic stress indicators or early warning indicators and identify the main features of an "optimal" overall early warning system;
- WS3 will progress with projects assessing interconnectedness and contagion risks among European banks.

It is planned that MaRs will report on its final results in the spring of 2014.

With the additional efforts, MaRs is likely to be able to complete most of what it originally planned. In some areas, this is expected to make major contributions to the understanding of systemic instability and policy responses, both in terms of fundamental research frameworks and in terms of the analytical toolkits available to central banks. At the same time, it is also clear that the experience of the crisis suggests that additions to the existing economic frameworks which amount to a new paradigm may be needed. Although a number of MaRs researchers have made very valuable steps in this direction, while nonetheless staying relatively close to standard economic equilibrium approaches, it is clear that the establishment of a new paradigm is exceedingly ambitious for a central bank research network. It is, instead, desirable that the academic sector significantly intensifies efforts in this area, notably representing widespread financial instability in models of the aggregate economy and introducing financial regulatory instruments into such frameworks, potentially also considering approaches from disciplines other than economics. For example, in the European System of Central Banks (ESCB) it has not been possible so far to seriously consider approaches that move definitively away from concepts based on rationality and equilibrium (one recently discussed is "agent-based modelling").

1. Introduction[2]

In March 2010 the General Council of the European Central Bank (ECB) approved the establishment of the Macro-prudential Research Network (MaRs). The objective of MaRs is to develop core conceptual frameworks, models and/or tools that would provide research support in order to improve macro-prudential supervision in the European Union (EU). MaRs was set up for an initial period of two years. During this time, three work streams have been pursued:

- macro-financial models linking financial stability and the performance of the economy – work stream 1 (WS1);
- early warning systems and systemic risk indicators – work stream 2 (WS2); and
- assessing contagion risks – work stream 3 (WS3).

In October 2011 and October 2012 MaRs held large public conferences at the ECB in Frankfurt in which the best research from all three work streams was presented, alongside external papers from academics and other authorities addressing MaRs research questions.[3] Some general information about the network, its mandate, organisational structure and working papers is also publicly available on the ECB website.[4]

The purpose of this report is to summarise the results of the research and the progress achieved by MaRs during the initial period of two years. The report is structured as follows. The rest of this introduction briefly summarises the activities of the network as a whole. The following three chapters summarise the results found from the analyses carried out in each of MaRs' three work streams, focusing in particular on the research questions asked by the General Council at the start of the network. The last chapter assesses the overall progress and outlines the plan for the work to be conducted before the planned closing the network at the end of 2013. There are two annexes containing a list of all ESCB economists contributing to MaRs and the programmes of the 2011 and 2012 conferences.

This report mainly covers papers produced under MaRs. While it may occasionally refer to other related literature or other reports in related areas, it cannot provide a full survey of the relevant literature outside MaRs. Moreover, it should be borne in mind that the research and papers covered are still in different stages

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[2] This report was drafted by a team led by Philipp Hartmann (ECB) and involving Paolo Angelini (Banca d'Italia), Laurent Clerc (Banque de France), Carsten Detken, Cornelia Holthausen, Angela Maddaloni and Kalin Nikolov (all ECB), and Kateřina Šmídková (Česká národní banka). It is based on inputs from a large number of MaRs contributors (see Annex 1) and benefited from comments by ESCB Heads of Research.

[3] The programme, papers, presentations and speeches are available on the ECB website under the following links: http://www.ecb.europa.eu/events/conferences/html/mar_net.en.html http://www.ecb.europa.eu/events/conferences/html/mar_net2.en.html. See also Annex 2 in this report.

[4] http://www.ecb.europa.eu/home/html/researcher_mars.en.html.

of completion. In particular, for the projects that are not yet published at least as working papers, results may still change and one should be cautious in drawing firm policy conclusions from them.

MaRs is managed in a light structure by the chairman, Philipp Hartmann (ECB), and the network secretary, Angela Maddaloni (ECB), in cooperation with two coordinators for each of the three MaRs work streams: WS1 – Laurent Clerc (Banque de France) and Philipp Hartmann; WS2 – Carsten Detken (ECB) and Kateřina Šmídková (Česká národní banka); and WS3 – Paolo Angelini (Banca d'Italia) and Cornelia Holthausen (ECB). Professor Xavier Freixas (Universitat Pompeu Fabra) acts as an academic adviser and consultant. In 2012 Professor Hans Degryse (Katholieke Universiteit Leuven) was hired as a second consultant. Given differences in the nature, timing and context of the three works streams, each of them follows its own approach in executing the research, while information is regularly exchanged among them.

The MaRs work programme currently has two large joint cross-country projects and 126 individual projects. The joint cross-country projects, in which a large number of EU NCBs participate, concern the development of a "canonical model" for assessing macro-prudential policies as part of WS1 and the development of a financial crises database for the EU27 as part of WS2. At the end of 2011, WS3 also added a special initiative on research assessing sovereign contagion risks in Europe. The individual projects currently active include 72 in WS1, 41 in WS2 and 21 in WS3, as well as 15 projects with a special focus on sovereign contagion. MaRs research papers are published in the working paper series of the contributing NCBs and in the ECB Working Paper Series (with a "MaRs" stamp on the cover page and a brief description of MaRs inside). So far, 23 papers have been published as ECB working papers (seven from WS1, 14 from WS2 and two from WS3) and 16 papers have been accepted for publication and are forthcoming (ten from WS1, three from WS2 and three from WS3). Nine papers have already been published in journals (five from WS1 and four from WS2), including the Journal of Financial Economics, the Economic Journal and Economic Policy.

2. Macro-financial models linking financial stability and the performance of the economy

Much of the work in the work stream on macro-financial models linking financial stability and the performance of the economy constitutes relatively fundamental research. Therefore, it was expected that the projects in this work stream would not lead to operational policy tools during the initial two years of MaRs. Its main objectives are to develop theoretical and empirical frameworks that integrate realistic characterisations of widespread financial instability in models of the aggregate economy, allow the analysis of transmission channels between financial instability and macroeconomic variables, explain the recent crisis and assess policies addressing systemic risks. In pursuing these objectives, WS1 also provides some foundations for systemic risk research in general and for the analyses conducted under WS2.

The main research questions asked by the General Council in this regard are: *(i) How can financial instability be represented in an aggregate economic model? (ii) How does widespread financial instability affect the*

real economy? (iii) What are the main transmission channels of financial instability at the aggregate level? (iv) What role is played by non-linearities, amplification and feedback effects? (v) What are the cumulative effects of the two-way interaction between financial instability and the performance of the economy at large, including the build-up and unravelling of financial imbalances? (vi) How can the leverage cycle be described theoretically and empirically? (vii) How can these models help understand the causes and features of the recent financial crisis? (viii) How can models help identify the appropriate macro-prudential policies to maintain systemic stability? Arguably, the first and the last questions in particular point to significant gaps in current economics, as laid bare by the ongoing financial crisis. For the purpose of summarising the research work done so far, they are synthesised in six areas, which constitute the sections of this chapter.[5]

The work programme for WS1 currently includes 64 individual research projects and the joint cross-country project on the "canonical model" for assessing macro-prudential policy, which started in the summer of 2011. Authors have delivered 41 draft papers so far, of which 17 have been published or have been accepted for publication as ECB working papers. Although they are at different stages of development, all the 41 draft papers feed into the answers to the MaRs WS1 research questions below. Many of the other projects have also made progress, but are not covered below, as no draft paper with results is available as yet.

2.1 Representation of widespread financial instability in aggregate models

The literature has identified three phenomena that can make financial instability widespread. These three broad forms of systemic risk are contagion, the endogenous build-up and unravelling of widespread imbalances and aggregate shocks (or combinations of these three).[6] Systemic risk can be described as the risk that financial instability will become so widespread that it impairs the functioning of the financial system to such an extent that growth and welfare suffer materially. Typically, financial instability and its spread are characterised by elements such as amplification effects, non-linearities (a key one being the default of financial intermediaries) and illiquidity. Long before the present crisis, the theoretical and empirical finance literature had already provided good descriptions of the nature and sources of (non-systemic) financial instability, in particular in terms of single bank runs and crashes in specific financial markets. The same

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[5] There is other work produced within and outside the ESCB which touches on some related issues. For example, an ECB Occasional Paper is in the process of publication that analyses the role of macro-financial linkages from an empirical perspective (Hubrich, K., A. D'Agostino, M. Červená, M. Ciccarelli, P. Guarda, M. Haavio, P. Jeanfils, C. Mendicino, E. Ortega, M.T. Valderrama and M.V. Endrész, "Financial Shocks and the Macroeconomy: Heterogeneity and Non-linearities"). [**to be double-checked again at proof-reading stage**].

The Basel Committee on Banking Supervision has recently published two working papers by the Transmission Channels sub-group of its Research Task Force (RTF) on "Models and tools for macroprudential analysis" (http://www.bis.org/publ/bcbs_wp21.htm) and "The policy implications of transmission channels between the financial system and the real economy" (http://www.bis.org/publ/bcbs_wp20.htm). These two surveys of the literature are broader in scope than MaRs. In particular, a lot of emphasis is also given to macro-financial linkages that are not related to financial instability and to micro-prudential considerations.

[6] See, for example, the survey in ECB (2009).

applies to some key elements of systemic risk within the financial system, in particular bank and financial market contagion (mainly relating to MaRs WS3, which is covered in section 4 below).[7]

The aim of incorporating such phenomena in aggregate models is to support macro-prudential policies whose objective it is to contain systemic risks. Models that do not have realistic characterisations of widespread ("systemic") financial instability might not provide a sound basis for macro-prudential policy advice, because they cannot capture the main rationale and objective of such policies.[8] Imagine, for example, a theory about price stability or monetary policy without a good representation of inflation. Models that do not include such characterisations of systemic instability in an aggregate or macroeconomic model may not allow for a full welfare analysis and may miss important interactions between the financial sector and the real economy. Once realistic characterisations of widespread financial instability are incorporated in aggregate models, there is not only a sound broad basis for assessing systemic risks and macro-prudential policies but also a basis for studying the interactions between macro-prudential and monetary (or other) policies. The challenge is, however, that theories of monetary stability are much more developed in macroeconomics than theories of financial stability, partly because price stability is much easier to characterise than the more complex phenomenon of financial (in)stability. As a consequence, there were only very few examples in the literature of attempts to work towards the above aim.[9] From such a starting point, it was expected that progress would take time.

A preliminary step is to ascertain empirically that financial factors can be influential in a macroeconomic environment. The ongoing financial crisis could not have illustrated the relevance of financial factors for growth and welfare more strongly. Several MaRs papers use standard vector autoregression (VAR) or structural factor approaches to estimate for various countries whether and to what extent a variety of financial variables and shocks influence, for example, growth and inflation (Abildgren 2010, Alessi 2011, Fornari and Stracca 2012, Guarda and Jeanfils 2012, Tamási and Világi 2011). The general, and expected, conclusion is that financial factors do play an important role in the macroeconomy.

However, financial shocks and fluctuations do not necessarily constitute financial or even systemic instability as defined above. Is there a need to identify widespread financial instability more precisely? One can illustrate the answer to this point by comparing the very careful paper by Andreasen, Ferman and Zabcyk (2012) with a number of papers in the literature. These authors introduce a representative bank into a standard dynamic stochastic general equilibrium (DSGE) model and analyse the impact of maturity transformation, a key banking function, but do not allow for banking instability. An important result of this analysis is the strong "credit attenuation effect" that the maturity transformation has on the macroeconomy. Output reacts

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[7] Although instrumental as a starting point for most MaRs research, this body of literature is much too voluminous to be covered in this report. De Bandt and Hartmann (2000) provide an extensive survey of the financial contagion literature and discuss how it relates to the main non-systemic financial instability research.

[8] See also the work by WS2 on measuring systemic risk and financial stress in section 3.1 of this report.

[9] ECB (2010) discusses how far contemporaneous macroeconomics was from reaching this aim until recently.

much less to standard shocks, such as productivity or monetary policy shocks, when banks are performing maturity transformation than when they are not. Contrast this with experiences from the financial crisis and other recent research, in which maturity transformation plays an important amplifying role in the macroeconomy. In other words, making the additional step from financial factors or frictions to realistic characterisations of widespread financial instability may be rather crucial. It may turn some results upside down.

2.1.1 Theoretical research

Theoretical research in this field is very important, as we are still lacking aggregate theoretical models that provide a sound basis for analysing systemic risk, as defined above, and macro-prudential policy. In terms of preliminary steps to look for elements that could be used to improve on this situation, there are four strands of literature. First, the theoretical part of the extensive financial instability literature in finance referred to above delivers many insights into what to introduce into models of the aggregate economy. Second, there was some influential pre-crisis general equilibrium literature on asset prices deviating from fundamentals (Tirole 1985 and Weil 1987). Despite its elegance, this "rational bubbles" literature made little progress in enhancing the understanding of systemic risk, because its focus on over-investment in the real economy implied that bubbles would lead to a welfare-improving contraction in economic activity. Third, general equilibrium models with incomplete markets (Geanakoplos and Polemarchakis 1986) featured imperfectly functioning credit markets and could be extended with defaults of agents (Dubey, Geanakoplos and Shubik 2005). Goodhart, Sunirand and Tsomocos (2005 and 2006) were probably the first to develop this approach to systemic risk analysis, notably by incorporating defaultable heterogeneous banks in such modelsl. Fourth, the standard literature on macro models with credit frictions (Bernanke and Gertler 1989, Kiyotaki and Moore 1997 and Bernanke, Gertler and Gilchrist 1999) illustrated financial accelerators in regular business cycle fluctuations, but did not feature many key elements characterising financial instability.

Broadly in parallel with MaRs, a few outside academics have also made efforts to improve this rather unsatisfactory situation. For example, Brunnermeier and Sannikov (2012), Bianchi and Mendoza (2010), Kiyotaki and Gertler (2012) and Corbae and D'Erazmo (2012) are working on macroeconomic models with more elaborate financial sectors in which bank defaults and non-linearities are represented. The macro bubbles literature has also moved forward, owing to the insight that, in an environment in which agents are credit-constrained, asset price misalignments can be the cause of boom-bust cycles (Martin and Ventura 2012 and Farhi and Tirole 2012). The MaRs research summarised below focuses in particular on the build-up and unravelling of widespread imbalances or aggregate shocks or combinations of the two. All the theoretical papers prepared under MaRs in this area use general equilibrium approaches.

Eichberger, Rheinberger and Summer (2011) make a fundamental contribution to this field of research by studying default risk in a general equilibrium model of a two-period exchange economy in which agents borrow from and lend to each other through bonds. This work builds on Dubey, Geanakoplos and Shubik

(2005), but models financial default in a more realistic manner which allows the authors to analyse systemic risk (a chain of defaults in their framework). Agents are subject to endowment shocks and construct bond portfolios so as to optimise their consumption plans. An agent defaults on its bonds when the shock is so large that the value of the agent's liabilities exceeds the value of its assets. The assets of this agent are then seized and distributed among the creditors, realising a haircut determined by the initial loss ("bankruptcy rules"). Systemic instability emerges when the endowment shocks are so severe and widespread relative to the risk attitude of agents that a larger number of agents default. A main point of the paper is to illustrate the endogenous and interconnected nature of default risk. Models and regulatory approaches (see sub-section 2.6.1) that treat default risks exogenously may be subject to significant biases and mistakes.

Boissay (2011) characterises widespread financial instability in a static general equilibrium model representing a number of features of the present crisis (see sub-section 2.5). The model has multiple equilibria. The crisis equilibrium is characterised by a drying-up of inter-agent lending, liquidity hoarding and de-leveraging by financial agents, and a reduction in the financing of investment projects and consumption. The equilibrium in tranquil times is self-fulfilling and has a liquid inter-agent ("interbank") market, high leverage and many risky agents receiving funds. The crisis equilibrium exists for certain parameter configurations, which describes a situation of systemic "fragility". It materialises when financial agents ("banks") lose confidence in other financial agents ("banks") to whom they lend to put their money in profitable investment projects rather than misusing the funds. A coordination failure (like, for example, in standard bank run models à la Diamond and Dybvig 1983) emerges among the financial agents, which leads to the switch from the good to the bad equilibrium. The reason is that lending agents cannot observe the skills/behaviour of the borrowing agents (asymmetric information). As a consequence, the economy can develop widespread endogenous imbalances in terms of high leverage and sizeable inter-agent markets, which are subject to the fragility described above.

Boissay further extends the model to two countries. In one country (the "emerging economy") the enforceability of financial contracts is weak and in the other (the "industrial country") it is strong. As a consequence, capital flows from the emerging economy to the industrial country, thereby creating a "global imbalance". Again, there are multiple equilibria and a switch to a crisis equilibrium can happen in which global capital flows freeze and the industrial country has to de-leverage.

Boissay, Collard and Smets (2012) incorporate a representation of this mechanism of asymmetric information between lenders and borrowers leading to fragility in the lenders' wholesale funding markets in a textbook real business cycle model. With this dynamic characterisation, the model can generate an endogenous long boom with growing imbalances that eventually unravel, causing a financial crisis. Calibrating the model to historical data, they can account for the dynamics of regular business cycles and crisis business cycles in industrial countries since the end of the nineteenth century and find that crises can break out at the top of the business cycle, in the midst of a credit boom, and that the rare business cycle downturns that are associated

with the breakdown of wholesale funding markets for lenders are much more severe than regular recessions (Schularik and Taylor 2009, Claessens, Kose and Terrones 2012 and Abiad, dell'Arriccia and Li 2010). Since the move to a crisis is no longer represented as a switch between different equilibria, crises become predictable. In fact, the model provides a measure of the probability of a crisis cycle emerging in the future that could be used as a theory-based early warning indicator.

Lambertini, Mendicino and Punzi (2010) and Gomes and Mendicino (2011) explain housing boom-bust cycles in a general equilibrium model by appealing to fluctuations in household expectations of future macroeconomic developments. A boom can occur if households become optimistic about the future, leading to expectations of house price appreciation. Among others, expectations about future productivity gains or low interest rates lead them to take on more debt and buy more houses. However, if future productivity or monetary policy shocks dash the positive expectations, then households have to reverse their behaviour and de-leverage, with potential consequences in terms of macroeconomic instability. Derviz (2011) explains equity boom-bust cycles through ex ante upwardly biased expectations about corporate prospects, which are not subsequently met.

Aoki and Nikolov (2011) introduce financial intermediaries that can default into a general equilibrium model of bubbles à la Martin and Ventura (2012). Banks take deposits and provide loans to firms, but can also invest in an asset which never pays dividends and hence has no fundamental value. Because firms and banks are credit constrained this decreases interest rates, leading to "search for yield", which can involve the increase in asset prices above their fundamental value. During a "search for yield episode" the "zero-dividend" asset can have a positive value ("bubble"), as investors hold it purely in the expectation that it will appreciate in price. There are multiple equilibria: one where the bubble asset has value and another where it does not, because investors do not have confidence in its future value. Financial instability is characterised by a switch from the first to the second equilibrium, which reduces the net worth of the banking system and causes a credit crunch and a deep recession. In the absence of government intervention, the bubble's collapse may also lead to the insolvency of the banking system. Using the same model, Aoki and Nikolov (2012) show that the emergence of a bubble is accompanied by a very large increase in the ratio of money and credit to GDP and much of the credit is "wasted" on financing unproductive bubble holdings. This provides theoretical support to empirical studies which have found that aggregate money and aggregate credit are good leading indicators of future financial instability. However, these aggregates need to cover all credit providers, including shadow banks, since they will otherwise fail to give the right signals.

De Walque, Pierrard and Rouabah (2010) make an important step by introducing banks and a representation of their default (building on Goodhart et al. 2005 and 2006) in a micro-founded DSGE model. There are two banks in the economy choosing their balance sheets endogenously; one a net borrower and the other a net lender in the interbank market. The representation of bank default is not that the bank disappears from the economy, its balance sheet is liquidated and creditors are reimbursed with a hair-cut determined by the extent

of bank losses, but that the defaulting bank continues, faces a disutility and pays a special cost in the next period. This cost increases the interbank rate and reduces interbank lending, ultimately affecting the real economy and amplifying cycles (see sub-section 2.2 below).

Derviz (2012) studies an economy in which firms hold bank liabilities for diversification purposes. The benefit of these diversified asset holdings is a reduction in the firm's default frequency in normal times. However, the paper shows that such diversification increases financial fragility. Because bank liabilities themselves are backed by loans to the corporate sector, the economic structure ends up looking like a chain of leveraged claims. The value of bank bonds depends on the values of corporate debt and equity. These in turn depend on the value of corporate holdings of bank debt and so on. Combining insights from the literature on financial stability risks associated with collateral (Dubey et al. 2005) and on diversification (Ibragimov, Jaffee and Walden 2011) in a Keynesian production economy, the paper demonstrates how long and inter-connected intermediation chains can amplify shocks and increase systemic risk.

2.1.2 Empirical research

The first key contribution by MaRs researchers to the question of how to integrate widespread financial instability in empirical macroeconomic models using European data was made by Hartmann, Hubrich, Kremer and Tetlow (2012). They introduced the Composite Indicator of Systemic Stress (CISS), which was developed as part of WS2 as a measure of systemic financial instability, into a Bayesian Markov-switching vector autoregression model (à la Sims and Zha 2006) of the euro area estimated with monthly data between 1987 and 2010. The other variables in the VAR are production growth, inflation, loan growth and the short-term interest rate. The CISS aggregates financial stress in the main financial markets and among the main types of financial intermediary in a financial system, putting particular emphasis on the dependence between these different components of a financial system (see sub-section 4.1 on MaRs WS2 and Holló, Kremer and Lo Duca 2012). This ensures its clear focus on systemic instability, which is well reflected in the fact that the CISS assumed unprecedented levels close to its maximum value for extended periods of time during the recent financial and sovereign debt crises.[10] The second way in which the Hartmann et al. approach captures widespread financial instability is by allowing two types of regime change driven (endogenously) by the data: first, the parameters connecting the five variables can switch (between three regimes) and, second, the variances of the error terms – reflecting the size of shocks and the general uncertainty around economic relationships – can switch (between two regimes). In fact, the authors find that the most dramatic regime changes (of both types) tend to coincide exactly with the most severe financial crises, illustrating that an economy may function fundamentally differently in times of systemic instability than in tranquil times. The transition may also be highly non-linear (see also sub-section 2.3). The analysis conducted in the paper

[10] A companion paper for US data uses a similar econometric methodology, but incorporates a more standard financial stress index (Hubrich and Tetlow 2010).

concentrates in particular on how an upward shock on the CISS affects the other variables, notably industrial production growth, depending on the regime the economy is under.

Guarda, Rouabah and Theal (2011) argue that macro-prudential stress tests could better capture widespread financial instability if the shocks fed into the VARs used in these tests were allowed to have "fat tails". They introduce a mixture vector autoregressive model, i.e. a VAR in which the errors are composed of a mixture of normal distributions and therefore have more frequent extreme events than the standard normal (based on the methodology developed by Fong, Li, Yau and Wong 2007), into the stress testing framework used at the Banque centrale du Luxembourg. They find that bank capitalisation levels under a stressed scenario turn out to be significantly lower when tail events are accounted for than when using a regular VAR with normally distributed shocks.

Four other empirical papers available in WS1 start from specific financial shocks in linear VAR or factor models. So, the extent to which they can capture widespread financial instability depends very much on the nature, severity and breadth of these shocks.[11]

Abildgren (2010) estimates a quarterly VAR with nine endogenous variables for Denmark between 1948 and 2010. The main financial shock considered, and therefore the measure of widespread financial instability, is an exogenous one-standard deviation increase in banks' aggregate write-down ratio. This ratio is defined as loan impairment charges in per cent of loans and guarantees, but it is open to different interpretations. It could be interpreted as a measure of current weaknesses in the banking sector, or as a forward-looking indicator, because it reflects the banks' expected future losses. Historically, write-downs have been booked one to two years before the losses are realised. The write-down ratio could also be interpreted as a measure of instability arising from factors within the banking sector (for instance, a sudden reassessment of the credit quality of banks' loan portfolios or a sudden extraordinary increase in the banking sector's risk aversion) or from factors outside the banking sector (for instance, weakened confidence in the banking sector, which increases the saving behaviour of households and firms).

Guarda and Jeanfils (2012) augment the standard VAR with five financial variables (real stock prices, real house prices, the term spread, the loans-to-GDP ratio and the loans-to-deposit ratio) for 19 industrialised countries and quarterly data between 1980 and 2010. They find that the five financial shocks contribute up to a third of real fluctuations, with asset prices contributing most. Moreover, the combined contribution of the five financial shocks is usually higher for fluctuations in investment than in consumption. Last, their contribution is larger during episodes of financial boom and bust.

Tamási and Világi (2011) estimate a quarterly Bayesian structural VAR with seven endogenous variables for Hungary between 1995 and 2009. They try to capture credit supply shocks in two ways: 1) through a "risk

[11] Surprisingly, when MaRs started there was hardly any literature following this approach. For an overview of what existed at the time, see the ECB Occasional Paper referred to in footnote XX **[to be double-checked at proof-reading stage]**.

assessment shock" described by a joint increase of the corporate default rate and the quantity of credit and 2) through a "policy shock" described by an increase in the difference between corporate bond and money market rates ("credit spread").

Fornari and Stracca (2012) estimate quarterly VARs with seven endogenous variables for 21 countries and aggregate the results afterwards. A financial shock is identified by postulating that a positive (negative) financial shock has a positive (negative) impact on the ratio between the share price of the financial sector and the composite stock market index. This intuition relies on the fact that the financial sector is at the heart of the financial intermediation process that is subject to disturbance and that it is significantly more leveraged than the rest of the economy. A shock that is accompanied by rising leverage and less stringent credit constraints has a larger impact on the return on equity of the sectors that are most exposed to the external finance premium and therefore benefit more from favourable financing conditions (see also section 2.4 on the "leverage cycle").

Alessi (2011) estimates the structural factor model of Forni, Giannone, Lippi and Reichlin (2009) for eight euro area countries and the euro area as a whole between 1980 and 2009. A large number of variables (more than 200) and parameter restrictions are used to identify three types of financial shock: one denoted as an "equity price bust" (associated, inter alia, with a year-on-year 10 percentage point decline in the equity market index), another as a "housing market decline" (associated, inter alia, with a year-on-year 10 percentage point decline in the housing price index) and the last as a "credit crunch" (associated, inter alia, with a 1% decline in credit).

Costeiu and Neagu (2012) develop an analytical tool to assess whether a banking sector is adequately prepared to orderly withstand losses resulting from corporate defaults and macroeconomic factors. The aggregate model links the probability of default for the corporate sector, estimated from micro data, with a macroeconomic module. The tool is applied to a European emerging economy.

2.2 Transmission channels of financial instability in aggregate models, amplification and feedback effects

The ultimate gauge for the assessment of financial instability is the effect on the economy at large, in particular on growth and welfare. What the research has to say about how an event of financial instability is transmitted to the real economy is, therefore, important. A challenge is that some of the representations of financial instability in sub-section 2.1 above are more widespread (more "systemic") or more realistic than others. An attempt is made in this section to illustrate transmissions even in cases where the representation of financial instability is rather "mild". Since most MaRs research in this regard is based on theoretical general equilibrium models and empirical VAR models, it generally captures the two-way interaction between the financial system and the real economy. This contrasts with standard stress testing approaches regularly used in financial stability assessments, where only the first round effect of a macroeconomic shock scenario on banks is considered, but not the feedbacks from any emerging bank instability to the real economy.

2.2.1 Theoretical research and calibrated macro models

Most theories of financial transmission work through the supply of and demand for loans. Traditional macro models with financial frictions (Bernanke, Gertler and Gilchrist 1999, Kiyotaki and Moore 1997) rely on the link between borrowing capacity and collateral asset values. In other words, they are models where credit constraints affect mainly loan demand. Post-crisis macro models (Gertler and Karadi 2009, Gertler and Kiyotaki 2012 and others) focus on credit supply disruptions.

In Aoki and Nikolov (2011), the bursting of the asset bubble implies that bank losses reduce the banks' net worth. The leverage constraints on banks become binding and they curtail credit supply. This, in turn, reduces the net worth of non-financial firms, which constrains their loan demand and further depresses bank margins and banks' ability to lend. As a consequence, the initial shock is significantly amplified. The interaction of loan supply and loan demand implies that bank capital, loan supply and output return to pre-crisis levels only slowly. Liquidity hoarding and de-leveraging in the crisis equilibrium in Boissay's (2011) theory have the effect that part of the savings collected by financial agents is no longer re-distributed through lending to the real sector. This lowers aggregate investment relative to the tranquil equilibrium. In Eichberger et al.'s (2011) theory, the breakdown of risk sharing among agents implies that their consumption plans become less favourable relative to their preferences.

The effects of financial frictions in DSGE models are usually assessed by calibrating the models to major economies and imposing productivity or monetary policy shocks to analyse whether the frictions increase the amplitude or persistence of the adjustment path of major macroeconomic variables. In de Walque et al. (2010) the shocks may lead a bank to "default", i.e. pay the bankruptcy cost in the next period. This increases the interbank rate, which translates into higher lending rates for firms and therefore reduced loans and investment. Some non-financial firms may also default as a consequence, which impairs banks and feeds back to the interbank market. These interactions between the interbank market and the real economy lead to the amplification of macroeconomic cycles. The very relevant other DSGE paper with banks, but without a representation of their default, is discussed in sub-section 2.4, because the transmission between financial and real sector is closely tied to the "leverage cycle". In Derviz (2012), bank losses on their holdings of the debt and equity of firms causes bank defaults and a financial crisis.

The theory of Lambertini, Mendicino and Punzi (2011) mentioned above works through the demand for housing. Optimistic expectations about future developments in several sectors of the economy can trigger an upturn in housing demand and housing prices that starts a boom-bust cycle characterised by co-movement in GDP, consumption, investment, hours worked and real wages. In particular, news of both productivity and monetary policy shocks can be a source of empirically plausible booms in house prices. However, only expectations of shocks related to the behaviour of nominal variables, such as the policy rate or the inflation rate, that are not met are also likely to cause a subsequent macroeconomic recession. Credit conditions also

play an important role in contributing to boom-bust cycles driven by news of shocks originating in other sectors of the economy.

2.2.2 Empirical research

The wide scope for interdependencies between all the variables make VAR analyses relatively flexible in capturing feedback effects (also between financial and real variables) and a variety of transmission channels. It is not possible, however, to directly test theoretical hypotheses, but the ordering of variables and identification of restrictions make certain theoretical explanations more plausible than others. In Hartmann, Hubrich, Kremer and Tetlow's (2012) paper industrial production growth is ordered first and the CISS last and the focus is on how systemic financial instability affects overall economic activity, taking all real and financial feedback effects into account without imposing too many economic restrictions. In other words, the results should reflect both credit supply effects (banks impaired by financial instability lend less) and credit demand effects (firms and households invest and consume less due to the heightened uncertainty or capital losses caused by financial instability, leading them to borrow less) without, however, disentangling their relative importance. A main result of this analysis is that a sizeable increase in systemic instability in the parameter and variance regime of tranquillity has only a very limited effect on growth. In contrast, in the regime where parameters and variances have switched, the impulse response function of a CISS shock shows a large and protracted economic downturn in the euro area. Taken together with the results reported in sub-section 2.1.2, this implies that the fundamentally differently functioning economy subject to systemic financial instability also suffers a much more severe recession than a model that cannot accommodate regime changes would predict.

In Abildgren's (2010) paper the aggregate write-down ratio is ordered last and the effects from a shock on it on aggregate credit and GDP is likely to capture a bank lending channel. The results suggest a statistically significant and persistent negative effect of sizeable bank write-downs on credit, house prices and GDP growth in Denmark. For example, the extraordinary increase in write-downs in Denmark in 2008 led to real GDP being around 3% lower in the first half of 2010 than in a baseline scenario without a financial crisis. The two credit supply shocks in Tamási and Világi (2011) have different effects on the real economy. The "risk assessment shock" has a significant but short-lived effect on GDP growth, but not on the credit spread. In contrast, the "policy shock" induces significant short-lived adjustments in both the quantity and the price of credit. This leads the authors to read the former as a loan allocation mechanism and the latter as a price allocation mechanism. Moreover, they find that in Hungary the interest rate channel of a monetary policy shock is more important than the credit channel. Finally, the authors show that credit supply shocks nevertheless contributed significantly to the decline in growth in Hungary starting in early 2009, although at the same time unidentified shocks increased in importance.

Fornari and Stracca (2012) find, first, that a financial shock has significant influence on output, investment and the price level. These results are not driven by periods of credit boom and bust, including the 2007-2009

financial crisis. Variance decomposition analysis suggests that at a horizon of 24 quarters the financial shock explains 18% of the CPI variability, 13% of GDP and investment variability and 23% of the variability in credit to the private sector. Therefore the financial shock plays a significant role in explaining business cycle fluctuations. Surprisingly, the propagation of the financial shocks is found not to depend on the financial and economic features of specific countries.

Also the semi-structural factor analysis of Alessi (2011) allows the transmission of the three financial shocks considered to be quantified. The shock decreasing real equity prices by 10 percentage points a year leads to a 0.3 percentage point yearly decline in real GDP growth after half a year, which does not revert to benchmark levels until five quarters later. According to this estimated elasticity, the further 30 percentage point drop in the year-on-year growth rate of equity prices, which took place in the fourth quarter of 2008 (assuming it was fully unanticipated, while the equity market was actually already down by 30% year-on-year when Lehman collapsed), would have led to a further growth decrease of about 0.9 percentage point by the second quarter of 2009 compared to the end of 2008. The concomitant effects of other adverse shocks actually reduced 2009 second quarter growth by 3 percentage points compared to six months before. The model predicts that, after the shock to equity price growth, it would take between three and five quarters to return to pre-crisis levels, which indeed happened around mid-2009. Turning to inflation, its estimated response is negative, but in general small or not significantly different from zero.

A shock causing an unanticipated ten percentage point drop in year-on-year house price inflation decreases housing investment growth by 0.6 percentage points in the quarter following the shock and leads to a fall in the real GDP year-on-year growth rate of about 1.6 percentage points after three to four quarters. Growth reverts to pre-shock levels after two years, according to the point estimate. The response of inflation is not significant, however. According to the point estimate, inflation decreases by 0.75 percentage point in about two years.

In response to a one percentage point decline in credit growth, output growth decreases by 0.2 percentage point after three quarters, while inflation decreases by slightly less than 0.1 percentage point over the same horizon. In both cases, the response becomes insignificant after about one year. House price inflation decreases by 0.4 percentage point after three quarters, while the response of equity prices is not significant (the point estimate being actually around zero in the medium to long run). Not surprisingly, M3 growth decreases at impact by about the same amount as credit growth. The long-term and short-term nominal rates also decrease at impact, by 25 basis points.

Moving away from VAR and factor analyses, Beck, Jakubik and Piloiu (2012) analyse the determinants of aggregate non-performing loans as an important aspect of the transmission of financial instability. Conducting dynamic panel estimations for 75 countries (a much wider coverage than previous similar cross-country studies, such as Nkusu 2011) over the past decade, they find the most important determinants to be real GDP growth, lending interest rates, share prices (in particular in countries where the stock market is

large) and exchange rates. The latter two results are novel. In fact, after controlling for the state of the business cycle, unhedged foreign currency borrowing, which tends to be particularly pronounced in countries with pegged or managed exchange rates, turns out to be the most significant source of loan losses. Treating real GDP growth as endogenous, the methodology implicitly takes into account feedback effects from non-performing loans into economic activity.

Neagu and Mihai (2012) develop a liquidity tool to highlight the transmission channels of a capital outflow shock to the banking and real sectors. The tool incorporates feedback from the banking sector to the real economy and a link from liquidity to solvency, and it is used for (i) testing the capacity of the banking sector to withstand sudden stops in capital flows and gauging the consequences of the liquidity stress for solvency ratios, (ii) quantifying the liquidity deficit that a central bank might have to accommodate (for both total and foreign exchange positions), (iii) assessing the impact of the sudden stop on credit supply, and (iv) evaluating some policy options.

Building on the bank-firm relationship literature, Abildgren, Vølund Buchholst and Staghøj (2011) focus on asymmetries in the transmission of financial instability, using a unique micro dataset of 37,000 non-financial firms in Denmark over the last one and a half decades. Based on credit scoring techniques, they find that the health of a firm's bank influences the firm's probability of default (see Gibson 1995 for a related study about Japan using corporate investment). More precisely, weak firms – who cannot easily switch bank – with a relationship to a weak bank were more likely to default during the crisis of 2008-2009 than firms with a similar balance-sheet structure but a relationship to a sound bank.

Abildgren (2012) uses a structural vector autoregression model to study the real effects of credit supply shocks coming from the traditional commercial banking sector. Inspired by a related "financing mix" strategy developed by Kashyap, Stein and Wilcox (1993) for the United States, credit supply shocks are identified by examining the share of commercial bank lending in the total supply of credit to the non-financial sector in Denmark. A fall in the share that cannot be explained by developments in economic activity, interest rates, share prices etc. is interpreted as a negative supply shock, while a rise in the share is interpreted as a positive supply shock. The Danish financial system is dominated by very safe mortgage banks, which have been made immune to financial instability by tight regulation. In contrast, commercial banks have specialised in riskier loans, so credit supply shocks are likely to originate from these financial institutions. The paper, however, finds that credit supply shocks coming from the commercial banking sector have not had large real effects in Denmark over the past 90 years. This result holds even during periods of major banking crisis. This might reflect government interventions during times of financial crisis. However, it might also reflect the fact that the real effects of financial crises in Denmark have been driven more by their damaging impact on consumer and business confidence than by credit supply restrictions.

Neagu, Costeiu and Tarta (2012) investigate whether banks' lending decisions amplify negative feedbacks from the corporate sector, leading to higher vulnerabilities in the financial system. The model is tested for the

case of a European emerging country. The findings highlight that before the crisis companies with access to bank loans in this country were able to deliver higher value added growth rates than firms constrained in their access to loans. During the crisis, however, the situation reversed. This supports the idea that the economy could benefit from creditors pursuing a longer-term approach in their lending decisions.

2.3 The role of non-linearities

Non-linearities are a central element of financial instabilities, in particular in the transition from stability to instability and potentially also in the transmission of financial instability to the macroeconomy, but they are particularly difficult to capture in aggregate models. For example, standard DSGE models tend to be solved by linearising them around the steady state. Broadly in parallel with some outside efforts (see, for example, Brunnermeier and Sannikov 2012 and Bianchi and Mendoza 2011), a number of theoretical MaRs papers currently capture non-linearities, for example by appealing to multiple equilibria or by modelling occasionally binding borrowing constraints.

In both Boissay (2011) and Aoki and Nikolov (2011), the switch from one equilibrium to the other implies a major discontinuity in most of the major variables, both financial and macroeconomic. In both cases, it is the unravelling of a widespread imbalance. By virtue of the nature of multiple equilibria supported by self-fulfilling expectations, the cause of the switch is not modelled. Boissay, Collard and Smets (2012) introduce non-linearities through transitions between regimes that are, however, not multiple equilibria arising from coordination failures between agents. The regime change occurs endogenously when a credit boom leads to too many bad borrowers and the interbank market consequently freezes.

A second non-linearity in Aoki and Nikolov arises from occasionally binding constraints, whose emergence depends on the behaviour of asset prices. In times without a bubble, the banks' leverage constraint binds and capital is a limiting factor in loan supply – capital is scarce and banks earn large margins. But when, for example, banks face competition from other intermediaries that are not subject to this constraint, bank margins decrease and their incentive to invest in an asset with a bubble increases significantly. This, in turn, creates financial fragility. Mendicino (2012) examines the response to shocks of a non-linear model with collateral constraints. The non-linearity again arises from the presence of occasionally binding constraints and leads to higher precautionary savings (lower leverage) as agents anticipate the costly consequences of credit constraints binding in recessions requiring asset fire sales. Nevertheless, Mendicino shows that the precautionary behaviour of borrowers does not prevent credit constraints from binding in downturns. This in turn makes the economy's response to shocks asymmetric – negative shocks are propagated more strongly than positive ones.

Derviz (2011) models real activity disruptions as a result of the bursting of financial bubbles that can follow even a very small shift in economic sentiment. In particular, the model shows how a transition from classical relationship-based commercial banking following the "know your customer" principle to arm's length lending (which, taken to the extreme, can mean securitisation and the typical problems of the originate-and-

distribute approach) can disrupt the equilibrium debt-equity financing mix, thereby wiping out real activity (implying a transition from a purely financial turbulence to a recession). The model captures the potential diversion of funds by financial intermediaries and how this can translate into a crisis with adverse real effects: the wholesale banker, indifferent between delegating and not delegating lending decisions to an agent with superior knowledge, can channel the depositors' money to a portfolio of arm's length loans, which may then break down as a consequence of a purely informational shock.

On the empirical side, the MaRs paper by Hartmann, Hubrich, Kremer and Tetlow (2012) suggests that in practice such non-linear adjustments are material. The switches between the three parameter and two variance regimes lead to large changes in the growth implications of widespread financial instability. This could be due to shifts between multiple equilibria but also other mechanisms. First, the non-linearities offer an explanation of why traditional linear macroeconomic models underestimated so dramatically the real implications of the financial crisis that worsened so much in September 2008 or of the sovereign debt crisis which followed in May 2010. Second, they can also contribute to explanations of why in the past some researchers using linear estimation methods struggled to find an important role for financial shocks in driving economic fluctuations. The effect of financial shocks on the real economy estimated by Hartmann et al. is large and long-lasting under infrequent high financial stress regimes and small and short-lived in tranquil times. The mixture VAR model of Guarda, Rouabah and Theal (2011) discussed in sub-section 2.1.2 also has non-linearities which exacerbate counterparty credit risk in stress tests and thereby contribute to the more dramatic erosion of bank capital under stressed scenarios in the model.

By definition, the various linear VARs produced under MaRs cannot capture the non-linearities discussed in this sub-section. But one could perhaps interpret the exogenous financial shocks studied by Abildgren (2010), Alessi (2011), Fornari and Stracca (2012) and Tamási and Világi (2011) as discontinuities, which would then lead to a linear adjustment. However, the models do not explain where these discontinuities come from and it is also relevant how large they are.

2.4 Descriptions of the leverage cycle

While the fundamental role of debt dynamics in financial crises has a long history (Minsky 1977, Kindleberger 1978, Schularick and Taylor 2009), the formal modelling of a leverage cycle seems to go back to Geanakoplos (2003 and 2009) and his address to the 8th World Congress of the Econometric Society in 2000. At some level it describes the observation that leverage (broadly the ratio of debt to equity) shows large fluctuations over time, is a major determinant of asset prices and therefore (through the use of assets as collateral and related risk management techniques, such as risk-sensitive margin requirements) amplifies fluctuations in credit and economic activity. Owing to the significant build-up of leverage in the run-up to the current crisis, the topic has received renewed interest, including in the academic literature. For example, Adrian and Shin (2010) show empirically that pro-cyclical leverage works strongly through broker-dealer balance-sheets and their activities in repo markets. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010)

constructed theoretical macro models in which bank leverage is a key determinant of aggregate credit supply. Accordingly, one of the research questions in WS1 concerns the description of the leverage cycle.

The model of Rannenberg (2011) combines leverage of both banks and borrowers (non-financial sector). Banks have a costly state verification problem vis-à-vis borrowing entrepreneurs (the agents accumulating the capital stock, as in Gertler and Karadi 2011) and a moral hazard problem in relation to their depositors (as in traditional financial accelerator models – Bernanke, Gertler and Gilchrist 1999). The leverage of both the lender (bank) and the borrowing entrepreneur affects the spread between the interest rate on loans and the risk free rate, i.e. the external finance premium, and this cost is transmitted to the price of capital goods and investment.

The bank's leverage constraint arises because, after collecting household deposits, a bank could divert a fraction of its assets and declare bankruptcy. Therefore the bank will only be able to attract household deposits if its expected lifetime profitability is sufficiently high that it has no incentive to divert assets. Hence an increase in the bank's leverage today, and thus also in the potential benefit of diverting assets, has to be matched by an increase in expected lifetime profitability, which means an increase in the expected profit margin on bank loans. Furthermore, a decline in expected future bank leverage relative to today's bank leverage also requires an increase in the expected profit margin. Low expected future loan demand relative to the bank's own funds lowers the bank's expected lifetime profitability and thus restricts today's loan supply. Thus an expected banking sector de-leveraging increases today's external finance premium.

Both a monetary tightening and an adverse productivity shock trigger a banking sector de-leveraging. The response of the external finance premium, and thus output and investment, both to a monetary tightening and an adverse productivity shock is amplified as compared to a conventional financial accelerator-type model where only the leverage of entrepreneurs drives the external finance premium. A negative shock to the net worth of entrepreneurs causes a deeper downturn than in a conventional financial accelerator model. The increase in entrepreneurial borrowing and leverage associated with the sudden loss of funds increases the external finance premium, just as in a conventional financial accelerator model. The increase in entrepreneurial borrowing requires in turn an increase in bank leverage, which, in the presence of a leverage constraint in the banking sector, requires a further increase in the external finance premium, thereby causing the comparatively deeper downturn. As regards a negative shock to the net worth of banks, the bank leverage constraint also implies a deeper economic downturn than is the case in a standard accelerator model, again through increased bank leverage.

The paper by Boissay (2011) also belongs to the literature that sheds light on leverage cycles, in particular reversals in bank leverage through the collapse of wholesale funding markets. In this model, reversals in leverage follow coordination failures among lenders in wholesale markets. These may cause switches from a tranquil equilibrium, characterised by too much liquidity in the interbank market and high leverage, to a crisis equilibrium, characterised by the drying up of liquidity and substantial de-leveraging. In the later paper,

Boissay, Collard and Smets (2012), the leverage of the aggregate banking sector increases during the boom, before collapsing when the wholesale funding markets freeze, leading to a crisis with a credit crunch.

A leverage expansion during the boom phase and a sharp contraction in the bust is also modelled in Aoki and Nikolov (2011). In this model, the leverage expansion is due to asset prices exceeding their fundamental values. In the hands of banks, bubbles pose a significant threat to financial stability, since banks' net worth is damaged by a collapse in over-exuberant asset prices. A systemic banking crisis then occurs and the provision of credit suddenly contracts. Firms face high lending rates and contract investment and employment as a result. The result of this analysis would suggest that limits on bank leverage could prevent excessive exposure to misaligned assets and help to mitigate the credit crunch accompanying the bust.

The paper by Nikolov (2012) focuses on modelling endogenous leverage, where borrowers can pledge not only tangible assets but also their reputation for repayment. It extends Kiyotaki and Moore's (1997) credit cycle concepts with market exclusion as a punishment for default, as for example in Alvarez and Jermann (2000). When a borrower's reputation for repayment is valuable, leverage is high and down-payment requirements on asset purchases are low. Such a situation occurs when agents are optimistic about future growth prospects and when uncertainty is low. Pessimism about the future or a rise in uncertainty work in the opposite direction, forcing borrowers to deleverage and amplifying the downturn in economic activity. The paper argues that the leverage cycle contributes substantially to macroeconomic and financial volatility.

Bhattacharya, Goodhart, Tsomocos and Vardoulakis (2011) examine the effect of leverage, as a path-dependent process, on financial stability by linking learning to risk-taking behaviour. Banks are constrained in increasing their leverage and in taking more risk by endogenously higher credit spreads, which creditors charge in anticipation of higher default. However, both banks and creditors become more optimistic about future profitability over a prolonged period of good realisations and low volatility. As a result, banks can secure lower borrowing rates, while, at the same time, continuing to increase their risk-taking. This increases the risk to financial stability should a bad shock materialise. The model suggests that limits on the leverage ratio are not a sufficient tool to mitigate the adverse consequences of the leverage cycle, given that banks can deleverage internally by reducing the weight of safer assets in their portfolio. Moreover, capital requirements in the spirit of Basel II cannot account for the procyclicality in risk-taking given that risk-weights are calculated on the basis of expected losses and are biased by optimistic expectations. On the contrary, a requirement concerning the relative portfolio allocation between riskier and safer assets can reduce financial instability and improve welfare.

Dufrenot, Klaus, Malik and Vardoulakis (2012) attempt to empirically test the prediction of leverage cycle theories that real economic activity should not only depend on realised shocks, but also on past optimising behaviour and risk-taking of financial institutions. As a proxy for real economic activity, they use the net tightening of credit standards index obtained from the Federal Reserve's Senior Loan Officer Opinion Survey on credit conditions/bank lending practices. They implement a time-varying transition probability Markov-

switching model and construct a leading indicator based on the leverage of broker dealers and commercial banks in the United States. Their indicator is found to carry significant information on the evolution of credit conditions. Moreover, the response of credit standards to changes in the leading indicator differs among regimes. When credit standards are relatively soft, higher leverage and more risk-taking signal a deterioration in future credit conditions, while they signal a recovery within an already tightening regime. Finally, the analysis also considers price-based measures, such as the VIX index, the TED spread (the difference between the interest rates on interbank loans and on short-term US government debt) and the spread between the yields of Moody's Baa and Aaa corporate bonds, and finds that these measures cannot act as leading indicators for credit conditions as leverage cycle theories would predict.

The paper by Lambertini, Mendicino and Punzi (2011) provides a characterisation of the leverage cycle for households' indebtedness related to mortgage loans. In particular, since households borrow a fraction of the future expected value of their houses, their leverage increases during periods of optimism about the macroeconomy and future house prices. The demand for housing increases and so do house prices. If expectations are not fulfilled, the bust that ensues goes hand in hand with a dramatic drop in both the quantity and the price of houses, thus reversing the leverage. Therefore, lower loan-to-value ratios reduce the severity of boom-bust cycles in household debt, consumption and GDP. These results highlight the importance of taking into account the effect of credit standards and financial regulation on house price dynamics in the standard macroeconomic frameworks used for policy analysis.

Alessandri, Meeks and Nelson (2012) build a detailed model of the financial system which focuses on the interaction between the traditional financial sector and the "shadow banking" sector. Shadow banks securitise loans, which expands the pool of available collateral assets, thereby reducing credit constraints.[12] However, the growth of securitisation has two effects on the aggregate financial system. First, it increases leverage, making the system more vulnerable to a sudden decline in net worth. Second, securitisation makes the net worth of "shadow banks" a key determinant in the supply of collateral assets at the aggregate level. When shadow banks experience losses on their asset holdings, this reduces the amount of securitised assets they can supply and this decline in the available collateral forces an economy-wide de-leveraging. The authors show that this mechanism can generate substantial volatility in the real economy in line with recent experiences.

Maddaloni and Peydró (2012) focus on how leverage cycles may be affected by monetary policy conditions. Contributing to the recently very active literature on how monetary policy influences credit supply (e.g. Jiménez, Ongena, Peydró and Saurina 2012), they show that low monetary policy rates affect the lending conditions that banks apply to borrowers and thereby spur credit growth and increase borrowers' leverage. In countries where there are lower limits on loan-to-value ratios, though, this effect is significantly smaller. Low monetary policy rates, by relaxing bank balance sheet constraints and easing bank funding, also affect banks'

[12] The paper by Goodhart, Kashyap, Tsomocos and Vardoulakis (2012), discussed in sub-section 2.6 on policy analyses, includes a representation of shadow banking in a general equilibrium model with default.

leverage, which tends to increase in "good times". Stringent capital regulation policies can partly counteract this impact and prevent the (excessive) accumulation of risk by banks.

Other MaRs researchers have focused on the empirical analysis of leverage during the business and credit cycles and the interaction with other macro-policies, primarily monetary policy. Mesonnier and Stevanovic (2012) study the consequences of new regulations which tighten bank capital requirements in a data-rich environment by using a combination of bank panel regressions and macroeconomic factor models. Bank leverage shocks are identified as innovations to the capital-to-assets ratio for a sample of large US banks, while controlling for the possible influence of other macroeconomic shocks. The results suggest a significant contractionary impact of an unexpected shock reducing the leverage of large banks. Moreover, the effects on output are clearly asymmetric: a deleveraging shock contracts investment and output, while a shock increasing leverage has little to no effect on real activity. This asymmetry, coupled with the use of microeconomic information, could partly explain why other studies, like Berrospide and Edge (2010) and Guarda and Jeanfils (2012), find little or no effects of shocks to bank leverage on the real economy. Based on these observations, a switch to tighter capital regulations should preferably be gradual and operate preferably through accumulated earnings in order to minimise the short run negative consequences for the economy.

Fornari and Stracca (2012) concentrate on the impact of financial shocks on key indicators of real activity and financial conditions. Financial shocks are related to the leverage of financial institutions – albeit indirectly. They find that these shocks exert a significant influence on GDP and investment, but it is difficult to disentangle the effects of demand shocks from those of supply shocks.

2.5 Causes and features of the recent financial crisis

This section focuses on the subset of papers specifically devoted to explaining the causes and describing the features of the recent financial crisis.

A common aim of many of these contributions is to properly identify the channels through which financial shocks may affect the real economy. A key issue is understanding the role of credit conditions in the financial sector and the extent to which shocks are autonomous and different from credit demand or supply shocks, which can have their roots within or outside the financial sector.

Both the Bayesian structural VAR model estimated by Tamási and Világi (2011) for the Hungarian economy and the structural factor model developed by Alessi (2011) tend to show that credit shocks have macroeconomic effects, but that these shocks neither have a dominant role in explaining the recession in 2008 nor have long-lasting effects on the economy.

By contrast, Abildgren (2010), using a long span of data (1948-2010) for the Danish economy, finds evidence of a significant and long-lasting negative impact of an exogenous shock to the banking sector's write-down ratio on real GDP. This shock might be interpreted as a sudden reassessment of the credit quality of the banks' loan portfolio or as an increase in the banking sector's risk aversion. Extending the literature on the

costs of financial crises (see e.g. Hoggarth, Reis and Saporta 2002), Abildgren, Vølund, Qureshi and Staghøj (2011) find that the recent financial boom-bust cycle in Denmark led to a net output loss of over 2% of GDP.[13] In other words, the credit cycle in Denmark was associated with a lower average level of output than in a hypothetical situation in which no financial shocks occurred.

Guarda and Jeanfils (2012) argue in the context of their VAR enhanced with financial variables that the collapse in asset prices since 2007 is an important cause of the recession in the euro area. Hartmann, Hubrich, Kremer and Tetlow (2012) find important regime changes that fundamentally changed the behaviour of the euro area economy at key points during the crisis. Maddaloni and Peydró (2012) present evidence that the long period of low interest rates led to an increase in bank risk-taking, thereby contributing to the current crisis.

As described in sub-section 2.1.1, MaRs WS1 has also produced several examples of theoretical macro-financial models that attempt to study financial instability in ways that are not only innovative but also explain causes and features of the global financial crisis. Boissay (2011) and Boissay, Collard and Smets 2012 stress the causal relationship between financial imbalances and the fragility of the wholesale financial market. It is shown that the financial system is fragile only when there is too much liquidity available relative to the quality of existing investment opportunities and real sector productivity. Boissay's (2011) model is consistent with the following features of the recent financial crisis: 1) the development of a highly leveraged market-based banking sector preceding the crisis in which broker-dealers assumed a greater importance in the supply of credit to the real economy; 2) external imbalances characterised by a large and persistent current account deficit of the United States and large surpluses of Asian emerging market economies; 3) domestic imbalances in that the financial deepening process in the run-up to the crisis was not accompanied by comparable changes in the real sector; and 4) materialisation of the crisis in the form of a sudden and wide-ranging freeze of liquidity in key financial markets, an abrupt deleveraging in the market-based banking sector, and falls in international trade, productivity and aggregate output.

Aoki and Nikolov (2011) model directly the effect of an asset bubble collapse on financial stability. This approach is motivated by the fact that the fall in US house prices is often cited as a key cause of the crisis. The authors argue, however, that the collapse of the housing bubble was not in itself the cause of the crisis. It was the banking system's exposure to the bubble that made it the trigger of the global financial crisis we are living through today. The key contrast is with the collapse of the dot-com bubble, which had little effect on the real economy because it was held by ordinary unleveraged investors. The authors argue that two factors contributed to the build-up of banks' exposure to the housing bubble of 2003-2007: 1) implicit government guarantees encouraged banks to hold risky assets; 2) growing financial sector competition reduced banks' profits from traditional activities and led to increased risk-taking. Both factors contributed to the housing

[13] The net output loss offsets the output losses during the recession against the output gains during the boom. A positive net output loss indicates that the overall level of output declined as a result of the boom-bust episode.

boom and to the severity of the subsequent banking crisis and recession. Derviz (2011) also looks at the conditions for the formation of costly asset price bubbles. He argues that limited liability and weak corporate governance (too big to fail) can lead to the build-up of large asset overvaluations and a crisis when these are corrected.

Angelopoulou, Balfoussia and Gibson (2012) construct traditional financial conditions indices (FCIs) for the euro area and selected individual countries based on a wide range of price, quantity and survey data. Although such FCIs were originally designed for monetary policy purposes, they can also be used to tell narratives of the run-up to and unfolding of the financial crisis. Looking at the euro area as a whole, the results suggest that financial conditions became progressively looser between mid-2003 and the beginning of 2007, after which they tightened sharply. Aggressive monetary policy easing by the ECB turned the situation around, prompting a gradual loosening of financial conditions. Thereafter, the euro area sovereign debt crisis took its toll, causing financial conditions to tighten again. The results for selected euro area countries point to considerable heterogeneity across countries, with the southern part of Europe experiencing a stronger deterioration in financial conditions in the second half of 2011, something which is not evident in Germany where financial conditions continued to improve. At the end of 2011, however, financial conditions still remain tighter than they were before the failure of Lehman Brothers.

2.6 Identification of macro-prudential policies, monetary policy issues and their interaction

2.6.1 Identification and assessment of macro-prudential regulatory policies

Substantial efforts have been devoted in policy circles to increasing the list of macro-prudential regulatory policy instruments, including in the context of reports by the Committee on the Global Financial System[14] and working groups of the European Systemic Risk Board (ESRB). Research carried out in MaRs has increasingly focused on analysing such regulatory instruments, albeit a narrower set. The most comprehensive analysis is provided in a paper by Goodhart, Kashyap, Tsomocos and Vardoulakis (2012a) which builds on the theoretical framework of general equilibrium models with default already introduced in sub-section 2.1.1. The effectiveness of five different regulatory policy instruments (limits on loan-to-value ratios, capital requirements for banks, liquidity ratio requirements, dynamic loan loss provisioning and margin requirements on repurchase agreements used by shadow banks) is investigated in the context of a general equilibrium model. This model, itself, is innovative as it introduces a shadow banking system which allows for the analysis of regulatory arbitrage. The model also embeds heterogeneous agents and default in equilibrium. The policy instruments are aimed at combating externalities related to defaults, credit crunches and asset fire sales. The tools may be useful if they can limit amplification mechanisms, but they may also create other distortions.

[14] See for instance Committee on the Global Financial System (2010).

The main results are as follows. First, all the regulatory instruments apart from liquidity requirements result in reduction in mortgage availability, which reduces the welfare of more prosperous households. Second, the welfare of the latter is relatively insensitive to the regulations. Liquidity requirements are very different to other regulations, as they tend to increase credit availability to poorer households and thereby increase their welfare. Third, dynamic provisioning, like liquidity requirements, can effectively lean against the wind. However, liquidity requirements may be pro-cyclical if the liquidity ratio is binding during the boom, as it may create massive fire sales during the bust. Finally, no single regulatory instrument is effective in offsetting the many distortions arising from a default. Instead, the authors suggest that the multiple sources of inefficiency require the application of multiple policy instruments.

This issue is further investigated in a companion paper (Goodhart, Kashyap, Tsomocos and Vardoulakis 2012b) in which the authors focus on combining regulatory instruments to study their joint effects when they are simultaneously deployed. The main finding is that controlling fire-sale risk is critical to improving overall economic performance, but not all strategies are equally effective in controlling this risk. The best regulatory combination in the model includes higher minimum capital requirements together with larger capital buffers and margin requirements (to contain incentives for regulatory arbitrage) during an asset price boom. Another key finding is that indiscriminate combinations of regulatory instruments can easily be welfare reducing. Further research is therefore needed to better understand the complex channels through which regulatory instruments interact.

Most MaRs papers so far generally consider only one macro-prudential instrument in the form of a loan-to-value (LTV) ratio. This choice mainly stems from the fact that housing tends to play a big role in amplification and frequently serves as collateral in financial transactions. In most contributions, an LTV ratio is an efficient tool to dampen housing amplification and the magnitude of the financial cycle. However, in the context of an extended version of Kiyotaki and Moore (1997), Mendicino (2012) casts some doubt on the effectiveness of static versions of the LTV ratio. She presents a model in which collateral requirements affect the sensitivity of output to both productivity and credit market shocks. Tighter collateral requirements imply larger sensitivity of output to changes in aggregate productivity, but lower variability induced by shocks originated in the credit market. The consequence is that the dampening effect on the transmission of some shocks and the amplifying effect on others make discretionary lower LTV caps ineffective as a macro-prudential stabilisation tool. It is rather the implementation of time-varying LTV ratios which leads to welfare improvements.

Although not fully focused on policy analysis, a couple of papers deliver interesting insights into the use of micro-prudential instruments for macro-prudential purposes and the related trade-offs. De Walque, Pierrard and Rouabah (2010), for instance, find in the context of their DSGE model that imposing a minimum capital ratio without risk weights (something similar to the leverage cap or ratio considered in Agur and Demertzis 2011) reduces the long-run level of output, but improves the resilience of the economy to shocks. By contrast,

introducing a risk-sensitive capital requirement increases business cycle fluctuations. Horváth, Seidler and Weill (2012) argue that there may be a trade-off between strong capital positions and banks' role as liquidity providers. Using a comprehensive dataset for Czech banks between 2000 and 2010, they find that there is a two-sided Granger causal relationship between bank capital and bank liquidity creation. Boissay (2011) considers the impact of the liquidity coverage ratio (LCR) in the context of a two-country framework. On one hand, such an instrument reduces funding liquidity risk and ensures that banks are able to roll over their short-term debt; on the other hand, it may divert banks from financing the real sector and hinders entrepreneurs' investments. Overall, the model suggests that there is an interval for the LCR over which financial crises are ruled out, while market efficiency is preserved.

These two papers implicitly assume that the macro-prudential authority has sufficient leeway in using its own policy instruments or is entrusted with sufficient legal powers to impose changes in instruments at the disposal of micro-prudential regulators. However, policies aimed at stabilising the system do not necessarily need to be consistent or associated with a decrease in individual risks. This issue, which is crucial for the practical implementation of macro-prudential policies, has so far not been addressed in MaRs.

Papers in MaRs have also stressed the need for other macro-prudential policy measures in addition to capital and liquidity requirements and LTV ratios, which are the most frequently discussed. Based on their results concerning the determinants of non-performing loans reported in sub-section 2.2.2, Beck, Jakubik and Piloiu (2012) suggest that limiting foreign currency borrowing may be important and policies discouraging currency mismatches (for example, via differential reserve requirements for foreign currency denominated loans) could help to insulate bank asset quality from exchange rate depreciations.

Finally, some research has started to analyse the extent to which macro-prudential policy should be given to supranational bodies, as has been the case in Europe with the inception of the ESRB. For example, Derviz and Seidler (2012) analyse the incentives for fair cooperation related to the delegation of macro-prudential policies to a supranational body. This analysis is carried out in the context of a signalling game of imperfect information between the national and the supranational supervisors. The paper suggests that, even in the absence of evidently conflicting goals, the non-transferrable nature of some regulatory information creates incentives to misreport. The empirical results of Ongena, Popov and Udell (2011) point to a different conclusion on the desirability of cross-border coordination of regulatory activities. The paper shows that restrictive but inefficient regulation at home leads multinational banks to lower lending standards in foreign markets. Such cross-country spillovers of domestic regulation suggest some need for coordination or perhaps even entrusting regulatory policy to a supranational body.

2.6.2 Progress on a "canonical model" for assessing macro-prudential regulatory policies

The joint cross-country project on developing a "canonical model" for assessing macro-prudential regulatory policies was added to the MaRs agenda after the summer of 2011. Nine NCBs and the ECB are engaged in

the project in a collective effort on behalf of the European System of Central Banks (ESCB) as a whole.[15] The idea is to develop a policy assessment tool that is both based on widely accepted principles and makes significant advances in introducing a sophisticated financial sector that can exhibit widespread financial instability and associated externalities, many financial frictions and various forms of heterogeneity. Substantial progress has been made, and only a few elements are missing from the first "prototype".

The model which has been developed belongs to the family of dynamic stochastic general equilibrium (DSGE) models, although going very significantly beyond the standard DSGE models used in macroeconomics. The modelling efforts are primarily devoted to introducing: 1) agent heterogeneity, in particular in the form of liquidity/financial constraints; 2) a stylised banking system consisting of two specialised banks financing the economy; 3) an interbank market which connects these two banks and through which shocks are transmitted; and 4) the possibility for agents to default in equilibrium. The policy instruments considered are capital and liquidity requirements (including counter-cyclical buffers), leverage ratios, dividend restrictions, LTV ratios, loan-to-income ratios and certain taxes or levies. The model should also provide some scope to study the interactions between monetary and macro-prudential policies (see also sub-section 2.6.3).

The elements of the model that have already been derived are:

- Firms' optimisation problem: Risk-neutral firms are run by delegated managers. The firms are owned by households who decide how much equity to put in the firm and how to allocate it between production and other investment. The manager chooses the level of labour, the investment in new capital and the level of bank borrowing.
- Business loan contract and default: After production has taken place, the manager chooses whether to default on the business loan taken. It is assumed that default occurs when the return from the investment is lower than the interest payment to service the debt. A surviving firm returns the profit to its shareholders, raises new equity and rolls over its debt in order to produce for the following period. A defaulting firm exits the system. The bank forecloses the collateral, which consists of the output, the capital used for production and any other investment made by the firm.
- Banks' optimisation problem: Whether it specialises in mortgages or business loans, a bank raises deposits in a competitive market, participates in the interbank market, accumulates reserves, decides on its cash holding for the next period and distributes dividends to its shareholders, taking into consideration the maturity mismatch between assets and short-term liabilities. The objective of the bank is to maximise a concave function of the expected flow of dividends. A concave function is assumed for the following reasons:

[15] The NCBs involved are from the Czech Republic, Germany, Estonia, Spain, France, Lithuania, Hungary, Poland and Portugal.

  - to guarantee realistic elasticities for lending and funding decisions;
  - to introduce portfolio diversification, since the bank will not only care about the expected payoff of its portfolio, but also about the underlying risk; and
  - to have a precautionary motive to price savings and the demand for liquidity into the bank's decisions.

- Central bank intervention in the interbank market: The central bank intervenes directly in the interbank market by setting the inter-temporal interest rate according to a rule to be specified and by offering the required liquidity to clear the markets.

- Household's optimisation problem: The decision to offer labour, to deposit savings, to purchase housing and consumption goods.

The areas that still remain to be fully developed are as follows:

- Primary and secondary market for bank equity: The bank can accumulate reserves over time and can absorb losses on its assets by reducing its equity. The price of equity in the secondary market will depend on the future expected flow of dividends, priced by the households' stochastic discount factor. However, the bank may choose to raise new equity at any point in time. The modelling of the primary market is more complicated. The issues that need to be dealt with are the number of new shares that the bank chooses to issue, the dilution of old shares and the amount of money households are willing to inject into the bank

- The mortgage contract: So far, only one-period loan contracts backed by housing as collateral have been considered. Such a loan is homogenous for all borrowers, unlike the collateral backing business loans (the value of which depends on idiosyncratic productivity shocks). Thus, the bank cannot diversify its portfolio of mortgages, owing to the lack of additional household heterogeneity, which can introduce discontinuities and computational complications. However, borrowing households can choose to partially default on their mortgages, which is equivalent to a diversified portfolio from the bank's perspective. The conditions under which there is partial mortgage default in equilibrium remain to be derived.

To allow for its maximum use, the model would ultimately have to be coded, calibrated and estimated.

Although many central banks are presently working on models for assessing macro-prudential policies, MaRs researchers are not aware of developments closely comparable to this one. Previous large-scale modelling efforts for assessing systemic risks which stand out in the central banking community include, for example, the Bank of England's Risk Assessment Model for Systemic Institutions (RAMSI, see e.g. Alessandri et al. 2009) and the Oesterreichische Nationalbank's Systemic Risk Monitor (see Boss, Krenn, Puhr and Summer 2006). The RAMSI model is, however, not a single coherent model of, for example, the DSGE type. It is more a set of different modules that can be combined according to need.

2.6.3 Interactions between macro-prudential and monetary policy

By their very nature, macro-prudential policies are likely to interact with two other sets of policies. First, given their macro perspective and their attempts to address pro-cyclicality in the financial system, macro-prudential policies may interact with other stabilisation policies, such as monetary and fiscal policies. Second, due to the nature of the instruments at their disposal, macro-prudential policies are likely to interact with micro-prudential policies in their attempts to address systemic risk.[16] In both cases, such interactions may give rise to conflicts between objectives and contradictory policy recommendations or measures. Identifying the circumstances under which such conflicts occur is of primary importance to the policy-maker and one of the goals of the research conducted in WS1.

Starting with Jan Tinbergen's (1952) seminal assignment problem, there is now a vast academic and policy literature on the optimal number of policy instruments and their relationships (e.g. Poole 1970, Woodford 2003, Benigno and Woodford 2012). But this pre-crisis analysis did not include financial instability, let alone macro-prudential policy.

MaRs WS1 has completed several papers dealing mostly with the first kind of interaction, focusing on the interaction of macro-prudential and monetary policy. In most of these contributions, macro-prudential policy consists of fixing LTV ratios to limit excess credit growth or pro-cyclical credit developments. In one paper, however, (Agur and Demertzis 2011) the macro-regulator's tool is a leverage cap.

The key policy question, which is common to these contributions, is whether monetary policy should "lean against the wind" or should rather focus on price stability in the strict sense, leaving the objective of dampening the financial cycles in the upturn to supervisory authorities. Before the crisis, the standard academic answer to this question was not to lean against the wind with monetary policy (for example, Bernanke and Gertler 2000). According to this "doctrine", monetary policy would rather "mop up" the consequences after a bubble had burst, if a serious economic downturn made that necessary. Monetary policy would counter credit booms only if they led to higher inflation. This view would imply a certain asymmetry of monetary policy over the financial cycle. Borio and Lowe (2002), Issing (2003) and Borio and White (2004), however, put forward strong dissenting arguments long before the financial crisis, arguing, for example, that the asymmetry would make the emergence of bubbles more likely.

One important advance made in MaRs research is to take regulatory policy, as a second option for "leaning against the wind", explicitly into account. Interestingly, three contributions build on the model of the housing market developed by Iacoviello and Neri (2010), which is a DSGE model incorporating financial frictions and heterogeneous agents. In addition, these three papers share similar goals of assessing alternative policies in terms of their effectiveness in mitigating boom-bust cycles and macroeconomic volatility and their impact on welfare. While both Angelini, Neri and Panetta (2010) and Beau, Clerc and Mojon (2012) use an ad hoc

[16] Macro-prudential policies are also likely to interact with other policies, including social policies supporting home ownership.

loss function to measure the effectiveness of alternative policies, Lambertini, Mendicino and Punzi (2011) explicitly derive the welfare function and compare alternative policy rules in terms of a consumption equivalent measure.

Angelini, Neri and Panetta (2010) study the interaction between monetary policy and macro-prudential policy in two different cases, cooperative and non-cooperative. In the first case, both policies are jointly and optimally chosen by the same policy-maker with two instruments (the interest rate and the capital requirement or LTV ratio). In the second, policies are implemented by two independent authorities. The central bank aims to stabilise the variances of inflation, output and the interest rate, taking the macro-prudential authorities' policy rule as given. The macro-prudential authority in turn stabilises the loan-to-output ratio and sets a capital requirement, taking the central banks' rule as given. In normal times, that is when the business cycle is mainly driven by supply shocks, the authors find that macro-prudential policy generates only modest benefits for macroeconomic stability over a standard monetary policy rule. There may even be configurations under which the lack of cooperation between the two authorities leads to conflicting policies. By contrast, the benefits of introducing macro-prudential policy tend to be sizeable when financial or housing shocks are the main drivers of the economic cycle. An important finding of the paper is that under such circumstances a cooperative central bank will "lend a hand" to the macro-prudential authority in order to improve overall economic stability.

In a two-period general equilibrium model of mixed bank credit/equity financing of production, Derviz (2011) finds that macro-prudential (defined similarly to Angelini, Neri and Panetta 2010) and monetary policies often produce very similar outcomes that are hard to distinguish if one only observes conventional macroeconomic indicators. The argument is that both affect the same fundamentals. In this setting, macro-prudential restrictions in response to credit excesses are preferred by banks to monetary tightening, because bank profits are less affected by the former.

Beau, Clerc and Mojon (2012) provide an extension to previous contributions by investigating empirically the circumstances under which monetary and macro-prudential policies have a compounding, neutral or conflicting impact on price stability. For this purpose, a DSGE model, very close to the one used by Angelini et al. (2010), is estimated for the euro area over the period 1985-2010. Four policy regimes are assessed, depending on two elements: the monetary objective (i.e. whether or not the interest rate rule factors in financial stability considerations) and the existence or not of an authority responsible for maintaining financial stability which can lean against credit developments without affecting the short-term interest rates. The analysis developed in the paper delivers two important results: first, the policy regime is irrelevant for the dynamics of inflation for the shocks that are typically the primary drivers of inflation; second, following asset price or credit supply shocks, a combination of an independent macro-prudential policy which leans against credit growth and a monetary policy focused on price stability is the best combination for price stability.

Building upon the same framework extended to incorporate expectations-driven cycles, Lambertini, Mendicino and Punzi (2011) carry out similar exercises to evaluate policies, but under a richer stochastic structure, since they allow for booms and busts in house prices and credit. The paper confirms that a "Taylor-type rule" is not optimal and that an interest rate rule that also responds to financial variables is welfare improving. The authors compare the effectiveness of counter-cyclical LTV ratios – management of the leverage of the household sector – with more traditional policies, such as interest rate rules that respond to financial variables. As in Beau et al. (2012), the authors find that counter-cyclical LTV rules leaning against credit growth do not increase inflation volatility and are more effective in maintaining a stable provision of financial intermediation than interest rate rules responding to financial variables. However, they highlight the following trade-off based on welfare criteria. Borrowers prefer LTV rules since they benefit from the more stable supply of credit implied by active macro-prudential policy. In particular, such policy reduces the volatility of debt, but increases its average level, thereby allowing higher levels of consumption by borrowers. By contrast, lenders are better off under an interest rate rule that responds directly to credit growth and more effectively stabilises consumption, that is reduces its volatility and thereby uncertainty.

Agur and Demertzis (2011) use a different set-up to study the interaction between monetary and regulatory policies. They have a two-period model in which banks choose how much leverage to take on and which type of project ("excessively risky" or "good") to invest in. Macro-prudential policy is implemented through a leverage cap, in line with the leverage ratio recently introduced in Basel III. This policy instrument gives rise to the following trade-off for the regulator. Forcing banks to deleverage can help reduce their incentives to take on excessive risk. Since bank finance is the only source of funding in the economy, however, limiting leverage also implies downsizing firms. Besides, monetary policy affects banks' behaviour through different channels: on one hand, by directly or indirectly (through risk premia) influencing the cost of debt funding, an increase in the policy rate raises excessive risk taking; on the other hand, monetary tightening both affects the optimal debt choice of banks, leading to fewer banks taking on excessive risk, and pushes more banks into inactivity. The paper implies three messages for policy-makers aiming to prevent excessive risk taking in the banking sector: 1) low interest rates should be used for short periods only in order to avoid excessive risk taking; 2) greater correlation between banks' returns raises the impact of monetary policy on welfare; 3) an interest rate hike is most effective at preventing the build-up of bank risk when the level of debt among banks is still relatively low.

Maddaloni and Peydró (2012) present evidence of a strong link between a low interest rate policy and bank risk-taking in the euro area, with implications for the joint conduct of monetary and macro-prudential policies. When the control of inflation requires an extended period of loose monetary policy, macro-prudential policy may have to be tightened in order to prevent the build-up of imbalances.

3. Early warning systems and systemic risk indicators

The work stream on early warning systems and systemic risk indicators (WS2) offers relatively practical research which could be, and to some extent already is being used to build up the analytical toolkit for macro-prudential oversight in the EU. The following research questions were asked for this MaRs work stream: *(i) What are the key macro-prudential early warning indicators for groups of countries with relatively similar financial structures in the European Union? (ii) How can the different indicators be aggregated at the EU level? (iii) What are the best early indicators of widespread imbalances, asset price bubbles, credit booms and over-indebtedness, distinguishing in particular between credit and valuation developments that are driven by (fundamentally justified) factors in the real economy and developments that involve systemic risks? (iv) What are the best indicators of current systemic stress or instability?* Before the current crisis, many of these questions were already the subject of active research on which WS2 can build. Some of the developments for answering them may provide useful input also in WS1 research, for example measures of widespread financial instability that could be incorporated in empirical macroeconomic models. An important contribution of WS2 research is the focus on EU-relevant data, which tends to be neglected in much of the academic literature.

There are 41 projects in the current work plan, of which 13 are work in progress, and 28 are either completed or at a very advanced stage with a draft paper available. Moreover, the agenda contains a joint cross-country project on establishing a database of financial crises in EU countries. 17 papers have been published or have been accepted for publication in the ECB Working Papers Series with a "MaRs" stamp on the cover page. Four papers are forthcoming or have been published in academic journals. Despite their different stages of development, all these papers feed into this section.

WS2 projects have been building on the previous extensive literature on early warning models. Key papers published prior to the 2008/2009 crisis, such as Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999), strived to develop models that could warn against currency and banking crises in emerging economies. More recent papers, such as Alessi and Detken (2011) or Frankel and Saravelos (2010), revised early warning methodologies in order to improve their capacity to predict financial crises in developed economies and subsequently tested whether the revised methodologies were credible enough for policy-makers to act on their warnings. WS2 projects contribute to this recent wave of early warning literature by proposing new methodologies, such as self-organising maps (Sarlin and Peltonen 2011),[17] Bayesian model averaging (Babecký et al. 2011) and the log-periodic power law (Kurz-Kim 2012a), but also by providing empirical results for the European countries that had not been consistently researched previously.

[17] A self-organising map refers to an artificial neural network that produces a two-dimensional representation of a high-dimensional data space.

Many WS2 projects were aimed at extending the analytical toolkit available for macro-prudential oversight beyond data and risks for specific countries or markets. Some projects have tried to create composite indicators (Holló et al. 2012 and Louzis and Vouldis 2012) and to work more with EU-wide datasets, including the new EU-wide survey of crises (Babecký et al. 2011). In the area of systemic risk measurement, WS2 made contributions in estimating joint default probabilities of financial intermediaries, taking into account the non-Gaussian nature of defaults (Schwaab et al. 2011). With respect to measuring imbalances, WS2 work confirms the usefulness of monitoring excessive credit developments (Andersen et al. 2012), but cautions against applying simple de-trending methods to dynamic economies (Kelly et al. 2011 and Geršl and Seidler 2011). A novel way of calculating excessive credit developments has also been proposed which is based on a simple structural life-cycle model (Rubaszek and Serwa 2012).

This chapter starts by discussing how WS2 projects measure financial stress and systemic risk, also with a view to the potential use of such measures for forecasting or policy simulation purposes (sub-section 3.1). It then goes through various components of early warning systems, such as key early warning indicators, determinants of financial imbalances, and fiscal aspects of early warning systems and aggregation issues (sub-section 3.2).

3.1 Financial stress and systemic risk indicators

The indicators measuring current financial stress can serve several purposes, such as indicating the scope of financial/systemic stress, becoming a targeted variable in policy rules or stress test models, and entering early warning models as a predicted variable. All the purposes are covered by WS2 projects. Depending on the purpose, various types of indicator have been created: (i) partial or composite, (ii) discrete or continuous, (iii) high or low frequency,[18] (iv) aggregate or sector-specific, (v) country-specific or EU-wide, (vi) current or impact-focused.[19] Together, they illustrate the broad information basis available for early warning systems.

Each type of financial stress indicator comes with its own advantages and disadvantages. Composite indicators are often assumed to be more robust than partial indicators. Nevertheless, the creation of a composite indicator requires judgment concerning the selection of the weights assigned to each time series included in the indicator. Objective methods, such as those using maximum variance in the time series (principal components) do not have to deliver plausible results, since individual time series may eventually enter the composite index with unintuitive signs. Angelopoulou et al. (2012) and Babecký et al. (2011) are illustrations of how to tackle the creation of composite indicators, while Afonso et al. (2011a), for example, features a partial index reflecting a special focus on the role of ratings.

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[18] In some cases, financial stress indexes utilise large datasets with mixed frequencies.

[19] Some indicators measure current stress. Stress can also be measured in terms of the subsequent impact on the real economy (also called stress or crisis incidence) to take into account only those financial stress episodes that turn out to be costly in terms of GDP (impact-focused indicator). Between these, there are indicators measuring current fragility in the system, which could materialise as financial stress or instability in the future, in which case the indicator is in fact a predictive measure of financial stress.

Discrete indicators of stress are easier to define than continuous indicators. Periods of significant stress are usually clearly identifiable and researchers do not have to choose a particular variable to represent the degree of financial stress. On the other hand, discrete indicators usually exhibit much less variance than continuous indicators, which distinguish between the intensity of financial stress in different periods that would otherwise obtain the same binary representation. The new EU-wide dataset featuring country-specific discrete indicators for banking, currency and debt crises created by WS2 might serve as a benchmark for discrete indicators in the future.[20] Work on continuous indices can be found for example in Rouabah et al. (2012) and Lo Duca and Peltonen (2012).

Similarly, indicators measured at higher frequencies provide more observations and thus more variance to be explained by econometric models, but are more difficult to obtain, as some time series are only available at lower frequencies. Some data series are also available only for some countries, so it often proves difficult to construct EU-wide indicators composed of potentially interesting time series (for example, those connected to the real estate market). It is technically easier to construct impact-focused indicators, because impact (or incidence) on the real economy is easily measured after each systemic event by looking at variables such as GDP or employment. For example, the composite continuous financial stress index developed by Louzis and Vouldis (2012) for Greece might be difficult to replicate for all EU Member States due to country-specific bank balance sheet data. On the other hand, the continuous impact index of Babecký et al. (2011) was easy to compute for all EU Member States.

Owing to these advantages and disadvantages, it is advisable to keep several different approaches in the toolkit when constructing a comprehensive early warning system. This WS2 conclusion is in line with what the IMF (2011) and the BIS (Borio and Drehmann 2009) suggest.

Afonso et al. (2011a) use a high frequency continuous partial index for their event study analysis of 24 EU countries that examines the causality between ratings and financial stress as measured by daily sovereign yield spreads (and CDS). Afonso et al. (2011b) examine the effects of financial market conditions on fiscal policy using the quarterly financial stress index for selected EU countries constructed by Cardarelli et al. (2009). The composite continuous index consists of three components describing bank related stress, securities related stress and exchange rate stress.[21] Altunbas et al. (2011a, 2011b) work with a bank distress variable defined as the post crisis recourse to central bank financing.

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[20] Although the zero-one coding has indeed been easier than assessing the scope of each crisis, the subsequent study by Babecký et al. (2011) has indicated differences to codings done by previous academic studies. Future studies using such data should therefore be subject to robustness checks as to whether results are sensitive to a specific coding of crises.

[21] The index is a sum of the normalised values of all the sub-components: (i) bank related stress – beta of banking sector showing the perception of risk of the banking sector compared to other sectors in the economy, the TED spread (difference between the short-term interbank interest rate and treasury bills rate) and the inverted term structure; (ii) securities related stress – corporate bond spread, stock market returns and stock-market volatility; (iii) exchange rate stress – exchange rate volatility.

Andersen et al. (2012) assess their early warning indicators against a relatively impact-focused discrete financial stress index for the United Kingdom that defines financial crises as events during which the banking sector experiences illiquidity or insolvency that results in public intervention, bankruptcies or forced mergers of financial institutions.

Angelopoulou et al. (2012) analyse monetary policy during the crisis with the help of highly composite financial conditions indices for the euro area and selected EU countries, as described already in sub-section 2.5. A very broad dataset of prices, quantities, spreads and survey data is transformed into indices by extracting principal components, which are then checked against the narrative of financial conditions. Some observers (Brave and Butters 2011) argue that financial conditions indices can also be used for identifying the level of financial stress.

Babecký et al. (2011) employ two indices in their early warning system for a panel of 40 developed countries, including most EU countries. The first one is similar to the UK indicator of Andersen et al. (2012), a discrete impact-focused quarterly indicator that defines a crisis as an event in which at least two of the criteria apply. The second one is a continuous composite fully impact-focused indicator that measures the crisis incidence solely according to GDP, unemployment and fiscal costs. A similar fully impact-focused approach is also taken by Fornari and Lemke (2010).

Fiori et al. (2012) use a sector-specific index in their contagion analysis, similar to that of Segoviano and Goodhart (2009) (see section 4 of this report for MaRs contagion research). In line with a significant previous literature, the index measures banking stability using market data (such as equity prices and CDS spreads) for selected EU countries. In contrast, as already described in sub-section 2.1.2 of MaRs WS1, Holló et al. (2012) develop a continuous Composite Indicator of Systemic Stress (CISS) for the euro area. The main innovative feature of the CISS is the application of portfolio theory to the aggregation of individual stress indicators into the composite index. Specifically, the level of stress in the financial system as a whole is computed by aggregating five market-specific sub-indices of stress – comprising a total of 15 individual stress indicators – on the basis of a time-varying measure of the cross-correlations between them. The CISS thus puts relatively more weight on situations in which stress prevails in several market segments at the same time, capturing the idea that financial stress is more systemic and hence more hazardous for the real economy if instability spreads more widely across the whole financial system. In addition, the weights assigned to each sub-index are calibrated in proportion to their systemic importance, as measured by the relative strength of their impact on economic activity.

Louzis and Vouldis (2012) follow a similar approach and derive a composite continuous financial stress index for Greece with principal component analysis. They use a mixture of bank balance sheet and market data and incorporate a multivariate GARCH approach, which is able to capture abrupt changes in correlations. In addition, they check their financial stress index against a discrete index constructed from surveys for that purpose.

Rouabah et al. (2012) derive a composite continuous index for the Luxembourg banking sector. Different weighting methods are employed to combine several datasets (accounting data, information about market structure, financial and macroeconomic variables) in the index. Alignment of spikes across the three weighting methods (equal-variance weights, cumulative density functions and principal component analysis) deliver robust stress signals.

Sarlin and Peltonen (2011) and Lo Duca and Peltonen (2012) employ a continuous country-specific composite index that covers the main financial markets (money market, equity market and foreign exchange market) but not intermediaries. Specifically, they use the spread of the three-month interbank rate over the three-month government bill rate, negative quarterly equity returns, the realised volatility of the main equity index, the realised volatility of the nominal effective exchange rate and the realised volatility of the yield on the three-month government bill.

Several papers offer alternatives to financial stress indices. Szalai (2011) works with macroeconomic risk indicators for Hungary to measure stress in the economy. Saldías (2010) computes several distance-to-default indicators based on information from balance-sheets, equity and options markets.

To sum up, WS2 projects have provided a broad variety of measures of financial stress. They may serve as a good basis for methodological comparisons in future research, for example along the lines of the study by Bisias et al. (2012) devoted to systemic risk measures.

A different strand of literature is concerned with the direct measurement of systemic risk. Most common in the systemic risk literature are attempts to assess the cross-sectional distribution of systemic risk. In particular, the aim here is to quantify individual financial institutions' contributions to systemic risk. Several already existing papers have been particularly relevant for some of the work in WS2. Adrian and Brunnermeier (2011) propose the CoVaR measure of systemic risk. CoVaR is aimed at capturing tail dependence between the returns of financial institutions. Acharya et al. (2010) propose a theoretically motivated measure of systemic risk. The authors demonstrate that the capital shortfall of an institution in a systemic crisis is a function of the institution's excess leverage and its marginal expected shortfall (MES), which is its expected stock market loss on moderately bad days. Danielsson et al. (2011) also evaluate the performance of MES indicators. Adrian and Brunnermeier (2011) propose examining how an individual institution affects the system, while Acharya et al. (2010) suggest looking at how a systemic crisis affects individual institutions. Brownlees and Engle (2011) propose a refined estimator of MES. They rely on time series techniques to arrive at short-term forecasts of MES, and on simulations to predict MES over a six-month horizon. Hautsch et al. (2011) also seek to capture tail dependence between financial returns, but explicitly capture interdependencies between banks using a network approach.

The latter approach is applied by WS2 in Betz et al. (2012), who enhance their early warning model with a measure of cross sectional systemic risk. Schwaab et al. (2011) also explicitly aim to identify systemic risk by investigating the probability of joint failures in the financial system. A dynamic factor framework based on

state-space methods is used to derive the likelihood of simultaneous failures from macro-financial and credit-risk variables. Saldías (2010) develops a method to monitor systemic risk in the European banking system by constructing forward-looking distance-to-default series that capture interdependencies and joint risk of distress in systemically important banks. Zhang et al. (2011) assess the likelihood of joint and conditional failure for euro area sovereigns in the form of a coincident indicator of systemic sovereign risk (see also the contagion work stream of MaRs in section 4). Sarlin and Peltonen (2011) propose self-organising maps as a novel approach to visualise systemic risk. These maps are two dimensional plots of high-dimensional data distributions derived from complex clustering and projection techniques.

Based on a contingent claims approach, Saldías (2011) examines how distress is transferred in and between the financial and corporate sectors in the euro area.

3.2 Early-warning systems

The early-warning systems in use in the national central banks have been typically developed using the bottom-up approach in which single indicators or models are added over time. The toolkits available to policy-makers to identify financial instability and emerging imbalances at an early stage have been gradually expanded by incorporating various single early warning indicators and sometimes more complex early warning models. The early-warning systems are used to detect signals when one or several of the measures of financial stress or systemic risk, described in the previous section, are likely to reach critical values in the future. The early-warning systems also detect signals about various imbalances that can endanger financial stability in the future, such as excessive credit growth or asset price bubbles. The current early-warning systems are therefore multi-dimensional. They warn against several types of costly event that relate to different horizons (using current, pre-emptive and impact-focused indices), and they employ extensive datasets to assess when warning signals should be issued. In other words, they operate with several left-hand side variables (not necessarily correlated), several time lags and many right-hand side variables using the flexible bottom-up approach. The advantage of this approach is that both sets of variables (left-hand side and right-hand side) can be extended according to the policy needs and newly available research results quite flexibly. At the same time, however, it may be a challenge to ensure the overall optimality and coherence of the system with this approach.

The extension of the toolkits represents the major contribution of WS2 research. First, it has enriched the early warning systems by suggesting alternative measures of financial stress, systemic risk or imbalances, sometimes creating new datasets to do so (see Babecký et al. 2011 for the description of a new EU-wide dataset on crises created with the help of NCBs).[22] Second, it has improved early warning systems by proposing new methodologies and utilising new data sources to predict the selected left-hand side variables.

[22] This harmonised data set of crises in the EU is made available for all interested researchers on the ECB website, for example, under the following link [INSERT LINK],

3.2.1 Key macro-prudential early-warning indicators and models

Research can contribute in several ways to the development of an early-warning system: (i) by identifying which early warning indicators should be part of it (either as single early-warning indicators or indicators inside early-warning models) and identifying time lags between left-hand side and right-hand side variables, (ii) by providing useful graphical communication tools, and (iii) by testing the predictive power of various parts of the system. These tests constitute an important part of research work, since the previously published studies reported excessive noise-to-signal ratios (Berg and Pattillo 1998) and consequently credibility was difficult to gain. In all three areas, WS2 projects are playing a role in the ongoing debates that were triggered by the "pre-MaRs" literature.

The single indicators that are best in predicting left-hand side variable have usually been selected in the spirit of the 1990s literature (Kaminsky et al. 1998). The single-indicator approach was transparent, but it contained a risk of underestimating the probability of the crisis if more indicators were close to, but below, their individual threshold values (Borio and Lowe 2002). More recent multi-variable early-warning models that avoid such risk have estimated the probability of a costly event (financial instability or a crisis) from a set of many potential early-warning indicators, assuming a fixed time lag (Frankel and Saravelos 2010 and Rose and Spiegel 2009). In the case of the discrete left-hand side variable and the signalling approach, each early warning indicator has been evaluated separately by minimising either the signal-to-noise ratio (Kaminsky 1999) or a policy-maker's loss function (Demirgüc-Kunt and Detragiache 1999 and Bussière and Fratzscher 2008). In the case of the discrete choice approach (multinomial logit) and the continuous left-hand side variable approach, models have been estimated retaining insignificant indicators. Various papers also assessed the importance of banking sector characteristics for financial stability (Jeitschko and Jeung 2005, Cihak et al. 2009, Fahlenbrach et al. 2011).

Recent research has strived to improve early warning models by developing new techniques and employing more extensive datasets. Specifically, it has offered policy-makers the explicit choice to pre-select their preferences regarding missed crises and false alarms and evaluated indicators according to their usefulness (Alessi and Detken 2011). Moreover, it improved the toolkits with methods such as Markov switching (Abiad 2003), a composite non-parametric model (Apoteker and Barthélémy 2005), non-parametric clustering methods like the binary recursive tree method (Barrel et al. 2009), and the multinomial logit model (Bussière and Fratzscher 2006). These methods are also explored in the WS2 work, except for non-parametric methods that can lead to simple conditional rules of thumb for a small set of indicators describing vulnerable situations. Cross-country studies have been extended from emerging market samples to larger samples, including both emerging markets and developed countries (Frankel and Saravelos 2010).

WS2 contributions can be summarised as follows. First, there is now much more elaborate work on European data, both country-specific as well as EU-wide. Second, several new methodologies have been proposed to select early warning indicators from a vast set of potential indicators and to detect optimal time lags for these

indicators. Third, several graphical tools have been developed that can be used to communicate early warning signals to policy-makers and the public. Fourth, methods for assessing the predictive power of early warning models have been refined.

Regarding data, WS2 early warning models cover most of the EU27 countries, either individually or as a part of cross-country datasets, while the previous literature examined mainly emerging markets or large international datasets. WS2 models work with traditional macro-financial variables (Andersen et al. 2012, Babecký et al. 2011, Holló et al. 2012, Rouabah et al. 2012, Schwaab et al. 2011, Lo Duca and Peltonen 2012 and Louzis and Vouldis 2012, Kurz-Kim and Islami 2012), market and balance sheet data (Fiordelisi et al. 2011, Altunbas et al. 2011, Louzis and Vouldis 2012, Lo Duca and Peltonen 2012 and Saldías 2011), credit risk data (Schwaab et al. 2011) and surveys (Babecký et al. 2011, Louzis and Vouldis 2012). Some projects investigate whether aggregation across the EU countries is supported by the data. For example, cluster analysis indicates that aggregation is possible (Babecký et al. 2011). The possibility of pooling the EU27 data in a factor structure has also been examined (Schwaab et al. 2011).

In addition to previously employed methods, the early warning indicators in WS2 papers are selected and assessed with the help of Bayesian model selection criteria (Babecký et al. 2011), the computation of optimal thresholds for policy action (Lo Duca and Peltonen 2012) or a partly non-linear and non-Gaussian factor model (Schwaab et al. 2011). WS2 research has drawn attention to the issue of time lags for warning indicators. Some studies rely on judgment and on the existing literature, which usually works with fixed lags (Sarlin and Peltonen 2011). Other studies propose testing the lag structure with systematic lag selection for each indicator by panel VAR (Babecký et al. 2011) or probVAR (Fornari and Lemke 2010).[23]

WS2 papers have proposed several graphical tools that can be utilised when communicating with policy-makers and the public. A novel methodology presents the results with the help of "self-organizing maps" (Sarlin and Peltonen 2011). Interesting options are also offered by Bayesian model averaging (Babecký et al. 2011), the financial stability map pioneered by the IMF (Lo Duca and Peltonen 2012) and fan charts (Rouabah et al. 2012). In the first case, the data are projected onto a two-dimensional topographic grid of nodes. In the second case, graphical outcomes from Bayesian model averaging display for each variable and time lag scores in predictive power and sort alternatives from best to worst performers. In the third case, the graph shows both determinants of systemic risk and their dynamics over time. In the fourth case, the forecast of a financial stress index is presented in a chart analogous to the well-known inflation fan charts. Confidence intervals for the projection path are constructed using Monte Carlo simulations.

Regarding tests of predictive power, various methods have been applied by WS2 projects according to the type of the model (or indicator): (i) tests based on the noise-to-signal ratios and minimised policy loss functions (Andersen et al. 2012 and Babecký et al. 2011, Lo Duca and Peltonen 2012 and Sarlin and Peltonen

[23] ProbVAR is a combined model based on vector autoregression with endogenised regressors and a probit approach.

2011), where the relative frequency of false alarms (type-I errors) and missed crises (type-II errors) depends on policy-makers' preferences, and (ii) tests based on the in-sample fit (compared with a simple autoregressive function of the left-hand side variable) or sometimes out-of-sample performance and the mean squared errors compared to naive models such as a random walk (Babecký et al. 2011, Fornari and Lemke 2010 and Lo Duca and Peltonen 2012).

WS2 results suggest that the following indicators should be considered when constructing an early warning system:[24] term and credit spreads (Andersen et al. 2012 and Fornari and Lemke 2010), credit-to-GDP and house price gaps (Andersen et al. 2012 and Babecký et al. 2011), intra-financial credit (Andersen et al. 2012), credit risk conditions when decoupled from macro-financial fundamentals (Schwaab et al. 2011), credit growth (Lo Duca and Peltonen 2012), loan growth and customer deposits (Altunbas et al. 2011), equity valuations (Lo Duca and Peltonen 2012, Sarlin and Peltonen 2011 and Saldías 2011), stock returns (Fornari and Lemke 2010), real equity growth (Sarlin and Peltonen 2011), terms of trade (Babecký et al. 2011), current account deficit (Sarlin and Peltonen 2011), country specific macroeconomic imbalances (Betz et al. 2012), lower bank efficiency approximated by the inefficiency score (Fiordelisi et al. 2011), a bank contagion effect derived from network analysis (Betz et al. 2012), leverage (Sarlin and Peltonen 2011), asset price misalignments due to market sentiment (Dunne et al. 2012), the dynamics of absolute excess returns as a herding measure for stock markets (Kurz and Kurz-Kim 2012), and global macroeconomic variables such as global credit volume, global GDP growth, global real credit growth, global leverage, global real equity growth, global equity valuation, and commodity prices (Babecký et al. 2011, Lo Duca and Peltonen 2012 and Sarlin and Peltonen 2011). Moreover, some of these variables (credit gaps) are also found to produce acceptable policy reactions in macro-prudential policy rules (Andersen et al. 2012). It is worth noting that some approaches do not allow the identification of individual indicators due to their composite nature (Rouabah et al. 2012).

3.2.2 Determinants of credit growth and identification of widespread financial imbalances (including asset market bubbles)

Most early warning systems incorporate various indicators and models of widespread imbalances, asset price bubbles, credit booms and over-indebtedness. Given the general consensus that excessive credit developments have been at the root of most systemic crises (Reinhart and Rogoff 2009), the focus has been on addressing the question of how to determine the "excessive" part of credit growth, leverage or asset price valuations. Credit gaps can either be used as explanatory variables in predicting asset price booms and banking crises or as dependent variables, if the credit boom itself is to be predicted. Using a multi-regime regression model, Serwa (2011) identifies different economic states of the market for credit to households (e.g. a normal regime and a boom regime). Rubaszek and Serwa (2012) are proposing a structural approach

[24] Despite improvements in the early warning models, predicting the timing of a crisis remains an extremely difficult task. The findings show which variables to look at rather than when exactly to expect the next crisis.

where a life-cycle model with individual income uncertainty is developed. The analysis shows how various macroeconomic factors (loan-deposit interest rate margin, income dispersion and uncertainty, income persistence and the replacement ratio) affect the equilibrium value of household credit. Preliminary results on how to derive equilibrium credit growth with this model are available. Other single-country studies confirm the ability of credit-to-GDP gaps to predict financial crises (Andersen et al. 2012 for the United Kingdom and Kelly, McQuinn and Stuart 2011 for Ireland). Kelly, McQuinn and Stuart (2011) develop a regime-switching model for the credit-to-GDP ratio which can be used to determine states of excessive credit supply as well as to run counter-factual simulations. Geršl and Seidler (2011), like Kelly, McQuinn and Stuart (2011) for Ireland, challenge the use of simple Hodrick-Prescott filtered credit gaps (as suggested in the counter-cyclical capital buffer regulation of Basel III) when analysing central and eastern European (CEE) countries, as the error incurred when associating the trend with fundamentals is particularly large for countries undergoing dynamic adjustment processes. An alternative approach using empirically estimated equilibrium credit gaps seems to perform better in signalling excessive credit growth. It relies on regressing credit-to-GDP ratios for a set of countries outside the CEE region on economic fundamentals and then applying the derived elasticities to CEE countries.

Identifying asset price bubbles remains a very challenging field of research. The great reluctance to acknowledge the existence of asset price bubbles (see e.g. Garber 1990 or Ventura 2003) and to use the term "bubble" is declining in the research community following the experience of the financial crisis. But, of course, the empirical difficulties in identifying inaccurate pricing remain, as, for example, proof would be needed that expectations of future cash flows and discount rates were clearly unrealistic. Nevertheless, a few projects in WS2 are aimed at improving on simple statistical methods to identify asset price booms and bubbles. Dunne, Forker and Stuart (2012) evaluate the contribution of (non-linear and interactive) sentiment effects on the Eurostoxx 50 and find that the ratio of average squared "implied" long-run earnings growth derived from an ex ante valuation of equity markets with and without sentiment produces an indicator containing an early warning of asset price misalignments. Kurz-Kim (2012b) introduces a novel technique to produce an alarm index from a composite crash model for stock market crashes. Sousa and Sousa (2011) predict real stock returns for the euro area, the United States and the United Kingdom using Bayesian model averaging. In the out-of-sample exercise, the model improves predictability for the euro area four to eight quarters ahead. Such an approach could be used to detect significant deviations from fundamentally justified returns. Kurz-Kim (2012) develops a model to compute equity price bubbles (predict crashes) and combines it with an estimation of the intensity of herding behaviour to also assess the short-run dynamics of equity prices. Kurz-Kim and Scharnagl (2012) use a simple test based on the Welch statistic to detect bubbles in stock markets.

3.2.3 The role of fiscal developments in financial instability

Early warning models of fiscal vulnerabilities should belong to the standard toolkit for systemic risk analysis. This is not so much because fiscal crises tend to follow banking crises (see Reinhart and Rogoff 2009), but because concerns about fiscal sustainability can also trigger a banking crisis (lack of credible backstop mechanisms and/or reduction in collateral for domestic banks holding their own sovereign bonds and the likely contagion effects, especially in integrated economic areas). Afonso, Furceri and Gomes (2011) provide evidence of spillover effects from rating downgrades of fiscally weak countries to bond yields and sovereign CDS spreads of fiscally strong countries. This is a relevant way of identifying sources of systemic risks that can be exacerbated through cross-country bond holdings (see also sub-section 4.3 on sovereign contagion). Afonso, Baxa and Slavík (2011) provide evidence using a threshold VAR model that fiscal multipliers may be larger in periods of financial stress, which illustrates the potential for negative feedback loops when concerns about debt sustainability have to be addressed by austerity measures in periods of financial stress. Ejsing, Lemke and Margaritov (2011) develop a sophisticated approach to reconcile the different frequencies of public deficit releases and financial market data. The approach could be used to estimate implausible CDS spreads (given an estimate of the current deficit) or, conversely, which deficit would correspond to the current CDS spread, assuming the latter reflected an appropriate assessment of the fiscal situation. Checherita-Westphal and Holm-Hadulla (2012) estimate a system of simultaneous equations (with panel three-stage least squares) capturing real economic growth, interest rates and primary public balances in order to capture relevant feedback effects. This approach allows fiscal vulnerabilities to be assessed in a more reliable way than simple calculations based on single-equation debt arithmetic, because pernicious feedback loops are at play when fiscal concerns arise. The model results show that at high debt levels, fiscal consolidation has a more positive effect than suggested by simple debt arithmetic, while this effect is reversed for low debt levels.

3.2.4 Aggregation of early-warning indicators and models

One of the pertinent issues in devising an early warning system for the EU is the question of optimal aggregation of country results and the breadth of country/institutional coverage. Owing to the low number of national crises episodes, it is also difficult to derive reliable and efficiently estimated national early warning models. Some cross country/institution pooling is therefore reasonable. On the other hand, the acceptance of the warning signals by national policy-makers will depend on whether indicators and thresholds are derived from a pool of countries/institutions deemed to be representative for the country/institution under scrutiny. For example, WS2 researchers find that even one of the most prominent early warning indicators, the credit-to-GDP gap, does not perform well for all EU countries if the gap is calculated by means of simple de-trending methods. In this regard, tests of whether pooling assumptions are supported by the data are valuable.

Several WS2 projects have already made progress in this respect or have proposed promising avenues for further research. For instance, Schwaab, Koopman and Lucas (2011) demonstrate that different coincident

risk indicators (credit risk information such as actual failures from the Moody's database) can be pooled in a factor structure to extract a joint indicator for the EU27. Saldías (2010 and 2011) and Betz, Sarlin and Peltonen (2012) pool data across individual EU banks.

Some projects currently use a euro area sample that could be extended to the EU level. For example, Checherita-Westphal and Holm-Hadulla's (2011) sovereign debt analysis focuses on the euro area but their panel structure could, in principle, be generalised to the EU level, subject to data availability. Kremer and Lo Duca (2012) already have a first preliminary version of an aggregated CISS including some non-euro area EU countries. This preliminary EU CISS does not differ substantially from the euro area CISS. Sarlin and Peltonen (2011) successfully signal a systemic financial crisis in the first quarter of 2006 for the euro area aggregate. Such an aggregation of the individual indicators could be applied to an EU entity, mapped onto the self-organising financial stability map, and the corresponding crisis probability could be computed. Zhang, Schwaab, and Lucas (2012) provide a joint measure of sovereign risk for ten euro area countries. This measure is calculated by combining the prices of CDS insurance against sovereign default (an indicator of perceived credit risk) across different euro area countries in a dynamic reduced-form model.

Regarding projects that focus on single countries, aggregation for Dunne et al.'s (2012) sentiment indicator (which currently focuses on the United States) would be straightforward: the indicator would combine country-specific indicators according to the size of their equity market. While planned for future research, the aggregation has not yet been carried out. As to the financial vulnerability index for Luxembourg of Rouabah, Guarda, and Theal (2012), the authors expect that a component series of the index may vary by country, given the characteristics of individual Member State economies. As far as stock markets are concerned, Kurz-Kim's (2012) early warning indicator could be aggregated at the EU level according to the composition of the Euro-Stoxx50 index. Overall, the issue of acceptable and optimal aggregation deserves further attention.

4. Assessing contagion risks

The intended main focus of this work stream was to assess the scope for cross-border contagion across EU countries, complementing previous pan-European research using stock market data[25] and previous research on contagion risk within EU countries.[26] Based on a vast academic literature,[27] a possible benchmark definition of contagion is that contagion exists when instability in a specific financial intermediary or market is transmitted to one or several other intermediaries or markets, notably when this transmission is not caused by common factors or fundamentals and/or is of particular strength ("extreme"). Relevant research questions

[25] See e.g. Hartmann, Straetmans and de Vries (2006) or Gropp, Lo Duca and Vesala (2009).

[26] Most of this research was based on counterfactual simulations using confidential and incomplete national bank balance-sheet data. See, for example, Upper and Worms (2004) for Germany, Lelyveld and Liedorp (2006) for the Netherlands, Degryse and Nguyen (2007) for Belgium and Mistrulli (2007) for Italy.

[27] For surveys see, for example, de Bandt and Hartmann (2000), Claessens and Forbes (2001), ECB (2005 and 2009) and de Bandt, Hartmann and Peydrò (2010).

concern, for example, spillovers across different types of financial intermediary, feedback effects which amplify contagion, and the distinction between the unravelling of imbalances and contagion.

WS3 presently has 21 individual projects and 15 projects as part of the special initiative on sovereign contagion risk. 13 draft papers are available so far, of which five have been published in or accepted for the ECB Working Paper Series. Although they are at different stages of development, all available papers were used in writing this section. The first sub-section summarises the results of individual research papers. Sub-section 4.2 describes the results of the initiative on sovereign contagion.

4.1 Money market structures, interbank contagion and spillovers across economic sectors

A first set of individual research papers under MaRs WS3 analyses the nature of interbank lending structures helpful for assessing interconnectedness among banks. Understanding such structures is a vital first step towards gauging the extent of contagion risks in the banking sector.[28] Craig and von Peter (2010) and Memmel, Sachs and Stein (2011) use data on the German interbank market drawn from the Deutsche Bundesbank credit register. Craig and von Peter (2010) provide evidence of tiering in the interbank market: most banks do not lend to each other directly, but through money centre banks acting as intermediaries. Since these money centre banks are clearly vital to the network, the paper argues that interconnectedness is another important measure of systemic relevance, correlated with but independent of size. Tiering in the money market has received limited attention in the literature so far, and what attention there has been has come mainly from central bank researchers.[29] Memmel, Sachs and Stein (2011) have actual data on interbank loan write-offs, which suggest that the distribution of the loss given default (LGD) is strongly bimodal (u-shaped). In other words, in the event of default, a relatively large share of cases experienced either a tiny loss (between zero and 10% of the exposure) or a very large loss (between 90 and 100%). This finding, likely reflecting the presence of fully collateralised exposures (through repos) and totally uncollateralised exposures (through interbank deposits), stands in contrast to usual assumptions of an intermediate LGD of around 40%. Simulations conducted taking this feature into account show that the interbank system is more fragile than appears to be the case when simulations fix LGD at the sample mean.

Halaj and Kok (2012) study a network of interbank claims with the aim of assessing contagion risks. As bilateral exposures of the banks in their dataset (which consists of large, European banks) are not available, but only their aggregate exposures, they take a novel approach and simulate the matrix of all bilateral interbank claims. This approach has the advantage of allowing extreme events to be studied and, indeed, it is

[28] Networks of interbank relationships have been analysed theoretically to quite some extent, See, for instance, Allen and Gale (2000), Freixas et al. (2000), Leitner (2005), or, more recently, Caballero and Simsek (2012).

[29] Exceptions are Ehrmann and Worms (2004) and Upper and Worms (2004), who use aggregate data when trying to characterise the market structure. Furfine (1999) provides an in-depth analysis of trading structures and tiering in the US federal funds market. Freixas and Holthausen (2005) explain the tiering phenomenon theoretically with asymmetric information.

found that the failure of one bank in the network detrimentally affects other banks' solvency only as a tail risk event. Moreover, contagion effects are found to be highly non-linear, crucially depending on the exposure of individual banks to each other. Finally, the paper takes into account the possibility of fire sales. It is found that the possibility of fire-selling assets increases the effects of bank failures on bank capital. The consideration of such amplification effects in interbank contagion was largely absent in the growing literature using counter-factual simulations, which may explain the limited contagion risk that was often found.

With the highly connected worldwide financial structure, financial contagion naturally does not stop at borders. Often, the interconnectedness runs through banks that are internationally active and have subsidiaries abroad. Such parent-subsidiary relationships have the potential to be channels of contagion across borders. In this spirit, Derviz and Raková (2011) undertake a theoretical and empirical analysis of the role which the condition of a parent bank may have on the interest rate setting of its affiliate – a subsidiary or branch – in a foreign country. The host country under consideration in the empirical part of the study is the Czech Republic, whose banking sector is dominated by institutions under foreign control. Altogether, the parent influence, although occasionally statistically significant, appears to be of subordinate importance economically, at least in the Czech banking sector in the pre-crisis period (i.e. before 2008).

Another paper studying interconnectedness in a cross-border context is Castren and Rancan (2012). This paper uses financial accounts data to construct financial networks for individual euro area countries, which are then connected to a large euro area wide macro-network. Thus, in contrast to the above studies, no data on individual financial institutions are used, but rather aggregated data, which allow broader interrelationships between countries to be studied. In this framework, the contagious impact of negative credit shocks is simulated. It is found that the impact depends significantly on the location of the initial shock as well as on the centrality (as measured by the number of connections) and other connectivity properties of the sectors and countries concerned. In particular, sectors and countries which were highly integrated before the crisis were also found to be those most exposed to shocks during the crisis, as well as to shocks stemming from remote parts of the system. Moreover, the impact of the shock is found to vary considerably over time, partly due to the fact that the degree of interconnection has decreased over time during the period studied, mainly as a consequence of the effects of the financial crisis.

Also Degryse, Elahi and Penas (2012) study the fragility of banking systems from a regional perspective. Fragility is defined as a situation when countries' banking stock indices in a region have jointly very low returns, and it is explained by a series of regional characteristics such as liquidity, capitalisation, competition, diversification, and presence of foreign banks in a region. It is found that regional banking system fragility is reduced when banks in the region jointly hold more liquid assets, are better capitalised, and when regional

banking systems are more competitive.[30] Regarding Europe, an increase in regional conditional stock market volatility, and a fall in domestic currencies are found to increase banking system fragility. Moreover, higher liquidity levels significantly reduce the fragility. Interestingly, the level of capitalisation does not seem to play a role, possibly due to the fact that Europe has on average lower capital ratios than, for instance, the United States. In addition, higher concentration in the banking sector increases the probability that Europe will experience very low returns in its banking index. In a second part, the paper analyses the possibility of contagion within and across regions. It is found that intra-regional banking contagion is important in all regions, but it is substantially lower in developed regions than in emerging market regions. For cross-regional contagion, the contagion effects of Europe and the United States on Asia and Latin America are found to be significantly higher than the effects between Asia and Latin America.

In many respects, economic contagion seems to be a phenomenon that is predominantly observed in financial systems rather than in other sectors of an economy. To explore why, Silva (2010) uses financial accounts data to draw an inference about the level of interconnectedness among sectors of the Portuguese economy. Raw data was used to obtain who-to-whom accounts for loans and deposits. For other instruments, maximum entropy was used. The paper replicates the approach adopted by Castren and Kavonius (2009) for the analysis of the euro area financial accounts. The results suggest that the network of bilateral linkages in Portugal is similar to that of the euro area, with the financial system concentrating two thirds of all bilateral relations in the economy. By applying contingent claim analysis at the sector level, the methodology allows losses stemming from the market price of credit risk to be distinguished from the remaining losses. The results suggest that the latter account for the vast majority of losses. However, the risk-related effect is highly non-linear, implying that it rises steeply as sector fragility increases. In addition, this aggregate approach does not capture intra-sectoral fragility, which would further increase risk related losses.

Idier (2011b) contributes to the literature deriving market-based indicators of systemic risk. He proposes a Markov switching multifractal model with dynamic conditional correlations to improve a companion paper (Idier 2011a) in order to assess market contagion over several horizons and disentangle, for example, short-term crisis contagion from long-run market integration. The contribution is methodological, but applications for market contagion or market sensitivity to global shocks may also be considered.

4.2 Special initiative on sovereign contagion risk

MaRs WS3 was originally meant to focus on interbank contagion. The European sovereign debt crisis that started at the end of 2009/in early 2010, however, demonstrated the importance of sovereign debt exposures. Indeed, the increase in sovereign bond spreads, first in some euro area countries and later in others, suggests that it may not only be idiosyncratic factors (government debt levels) or exposures to common shocks (due to

[30] Freixas et al. (2000) and Allen and Gale (2000) argue that a better capitalised banking system helps in reducing possible contagion effects. See Carletti and Hartmann (2003) for an overview of the relationship between competition and financial stability.

the financial crisis) that caused the rise in spreads, but also contagion.[31] Here, financial stress for one country's sovereign may spread both to other countries' sovereigns and to the financial sector. In the light of these developments, and given the scarce literature on sovereign contagion at the time, the MaRs coordinators decided in late 2011 to dedicate a special initiative to this matter.

This section summarises the findings of the papers contributed to this initiative. The papers use a variety of data: sovereign CDS spreads (Broto and Perez-Quiros 2012, Donati 2012, Fornari 2012, Kocsis 2012, Zhang et al. 2012), sovereign bond yield spreads (Barbosa and Costa 2010, Claeys and Vasicek 2012, De Santis 2012), and bank equity returns (Mink and De Haan 2012). Some of these papers are also interesting from the perspective of MaRs WS2 on early warning systems and systemic risk indicators.[32]

In order to investigate the extent of sovereign contagion, the authors in WS3 use a wide range of econometric methodologies, ranging from dynamic factor models (Broto and Perez-Quiros 2012, Barbosa and Costa 2010), multivariate frequency decompositions (Donati 2012), cointegration analysis and regressions (De Santis 2012), an event study based on bank equity data (Mink and De Haan 2012), forecasting error variance decompositions from vector autoregressions (Claeys and Vasicek 2012), to a dynamic copula for dependence (Zhang, Schwaab, and Lucas 2012).

Most of these studies find that European sovereign credit spreads – measured either as CDS spreads or government bond yield spreads over German bonds – are highly correlated, in particular before the onset of the sovereign debt crisis at the end of 2009. As a common finding, the first principal component (a common factor) explains up to 80% of the common variation across CDSs across both core and peripheral euro area countries (Broto and Perez-Quiros 2012, Barbosa and Costa 2010, Kocsis 2012, and Zhang, Schwaab, and Lucas 2012). Much of the behaviour of sovereign bond yields before the onset of the sovereign crisis can be explained by global risk aversion proxies – such as the US VIX index – rather than country-specific fundamentals. Afterwards, the importance of these global factors appears to have decreased, hand in hand with the increasing importance of idiosyncratic developments, consistent with investors "waking up" to different risk profiles across countries around 2009 (Broto and Perez-Quiros 2012).

Most authors in WS3 find evidence of sovereign contagion in the euro area since the onset of the euro area debt crisis in late 2009. In particular, bond yields or CDS spreads in some countries of the euro area appear to have been impacted by other countries' bond yields or CDS spreads (Broto and Perez-Quiros 2012, De Santis 2012, Donati 2012, Kocsis 2012 and Zhang, Schwaab, and Lucas 2012).

The remainder of this section provides a brief summary of the key findings of each paper.

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[31] Constancio (2012) discusses the early evidence on sovereign contagion in Europe.

[32] For example, both Broto and Perez-Quiros (2012) and Zhang et al. (2012) contain risk measures that are interesting from a financial stability surveillance perspective.

Broto and Perez-Quiros (2012) find some evidence that Greece has been a source of sovereign risk contagion during most of 2010. Other countries, such as Italy and Spain, are also found to have become important sources of contagion in 2011. In their dynamic factor modelling framework, spillover effects from different countries on common factors can be identified in real time.

Claeys and Vasicek (2012) find significant spillover effects in euro area bond yields based on an analysis of many bivariate pairs of yields. The authors also find that these spillover effects have increased in magnitude since 2007. Moreover, they document significant spillovers from news about rating downgrades to the yields of other government bonds. The authors point out that it is particularly hard to distinguish contagion from common factor dynamics in their vector autoregressive framework, but argue that the large increase in spillovers are at least indicative of increased contagion concerns.

De Santis (2012) finds that (i) safe haven motives such as flight-to-quality, (ii) country-specific sovereign credit risk, and (iii) a contagion effect from Greece together explain most of the observed developments in sovereign spreads. He also finds that contagious spillovers from Greece have a larger impact on countries with relatively weak fundamentals, such as Ireland, Portugal, Italy and Spain, but also Belgium and France. As a result, stressed countries may not only be the source of such shocks, but may also be the most affected by them.

Donati (2012) estimates a multivariate frequency decomposition model to extract shocks that impact stressed countries' respective sovereign default risks at different frequencies. In a second step, estimates of these shocks are added as explanatory variables in the modelling of core country risk conditions. The author finds that the former helps in the prediction of the latter, and argues that this increase in forecasting performance is evidence of significant spillover effects. It is yet unclear what role is played by global risk aversion and other components common to all time series.

Zhang, Schwaab, and Lucas (2012) use CDS data on euro area countries to investigate how the risk of a credit event for a given country in the euro area is affected if a credit event materialises in another country. For example, the authors estimate the probability of an Italian sovereign default over a one-year horizon, if a default had just happened in Spain. Estimating such conditional probabilities requires a proper multivariate model. Based on a dynamic copula framework, the authors document a large degree of risk "interconnectedness", substantial time-variation in the dependence structure and relatively large expected risk spillovers from a sovereign credit event.

Kocsis (2012) investigates the drivers of CDS spread changes across many developed and emerging markets. He finds that CDS spreads from stressed countries also affect non-euro area countries, such as Hungary, although the effect is indirect and relatively weak.

Barbosa and Costa (2010) find that an increase in global risk aversion, a decrease in country-specific debt market liquidity, and the deterioration of public finances in several countries suffice to largely explain rising

yields in euro area peripheral countries for the period from 2008 up to early 2010. Hence, contagion is not "needed" as an additional factor to explain rising yields, in this period.

Mink and De Haan (2012), using an event study approach, qualify the above contagion results by distinguishing the impact of "news about Greece" from the impact of "news about a Greek bailout" on bank equity prices in 2010. The latter news is considered to be indicative of the willingness of euro area heads of state to support a country in need, rather than referring to bad, potentially contagious events that are Greek in origin. The authors find that news about Greece does not lead to abnormal returns, while news about a Greek bailout does. The result holds even for banks that are not directly exposed to Greece or other indebted peripheral countries. The authors also find, however, that sovereign bond prices of Portugal, Ireland and Spain do react to both kinds of news from Greece, which is in line with the above studies.

Assessing the conclusions from this initiative, almost all contributors to it agree that distinguishing between contagion and instability arising from shared exposures to common factors is crucial for policy purposes, but hard to do in practice. If contagion is defined as a residual after common components are taken into account, then the estimated extent of contagion effects depends on completeness in the choice of right-hand-side conditioning variables.[33]

5. Conclusions and way forward

5.1 Overall assessment of the progress of MaRs after two years

Overall, MaRs has made significant progress over the last two years, both in terms of individual and joint cross-country projects, addressing most of the research questions asked by the General Council. Ever more ECB working papers with the "MaRs" stamp are coming out and the first papers have been published in high-ranking journals, such as the Journal of Financial Economics, the Economic Journal and Economic Policy.

WS1 has given many answers to all its research questions. In particular, it has made very significant progress in incorporating realistic characterisations of widespread financial instability in theoretical and empirical macroeconomic models. This could be described as a major effort in helping to meet one of the biggest challenges in contemporary economics posed by the financial crisis. Moreover, WS1 is successfully building on this fundamental research, and starting to deliver a growing number of models and tools that can be used to assess macro-prudential policies. It is of great importance that the joint cross-country project to develop a "canonical model" for assessing macro-prudential regulatory policies is fully completed as soon as possible, so that it can start to be used in the ESCB. Finally, as expected, owing to the relatively fundamental nature of the research in WS1, MaRs' initial two years were not enough to transform many of the developments into operational tools.

[33] These conclusions are exactly in line with the problems found in the empirical bank contagion literature (de Bandt and Hartmann 2000).

WS2 has met the expectations of a swift start at the beginning of MaRs in order to rapidly enlarge and refine analytical toolkits for macro-prudential surveillance. It has developed new tools for systemic risk measurement and early warnings, designed novel ways of displaying the results of tools and applied existing models to European data. In a collective effort it has established a benchmark database of crises in EU countries that the ESCB and outside researchers can use in the future. At the same time, it has not yet been possible to conduct comparative studies in which the value of different systemic risk measures or early warning tools are pitched against each other in order to allow better differentiation between them. Finally, while there has been a lot of work on individual tools, there has not yet been enough time to derive the main desirable characteristics of an "optimal" overall early-warning system.

WS3 has delivered a number of valuable studies on relevant money market structures, on bank contagion and spillovers across the main economic sectors using financial accounts, also from a cross-border perspective. Although significant progress was made, more work is needed in deepening the available analysis and tools on cross-border bank contagion risks in Europe. The special initiative on sovereign contagion risk was also a success, producing many results and tools relevant for the ongoing crisis in Europe.

5.2 Continuation of MaRs

On the basis of the assessment of the work done so far, the General Council of the ECB has decided to continue MaRs until the end of 2013. In the additional time, the focus of the work should be on joint cross-country projects, MaRs research questions for which a broader basis of answers and a greater robustness of results would be desirable, and analytical tools designed to support macro-prudential policy-making:

- WS1 will focus in particular on the completion of various versions of the canonical model for assessing macro-prudential regulatory policies, their programme infrastructure and coding, their calibration and a first use in a set of regulatory policy simulations, and on the implementation of a number of analytical tools from the other newly available macroeconomic models incorporating widespread financial instability as well as their preparation for regular use;
- WS2 will conduct comparative performance assessments of different systemic stress indicators or early warning indicators and identify the main features of an "optimal" overall early warning system;
- WS3 will progress with assessing interconnectedness and contagion risks among European banks.

Moreover, in the additional time, MaRs should also further develop its interaction with researchers working on similar issues in academia and in authorities other than EU central banks.

It is planned that MaRs will report on its final results in spring 2014 and then the network will be closed. Further macro-prudential research that may be needed would be included in the regular research programmes of ESCB members or in the technical sub-structures of relevant decision-making bodies (such as the ESRB or any other bodies emerging from ongoing supervisory reforms in the EU/euro area).

With the additional efforts, MaRs is likely to be able to complete most of what it originally planned. In some areas this is likely to make major contributions to the understanding of systemic instability and policy responses, both in terms of fundamental research frameworks and in terms of the analytical toolkits available for central banks. At the same time, it is also clear that the experience of the crisis suggests that additions to the existing economic frameworks which amount to a new paradigm may be needed. Although a number of MaRs researchers have made very valuable steps in this direction, some of which deserve to be taken up in teaching and for further development at universities, it is clear that the establishment of a new paradigm is exceedingly ambitious for a central bank research network. It is instead desirable that the academic sector significantly intensifies efforts in this area, notably representing widespread financial instability in models of the aggregate economy and introducing financial regulatory instruments into such frameworks. Some of these efforts should probably also move away from standard economic equilibrium approaches, potentially considering approaches from disciplines other than economics. For example, in the ESCB in general it has not been possible so far to seriously consider approaches that move definitively away from concepts based on rationality and equilibrium (one recently discussed is “agent-based modelling”).

Annex 1: List of MaRs contributors

Annex 2: MaRs conferences

5-6 October 2011 MaRs conference agenda

First Conference of the Macro-prudential Research (MaRs) network of the European System of Central Banks

hosted by the European Central Bank

5-6 October 2011, Frankfurt am Main

Programme

Wednesday, 5 October 2011

8.15 a.m. - 8.45 a.m.	Registration
8.30 a.m. - 9 a.m.	Welcome coffee
9 a.m. - 9.15 a.m.	**Opening remarks** **Jean-Claude Trichet** (President of the European Central Bank)
9.15 a.m. - 10.30 a.m.	**SESSION 1: FINANCIAL INSTABILITY AND THE MACROECONOMY (75 mins)** **CHAIR: PHILIPP HARTMANN (European Central Bank)** **Paper 1**: *"Bubbles, Banks and Financial Stability"* by **Kosuke Aoki** (University of Tokyo) and Kalin Nikolov (European Central Bank) (25 mins)

Paper 2: *"Financial Crises, Credit Booms and External Imbalances: 140 Years of Lessons"*

by Oscar Jordá, Moritz Schularick (Freie Universität Berlin) and Alan M. Taylor (Morgan Stanley) (25 mins)

Discussant: **Jaume Ventura** (Pompeu Fabra University and CREI) (15 mins)

General discussion (10 mins)

10.30 a.m. - 10.45 a.m. **Coffee break**

10.45 a.m. - 12 p.m. **SESSION 2: LEVERAGE CYCLES AND MACRO-FINANCIAL LINKAGES (75 mins)**

CHAIR: XAVIER FREIXAS (POMPEU FABRA UNIVERSITY)

Paper 1: *"Asymmetric Information in Credit Markets, Bank*

Leverage Cycles and Macroeconomic Dynamics"

by **Ansgar Rannenberg** (Nationale Bank van België/Banque Nationale de Belgique) (25 mins)

Paper 2: *"Leverage, Balance Sheet Size and Wholesale Funding"*

by H. Evren Damar, Césaire A. Meh and **Yaz Terajima** (Bank of Canada) (25 mins)

Discussant: **Luc Laeven** (International Monetary Fund) (15 mins)

General discussion (10 mins)

12 p.m. - 12.50 p.m. **POLICY KEYNOTE**

VÍTOR CONSTÂNCIO (VICE-PRESIDENT OF THE European Central Bank)

12.50 p.m. - 2 p.m. **LUNCH**

2 p.m. - 3.50 p.m. **SESSION 3: MACRO-PRUDENTIAL POLICY (110 mins)**

CHAIR: LAURENT CLERC (Banque de France)

Paper 1: *"Leaning Against Boom-bust Cycles in Credit and Housing Prices"*

by Luisa Lambertini (École Polytechnique Fédérale de Lausanne, College of Management), **Caterina Mendicino** (Banco de Portugal) and Maria Teresa Punzi (University of Nottingham) (25 mins)

Paper 2: *"Macro-prudential Policy and the Conduct of Monetary Policy"*

by Denis Beau, Laurent Clerc and Benoît Mojon (Banque de France) (25 mins)

Paper 3: *"Financial Regulation in General Equilibrium"*

by Charles A.E. Goodhart (London School of Economics), Anil Kashyap (University of Chicago), **Dimitrios P. Tsomocos** (University of Oxford) and **Alexandros P. Vardoulakis** (Banque de France) (25 mins)

Discussant: **David Aikman** (Bank of England) (20 mins)

General discussion (15 mins)

3.50 p.m. - 4.05 p.m. **Coffee break**

4.05 p.m. - 5 p.m. **RESEARCH KEYNOTE**

MARKUS BRUNNERMEIER (Princeton University)

5 p.m. - 6.15 p.m. **SESSION 4: CONTAGION RISK (75 MINS)**

CHAIR: PAOLO ANGELINI (Banca d'Italia)

Paper 1: *"Contagion at the Interbank Market with Stochastic LGD"*

by Christoph Memmel (Deutsche Bundesbank), **Angelika Sachs** (Ludwig-

Maximilians-Universität, Munich) and Ingrid Stein (Deutsche Bundesbank) (25 mins)

Paper 2: *"Funding Costs and Loan Pricing by Multinational Bank Affiliates"* by **Alexis Derviz** and Marie Raková (Česká národní banka) (25 mins)

Discussant: **Morten Bech** (Bank of International Settlements) (15 mins)

General discussion (10 mins)

8 p.m. Dinner

Thursday, 6 October 2011

8.30 a.m. - 9 a.m. Coffee

9 a.m. - 10.15 a.m. **SESSION 5: FINANCIAL STABILITY INDICATORS (75 mins)**

CHAIR: KATEŘINA ŠMÍDKOVÁ (Česká národní banka)

Paper 1: *"A Financial Systemic Stress Index for Greece"*

by Dimitrios P. Louzis and **Angelos T. Vouldis** (Bank of Greece) (25 mins)

Paper 2: *"Mapping the State of Financial Stability"*

by **Peter Sarlin** (Åbo Akademi University) and Tuomas A. Peltonen (European Central Bank) (25 mins)

Discussant: **John Theal** (Banque centrale du Luxembourg) (15 mins)

General discussion (10 mins)

10.15 a.m. - 11.10 a.m. **RESEARCH KEYNOTE**

JEAN-CHARLES ROCHET (Universität Zürich)

11.10 a.m. - 11.25 a.m.	**Coffee break**
11.25 a.m. - 1.15 p.m.	**SESSION 6: EARLY WARNING MODELS (110 mins)** **CHAIR: CARSTEN DETKEN (European Central Bank)** **Paper 1**: *"Early Warning Indicators of Economic Crises: Evidence from a Panel of 40 Developed Countries"* by Jan Babecký, **Tomáš Havránek**, Jakub Matějů, Marek Rusnák, Kateřina Šmídková and Bořek Vašíček (Česká národní banka) (25 mins) **Paper 2**: *"Predicting Recession Probabilities with Financial Variables over Multiple Horizons"* by Fabio Fornari and Wolfgang Lemke (European Central Bank) (25 mins) **Paper 3**: *"Business Cycles, Monetary Transmission and Shocks to Financial Stability"* by **Kim Abildgren** (Danmarks Nationalbank) (25 mins) Discussant: **Ray Barrell** (Brunel University) (20 mins) General discussion (15 mins)
1.15 p.m. - 1.20 p.m.	**CLOSING**
1.20 p.m. - 2.30 p.m.	**LUNCH**

30-31 October 2012 MaRs conference

Second Conference of the Macro-prudential Research (MaRs) Network of the European System of Central Banks

hosted by the European Central Bank

30-31 October 2012, Frankfurt am Main

Programme

TUESDAY, 30 OCTOBER 2012

08:15 – 08:45	Registration
08:30 – 09:00	Welcome coffee
09:00 – 09:15	**OPENING REMARKS** **MARIO DRAGHI (PRESIDENT, EUROPEAN CENTRAL BANK)**
09:15 – 10:15	**POLICY KEYNOTE: "THE FUTURE OF FINANCIAL REGULATION: BACK TO FUNDAMENTALS"** **STEPHEN CECCHETTI (ECONOMIC ADVISER AND HEAD OF THE MONETARY AND ECONOMIC DEPARTMENT, BANK FOR INTERNATIONAL SETTLEMENTS)**
10:15 – 11:05	**"REPORT ON THE FIRST TWO YEARS OF THE MACROPRUDENTIAL RESEARCH NETWORK"** **PHILIPP HARTMANN (EUROPEAN CENTRAL BANK AND CHAIR OF MARS)**
11:05 – 11:20	Coffee break

11:20 – 13:10

PARALLEL SESSIONS

SESSION 1:
ROOM:…..
(110 mins)

FINANCIAL INSTABILITY AND THE MACROECONOMY

CHAIR: Xavier Freixas (Universitat Pompeu Fabra)

PAPER 1: 'Booms and Systemic Banking Crises'
Frederic Boissay* (European Central Bank), Fabrice Collard (University of Bern) and Frank Smets (European Central Bank) (25 mins)

PAPER 2: 'Stress-testing US Bank Holding Companies: A Dynamic Quantile Regression Approach'
Francisco Covas* (Federal Reserve Board), Ben Rump (Federal Reserve Board) and Egon Zakrajsek (Federal Reserve Board) (25 mins)

PAPER 3: 'Bank Overleverage and Economic Fragility'
Ryo Kato* (Bank of Japan) and Takayuki Tsuruga (Kyoto University) (25 mins)

DISCUSSANT: John Geanakoplos (Yale University) [TBC] **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

SESSION 2
ROOM:….
(110 mins)

EARLY WARNING MODELS

CHAIR: Carsten Detken (European Central Bank)

PAPER 1: 'Predicting Bank Distress and Identifying Interdependencies amongst European Banks'
Frank Betz (European Central Bank), Silviu Oprica (European Central Bank), Thomas Peltonen (European Central Bank) and Peter Sarlin* (Abo Akademi University) (25 mins)

PAPER 2: 'Banking, Debt and Currency Crises: Early Warning Indicators for Developed Economies'
Jan Babecky (Czech National Bank), Thomas Havranek (Czech National Bank), Jakub Mateju (Czech National Bank), Marek Rusnak (Czech National Bank), Katerina Smidkova (Czech National Bank) and Borek Vasicek* (Czech National Bank) (25 mins)

PAPER 3: 'Formal Identification of Sentiment Effects in Asset Markets'

Peter Dunne* (Central Bank of Ireland), John Forker (University of Bath), Ronan Powell (University of New South Wales) and Andrey Zholos (Queen's University Management School) (25 mins)

DISCUSSANT: Philip Davis (National Institute of Economic and Social Research) **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

13:10 – 14:20 Lunch

14:20 – 16:10

PARALLEL SESSIONS

SESSION 3
ROOM:….
(110 mins)

MACRO-PRUDENTIAL POLICY

CHAIR: Ignazio Angeloni (European Central Bank)

PAPER 1: 'A Macro-economic Model of Endogenous Systemic Risk-taking'

David Martinez-Miera (Carlos III) and Javier Suarez* (CEMFI) (25 mins)

PAPER 2: 'An Integrated Framework for Analysing Multiple Financial Regulations'

Charles Goodhart (London School of Economics), Anil Kashyap (Chicago Booth), Dimitrios Tsomocos (Oxford University) and Alexandros Vardoulakis* (European Central Bank) (25 mins)

PAPER 3: 'A Model for Assessing Macro-prudential Regulatory Policies'

Laurent Clerc* (Banque de France), Alexis Derviz (Czech National Bank), Caterina Mendicino (Bank of Portugal), Livio Stracca (European Central Bank) and Alexandros Vardoulakis (European Central Bank) (25 mins)

DISCUSSANT: Michael Kumhof (International Monetary Fund) **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

SESSION 4
ROOM:….

CONTAGION IN FINANCIAL NETWORKS

(110 mins)

CHAIR: [TBC]

PAPER 1: **'Derivatives and Credit Contagion in Inter-connected Networks'**
Sebastian Heise (King's College, London) and Reimer Kuhn* (King's College, London) (25 mins)

PAPER 2: **'Size and Complexity in Model Financial Systems'**
Nim Arinaminpathy (Princeton University), Sujit Kapadia* (Bank of England) and Robert May (Oxford University) (25 mins)

PAPER 3: **'Bank Networks, Inter-bank Liquidity Runs and the Identification of Banks who are too Inter-connected to Fail'**
Alexei Karas (Roosevelt Academy) and Koen Schoors* (Ghent University) (25 mins)

DISCUSSANT: Ester Faia (Goethe University Frankfurt) **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

16:10 – 16:25 Coffee break

16:25 – 18:15

PARALLEL SESSIONS

SESSION 5:
ROOM:…
(110 mins)

CROSS-BORDER BANK CONTAGION

CHAIR: [TBC]

PAPER 1: **'Determinants of Banking System Fragility: A Regional Perspective'**
Hans Degryse* (Tilburg University and KU Leuven), Mohamed Elahi (CBER) and Maria Penas (Tilburg University) (25 mins)

PAPER 2: **'Shocks Abroad, Pain at Home? Bank-Firm Level Evidence on Financial Contagion During the Recent Financial Crisis'**
Steven Ongena* (Tilburg University), Jose-Luis Peydro (Universitat Pompeu Fabra) and Neeltje van Horen (De Nederlandsche Bank) (25 mins)

PAPER 3: **'Vulnerable Banks'**
Robin Greenwood (Harvard University), Augustin Landier (University of Toulouse) and David Thesmar* (HEC Paris) (25 mins)

DISCUSSANT: Robert de Young (University of Kansas) **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

SESSION 6:
ROOM:…
(75 mins)

LEVERAGE CYCLES AND MACRO-FINANCIAL LINKAGES

CHAIR: Heather Gibson (Bank of Greece)

PAPER 1: 'House Prices, Credit Growth and Excess Volatility: Implications for Monetary and Macro-prudential Policies'
Paolo Gelain (Norges Bank), Kevin Lansing * (Federal Reserve Bank of San Francisco and Norges Bank) and Caterina Mendicino (Bank of Portugal) (25 mins)

PAPER 2: 'Bank Leverage Shocks and the Macro-economy: A New Look in a Data-rich Environment'
Jean-Stephane Mesonnier* (Banque de France) and Dalibor Stevanovic (UQAM) (25 mins)

DISCUSSANT: Kim Abildgren (Danmarks Nationalbank) **(15 MINS)**

GENERAL DISCUSSION (10 MINS)

20:00 Dinner

WEDNESDAY, 31 OCTOBER 2012

08:30 – 09:00 Coffee

09:00 – 10:50

SESSION 7:
ROOM:…
(110 mins)

SOVEREIGN CONTAGION AND RUNS ON MONEY-MARKET FUNDS

CHAIR: Cornelia Holthausen (European Central Bank)

PAPER 1: 'Conditional Probabilities for Euro-area Sovereign Default Risk'
Andre Lucas (University of Chicago), Bernd Schwaab* (European Central Bank) and Xin Zhang (Sverige Riksbank) (25 mins)

PAPER 2: 'Liquidity Shocks, Dollar Funding Costs and the Bank Lending Channel during European Sovereign Crisis'
Ricardo Correa (Federal Reserve Board), Horacio Sapriza (Federal Reserve

Board), and Andrei Zlate* (Federal Reserve Board) (25 mins)

PAPER 3: 'Runs on Money-market Mutual Funds'
Russ Wermers* (University of Maryland) (25 mins)

DISCUSSANT: Sascha Steffen (ESMT European School of Management and Technology) **(20 MINS)**

GENERAL DISCUSSION (15 MINS)

10:50 – 11:05 Coffee break

11:05 – 12:55

SESSION 8: ROOM:… (110 mins)

FINANCIAL IMBALANCES AND POLICY RESPONSES

CHAIR: Heinz Hermann (Deutsche Bundesbank)

PAPER 1: 'Macro-prudential Regulation Versus Mopping Up After the Crash'
Anton Korinek* (University of Maryland) and Olivier Jeanne (Johns Hopkins University) (25 mins)

PAPER 2: 'Optimal Monetary and Prudential Policies'
Fabrice Collard (University of Bern), Harris Dellas (University of Bern), Behzad Diba (Georgetown University) and Olivier Loisel* (ENSAE ParisTech) (25 mins)

PAPER 3: 'Prudential Policy for Peggers'
Stephanie Schmitt-Grohe* (Columbia University) and Martin Uribe (Columbia University) (25 mins)

DISCUSSANT: Enrico Perrotti (University of Amsterdam) (20 MINS)

GENERAL DISCUSSION (15 MINS)

12:55 – 14:15 Lunch

14:15 – 16:15 **POLICY PANEL ON "THE EUROPEAN BANKING UNION"**

CHAIR: VÍTOR CONSTÂNCIO (VICE-PRESIDENT,

EUROPEAN CENTRAL BANK)

SPEAKERS: **SHARON BOWLES** (CHAIR, COMMITTEE ON MONETARY AND ECONOMIC AFFAIRS OF THE EUROPEAN PARLIAMENT)
N.N. (EUROPEAN COMMISSION; TBC)
THOMAS HOENIG (DIRECTOR, US FEDERAL DEPOSIT INSURANCE CORPORATION)
ERKKI LIIKANEN (GOVERNOR, BANK OF FINLAND)
ANDRÉ SAPIR (PROFESSOR OF ECONOMICS, UNIVERSITÉ LIBRE DE BRUXELLES, AND CHAIR OF THE ADVISORY SCIENTIFIC COMMITTEE OF THE EUROPEAN SYSTEMIC RISK BOARD)

16:15 – 16:25 CLOSING

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