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ESCB HEADS OF RESEARCH

**REPORT ON THE MACRO-PRUDENTIAL RESEARCH
NETWORK (MARS)**

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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). That network has pursued 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);
- assessing contagion risks – work stream 3 (WS3).

This report summarises the results of MaRs' research and the progress it has made on behalf of the European System of Central Banks (ESCB) in terms of the analytical underpinnings of macro-prudential policies. It provides an overview of the network's activities and output, reviews the findings of each of the three work streams (focusing in particular on answers to the research questions asked by the General Council when the network was established) and concludes with an overall assessment at the end of this summary.

General output and organisation

MaRs has produced 161 individual research papers so far (65 in WS1, 51 in WS2 and 45 in WS3). Of those papers, 72 have been published, have been accepted for publication or are forthcoming in the ECB Working Paper Series, with a "MaRs" stamp on the cover page. 50 papers have been published in academic journals, including a few top journals (such as the Journal of Financial Economics, the Economic Journal or the Journal of Monetary Economics). Many of the other papers are in the process of being published.

MaRs also pursued three joint cross-country projects involving many different EU central banks: one developing a macroeconomic model for assessing macro-prudential regulatory policies under WS1; another performing a comparative assessment of different early warning models based on a jointly developed database of financial crises in EU countries under WS2; and a third analysing euro interbank market structures for assessing contagion risks using a joint database from the TARGET2 payment system under WS3. In response to recent developments, WS3 also pursued a special initiative looking at research assessing sovereign contagion risks in Europe.

In addition to the internal meetings and workshops organised by the different work streams and their sub-teams, MaRs has held three public conferences at the ECB – the first in October 2011, the second in October 2012 and the third in June 2014. In each case, 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 has operated with a light management structure, in which representatives of the ECB, the euro area and non-euro area national central banks (NCBs) have participated, with an overall chairperson and two coordinators for each work stream. Professor Xavier Freixas (Universitat Pompeu Fabra, 2010-12), Professor Javier Suarez (CEMFI, Madrid, 2012-14) and Professor Hans Degryse (Katholieke Universiteit Leuven, 2012-14) have acted as academic advisers and consultants.

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

This work stream was intended largely to provide relatively fundamental research. Ultimately, though, it has also built on this investment to prepare one or two important analytical tools that could be used for regular policy support (notably the development of a macroeconomic model designed for assessing macro-prudential regulatory policy instruments). Its main objectives were: to develop theoretical and empirical frameworks that integrate realistic characterisations of widespread financial instability into models of the aggregate economy; to allow analysis of transmission channels between financial instability and macroeconomic variables; to explain the recent crisis; and to assess policies addressing systemic risks. In pursuing these objectives, WS1 has also laid foundations both for general systemic risk research and for the specific analysis conducted under WS2.

WS1 has produced several new theoretical and empirical frameworks looking at *how widespread financial instability can be integrated into aggregate models*. These core conceptual models have directly addressed one of the main weaknesses of current economics laid bare by the crisis and gone significantly further than other recent academic literature, incorporating so-called financial frictions in otherwise standard macroeconomic models. Theoretical results highlight the fundamental importance of bank defaults, the design of bankruptcy rules, fire sales and drastic discontinuities or other non-linearities in characterising financial instability. Most papers focus on the endogenous build-up and unravelling of widespread imbalances, on aggregate shocks or on interaction 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 and peer effects in maturity transformation; on the liability side, they are captured by banks assuming wholesale financing that contributes to the build-up of aggregate liquidity. Several of these features also correspond to the choice of indicators for the early warning models discussed in relation to WS2 below.

The research shows key *non-linearities in financial instability phenomena*, as well as the wider implications that emerge as a consequence of switches between multiple self-fulfilling equilibria, switches between parameter regimes and/or the effects of occasionally binding constraints (for example with regard to bank capital or household debt). One novel empirical approach applied to European data suggests that in times of severe systemic financial instability (captured by a new composite indicator described in more detail under WS2 below), regime changes make the macroeconomy behave fundamentally differently from its behaviour in tranquil times. As a consequence of the highly non-linear transition between regimes defined by different sets of estimated parameter and/or shock variances, the

impact of financial instability shocks on economic growth becomes much more pronounced. This provides one explanation of why the recession caused by the financial crisis has been so severely underestimated by most analyses and forecasts. This has started to be tested as an analytical tool for scenario analysis, nowcasting of systemic fragility, and even forecasting.

Theoretical and empirical MaRs research illustrates the *transmission of financial instability to the real economy* through constraints on credit supply, credit demand and the disruptive effect that the breakdown of risk-sharing has on households' consumption plans. 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.

WS1 has also produced a wealth of research describing the *functioning of the leverage cycle*. For example, 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 better captures the extent of macroeconomic fluctuations, because it allows firm and bank leverage to reinforce each other. Other DSGE research illustrates how shadow banking associated with securitisation or the presence of foreign currency loans amplifies the leverage cycle. Moreover, optimism about future house valuations may increase household leverage, demand for houses and real estate prices. If expectations are dashed, the result is over-borrowing, so households have to deleverage and the boom is followed by a bust. Similarly, research suggests that if a subset of agents deviates from rational expectations, the volatility and persistence in the dynamics of house prices, household debt and economic activity are magnified.

A growing number of theoretical MaRs papers have assessed 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, (general, sectoral and counter-cyclical) 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. Ways of refining some instruments have also been considered. For example, some WS1 research has found that the stabilising effects of LTV ratios set in response to real-estate bubbles are more effective when the ratios are varied in a counter-cyclical manner over time. This is a complex insight from a practical policy perspective, because in many countries LTV ratios are determined not by financial supervisory authorities, but by bodies subject to the general political process. Moreover, combining house values and wage income in a generalised collateral limit is similarly effective, suggesting that LTV ratios and debt-to-income limits as regulatory instruments should not be considered in isolation from each other. 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. For example, increasing capital requirements could induce banks to securitise loans and sell the asset-backed securities (ABSs) to shadow banks, which would fund those purchases with short-term repos backed by the ABSs. This regulatory arbitrage might have to be limited through margin requirements on repos, since otherwise the bank capital requirements would not reduce credit risk in the system, simply making it migrate to another type of financial institution that was vulnerable through short-term financing. In particular, controlling fire sale risk is critical to improving overall economic performance. However, not all strategies for controlling this risk are equally effective, and indiscriminate combinations of different regulations can easily become counterproductive.

As part of WS1, a large amount of effort has gone into the development of a macroeconomic reference model that can be used for the regular assessment of macro-prudential regulatory policies. Staff from several NCBs and the ECB have completed a core version of the model (calibrated to the euro area) as a joint cross-country project, focusing mainly on general capital requirements and counter-cyclical capital buffers (CCBs). It is being shared within the ESCB, so that NCBs can calibrate it to their respective countries.

The model combines several key features of widespread financial instability (such as excessive risk taking by banks), credit growth and its breakdown, and a type of indirect contagion effect across banks through funding costs (somewhat different from the direct interbank contagion addressed in WS3; see chapter 4 below). Aggregate shocks (for example to bank capital, investors' confidence in banks, house prices or productivity) and these features can lead to multiple defaults by heterogeneous banks (in line with the empirical systemic instability indicators displayed in the chapter on WS2 below), but also defaults by firms and households in equilibrium. This allows us to consider both the benefits (reduced likelihood of bank defaults and associated credit crunches) and the costs (reduced availability of credit) of financial regulation. Shocks and the transmission of financial instability are amplified in a variety of ways in the model. Particularly important in this regard is a non-linearity associated with the level of bank capital. When capital ratios are too low, negative aggregate shocks can lead to bank defaults, which set in motion adverse macro-financial feedback effects. When capital ratios are high (either because steady state capital ratios are high or because a CCB has been applied), even large shocks hardly destabilise banks and this amplification mechanism is entirely absent. Policy simulations for the model suggest that releasing the CCB following an adverse shock can be helpful in limiting the decline in credit, but only when this does not endanger bank solvency. If capital buffers are low to begin with, an attempt to maintain credit supply through a relaxation of capital requirements could become counterproductive because of its negative impact on bank funding costs.

While combining various features of the new generation of macro theories with financial instability, the model is still based on first principles, dynamic, stochastic and solved in general equilibrium (currently using up to second-order approximations). The plan is to extend the core version with a richer characterisation of liquidity features and nominal frictions, to assess liquidity regulations and the interaction between macro-prudential and monetary policy.

Turning to multi-country settings, WS1 research also suggests that capital requirements and LTVs may have significant *cross-border implications*, be it through generally high levels of financial integration or the possibility of trading credit risk through securitised products in an otherwise fragmented context. This raises the issue of whether regulatory policies that lie outside the EU's common legal framework, such as LTVs or debt-to-income limits, should also be made subject to some coordination. Moreover, empirical evidence on national macro-prudential policies causing cross-border capital flows raises the issue of multilateral surveillance at the global level.

As regards the *interaction 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.

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 individual countries. Some of the analytical tools that have been developed already feed into regular macro-prudential surveillance and have featured in official publications.

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 developing European-focused databases and new indicators. In particular, a Composite Indicator of Systemic Stress (CISS) has been developed that captures the systemic dimension by being broad in covering instability in the main financial markets and intermediaries and by aggregating these components taking their dependence into account, with their weights linked to their relationship with the real economy. Distance-to-default indicators have also been proposed to measure the probability of multiple bank failures.

Given the historical experience that the build-up of widespread financial imbalances is often a key source of systemic financial crises (which is now also reflected in the new generation of macro models with financial instability developed in WS1), WS2 researchers have applied novel methodologies in selecting *early warning indicators*. Building on standard discrete-choice models (logit and probit), they have tackled issues such as model uncertainty (through Bayesian model averaging), optimal time lags for the early warning indicators (through panel vector autoregression models (VARs)), cross-country differences (through random-coefficient models) and non-linearities and threshold effects (through binary regression trees and random forest algorithms). They have also applied existing methods using European data, used

new data sources and designed new visual representations of the results of tools (such as self-organising maps). Summarising the results of the multivariate analyses suggests that the key variables to monitor in early warning models are credit-to-GDP ratios (particularly deviations from trend values, termed “credit gaps”), measures of real estate price overvaluation such as house price gaps and house price-to-income ratios, credit growth, term and credit spreads, real equity price growth and other measures of asset price misalignment, as well as the current account-to-GDP ratio. 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. This indicator sends a warning signal when credit risk conditions are too benign.

Detecting imbalances in asset prices or credit developments is perhaps one of the most challenging areas of WS2 research. Empirical evidence warns against relying too much 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.

A collective cross-country project involving 27 EU central banks has produced a database of various types of crisis (banking, currency and sovereign debt crises) in EU countries, which has been made available to interested researchers on the ECB’s website. In the second stage of the project, this database was used by a cross-country team of around 20 researchers from seven NCBs and the ECB in an exercise aimed at comparing different early warning models and assessing their performance in predicting those crises, using a uniform set of statistical evaluation criteria. The exercise included nine models using a wide variety of methodologies, including multivariate logit models, Bayesian model averaging and binary trees. Several models in this exercise found that, in addition to determinants that are well established in banking crisis literature (such as variables related to credit to the private sector), other factors – including “global variables” (depicting developments that are common to all EU countries, including global shocks) and banking sector variables (e.g. the level of banking sector capitalisation, consistent with theoretical and empirical results in WS1 and WS3 respectively, and profitability) – play a key role in providing early warnings about future banking crises. Moreover, the importance of accounting for spatial (across countries) and temporal (within each country over time) dependence in early warning models was highlighted by a number of approaches. In terms of the relative performance of different specifications, the results indicate that – in general – more traditional models such as multivariate logit models tend to somewhat reduce both Type I errors (i.e. a failure to issue warnings about future crises) and Type II errors (i.e. the issuing of false warnings about future crises) compared with univariate models. Some novel approaches, such as binary regression trees, strongly reduce Type II errors. Therefore, determining which model is “best” depends inter alia on policy-makers’ relative aversion to making Type I and Type II errors. Against this background, it may be desirable to regularly apply a suite of early warning models, rather than trying to identify the single best performing model and using only that. This applies in particular in situations where policy-makers’ preferences regarding Type I and II errors are not the same across jurisdictions, are not stable over time or are not entirely clear. Being transparent about the relative

strengths and weaknesses of the different models, as well as the assumptions regarding preferences that are used to derive specific thresholds, should allow policy-makers to make the best use of the information content of MaRs' early warning indicators and tools.

Work stream 3: Assessing contagion risks

The intended focus of this work stream was primarily to assess the scope for cross-border bank contagion across EU countries, complementing previous research on contagion risk within EU countries. Contagion can be said to exist when instability in a specific financial intermediary or market is transmitted to one or more other intermediaries or markets, notably when this transmission is not caused by common factors or fundamentals and/or is of particular strength ("extreme"). One specific research question was whether there may sometimes be feedback effects which amplify contagion. As the literature has highlighted the important role of interbank markets in transmitting financial instability, a large number of WS3 papers have focused on *money market interlinkages and structures* and what they imply for bank contagion risks.

Considerable effort went into a joint cross-country project in which 15 researchers and several payment system experts from many ESCB central banks exploited transaction-level data from the TARGET2 large-value payment system. Applying the so-called Furfine algorithm, they derived bilateral interbank exposures from euro unsecured interbank lending and the related intraday interest rates from the payment information available for all countries using TARGET2. These datasets have been used, inter alia, to apply network theory to the study of interbank linkages and to conduct event studies in order to better understand the behaviour of cross-border banks. This extensive datawork will form the basis for both a wealth of future euro money market research and practical surveillance tools for regular monitoring of the stability of the euro interbank market.

Thus far, four main results have emerged from MaRs' WS3 research using these datasets. First, developments in interbank lending since 2008 show a substantial reduction in cross-border activity following the bankruptcy of Lehman Brothers. The ECB's liquidity injections through three-year longer-term refinancing operations coincided with a significant further decline in overall interbank market activity, but also with some normalisation of markets: proxies of market fragmentation, which had reached peak levels towards the end of 2011, significantly declined after the liquidity interventions. Second, there is significant evidence of spillovers between average country-level interbank market rates, but their dynamics and intensity vary substantially over time and between stressed and non-stressed countries.

Third, networks of euro money market relationships can be identified, which show tiering. As also found by MaRs WS3 researchers using non-payment data, many banks do not lend to each other directly, instead using "money centre" banks. In some cases, long-term bank-to-bank relationships can alleviate the impact of turmoil, because they make the availability of short-term funding more reliable. In other cases, however, they may transmit adverse shocks. (An interesting analogy was found in WS1, where a study of retail lending relationships in Denmark suggested that firms relying on relationship banks which were weakened by the crisis were more likely to default.) All in all, the detailed picture provided by the

TARGET2 data about the interbank network, tiering and relationships means that such data could profitably be used to improve indicators of interconnectedness for systemically important financial institutions (SIFIs), which are so important for macro-prudential policy. For instance, they could be used to determine capital surcharges for systemic importance.

Fourth, *bank contagion* can operate through channels other than the standard default cascades analysed in the literature using counterfactual simulations (where one failing bank causes losses for another bank that lent to it, so it also fails, and so on). For example, it can be transmitted and amplified through the balance sheet weaknesses of a borrowing bank (instead of its outright default), which weakens the balance sheet of the lending bank through market valuations, and so on. Alongside the TARGET2 data research, another WS3 project adopted a novel approach looking at how to complete the network of bilateral interbank exposures through stochastic simulations when precise data are not available. Importantly, it illustrates how fire sales of assets can amplify the extent of interbank contagion, which also turns out to be highly non-linear. Moreover, a project using credit register data suggested that owing to the presence of both unsecured and collateralised transactions, the distribution of losses from interbank exposures is strongly bi-modal (i.e. most losses are either very small or very large). This qualifies the usual assumption that loss given default averages around 40% and adds an element of fragility to the interbank system. Overall, the results confirm the findings in the literature to the effect that a simple mechanical approach to interbank linkages can give only a partial picture of contagion risks and, accordingly, that counterfactual simulations of outright bank defaults, without any additional behavioural and institutional considerations, usually find only limited contagion cascades.

A few more WS3 projects studied contagion phenomena using stock market data. One offered a global empirical study of spillovers in connection with regional banking fragility, defined as bank stocks in several countries in a given region simultaneously showing low returns. This fragility is generally reduced if banks in a given region hold more liquid assets, are better capitalised (in line with theoretical and empirical results found in WS1 and WS2 respectively) or are more competitive. In Europe, greater liquidity and capitalisation reduce the likelihood of certain countries' banking indices simultaneously showing low returns, but not the likelihood of many countries' banking indices showing low returns. Another paper developed a new methodology for disentangling short-term contagion phenomena from long-term market integration. Finally, WS3 research has made further progress in applying the network approach at the macro level, using harmonised financial accounts for euro area countries. For example, it has 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 also decided to add a special initiative on *sovereign contagion* research. The data used in the various projects include sovereign bond yield spreads, sovereign credit default swap (CDS) spreads and bank equity returns. The methodologies applied include 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 following the onset of the sovereign debt crisis in late 2009. One paper clarifies that bad news about a

country's economy may be confused with news about other countries showing a lack of commitment to supporting that country (a different trigger for contagion). Two dissenting papers argue that surges in co-movement in sovereign markets may be explained by the overall increase in volatility, and fundamental factors and risk aversion may be sufficient to explain sovereign yield increases.

Overall assessment

Macro-prudential regulation and supervision is still a relatively new policy area. Its conceptual and analytical underpinnings are certainly not as well developed as those of monetary policy. When the Macro-prudential Research Network was established, research supporting macro-prudential policies was, in many cases, arguably at a level comparable to monetary policy research in the 1950s or 1960s. While a central bank research network cannot change this on its own – and certainly not in just a few years – MaRs has made significant progress, as well as stimulating fresh thinking in the wider research community.

The work of MaRs researchers has, inter alia:

- helped, from an analytical perspective, to further clarify important concepts, such as systemic risk, widespread financial imbalances and macro-prudential regulation;
- developed several structural models incorporating financial instability in macroeconomics, representing core conceptual frameworks at the frontier of economic science, and illustrating how financial instability can be transmitted (often in non-linear ways) through the economy;
- proposed novel empirical approaches and assessed the robustness of existing approaches with a view to measuring widespread financial instability, identifying its origins, assessing its (often non-linear) interactions with the wider economy and warning about the risk of financial crises;
- started to assess a wide range of regulatory instruments proposed for macro-prudential policies;
- developed a number of analytical tools designed to support macro-prudential policy work (including models assessing regulatory instruments and the macroeconomic implications of financial crises, warning about contagion, financial imbalances or general crisis risks and adding features to stress tests) that are already in regular use or for which concrete plans for such regular use exist;
- put new (European) data sources to work in the area of macro-prudential analysis – data that could be used in the future for regular policy support and the validation of analytical tools.

In so doing, it has provided a range of answers to most of the research questions asked by the General Council when the network was first launched. In particular, notable progress has been made where human or data resources have been pooled across the ESCB to benefit from the expertise in those various central banks. This has led, for example, to:

- the development of a state-of-the-art macroeconomic model assessing the benefits, costs and transmission channels of different macro-prudential regulations, which is being shared within the ESCB;
- a comparative assessment of a suite of early warning models with the aid of a new database containing information on various crises across Europe;
- the operationalisation of a large amount of large-value payment data to derive interbank exposures, study the structure of money markets and assess cross-border contagion risks in Europe, which is already being used on a regular basis to monitor and interpret money market developments.

But there are also important areas that MaRs could not directly address. One is the use of research approaches that move definitively away from concepts based on rationality and equilibrium (such as “agent-based modelling”). In addition, MaRs did not have a mandate to generally review operational macro stress testing frameworks, but it made a few valuable research contributions regarding features of stress testing models. Instead, a core task was to develop macroeconomic models involving banks and financial instability, which have the potential – over time – to contribute to the development of more coherent macro stress testing frameworks, for example fully reflecting the two-sided interaction between the financial sector and the real economy. Moreover, MaRs was not designed to give conclusive advice on specific policy actions. While a lot more research is needed in the years ahead in order to support analytically the full development of the macro-prudential approach to financial supervision and regulation, MaRs has made enough progress to now bring this large coordinated research effort to a close. The ESCB has now achieved a solid basis in terms of macro-prudential research and an initial set of staff working on such issues. Necessary follow-up work can therefore be integrated into the regular work programmes of central banks’ research departments or take place via smaller coordinated efforts at the European level.

At the same time, it remains true that many of the models and tools to support macro-prudential policies devised by MaRs, other policy authorities and academia need not only to be developed further, but also to be integrated much more widely into the standard toolkits of the economics and finance professions. In other words, the experience of the crisis suggests that additions to the existing economic frameworks may be needed, amounting to a new paradigm. Although a number of MaRs researchers have made valuable steps in this direction, alongside efforts by economists at other policy authorities, such as the Bank for International Settlements or the International Monetary Fund, overseas central banks and a number of university professors (also cited in this report), the establishment of a new paradigm usually takes place in academia more generally. The participating central banks would therefore appreciate it if, in particular, the new aggregate frameworks incorporating widespread financial instability, their use for the assessment of macro-prudential regulatory instruments and their further development could be taken up more widely in academic research and teaching.

1. Introduction¹

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 was 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). It pursued 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);
- assessing contagion risks – work stream 3 (WS3).

MaRs has held three large public conferences at the ECB in Frankfurt – in October 2011, October 2012 and June 2014 – at which the best research from all three work streams has been presented, alongside external papers by academics and other authorities addressing MaRs' research questions.² Some general information about the network and its mandate, organisational structure and working papers is also publicly available on the ECB's website.³

The purpose of this report is to summarise the research findings and the progress achieved by MaRs. 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 then summarise the results of the analyses carried out in each of MaRs' three work streams, focusing in particular on the research questions asked by the General Council when the network was established. There are also two annexes, which contain a list of all economists from the European System of Central Banks (ESCB) who have contributed to MaRs, as well as the programmes of the 2011, 2012 and 2014 conferences.

This report mainly covers papers produced under MaRs. While the text often relates them to the literature they directly build on or refers to other reports in related areas, it cannot provide a full survey of all relevant literature outside MaRs. Moreover, it should be borne in mind that not all papers are entirely

¹ This report has been drafted by a team comprising Philipp Hartmann (team leader; ECB), Paolo Angelini (Banca d'Italia), Laurent Clerc (Banque de France), Carsten Detken, Fiorella De Fiore, Caterina Mendicino, Kalin Nikolov, Gerhard Rünstler, Willem Schudel (all ECB) and Kateřina Šmídková (Česká národní banka). It is based on input from a large number of MaRs contributors (see Annex 1) and has benefited from comments by ESCB heads of research, MaRs plenary members (see Annex 1), Hans Degryse (Katholieke Universiteit Leuven) and Javier Suarez (CEMFI).

² The various programmes, papers, presentations and speeches are available on the ECB's website through the following links: www.ecb.europa.eu/events/conferences/html/mar_net.en.html, www.ecb.europa.eu/events/conferences/html/mar_net2.en.html and www.ecb.europa.eu/events/conferences/html/140623_mars_net.en.html. See also Annex 2 to this report.

² The various programmes, papers, presentations and speeches are available on the ECB's website through the following links: www.ecb.europa.eu/events/conferences/html/mar_net.en.html, www.ecb.europa.eu/events/conferences/html/mar_net2.en.html and www.ecb.europa.eu/events/conferences/html/140623_mars_net.en.html. See also Annex 2 to this report.

³ www.ecb.europa.eu/home/html/researcher_mars.en.html.

complete at present. In particular, where projects have not yet even been published as working papers, some results could still change, so one should be cautious in drawing firm policy conclusions.

MaRs has a light management structure, with the chairman, Philipp Hartmann (ECB), aided by the network's secretaries (all from the ECB), Angela Maddaloni (2010-12), Kalin Nikolov (2012-13), Fiorella De Fiore (2012-14) and Gerhard Rünstler (2013-14), in cooperation with two coordinators for each of the three 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, 2010-14), Cornelia Holthausen (ECB, 2011-12) and Simone Manganelli (ECB, 2013-14). Professor Xavier Freixas (Universitat Pompeu Fabra, 2010-12), Professor Javier Suarez (CEMFI, Madrid, 2012-14) and Professor Hans Degryse (Katholieke Universiteit Leuven, 2012-14) have acted as academic advisers and consultants. Given the differences in the nature, timing and context of the three work streams, each followed its own approach in carrying out research, while information was regularly exchanged among them.

MaRs has conducted three large joint cross-country projects and produced 161 individual papers. The joint cross-country projects, in which a large number of NCBs have participated, concern the development of a macroeconomic model for assessing macro-prudential policies as part of WS1, the establishment of a financial crisis database for the EU27 as part of WS2, and the analysis of euro interbank lending structures to assess contagion risks using data from the TARGET2 large-value payment system. WS2 also added a comparative performance assessment for a series of early warning models, while WS3 also included a special initiative looking at research assessing sovereign contagion risks in Europe. WS1 produced 65 individual papers, WS2 produced 51 papers and WS3 produced 45 papers. MaRs research papers are published both 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, 57 papers have been published as ECB working papers (26 from WS1, 20 from WS2 and 11 from WS3) and 15 papers have been accepted for publication and are forthcoming (six from WS1, 7 for WS2 and two from WS3). 50 papers have already been published (or accepted) in journals (21 from WS1, 18 from WS2 and 11 from WS3), including the Journal of Financial Economics, the Economic Journal, the Journal of Monetary Economics, the Journal of Money, Credit and Banking, 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. Consequently, it was expected that only a few projects in this work stream would lead to analytical policy tools for regular use – albeit one or two of those would be fairly important (notably the development of a macroeconomic model designed to assess macro-prudential regulatory policy instruments). Its main objectives are: to develop theoretical and empirical frameworks that integrate realistic characterisations of widespread financial

instability into models of the aggregate economy; to allow analysis of transmission channels between financial instability and macroeconomic variables; to explain the recent crisis; and to assess policies addressing systemic risks. In pursuing these objectives, WS1 has also laid foundations both for general systemic risk research and for the analysis 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 to understand the causes and features of the recent financial crisis? (viii) How can models help to identify the appropriate macro-prudential policies to maintain systemic stability? Arguably, the first and last questions in particular point to significant gaps in current economics, as laid bare by the recent financial crisis. For the purpose of summarising the research work done, these questions are synthesised in six areas, which constitute the sections of this chapter.⁴

Under the work programme for WS1, 65 individual research papers and the deliverables of the joint cross-country project on the model for assessing macro-prudential policy have been produced. 30 of these papers have been published or accepted for publication in the ECB Working Paper Series. Although they are at various stages of development, all 65 draft papers feed into the answers to MaRs' WS1 research questions.

2.1 Representation of widespread financial instability in aggregate models

The literature has identified three phenomena that can make financial instability widespread: contagion, the endogenous build-up and unravelling of widespread imbalances, and aggregate shocks (or combinations of these three).⁵ 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.⁶ Typically, financial instability and its spread are characterised by elements

⁴ There is other work produced both within and outside the ESCB which touches on some related issues. For example, an ECB occasional paper analyses the role of macro-financial linkages from an empirical perspective (Hubrich et al., 2013). 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” (www.bis.org/publ/bcbs_wp21.htm) and “The policy implications of transmission channels between the financial system and the real economy” (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, as well as micro-prudential considerations.

⁵ See, for example, the survey in ECB (2009).

⁶ This economic definition, taken from ECB (2009), is quite similar to the legal one ultimately adopted by the European Parliament in the regulation characterising the role of the European Systemic Risk Board (ESRB; Regulation No 1092/2010, Article 2(c)).

such as amplification effects, non-linearities (a key one being defaults by financial intermediaries) and illiquidity.

Long before the present crisis, theoretical and empirical financial literature had already provided good descriptions of the nature and sources of (non-systemic) financial instability, particularly in terms of single bank runs and crashes in specific financial markets. The same applies to some key elements of systemic risk within the financial system, particularly bank and financial market contagion (mainly relating to MaRs WS3, which is covered in Chapter 4 below).⁷

The aim of incorporating such phenomena in aggregate models is to support macro-prudential policies that seek 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 objectives 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 incorporate 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 interaction between macro-prudential and monetary (or other) policies. The challenge, however, is that theories of monetary stability are much better 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 are still 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 investigate whether and to what extent a variety of financial variables and shocks influence, for example, growth and inflation in different countries (Abildgren 2010, Alessi 2011, Fornari and Stracca 2012, Franta et al. 2014, Guarda and Jeanfils 2012, and Tamási and Világi 2011). The general – and unsurprising – 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 characterise widespread financial instability more

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) offer 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 modern macroeconomics was from reaching this aim until recently. Recent work by IMF staff in this area includes Arregui et al. (2013).

precisely? One can see the answer to this point by comparing the very careful paper by Andreasen, Ferman and Zabczyk (2012) with the experience of banking crises. These authors introduce a representative bank into a standard dynamic stochastic general equilibrium (DSGE) model to describe the macroeconomic implications of maturity transformation – a key banking function – in tranquil times, i.e. without considering banking instability. An important result of this analysis is the strong “credit attenuation effect” that maturity transformation has on the macroeconomy. Output reacts 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 experience from the financial crisis and other recent research, in which maturity transformation plays an important amplifying role in the macroeconomy. In other words, taking the additional step from financial factors or frictions to realistic characterisations of widespread financial instability may be fairly crucial. It may turn some results upside down: something that appears to be stabilising the macroeconomy when banking instability is not considered may have a destabilising effect once banking crises are explicitly considered.

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 offers many insights regarding the question of 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 to include defaults by 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 models. 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 external academics have also made efforts to improve this rather unsatisfactory situation. For example, Bianchi and Mendoza (2010), Brunnermeier and Sannikov (forthcoming), Corbae and D’Erasmus (2012), Gertler and Kiyotaki (2012), He and Krishnamurthy (2012 and 2013), and Martinez-Miera and Suarez (2013) build macroeconomic models with more elaborate financial sectors in which non-linearities are represented. The last paper also incorporates bank defaults in

equilibrium.¹⁰ The macro-bubbles literature has also moved forward, owing to the fact that, in an environment in which agents are credit-constrained, asset price misalignments can cause 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 of 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 using 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. This 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. Defaults may initiate chain reactions because a creditor in a defaulting asset has fewer resources to deliver on another asset where it is the debtor. These indirect effects can be as important as the direct effects. Bankruptcy contagion is the result of interlocking asset trades that link short positions in possibly long chains. A main point of the paper is the illustration of the endogenous and interconnected nature of default risk. Models and regulatory approaches that treat default risks exogenously may be subject to significant biases and lead to policy mistakes (see Section 2.6.1).

Boissay (2011) characterises widespread financial instability in a static general equilibrium model representing a number of features of the present crisis (see Section 2.5). The model has multiple equilibria. The crisis equilibrium is characterised by a drying-up of inter-agent lending, liquidity hoarding and deleveraging by financial agents, and a reduction in the financing of investment projects and consumption. In tranquil times, the equilibrium 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 (as in standard bank run models such as Diamond and Dybvig 1983, for example) emerges among financial agents, which leads to the switch from the good to the bad equilibrium. The reason is that lending agents cannot observe the skills/behaviours 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 extends the model further to cover two countries. In one country (the “emerging economy”) the enforceability of financial contracts is weak, and in the other (the “industrialised country”) it is strong.

¹⁰ For a brief survey of the new theoretical macro literature incorporating financial instability, see Hartmann, Hubrich and Kremer (2013).

The resulting capital flows from the emerging economy to the industrialised country create a “global imbalance”. Again, there are multiple equilibria and there can be a switch to a crisis equilibrium, with global capital flows freezing and the industrialised country having to deleverage.

Boissay, Collard and Smets (2013) incorporate a representation of this asymmetric information mechanism between lenders and borrowers (which leads 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 are able to account for the dynamics of regular business cycles and crisis business cycles in industrial countries since the end of the 19th 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 a credit boom (in this model, driven by wholesale funding markets for lenders) are much more severe than regular recessions (Schularik and Taylor 2009, Claessens, Kose and Terrones 2012, and Abiad, Dell’Ariccia and Li 2010). Since the move to a crisis is no longer represented as a switch between different equilibria, as in Boissay (2011), 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.

Empirical early warning indicators and models for detecting aggregate credit imbalances constitute a central area of work for WS2, so they are discussed in Chapter 3 of this report. Some aspects of the empirical work by Bonfim and Kim (2013), which are discussed in greater depth in Section 2.5 below, are consistent with one of the premises of such theories – i.e. the notion that the build-up of widespread imbalances in the banking system can, inter alia, be driven by wholesale liquidity conditions. They find evidence that there are peer effects both in banks taking on funding liquidity risks and, to a somewhat lesser extent, in their liquidity creation through maturity transformation. Further supporting evidence is also provided by recent research on banking system vulnerabilities through the expansion of non-core liabilities (Hahn, Shin and Shin 2013).

Lambertini, Mendicino and Punzi (2010) and Gomes and Mendicino (2011) extend the housing model developed by Iacoviello and Neri (2010) to incorporate news shocks, as in Schmitt-Grohé and Uribe (2012). Housing boom-bust cycles emerge in a general equilibrium model by appealing to fluctuations in households’ expectations of future macroeconomic developments. A boom can occur if households become optimistic about the future, leading to expectations of house price appreciation. Among other things, 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 these positive expectations, households have to reverse their behaviour and deleverage, with potential consequences in terms of macroeconomic instability. Similarly, Derviz (2013b) explains equity boom-bust cycles through ex ante upwardly biased expectations about corporate prospects, which are not subsequently met.

Aoki and Nikolov (2012a) introduce financial intermediaries 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 a “search for yield”, which can involve asset prices increasing 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 equilibrium to the second, 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 leads to large-scale losses for the banking system that deplete its capital base and limit its ability to supply credit to the real economy. Using the same model, Aoki and Nikolov (2012b) suggest that the emergence of a bubble is accompanied by a very large increase in the ratio of money and credit to GDP and that much of the credit is “wasted” on financing unproductive bubble holdings. This provides theoretical support to empirical studies which have found that aggregate credit (and perhaps also aggregate money) growth is a good leading indicator of future financial instability (see, *inter alia*, Chapter 3 of this report on WS2). De Walque, Pierrard and Rouabah (2010) make an important contribution by introducing banks and a representation of their default (building on Goodhart, Sunirand and Tsomocos 2005 and 2006) in a micro-founded DSGE model. There are two banks in the economy choosing their balance sheets endogenously, one being a net borrower and the other being a net lender in the interbank market. The bank default is not represented by the bank being liquidated. Instead, the defaulting bank continues, but faces a disutility and pays a bankruptcy cost in the next period. This cost increases the interbank rate and reduces interbank lending, ultimately affecting the real economy and amplifying cycles (see Section 2.2 below).

Derviz (2013a) 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 value 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, Geanakoplos and Shubik 2005) and diversification (Ibragimov, Jaffee and Walden 2011), the paper demonstrates how long and inter-connected intermediation chains can amplify shocks and lead to financial crises.

2.1.2 Empirical research

The first key contribution by MaRs researchers to the question of how to integrate widespread financial instability into empirical macroeconomic models using European data was made by Hartmann et al. (2012). They incorporated the Composite Indicator of Systemic Stress, which was developed as part of WS2 as a measure of systemic financial instability, in a Bayesian Markov-switching vector autoregression (VAR) model (*à la* Sims and Zha 2006) of the euro area estimated using monthly data from 1987 to 2010. The other variables in the VAR were 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, putting particular emphasis on the interdependence of these components of the financial system (see Section 3.1 in the chapter on 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 attained unprecedented levels close to its maximum for extended periods of time during the recent financial and sovereign debt crises.¹¹

The second way in which the Hartmann et al. approach captures widespread financial instability is by allowing the data to drive two types of regime change at the macroeconomic level. The parameters connecting the five variables in the VAR can switch (between two regimes), and the variances of the error terms – reflecting the size of shocks and the general uncertainty around economic relationships – can also switch (between three regimes). The authors find that the most dramatic regime changes (for both types) tend to coincide with the most severe financial crises, suggesting that the economy functions in a fundamentally different way in times of systemic instability relative to tranquil times (see also Section 2.3 on non-linearities). Interestingly, when more traditional and less systemic financial stability or volatility measures replace the CISS, less convincing estimates of regime changes and/or relationships between financial instability and the macroeconomy are found.

Guarda, Rouabah and Theal (2013) argue that macro-prudential stress tests could better capture widespread financial instability if the shocks that fed into the VARs used in these tests were allowed to have “fat tails”. They incorporate 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 realisations than under the standard normal distribution (based on the methodology developed by Fong et al. 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.¹²

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 – which the VAR literature on feedback effects between banking problems and the macroeconomy (e.g. Anari, Kolari and Mason 2005) does not seem to have considered yet – is defined as loan impairment charges as a percentage 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

¹¹ A companion paper for US data uses a similar econometric methodology, but incorporates a more standard financial stress index (Hubrich and Tetlow 2010).

¹² Surprisingly, when MaRs was first established, 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 4.

two years before the losses are realised. The write-down ratio could also be interpreted as a measure of instability arising either 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).

As part of growing empirical literature exploring financial factors in business cycles (see, for example, the overview by Hubrich et al. 2013), 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 from 1980 to 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 fluctuations in consumption. Lastly, 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, building on the developing VAR literature identifying credit supply shocks – e.g. Helbling et al. (2010), Peersman (2011) or Meeks (2012). They try to capture credit supply shocks in two ways: (i) through a “risk assessment shock” described by a joint increase in the corporate default rate and the quantity of credit and (ii) through a “policy shock” described by an increase in the difference between corporate bond and money market rates (“credit spread”).

Franta et al. (2014) discuss whether fan charts generated from Bayesian vector autoregression models can be useful for assessing the credibility of stress tests conducted to evaluate financial stability. The article explores a dataset for the Czech Republic and macroeconomic scenarios that are used by Česká národní banka in stress tests for the banking sector. Using the generated fan charts, the article proposes a method for evaluating whether the assumptions that are employed in the bank's stress tests regarding the macroeconomic outlook are sufficiently adverse and consistent with past cross-correlations observed in the data. The results show that Česká národní banka's stress tests are sufficiently conservative in this respect.

Fornari and Stracca (2012) estimate quarterly VARs with seven endogenous variables for 21 countries between 1985 and 2010, aggregating the impulse response functions using the stochastic pooling approach devised by Canova and Pappa (2007). A financial shock is identified (through sign restrictions) 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 which is subject to disturbance and the fact 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 those 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 devised by Forni et al. (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 described as an “equity price bust” (associated, inter alia, with a year-on-year 10% decline in the equity market index), another as a “housing market decline” (associated, inter alia, with a year-on-year 10% decline in the housing price index) and the last as a “credit crunch” (associated, inter alia, with a 1% decline in credit).

Neagu, Costeiu and Tarța (2014) develop an analytical tool to assess whether a banking sector is able to withstand losses resulting from corporate defaults and macroeconomic factors. The aggregate model links the probability of the corporate sector defaulting, as estimated from micro data, with a macroeconomic module. The tool is applied to the Romanian banking sector.

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 wider economy, particularly the effect on growth and welfare. What research has to say about how an episode of financial instability is transmitted to the real economy is therefore important. One challenge is that some of the representations of financial instability in 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 area 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 feedback 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 supply of and demand for loans. Traditional macro models with financial frictions (Bernanke, Gertler and Gilchrist 1999, and Kiyotaki and Moore 1997) rely on the link between the borrowing capacity of private sector agents and collateral asset values. In other words, they are models where constraints mainly affect households’ and firms’ capacity to borrow (loan demand). Post-crisis macro models mainly focus on credit supply disruptions, which arise from endogenous leverage constraints for banks (e.g. Gertler and Karadi 2011, and Gertler and Kiyotaki 2010).

Models that capture financial instability – in the form of bursting asset bubbles, liquidity hoarding, endogenous bank runs or sovereign risk – rather than financial imperfections have different implications for the transmission of shocks to the aggregate economy. In Aoki and Nikolov (2012a), the bursting of the asset bubble implies that bank losses reduce the banks’ net worth. The leverage constraints on banks become binding and 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. Aoki and Nikolov (2013) extend this set-up in order to consider the effects of financial innovation on macroeconomic and financial stability. The emergence of shadow banking and greater use of bond financing lead to an expansion of firms' financing sources. However, this also reduces credit spreads and bank profits, encouraging intermediaries to increase their exposure to the bubble asset. When the bubble collapses, banks suffer larger losses and have to curtail lending more through the transmission channel outlined above, with larger implications for output.

Liquidity hoarding and deleveraging in the crisis equilibrium in Boissay's (2011) theory also have amplifying effects. 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 equilibrium in normal times. In Eichberger, Rheinberger and Summer's (2011) theory the breakdown of risk sharing produces welfare losses among consumers.

In contrast with Gertler and Kiyotaki (2012), who include a Diamond and Dybvig (1983) type of bank run in a DSGE model, Pusinskaite (2013) looks at how the effects of shocks on the real economy can be amplified using a DSGE model featuring bank runs that emerge as a unique equilibrium (as in the global games tradition; see Rochet and Vives 2004). Households are more concerned about bank default when bank leverage is high and the expected gross return on bank assets is low. So, the aggregate shocks that increase bank leverage or reduce the expected gross return on bank assets tend to increase the deposit withdrawal rate that banks face, as well as widening the spread between the expected rate of return on bank assets and deposit rates. As a result, firms' demand for credit falls, together with investment and output.

A related transmission mechanism arises in de Walque, Pierrard and Rouabah (2010). An adverse shock may lead a bank to "default", which is assumed to imply the payment of some 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. Such interaction between the interbank market and the real economy leads to the amplification of macroeconomic cycles.

Excessive volatility in housing markets can also spread to the real economy. The above-mentioned theory expounded by Gomes and Mendicino (2011) works through house price expectations and the demand for housing. Optimistic expectations about future developments in certain 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 likely to cause a subsequent macroeconomic recession.

Gelain, Lansing and Mendicino (2013) suggest that large swings in house prices and household debt – as observed in many industrialised countries over the last decade – can arise if agents do not fulfil the assumption of rational expectations. The incorporation of simple moving-average forecast rules for a

subset of agents (adaptive expectations) into a standard model of housing, such as the one developed by Iacoviello (2005), is found to significantly magnify the volatility and persistence of house prices, household debt and real economic activity. This form of expectations is consistent with the observation that market forecasts of future house prices tend to overpredict subsequent actual house prices when those prices are falling.

Some different conclusions on the role of housing markets in propagating aggregate shocks are obtained for the Czech Republic in Brůha and Tonner (forthcoming). Incorporating a housing market à la Iacoviello and Neri (2010) in Česká národní banka's forecasting model (a dynamic stochastic general equilibrium model for a small open economy (see Andrlé et al. 2009)), the authors find that the feedback between the housing market and the macroeconomy is weak. As a consequence, the amplification effects are very mild. The likely reasons are that the monetary policy rule in the Czech Republic does not explicitly contain house prices and the wealth effects stemming from home ownership are not significant.

Fiscal and financial instability affect each other and may provide further sources of amplification in the transmission of shocks to the real economy. Pierrard, Rouabah and Tabarraei (2013) examine the spillovers between sovereigns and banks in a dynamic general equilibrium model with a heterogeneous banking system, financial frictions in the banking sector and a financial accelerator mechanism à la Bernanke, Gertler and Gilchrist (1999).¹³ Financial frictions arise owing to the monopolistic position of deposit banks and the binding capital adequacy requirements for wholesale banks. Sovereign default risk affects financial intermediaries through two channels: capital losses and asset eligibility rules in capital requirements. First, through risk-weighted assets, bank losses impair the banks' capital position, increase interest rates on loans and bonds, and reduce those assets. Second, some of the banks' assets may cease to be eligible in the financial regulator's risk-weighted asset framework, in which case banks have to deleverage even more. Thus, the effect of capital adequacy is to amplify the impact of shocks on banks' balance sheets.

International spillover effects arise in the transmission of shocks, when economies are financially integrated. Dedola, Karadi and Lombardo (2013) develop a two-country-version of the model by Gertler and Karadi (2011), where the key financial friction is a moral hazard problem between banks and entrepreneurs that constitutes a constraint on banks' funding abilities. With perfect financial integration in the markets for banks' assets and liabilities, their balance sheet constraints are highly correlated across countries, giving rise to a high degree of financial and macroeconomic interdependence.

For small open economies, the exposure of domestic residents to foreign currency loans is a possible source of financial imbalances. Brzoza-Brzezina, Kolasa and Markarski (2013) build a two-country DSGE model that consists of a core and a peripheral country. Households have access to loans denominated in either domestic or foreign currency and are subject to a collateral constraint. One main finding is that the presence of foreign currency loans affects the transmission of shocks to the real

¹³ Some related empirical research on sovereign contagion was also conducted under a special initiative as part of WS3 (see Section 4.3).

economy and limits the effectiveness of monetary policy as a stabilising policy tool. Welfare analysis suggests that loans should predominantly be denominated in domestic currency.

2.2.2 Empirical research

The wide scope for interdependence between the included variables makes VAR analysis a flexible tool for capturing feedback effects (also between financial and real variables) and a variety of transmission channels. It is not possible to directly test theoretical hypotheses, but the ordering of the variables considered and potentially other identifying restrictions make certain theoretical hypotheses more plausible than others. In Hartmann et al. (2012), 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 (where banks impaired by financial instability lend less) and credit demand effects (where firms and households invest and consume less owing to the heightened uncertainty or capital losses caused by financial instability, leading them to borrow less), without, however, disentangling their relative importance. A key result of this analysis is that a sizeable increase in widespread financial instability in relatively tranquil regimes has only a very limited effect on growth. In contrast, when parameters and variances have switched to an extreme regime of systemic fragility, the impulse response function of a CISS shock shows a large and protracted economic downturn in the euro area. This large increase in the financial-real linkage is driven, in particular, by the change in the model parameters – i.e. a deep structural change in the economy. Moreover, counterfactual exercises suggest that loan growth plays a material role in the transmission of systemic financial instability to the real economy.

In Abildgren (2010), the aggregate write-down ratio is ordered last and the effects that a shock to that ratio have on aggregate credit and GDP are likely to capture a bank lending channel. The results suggest that sizeable bank write-downs have a statistically significant and persistently negative effect 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” leads to 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 seen in growth in Hungary as of early 2009, although at the same time unidentified shocks increased in importance.

Fornari and Stracca (2012) find that their financial shock (as defined in Section 2.1.2) has a significant influence on output, investment and the price level. These results are not driven by periods of credit boom

and bust, including the 2007-09 financial crisis. Variance decomposition analysis suggests that at a horizon of 24 quarters the financial shock explains 18% of CPI variability, 13% of GDP and investment variability and 23% of variability in credit to the private sector. Therefore, the financial shock plays a significant role in explaining business cycle fluctuations. Surprisingly, the propagation of financial shocks is found not to depend on the financial and economic features of specific countries.

Similarly, Konečný and Babecká Kucharčuková (forthcoming) report positive feedback between the real and financial sectors. The authors estimate a standard monetary policy model for the Czech Republic using a Bayesian threshold VAR with the credit spread as a threshold variable. Methodologically, they extend the single-equation Bayesian threshold model used by Chen and Lee (1995) to devise a multi-equation setting with block restrictions to account for external factors in a small open economy. The model also includes aggregate credit and non-performing loans (NPLs). They find that a positive shock to aggregate credit and a negative shock to NPLs increase industrial production, illustrating the pro-cyclical effects of financial variables.

Survey and expectation data may provide a useful tool for detecting financial imbalances in the housing market. Drawing on Leduc and Sill (2013) and Barsky and Sims (2012), Lambertini, Mendicino and Punzi (2013) incorporate these data in a VAR model that also includes standard macroeconomic variables. However, by contrast with previous papers, they also include housing market variables. The survey and expectations variables are found to be good predictors of house price developments and housing booms. Moreover, shocks to forward-looking survey variables which capture expectations of rising house prices account for a sizeable percentage of variation in economic activity.

The semi-structural factor analysis in Alessi (2011) identifies the transmission of three financial shocks, one to real equity price growth, one to house price growth, and one to credit growth. Negative shocks to real equity and house prices lead to pronounced and lasting responses in real GDP growth. Growth reverts to pre-shock levels only after five and two years respectively. In both cases, the response by inflation is negative, but in general small and insignificant. The response by output to a decline in credit growth is more short-lived in this model, dying out after about one year. Not surprisingly, M3 growth decreases on impact, by around the same amount as credit growth. Long-term and short-term nominal interest rates also decrease on impact, by 25 basis points, while the response by inflation is again small.

Moving away from VAR and factor analyses, Beck, Jakubik and Piloju (2013) 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 (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 (particularly in countries where the stock market is large) and exchange rates. 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 to economic activity.

Neagu and Mihai (2013) develop a liquidity tool to highlight the transmission channels from a capital outflow shock to the banking and real sectors. For example, the breadth of the liquidity shocks considered (across banking and real sectors) and the incorporation of features that are particularly relevant for emerging markets distinguish this from previous literature on liquidity stress testing frameworks, such as Van den End (2012) or Schmieder et al. (2012). 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 banking sector's capacity to withstand sudden stops in capital flows and gauging the consequences of 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 that the sudden stop has on credit supply, and (iv) evaluating a number of policy options.

Hałaj (2013) presents an approach accounting for real-financial feedback in stress testing exercises. The approach features an optimising model for banks' asset portfolios à la Markowitz (1952), so that adverse macro-financial shocks lead to an endogenous balance sheet adjustment. More precisely, banks aim for a portfolio composition that maximises risk-adjusted returns while taking into account regulatory capital and liquidity constraints. This is distinct from "rule of thumb" bank asset adjustments – as seen in Alessandri et al. (2009), for example. The micro-founded perspective also allows consideration of potential trade-offs between bank capitalisation/soundness and banks' propensity to extend credit to the economy.

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 with a weak bank were more likely to default during the crisis of 2008-09 than firms with a similar balance sheet structure but a relationship with 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 that 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 major banking crises. This might reflect government intervention and a tendency to migrate away from credit granted by commercial banks towards credit granted by mortgage banks in

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 restrictions on credit supply.

Neagu, Costeiu, and Tarța (2014) investigate whether banks' lending decisions amplify negative feedback from the corporate sector, leading to increased vulnerabilities in the financial system. The model is tested for the Romanian case, using micro data. The findings highlight the fact that, before the crisis, companies with access to bank loans were able to deliver higher levels of performance (value added growth rates, return on equity, etc.) than firms constrained in their access to loans. On the other hand, firms for which the application for lending was accepted were found to entail higher levels of risk than the rejected firms. This supplements the literature on firms' access to finance (for example, Beck et al. 2006), adding a stability angle, and supports the idea that the economy could benefit from creditors pursuing a longer-term approach in their lending decisions.

The effect of foreign currency loans on the performance of the corporate sector is evaluated in Endrész, Gyöngyösi and Harasztosi (2012). Using a novel dataset on Hungarian non-financial firms, the authors identify firms with currency mismatches and analyse their performance during the crisis. They find that firms with foreign currency loans suffered larger falls in investment and were more likely to go bankrupt. Endrész and Harasztosi (2014) extend the analysis to cover the pre-crisis period, showing that the introduction of foreign currency loans contributed to an increase in investment in Hungary, in line with other pre-crisis literature on central and eastern Europe (for example, Rancièrè, Tornell and Vamvakidis 2010, or Brown, Ongena and Yesin 2011).

2.3 The role of non-linearities

Non-linearities are a central element of financial instability – particularly 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 2014 and Bianchi and Mendoza 2010), 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 (2012a), the switch from one equilibrium to the other implies a major discontinuity in most 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 (2013) introduce non-linearities through transitions between regimes – which 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 freezes as a result.

A second non-linearity in Aoki and Nikolov (2012a) arises from occasionally binding constraints, whose emergence depends on the behaviour of asset prices. In the absence of 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.

In Dewachter and Wouters (2012), occasionally binding capital constraints for financial intermediaries – along the lines of He and Krishnamurthy (2012) – are incorporated in an otherwise standard DSGE model. Such constraints, when activated by adverse shocks that deplete the capital base of the intermediaries, disrupt the financial intermediation process and potentially lead to a crisis. In these situations, capital-constrained intermediaries experience a strong increase in the riskiness of their balance sheet position and are forced to adjust their asset and credit evaluation standards. The resulting asset price corrections and credit supply restrictions feed back to firms' and households' decisions, which in turn damage the macroeconomic environment further, increasing the probability of a vicious circle. While in He and Krishnamurthy (2012) the adverse effects that such a shock has on consumption are almost completely offset by investment, in this model, which also includes sticky prices and wages, the same shock also affects production, employment and aggregate demand. A notable implication of the non-linearity stemming from the occasionally binding constraint is that the covariance between financial variables (such as risk, volatility and asset prices) and real variables (such as investment and output) is stronger during economic downturns than during booms.

Mendicino (2012) builds on Kiyotaki and Moore (1997) to examine a non-linear model with collateral constraints. The non-linearity again arises from the presence of occasionally binding constraints. This leads to higher precautionary savings (lower leverage) as agents anticipate the costly consequences of binding credit constraints in recessions requiring asset fire sales. Nevertheless, Mendicino (2012) finds that the precautionary behaviour of borrowers does not prevent credit constraints from becoming binding in downturns. This, in turn, makes the economy's response to shocks asymmetric – i.e. negative shocks are propagated more strongly than positive ones.

Derviz (2013b) models real activity disruptions resulting from the bursting of financial bubbles, which can follow even a very small shift in economic sentiment. In particular, the model suggests a way in which a transition from classical relationship-based commercial banking (on the basis of the “know your customer” principle) to arm's length lending (which, taken to an 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 purely financial turbulence to a recession). The model captures the potential diversion of funds by financial intermediaries and shows 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 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, Hartmann et al. (2012) suggest that, in practice, such non-linear adjustments are material. The switches between two parameter regimes and three 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 as to why traditional linear macroeconomic models underestimated so dramatically the real implications of the intensification of the financial crisis in September 2008 or the sovereign debt crisis which followed in May 2010 (see, for example, the description of forecast errors in Trichet 2011). 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. (2012) is large and long-lasting under infrequent systemic financial fragility regimes and small and short-lived in tranquil times.

Moreover, Konečný and Babecká Kucharčuková (2014) assess non-linear feedback between the real and financial sectors. Similar to the aforementioned paper, the authors use a Bayesian VAR with two separate regimes, which depend on the size of credit spreads. Whereas the magnitudes of these real effects do not differ very much for credit spreads above or below the threshold in the Czech economy, suggesting only limited non-linearities in the response of the Czech real economy to financial shocks, their timing does. However, the effects of real variables on credit or NPLs are different across credit spread regimes.

The mixture VAR model employed by Guarda, Rouabah and Theal (2013), discussed in Section 2.1.2, also has non-linearities which exacerbate counterparty credit risk in stress tests, thereby contributing to more dramatic erosion of bank capital under stressed scenarios in the model.

Using a Bayesian VAR, Franta et al. (2014) find that modelling non-linearities is very important for accurate forecasts. More specifically, the results demonstrate that ignoring the zero lower bound generates the least accurate forecasts for the Czech economy and that various approaches to tackling the lower bound improve forecasts.

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, and 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, this describes the observation that leverage (broadly the ratio of debt to equity) shows large fluctuations over time and is a major determinant of asset prices and therefore amplifies fluctuations in credit and economic activity (through the use of assets as collateral and related risk management techniques, such as risk-sensitive margin requirements). 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) have 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 in Rannenberg (2012) combines the 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 like 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 benefits 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, expected banking sector deleveraging increases today's external finance premium.

Both monetary tightening and an adverse productivity shock trigger banking sector deleveraging. The response of the external finance premium, and thus output and investment, to both monetary tightening and an adverse productivity shock is amplified relative 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, 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 a 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.

Boissay (2011) also 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 an equilibrium in tranquil times, characterised by excessive liquidity in the interbank market and high leverage, to a crisis equilibrium, characterised by the drying up of liquidity and substantial deleveraging. In a later paper – Boissay, Collard and Smets (2013) – 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.

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 seen, for example, in Alvarez and Jermann (2000). When a borrower's reputation for repayment is valuable, leverage is high and down payment requirements for 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.

Growth in leverage during the boom phase and a sharp contraction in the bust phase is also modelled in Aoki and Nikolov (2011). In this model, the expansion of leverage 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 reduce investment and employment as a result. The results 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. Extending this framework, Aoki and Nikolov (2013) explore the importance of non-bank financing sources and shadow banking in stimulating banks' risk taking. They argue that the presence of shadow banking allows banks to expand hidden leverage and credit supply, depressing lending spreads. As a result, banks increase their holdings of risky bubble assets, which leads to more pronounced deleveraging in the event of a bust.

Meeks, Nelson and Alessandri (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.¹⁴ 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 of 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 available collateral forces economy-wide deleveraging. The authors suggest that this mechanism can generate substantial volatility in the real economy, in line with recent experiences. Gertler and Kiyotaki (2010) derive similar excess leverage and amplification of aggregate fluctuations from an imperfectly functioning interbank market in a DSGE model, but when they introduce a distinction between a regulated commercial bank branch and an unregulated investment bank branch, the consequences are immaterial because they assume unified ownership, so leverage is determined by a single joint financing constraint.

Bhattacharya et al. (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

¹⁴ The paper by Goodhart, Kashyap, Tsomocos and Vardoulakis (2012), discussed in section 2.6 on policy analyses, includes a representation of shadow banking in a general equilibrium model with default.

and in taking on more risk by endogenously higher credit spreads, which creditors charge in anticipation of higher default rates. 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. Thus, the model generates the volatility paradox (or paradox of financial instability) discussed in Borio and Drehmann (2009), Fostel and Geanakoplos (2012) and Brunnermeier and Sannikov (2014), which suggests that risk builds up during periods of tranquility and that volatility spikes follow – rather than precede – the realisation of adverse shocks. The model suggests that limits on the leverage ratio are not sufficient 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 pro-cyclicality in risk taking, given that risk weights are calculated on the basis of expected losses and are influenced by optimistic expectations. On the contrary, a requirement concerning relative volumes of riskier and safer assets in portfolios can reduce financial instability and improve welfare. This regulatory policy is close to the proposal made by Geanakoplos (2009), who suggests higher margin/haircut requirements on bank-generated asset holdings during good times.

Dufrénot et al. (2012) attempt to empirically test the prediction by leverage cycle theories that real economic activity should depend not only on realised shocks, but also on past optimising behaviour and risk taking by financial institutions. As a proxy for real economic activity, and in line with the results of Lown and Morgan (2006), they use the net tightening of credit standards 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, as developed by Filardo (1994), and construct a leading indicator based on the leverage of broker-dealers and commercial banks in the United States (which may also be useful for WS2). This leading indicator closely follows Adrian and Shin (2010), who show that broker-dealers are more aggressive than commercial banks in adjusting their leverage according to prevailing risk conditions. The indicator is found to carry significant information on the evolution of credit conditions. Moreover, credit standards' response to changes in the leading indicator differs across regimes. When credit standards are relatively relaxed, 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 short-term US government debt) and the spread between the yields of Moody's BAA and AAA-rated corporate bonds, and it finds that these measures cannot act as leading indicators for credit conditions in the way that leverage cycle theories would predict. These conclusions are in line with Borio and Drehmann (2009), Borio and Lowe (2002), Demirgüç-Kunt and Detragiache (2005) and work by MaRs in the context of WS2 (see Chapter 3 of this report), who say that credit and asset prices which deviate from long-term trends are the best early warning indicators of banking distress, albeit Dufrénot et al. (2012) focus on the unregulated financial sector, rather than the economy as a whole.

Lambertini, Mendicino and Punzi (2013) provide 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 that credit standards and financial regulation have on house price dynamics in the standard macroeconomic frameworks used for policy analysis.

Nuño and Thomas (2013) develop a DSGE framework in which financial intermediaries are subject to endogenous leverage constraints. Banks involve a moral hazard problem due to limited liability along the lines of the static model employed by Adrian and Shin (2011), which is different from the moral hazard in the DSGE model used by Gertler and Karadi (2011), where bankers can divert the funds entrusted to them by depositors. Higher uncertainty regarding asset returns, coupled with limited liability, makes it more attractive for banks to engage in inefficiently risky lending practices. In order to prevent them from doing so, institutional investors impose tighter constraints on banks' leverage. For given net worth, this deleveraging forces banks to reduce the size of their balance sheets, leading to a decline in funding for firms. This leads to a fall in capital investment by firms and a decline in aggregate output. The consequence is a positive co-movement between leverage, assets and GDP.

Other MaRs researchers have focused on empirical analysis of leverage during the business and credit cycles and the interaction with other macro-policies, primarily monetary policy. Maddaloni and Peydró (2012) focus on how leverage cycles can be affected by monetary policy conditions. Contributing to the very active recent literature on how monetary policy influences credit supply (e.g. Jiménez et al. 2012), they suggest 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' 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.

Mésonnier 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 reduces 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 evidence that

shocks to bank leverage affect the real economy. Based on these observations, a switch to tighter capital regulations should preferably be gradual and operate through accumulated earnings in order to minimise the short-run negative consequences for the economy.

2.5 Causes and features of the recent financial crisis

This section focuses on papers specifically devoted to explaining causes and describing features of the recent financial crisis. It is not intended to provide a complete history of the 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 either 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 also that these shocks do not play a dominant role in explaining the 2008 recession or have long-lasting effects on the economy.

By contrast, Abildgren (2010), using long data series (1948-2010) for the Danish economy, finds evidence that an exogenous shock to the banking sector's write-down ratio has a significant and long-lasting negative impact on real GDP. This shock might be interpreted as a sudden reassessment of the credit quality of banks' loan portfolios or as an increase in the banking sector's risk aversion. Extending literature on the costs of financial crises (see, for example, Hoggarth, Reis and Saporta 2002), Abildgren et al. (2011) find that the recent financial boom-bust cycle in Denmark led to a net output loss of over 2% of GDP.¹⁵ In other words, the credit cycle in Denmark was associated with a lower average level of output than a hypothetical situation in which no financial shocks occurred.

Guarda and Jeanfils (2012) argue, in the context of their enhanced VAR with financial variables, that the collapse in asset prices since 2007 is an important cause of the recession in the euro area. Hartmann et al. (2012) find important regime changes that fundamentally changed the behaviour of the euro area economy at key points during the crisis.

Another important issue is the question of which factors contributed to the build-up of widespread financial imbalances in the run-up to the financial crisis. Bonfim and Kim (2013) consider the role of collective liquidity risk taking strategies – as described theoretically, for example, by Ratnovski (2009) – among European and North American banks between 2002 and 2009. Building on Leary and Roberts' (2014) multivariate estimation of peer effects and considering five different indicators capturing various aspects of liquidity risk, they find that funding liquidity risk taking by banks – as measured by the ratio of loans to customer deposits – spilled over, in particular, to funding liquidity risk taking by other banks. In

¹⁵ 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.

addition, such peer effects are also quite robust for a proxy of the Berger-Bouwman (2009) measure of banks' liquidity creation and the ratio of liquid assets to the sum of customer deposits and short-term funding (which could be interpreted as a proxy for the Basel liquidity coverage ratio). Maddaloni and Peydró (2012) present evidence that the long period of low interest rates led to an increase in risk taking by banks, thereby contributing to the crisis.

As described in Section 2.1.1, 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 (2013) stress the causal relationship between financial imbalances and the fragility of the wholesale financial market. It is shown that the financial system is fragile 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: (i) the development of a highly leveraged market-based banking sector preceding the crisis, in which broker-dealers assumed greater importance in the supply of credit to the real economy; (ii) external imbalances characterised by a large and persistent current account deficit in the United States and large surpluses in Asian emerging market economies;¹⁶ (iii) 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 (iv) the materialisation of the crisis in the form of a sudden and wide-ranging freezing of liquidity in key financial markets, abrupt deleveraging in the market-based banking sector, and declines in international trade, productivity and aggregate output.

Aoki and Nikolov (2012a) directly model the effect that an asset bubble collapsing has 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 – a key factor in their model – that made it the trigger for the global financial crisis. This is in contrast to the collapse of the dot-com bubble, which had little effect on the real economy because those assets were mainly held by ordinary unleveraged investors. The authors argue – through the lens of their theory – that two factors may have contributed to the build-up of banks' exposure to the housing bubble of 2003-07: (i) implicit government guarantees encouraged banks to hold risky assets; and (ii) growing financial sector competition reduced banks' profits from traditional activities and led to increased risk taking. Both factors contributed to the housing boom and the severity of the subsequent banking crisis and recession.

Angelopoulou, Balfoussia and Gibson (2012) construct traditional financial conditions indices (FCIs) for the euro area and selected individual countries on the basis of a wide range of price, quantity and survey data. Although FCIs were originally designed for monetary policy purposes, they can also be used to tell the story 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

¹⁶ The pre-crisis capital flows from emerging market economies to industrial countries took the reverse direction compared to the capital flows preceding the emerging market crises of the 1980s and 1990s. The mechanism that can explain this feature was laid out in sub-section 2.1.1.

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. By the end of 2011, however, financial conditions still remained tighter than they had been before the failure of Lehman Brothers. Subsequent updating to mid-2013 suggests improving conditions in the euro area as a whole. Heterogeneity remains, however, with Germany, Ireland and Portugal largely recovering and standing at more normal levels. Greece and, to a greater extent, Spain, while showing improvement, still had relatively tight conditions in mid-2013.

2.6 Identification of macro-prudential policies, monetary policy issues and the interaction between the two

2.6.1 Identification and assessment of macro-prudential regulatory policies

Substantial efforts have been devoted in policy circles to clarifying the list of macro-prudential regulatory policy instruments, including in the context of reports by the Committee on the Global Financial System,¹⁷ the International Monetary Fund¹⁸ and the European Systemic Risk Board (ESRB).¹⁹ Research carried out in MaRs has increasingly focused on analysing such regulatory instruments, albeit a narrower set. The most comprehensive analysis is provided by Goodhart et al. (2012a), who build on the theoretical framework for general equilibrium models with default that was introduced in 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 is itself innovative, as it introduces a shadow banking system which allows for the analysis of regulatory arbitrage. The model also features 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.

The main results are as follows. First, all of the regulatory instruments apart from liquidity requirements result in a reduction in mortgage availability, which reduces the welfare of more prosperous households. Liquidity requirements are very different from other regulations, as they tend to increase poorer households' access to credit, thereby increasing their welfare. Second, dynamic provisioning, like liquidity requirements, can effectively lean against the wind. However, liquidity requirements may be

¹⁷ See, for instance, Committee on the Global Financial System (2010).

¹⁸ See, for instance, IMF (2013).

¹⁹ See ESRB (2014a and b).

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 investigated further in a companion paper (Goodhart et al. 2012b), in which the authors focus on combining regulatory instruments to study their joint effects when they are deployed simultaneously. 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 (time-invariant) minimum capital requirements, together with larger counter-cyclical 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 reduce welfare. Further research is therefore needed to better understand the complex channels through which regulatory instruments interact.

A series of MaRs papers have looked at one single macro-prudential instrument: the loan-to-value (LTV) ratio. This choice stems mainly 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 for dampening 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 mean that output is more sensitive to changes in aggregate productivity, but shocks originating in the credit market have less effect. The result 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. Instead, it is the implementation of time-varying LTV ratios, set up in a counter-cyclical manner, which leads to welfare improvements.

People often discuss whether LTVs or debt-to-income limits (DTIs) are better macro-prudential policy instruments, or whether they need to be combined. Gelain, Lansing and Mendicino (2013) discuss this in the context of their DSGE model with housing and backward-looking expectations, which was summarised in Section 2.2.1. They find that if policy imposes a collateral constraint on borrowing households that includes both a term for the housing value and a term for wage income, this generalised constraint acts like a time-varying counter-cyclical LTV, because unlike the value of housing, wage income does not go up with property bubbles. In line with Mendicino (2012), this makes the generalised debt limit more effective in dampening excessive macroeconomic volatility than a static LTV. Moreover, it is also more effective at smoothing general macroeconomic volatility than an interest rate rule enhanced by house price or credit growth, because such a monetary policy would have the unintended side effect of increasing inflation volatility. So, the paper can be interpreted as providing further arguments in favour of considering LTV and DTI-type regulations together, rather than in isolation.

Recent research efforts have also been devoted to the study of counter-cyclical capital buffers (see, for instance, Repullo and Suarez 2013 for a comprehensive literature review). Jokivuolle, Kiema and Vesala (forthcoming) provide a new rationale for them, which is based on De Meza and Webb's (1987) over-investment theory when there is asymmetric information between entrepreneurs and banks. They suggest that risk-sensitive capital requirements that are based on the observable risk properties of investment projects (like those in the internal ratings-based approach in Basel II and III) can be used to reduce adverse selection and implement the optimal allocation. This is possible because risk-sensitive capital requirements, unlike risk-insensitive requirements, provide a sufficient number of instruments to influence the relative prices of high-risk and low-risk loans and hence their allocation. In good times, when the probability of investment projects succeeding is relatively high, but also a relatively large percentage of high-risk projects tend to be financed because banks cannot distinguish well between good and bad entrepreneurs, capital should be high to counter the relatively large effect of market failure from asymmetric information. In bad times, when the probability of success is low – which is typical for recessions – the optimal risk-sensitive capital requirements should be lower than in good times, because fewer high-risk projects are financed, so the effect of market failure from asymmetric information is smaller.

Academic researchers have pointed out that macro-prudential regulations should also work against the externalities that the instability of individual large and complex financial institutions can exert on the financial system. Brunnermeier et al. (2009), for example, proposed that additional capital requirements should discourage banks from assuming such systemic positions. Shin (2010) and Perotti and Suarez (2011) suggest imposing taxes or levies on banks' non-core liabilities or short-term funding respectively. In fact, the Basel III framework now includes a capital surcharge for systemic financial institutions, although this is justified less ambitiously as an additional capital buffer, rather than as a means of directly reducing sources of systemic risk. Skořepa and Seidler (forthcoming) provide a critical assessment of the Basel approach from the perspective of domestic systemic financial institutions in the Czech Republic. The authors suggest, for example, that some indicators of systemic importance could differ from those applied to global systemic institutions, that the relative importance of the banking sector in the wider economy should be better taken into account, and that the usefulness of calculating indicators at the sub-consolidated level is not clear when domestic banks control large non-financial undertakings.

Although not all of them have focused fully on policy analysis, a couple of MaRs papers offer 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 2012) 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. Jokivuolle and Kiema (2014) incorporate a leverage ratio in the model devised by Repullo and Suarez (2004) in order to discuss the overall risk effects of one of the motivations for the Basel Committee to introduce such a ratio, namely putting a floor on potential mistakes in the risk assessments used to determine internal ratings-based capital requirements. Increasing a leverage ratio has, in principle, two effects: (i) increasing the safety of banks for which it is binding, and

(ii) reallocating loans from banks for which it is binding to those ones where it is not, up to the point where the ratings-based requirements start to become binding, thereby increasing the latter banks' credit risk. The authors argue that the stabilising effect is likely to dominate if the ratio is increased from a relatively low level. Moreover, they present a calibration of the model in which the leverage ratio requirement can be increased above the level decided by the Basel Committee without increasing the banks' average capital costs. Colliard (forthcoming) presents a theoretical model in which, inter alia, banks can strategically decide whether to misreport internal ratings-based risk assessments or not, rather than assuming random mistakes in risk assessments. He argues that a leverage ratio may not be the optimal regulatory solution to such a moral hazard problem in risk model selection. In his model, a mechanism penalising banks that report overly high losses ex post relative to their ex ante risk assessments may be preferable.

Horváth, Seidler and Weill (2014) 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 two-sided Granger causality between bank capital and bank liquidity creation. In line with Farhi and Tirole (2012b), Bonfim and Kim (2013) argue that their evidence on peer effects in liquidity risk management suggests that liquidity regulation should adopt more of a macro-prudential perspective. 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 hinder entrepreneurs' investments. Overall, the model suggests that there is an interval for the LCR above which financial crises are ruled out, while market efficiency is preserved.

The papers discussed above 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 to the instruments that are 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 decline in individual risks or vice versa (e.g. Crockett 2000, or Morris and Shin 2008). This issue, often called the "fallacy of composition", is crucial for the practical implementation of macro-prudential policies, but has not been specifically addressed in any of the MaRs papers.

MaRs papers 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 Section 2.2.2, Beck, Jakubik and PiloIU (2013) suggest that limiting foreign currency borrowing may be important and policies discouraging currency mismatches (for example, via different reserve requirements for foreign currency-denominated loans) could help to insulate bank asset quality from exchange rate depreciations.

Finally, some researchers have started to analyse macro-prudential policies in a cross-country context. Under the extremely high level of financial integration assumed in the two-country model used by Dedola, Karadi and Lombardo (2013), domestic regulatory policies would cause very large cross-border spillovers. For example, increases in regulatory capital would limit credit supply both at home and

abroad, and the emerging free-rider problem could create a case for international coordination. Żochowski (2014) develops a simplified two-country version of Goodhart et al.'s (2013) general equilibrium model with default in order to study the cross-border implications of changes in LTV ratios affecting credit demand where (i) mortgage and capital markets are fragmented, (ii) securitisation markets are present and (iii) the banks in the two countries have different attitudes towards risk. A key point is that, despite the limited financial integration, the possibility of buying foreign mortgage-backed securities (MBSs) may give rise to sizeable international “leakages” of unilateral LTV policies. More precisely, if a domestic regulatory authority responds to domestic mortgage credit growth with a lower LTV, domestic banks have an incentive to take on more credit risk by buying foreign MBSs, where credit demand is not constrained, thereby stimulating securitisation activities in foreign banks and potentially creating a distorted allocation of risk. For example, in Europe such arguments could lead to calls for the coordination of macro-prudential policy instruments that, under the present regulatory framework, lie exclusively in the hands of national authorities (such as LTVs or DTIs). MaRs research also provides empirical evidence of the presence of cross-border regulatory spillovers. Ongena, Popov and Udell (2013) present the first empirical evidence that restrictive but inefficient regulations at home lead multinational banks to lower lending standards in foreign markets. In fact, such cross-country effects may not simply lead to calls for coordination; they could even prepare the ground for federal regulatory and supervisory authorities, such as the Single Supervisory Mechanism (SSM) or the ESRB in Europe. Beirne and Friedrich (2014) adopt a global multilateral perspective, studying macro-prudential policies in 139 countries between 1999 and 2009 to identify their effects on national and international capital flows. In particular, there is evidence that a macro-prudential policy affecting a particular asset class within an individual country leads, *inter alia*, to cross-border bank flows out of the country. This effect is more pronounced the lower the domestic asset's return and the higher the level of economic integration with the recipient country. Capital-based policies tend to lead to greater international spillovers for countries with a large percentage of foreign currency loans. Accordingly, macro-prudential policies tend to be more effective in constraining domestic credit or maturity imbalances in economies with limited foreign currency lending or high returns on assets. The authors add, however, that cross-border spillovers tend only to be economically significant for a limited number of countries. Nevertheless, the implications of these results for the international coordination of macro-prudential policies are in line with the conclusions of the International Monetary Fund (see, for example, IMF 2011).

However, not all papers written within the network call for the coordination of policies or the establishment of supranational supervisory bodies. For example, Derviz and Seidler (2012) analyse incentives for fair cooperation in relation to the delegation of macro-prudential policies to a supranational body. This analysis is carried out in the context of a signalling game between the national and the supranational supervisors involving imperfect information. (In contrast to the theory of incentive-compatible mechanisms of inter-governmental cooperation (Dasgupta, Hammond and Maskin 1979) seen in other areas (e.g. taxes and environmental protection), the only preference misalignment is a derivative of disparate information sets.) The paper suggests that, even in the absence of clearly conflicting goals, the non-transferable nature of some regulatory information creates incentives to

misreport. Drawing on work by Quint and Rabanal (2013), Brzoza-Brzezina, Kolasa and Markarski (2013) develop a two-country core-periphery DSGE model with housing and a banking sector to study the effects of national and area-wide regulatory policies on output stabilisation in a currency union experiencing asymmetric shocks. Since the area-wide policy instrument is assumed to react to the average output of the two countries, it is relatively ineffective in stabilising the asymmetrically shocked output in both countries relative to national policy instruments focusing on national output stabilisation. Moreover, the authors argue that, in their model, a counter-cyclical LTV ratio is more effective in stabilising output than a counter-cyclical capital adequacy ratio for banks.

Box 1: A MACROECONOMIC MODEL FOR ASSESSING MACRO-PRUDENTIAL REGULATORY POLICIES

A central element of work stream 1 was a joint cross-country project developing a reference model for assessing macro-prudential policies. The team doing this work ultimately spanned four NCBs, the ECB and a MaRs consultant.²⁰ The aim of this project was to develop an analytical framework for the positive and normative analysis of macro-prudential regulation. To do this, the team integrated a number of important channels of financial instability (most importantly, explicit treatment of the default of heterogeneous banks) into an otherwise standard macroeconomic model. It is described as a “3D model” – on account of the unique fact that all three sectors considered (banks, households and firms) exhibit positive equilibrium default rates – and is shared across the European System of Central Banks.

The model itself is centred around financial intermediation based on banks. The latter receive equity capital from bank equity holders, take savings in the form of deposits and provide mortgage loans to households and corporate loans to firms. Excessive bank risk taking arises in the model as an unintended side effect of public safety nets. While these may be needed for consumer protection and safeguards against runs on short-term liabilities, they also remove the incentives that demandable debt imposes on bank managers. This leads to a build-up of credit imbalances (in the form of excessive credit) and elevated rates of borrower and bank defaults, especially following large negative shocks.

The core model focuses on various forms of capital requirement. Being calibrated to the euro area, it provides insight about the role of capital requirements, the trade-offs involved in determining their optimal level and the effectiveness of countercyclical adjustments. Specifically, it allows a comprehensive analysis of the benefits and costs and long and short-term effects of macro-prudential policies regarding the level of capital requirements and their potential adjustments both in the time dimension (counter-cyclical buffers or counter-cyclical adjustments) and in the cross-sectional dimension (sectoral capital buffers or sectoral risk weights).²¹

- The long-term impact of higher capital ratios

²⁰ The main findings are presented in the paper by Laurent Clerc (Banque de France), Alexis Derviz (Česká národní banka), Caterina Mendicino (Banco de Portugal), Stéphane Moyen (Deutsche Bundesbank), Kalin Nikolov (ECB), Livio Stracca (ECB), Javier Suarez (MaRs consultant, CEMFI) and Alexandros Vardoulakis (Banque de France and ECB, 2013).

Capital regulation can be used as a welfare improving response to excessive risk taking by banks and the economic fragility that this creates. When capital ratios are low, increasing them helps to correct banks' tendency to take on too much risk. This reduces bank and borrower defaults, which is beneficial since defaults are assumed to carry real resource costs in the 3D framework. Banks' equity funding in the model is limited by the wealth endogenously accumulated by the bankers who own and manage the banks. So, capital requirements force banks to make greater use of bankers' limited wealth, which may have a contractionary impact on credit provision and economic activity. In fact, once bank defaults are at a low level, further tightening of capital ratios only reduces credit supply, without doing much to diminish the (already low) degree of financial fragility. There is therefore an optimal level of capital requirements, which reflects a trade-off between the benefits and costs of regulation.

- The impact of higher capital ratios on shock amplification

The 3D model places banks' net worth and funding costs at the heart of the mechanism which amplifies the impact that exogenous shocks have on real economic activity. The amplification mechanism relies on the dynamics of three interconnected net worth channels (involving the wealth of households, entrepreneurs and bankers, which plays an important role in their borrowing decisions) and a risk premium that makes the cost of banks' deposit funding increase with the perceived risk of bank failure (capturing the existence of short-term bank liabilities that are not fully covered by the existence of the safety net). Large aggregate shocks cause some household and business borrowers to fail, and this depletes bank capital. Since the availability of bank capital is an important determinant of credit supply, this leads to a reduction in the availability of loans, bringing about further weakness in economic activity and a further rise in loan delinquencies. This is the bank loss amplification channel for financial instability.

If bank losses are significant and begin to cause bank failures, this reduces credit supply both directly and via its impact on banks' funding costs. When the banking system is fragile and bank defaults are running at high levels, investors require a higher risk premium in order to hold banks' (unprotected) short-term liabilities. Banks pass on the increased costs to their borrowers, exerting a contractionary effect on lending and economic activity.

The bank loss and bank funding amplification channels interact strongly. Lower bank net worth pushes up default rates and increases banks' funding costs. This interaction strongly amplifies the decline in credit supply following large negative shocks.

Capital requirements are beneficial by reducing the vulnerability of the financial system to large exogenous shocks. When banks are strongly capitalised, they barely contribute to the amplification of the aggregate shocks suffered by the economy. When they are weakly capitalised, they amplify shocks via the bank loss and bank funding channels described above.

- The impact of counter-cyclical capital ratio adjustments

The model can also be used to assess whether adjusting capital requirements in response to shocks contains amplification mechanisms and thereby improves welfare. The case of an adverse shock and the release of a capital buffer is examined. It turns out that lowering capital in such circumstances improves

²¹ Work has also started to extend the core model to include additional key features and policy instruments, such as liquidity risk and regulation, securitisation and nominal frictions, in order to examine the interaction between macro-prudential and monetary policy (see also Section 2.6.2).

welfare, if the *average* capital ratio is relatively high to begin with. This is because releasing the buffer helps to contain the decline in lending owing to the adverse shock.

If, however, average capital requirements are *ex ante* relatively low, their further relaxation in response to a negative shock can be harmful. At first sight, a counter-cyclical reduction in the requirements should allow banks to expand credit. But if the fragility of now under-capitalised banks deteriorates severely enough, an increase in banks' funding costs may offset the intended expansion of credit, having a detrimental net impact on GDP.

- The 3D model as a potential tool supporting macro-prudential policy

The preceding analysis has usefully been conducted with a rigorous micro-founded structural model capturing the benefits and costs of financial regulation in terms of lower costs of financial instability versus some foregone financing. This is a key feature of the 3D model approach that allows an explicit welfare analysis of capital (and potentially broader classes of macro-prudential) regulations. Previous studies, such as BIS (2010) and Miles et al. (2013), also attempted to assess benefits and costs of regulation, but not within a consistent, micro-founded modelling framework.

2.6.2 Interaction 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, given the nature of the instruments at their disposal, macro-prudential policies are likely to interact with micro-prudential policies.²² 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 policy-makers 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 quantity of academic and policy literature on the optimal number of policy instruments and their relationships (e.g. Poole 1970, Woodford 2003, and Benigno and Woodford 2012). But this pre-crisis analysis did not include financial instability, let alone macro-prudential policy.

WS1 has produced several papers addressing the first kind of interaction, focusing on the interaction between 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. However, in one paper (Agur and Demertzis 2011), the macro-prudential 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 instead focus on price stability in the strict sense, leaving the objective of dampening 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 (see, for example, Bernanke and

²² Macro-prudential policies are also likely to interact with other policies, including social policies supporting home ownership.

Gertler 2001). 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 dissenting arguments long before the financial crisis, arguing, for example, that this asymmetry would make the emergence of bubbles more likely.

One important advance made in MaRs research is to take explicit account of regulatory policy as a second option for “leaning against the wind”. Interestingly, three contributions build on the model of the housing market developed by Iacoviello and Neri (2010), which is a DSGE model incorporating heterogeneous agents and financial frictions. In addition, these three papers share similar goals, seeking to assess alternative policies in terms of their effectiveness in mitigating both boom-bust cycles and macroeconomic volatility and their impact on welfare. While both Angelini, Neri and Panetta (forthcoming) and Beau, Clerc and Mojon (2012) use an ad hoc loss function to measure the effectiveness of alternative policies, Lambertini, Mendicino and Punzi (2013) explicitly derive the welfare function and compare alternative policy rules in terms of a consumption-equivalent measure.

Angelini, Neri and Panetta (2014) study the interaction between monetary policy and a time-varying capital requirement 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). In the second, policies are implemented by two independent authorities. The central bank aims to stabilise the variance 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 to say, when the business cycle is driven mainly 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 producing excess instrument volatility. 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.

In a two-period general equilibrium model in which production is financed by a mixture of bank credit and equity, Derviz (2013b) finds that capital (defined similarly to Angelini, Neri and Panetta 2014) and monetary policies often produce very similar outcomes in terms of purely conventional macroeconomic indicators. The argument is that both affect the same fundamentals. In this setting, banks prefer capital restrictions to monetary tightening in response to credit excesses, because the former have less impact on their profits.

Beau, Clerc and Mojon (2012) go beyond 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, Neri and Panetta (2014), 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 short-term interest rates. The analysis developed in the paper delivers two important results: first, the policy regime is not relevant to the dynamics of inflation for the shocks that are typically the primary drivers of inflation; and second, following asset price or credit supply shocks, 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, but extending it to incorporate expectations-driven cycles, Lambertini, Mendicino and Punzi (2013) 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, Clerc and Mojon (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 also 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 – i.e. reduces its volatility and thereby uncertainty.

Agur and Demertzis (2012) 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 this 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 reduces excessive risk taking; on the other hand, monetary tightening not only affects banks’ optimal debt choice, leading to fewer banks taking on excessive risk, but also pushes more banks into inactivity. The paper implies three messages for policy-makers aiming to prevent excessive risk taking in the banking sector: (i) low interest rates should be used for short periods only, in order to avoid excessive risk taking; (ii) greater correlation between banks’ returns increases the impact that monetary policy has on welfare; and (iii) 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 banks' 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) comprises relatively practical research, which could be used – and, to some extent, already is being used – to strengthen the analytical toolkit for macro-prudential oversight in the EU. The following research questions are 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 has built. Some of the developments involved in answering them may provide useful input for WS1 research – for example, measures of widespread financial instability (e.g. CISS) that could be incorporated in empirical macroeconomic models. One important contribution made by WS2 research is its focus on EU-relevant data, which tends to be neglected in much of the academic literature.

There are 51 individual research papers available from this work stream. Moreover, a joint cross-country project establishing a database of financial crises in EU countries has also been completed. 27 papers have been published or accepted for publication in the ECB Working Paper Series with a “MaRs” stamp on the cover page. 18 papers have been published in academic journals or are forthcoming.

WS2 projects build on the extensive existing literature on early warning models. Key papers published prior to the 2008-09 crisis – such as Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999) – strove to develop models that could warn of currency and banking crises in emerging economies. WS2 projects, such as Alessi and Detken (forthcoming), Babecký et al. (2012) and Behn et al. (2013), as well as other papers such as Frankel and Saravelos (2010), revise early warning methodologies in order to improve their capacity to predict financial crises in developed economies. They also test whether these revised methodologies convey useful information for policy-makers who may want to act on their warnings. Several WS2 projects propose new methodologies, such as self-organising maps (Sarlin and

Peltonen 2013),²³ Bayesian model averaging (Babecký et al. 2012 and 2013),²⁴ binary decision trees and their extension in terms of the Random Forest (Alessi and Detken forthcoming, and Joy et al. forthcoming),²⁵ and the log-periodic power law (Kurz-Kim 2012a), or provide empirical results for European countries which have not previously been consistently researched (Behn et al. 2013).

Many WS2 projects aim to extend the analytical toolkit available for macro-prudential oversight beyond inspecting data and risks for specific countries or markets. Some projects try to create composite indicators (Holló et al. 2012, and Louzis and Vouldis 2012) and work more with EU-wide datasets, including the EU-wide survey of bank, sovereign debt and currency crises (Babecký et al. 2012). In the area of systemic risk measurement, WS2 research helps to estimate joint default probabilities for financial intermediaries, taking into account the non-Gaussian nature of defaults (Lucas et al. 2011). With regard to measuring imbalances, WS2 work confirms the usefulness of monitoring excessive credit developments (Alessi and Detken forthcoming, Andersen et al. 2012, and Babecký 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 based on a simple structural life-cycle model has also been proposed (Rubaszek and Serwa 2012, and Serwa 2013a).

This chapter first discusses how WS2 projects measure financial stress and systemic risk (thereby starting with Question (iv)), also with a view to the potential use of such measures for forecasting or policy simulation purposes (Section 3.1). It then goes through various components of early warning systems, such as key early warning indicators, determinants of financial imbalances (Question (iii)), fiscal aspects of early warning systems (Question (i)) and aggregation issues (Question 2). The chapter concludes with the results of a collective exercise comparing early warning models (Section 3.2.5).

3.1 Financial stress and systemic risk indicators

Besides their intrinsic usefulness in indicating the scope of systemic stress, financial stress indicators can be used for several other purposes, such as indicating the scope of financial/systemic stress, becoming a target variable in policy rules or stress test models or entering early warning models as a variable to be predicted.

Stress indicators can be classified as: (i) partial or composite; (ii) discrete (binary) or continuous; (iii) based on high or low frequency; (iv) aggregate or sector-specific; (v) country-specific or EU-wide; and

²³ A self-organising map is an artificial neural network that produces a two-dimensional representation of a high-dimensional data space. When applied to macro-prudential purposes, the Self-Organizing Financial Stability Map (SOFSM) allows the disentangling of the individual sources impacting on systemic risks. The SOFSM can be used to monitor macro-financial vulnerabilities by locating a country in the financial stability cycle: be it in the pre-crisis, crisis, post-crisis or tranquil state.

²⁴ Bayesian model averaging is a variable selection method used in model specification. It takes into account model uncertainty by going through all the combinations of models that can arise within a given set of variables.

²⁵ A decision tree, in particular a binary classification tree, is a partitioning algorithm which recursively identifies the indicators and the respective thresholds which are best able to split a sample into the relevant classes, for instance vulnerable and non-vulnerable periods. For early warning purposes, one can see whether the model predicts a future financial crisis simply by going down the classification tree according to the current values of the relevant indicators.

(vi) representing current or impact-focused indicators.²⁶ The potential strengths and weaknesses of these different variations are briefly discussed below.

By contrast with single or partial indicators, composite indicators are often assumed to be relatively robust. Having said this, the creation of a composite indicator requires judgment with regard to the selection of the weights assigned to each variable included in the indicator. For example, Altunbas et al. (2011 and 2012) work with a bank distress variable, which they define as post-crisis recourse to central bank financing. Cardarelli et al. (2009) develop a composite continuous index which consists of three components describing bank-related stress, securities-related stress and exchange rate stress.²⁷ Holló et al. (2012) develop a continuous Composite Indicator of Systemic Stress (CISS) for the euro area, which applies portfolio theory to the aggregation of individual stress indicators (covering both financial markets and intermediaries) in the composite index (see also Section 2.1.2 on WS1).²⁸ Other examples of composite indicators developed by WS2 include Angelopoulou et al. (2014), Babecký et al. (2012), Islami and Kurz-Kim (2013), Lo Duca and Peltonen (2013), Louzis and Vouldis (2012), Guarda et al. (2013), Sarlin and Peltonen (2013), and Āriņš et al. (2012). Conversely, Afonso et al. (2011a) present a partial index reflecting a particular focus on the role of ratings. Other partial and sector-specific indices include Brave and Butters (2011), and Fiori et al. (2012).

Turning to distributional properties, discrete (and particularly binary) indicators of stress are generally easier to define than continuous indicators, as periods of significant stress tend to be clearly identifiable. Moreover, this method of variable construction means that researchers do not have to select a particular variable to operationalise the degree of financial stress. Still, discrete indicators tend to be more arbitrary and, by construction, exhibit less variance than continuous indicators. Examples of a discrete approach include the discrete financial stress index for the United Kingdom developed by Andersen et al. (2012) and the EU-wide dataset developed by WS2 (and published in Babecký et al. 2012) featuring country-specific discrete

²⁶ 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 (i.e. impact-focused indicators). There are also indicators measuring current fragility in the system, which could materialise in the future as financial stress or instability, in which case the indicator is in fact a predictive measure of financial stress.

²⁷ The index is the sum of the normalised values for all the sub-components: (i) bank-related stress – beta of banking sector showing the banking sector’s perception of risk relative to other sectors in the economy, the TED spread (difference between the short-term interbank interest rate and the 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.

²⁸ Specifically, the level of stress in the financial system as a whole is computed by aggregating stress in five main segments of a financial system (listed at the start of Section 2.1.2, where the economic background to the CISS is explained in the context of its use in a macroeconomic model) – comprising a total of 15 individual market-specific stress indicators, three per segment – on the basis of a time-varying measure of the dependence between them. Thus, the CISS places 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 financial system. In addition, the weights assigned to each sub-index are calibrated in proportion to their relationship with economic activity. This captures the idea that the severity of systemic instability also needs to be gauged by its impact on growth.

indicators for banking, currency and sovereign debt crises.²⁹ Discussion of continuous indices can be found, for example, in Babecký et al. (2013), Fornari and Lemke (2010), Lo Duca and Peltonen (2013), and Guarda et al. (2013).

Indicators that are measured at higher frequencies (i.e. at least on a quarterly basis) provide more observations and thus contain more variance, but are at the same time more difficult to obtain, as many relevant variables are only available at lower frequencies. Moreover, some variables are available over a useful time span only for a limited number of countries (Afonso et al. 2011 and Cardarelli et al. 2009), complicating the construction of EU-wide indicators.³⁰

On a different note, several papers construct impact-focused indicators, because the impact of systemic events on the real economy can be measured by looking at variables such as GDP or employment. For example, the composite continuous financial stress indices developed by Louzis and Vouldis (2012) for Greece, by Āriņš et al. (2012) for Latvia and by Guarda et al. (2012) for Luxembourg might be difficult to replicate for all EU Member States owing to their country-specific data sources. However, Afonso et al. (2012) offer a high-frequency index for their event study analysis of 24 EU countries, while the continuous impact index in Babecký et al. (2013) was easy to compute for all EU Member States.

Several alternatives to financial stress indices have been put forward. Szalai (2011) works with macroeconomic risk indicators for central and eastern European countries to measure stress in the economy. Saldías (2013b) computes several distance-to-default indicators based on information from balance sheets, equity and options markets. Jokivuolle et al. (forthcoming) find that proprietary overnight loan rate data might provide useful short-term information for gauging banks' risks.

A different strand of literature is concerned with the quantification of individual financial institutions' contributions to systemic risk. It builds heavily on long-running research measuring bank contagion risks, as referred to at the start of Chapter 4 on WS3. Several more recent papers are considered to be particularly relevant for some of the work in WS2. Adrian and Brunnermeier (2011) propose the CoVaR measure of bilateral spillovers, which aims to capture the correlation between the large negative stock market returns of pairs of financial institutions.³¹ Castro and Ferrari (2014) develop tests of significance and dominance for CoVaR and find that, according to this statistical criterion, only a few financial institutions can be classified as systemically important. Acharya et al. (2010) 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.

²⁹ Although the zero-one coding is indeed easier than assessing the scope of each crisis, the subsequent study by Babecký et al. (2012) has indicated differences relative to coding done by previous academic studies. Future studies using such data should therefore be subject to robustness checks looking at whether results are sensitive to the specific coding of crises.

³⁰ Real estate prices (both residential and, in particular, commercial) are notable example of variables for which it is notoriously hard to find long time series for many EU countries which can easily be compared across countries.

³¹ A multivariate measure of negative tail dependence among larger numbers of banks applying extreme value theory to stock return data has been proposed by Hartmann, Straetmans and de Vries (2006).

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) focus more on 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. Idier et al. (2013) find that MES is correlated with standard balance sheet indicators of banks' financial soundness (like the tier-one solvency ratio), but is not better at predicting equity losses ahead of a crisis. Finally, Hautsch et al. (2011) seek to capture tail dependence between financial returns, but explicitly capture interdependence between banks using a network approach.

That last approach is applied by Betz et al. (2013), 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 (2013b) develops a method of monitoring systemic risk in the European banking system by constructing forward-looking distance-to-default series that capture interdependence and the joint risk of distress in systemically important banks. Based on a contingent claims approach, Saldías (2013a) examines how distress is transferred within and between financial and corporate sectors in the euro area. Finally, Bisias et al. (2012) present a methodological comparison of a small selection of systemic risk measures.

In conclusion, WS2 projects have developed a rich collection of measures of financial stress, all of which can help macro-prudential policy-makers to develop a comprehensive picture of potential risks emerging in the financial system. They will serve as a good basis for methodological comparisons in future research – for example, along the lines of the study by Bisias et al. (2012).

At the same time, the wide variety of approaches makes it a daunting task to derive any firm conclusions as to which indicators are the best. In the end, the “best” selection of indicators depends to a considerable extent on the aims and preferences of the policy-maker. Having said this, it is still possible to extract some common threads from the material discussed here. When it comes to achieving a broad perspective regarding the current level of financial stress, WS2 studies indicate that using continuous, composite indicators and using higher-frequency data is likely to be the most desirable approach, as these types of indicator enable policy-makers to identify potential adverse developments quickly. However, the same studies also highlight the need for further developments in terms of data collection across EU countries and over time, as several of these indicators are currently available only for a relatively small number of countries and years. For this reason, policy-makers may find it useful to supplement their monitoring with regular analysis of lower-frequency data on individual indicators that are available for more countries and longer time horizons, so as to obtain a more comprehensive picture of emerging systemic risks. Furthermore, considering binary stress data could help to identify potentially very costly tail events alongside the regular monitoring of continuous indicators. Finally, WS2 studies have demonstrated the importance of being able to compare stress levels across countries.

Therefore, WS2 recommends initially adopting a comprehensive approach as regards operationalising systemic stress indicators for use in the macro-prudential toolkit. In so doing, WS2 is acting in line with the suggestions made by the IMF (2011) and the BIS (Borio and Drehmann 2009).

3.2 Early warning systems

The early warning systems currently in place in many central banks have typically been developed using a bottom-up approach, in which single indicators or models have been added over time. The toolkits allowing policy-makers to identify financial instability and emerging imbalances at an early stage have gradually been expanded, incorporating various single early warning indicators and more complex multivariate early warning models. Those early warning systems are used to send signals as soon as one or more measures of financial stress or systemic risk (as described in the previous section) are likely to reach critical values in the future. Furthermore, these systems also detect potential imbalances that can endanger financial stability in the future, such as excessive credit growth or asset price bubbles. Thus, current early warning systems are multi-dimensional. They warn against several types of costly event relating to different time horizons (using current, pre-emptive and impact-focused indices), and they employ extensive datasets to assess when such signals should be issued. As such, early warning systems operate with various left-hand-side variables (which are not necessarily correlated), time lags and right-hand-side variables.

The main contribution made by WS2 research has been to extend this macro-prudential toolkit in the following two ways: first, WS2 research has enriched the early warning system literature by suggesting alternative measures of financial stress, systemic risk and imbalances, sometimes creating new datasets in order to do so;³² and second, it has improved early warning systems by proposing new methodologies and using new data sources to predict the selected left-hand-side variables.

3.2.1 Key macro-prudential early warning indicators and models

Past research has contributed to the development of early warning systems in several ways – for example, by selecting early warning indicators for analysis (either as single early warning indicators or as indicators inside multivariate early warning models), by identifying time lags between left-hand-side and right-hand-side variables, by providing useful graphical communication tools and by testing the predictive power of various parts of the system.³³

Starting with the identification of single indicators, the selection of variables has, in most cases, usually followed the early work on signalling models carried out in papers such as Kaminsky et al. (1998). The univariate signalling approach essentially maps the historical time series for a single indicator on past crises

³² A prominent example of this is the above-mentioned database developed by the ESCB on sovereign debt, currency and banking crises in the EU (see Babecký et al. 2012). This dataset is available to all interested researchers on the ECB's website: www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1485-annexes.zip.

³³ Such tests constitute an important aspect of research, as previously published studies reported excessive noise-to-signal ratios (Berg and Pattillo 1998), negatively affecting credibility.

and extracts a threshold value above which crises are likely to happen. This univariate approach is transparent and straightforward to apply, which makes it attractive for policy-makers. Yet, this approach risks underestimating the probability of a crisis if several other – potentially important, but unobserved – factors are close to (but below) their individual threshold values (Borio and Lowe 2002). More recent multi-variable early warning models have reduced this risk by estimating the probability of a future event (either financial instability or a crisis) using a set of several potential early warning indicators (Frankel and Saravelos 2010, and Rose and Spiegel 2009). For both the univariate and the multivariate approaches, it holds that in the case of a discrete left-hand-side variable, each early warning indicator or model is evaluated by minimising either the noise-to-signal ratio (Kaminsky 1999) or a policymaker's loss function (Demirgüç-Kunt and Detragiache 1999, and Bussière and Fratzscher 2006). In the case of the discrete choice approach (multinomial logit) and the continuous left-hand-side variable approach, models have been estimated retaining significant indicators. Various papers have also assessed the importance of banking sector characteristics for financial stability (Jeitschko and Jeung 2005, Cihak et al. 2009, and Fahlenbrach et al. 2011).

More 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 option of explicitly deciding whether they prefer missed crises to false alarms or vice versa, and it has subsequently evaluated indicators according to their usefulness given these preferences (Alessi and Detken 2011). Moreover, it has improved 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 WS2 work. Cross-country studies have been extended from emerging market samples to larger samples, including both emerging markets and developed countries (Frankel and Saravelos 2010).

Building on this previous work, WS2 research has contributed to the early warning literature in different ways. First, there is now much more extensive work on European data, both country-specific and EU-wide. Second, several new methodologies have been proposed regarding the selection of early warning indicators from the vast set of potential indicators and the 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.

As regards data, WS2 early warning models cover most of the EU27 countries, either individually or as part of cross-country datasets, while the previous literature has mainly examined emerging markets or large international datasets. WS2 models work with traditional macro-financial variables (Alessi and Detken forthcoming, Andersen et al. 2012, Babecký et al. 2012 and 2013, Behn et al. 2013, Csartos and Szalai forthcoming, Holló et al. 2012, Joy et al. forthcoming, Rouabah et al. 2012, Schudel forthcoming, Schwaab et al. 2011, Lo Duca and Peltonen 2013, Louzis and Vouldis 2012, and Kurz-Kim and Islami 2013), market and balance sheet data (Fiordelisi et al. 2011, Altunbas et al. 2011 and 2012, Louzis and

Vouldis 2012, Lo Duca and Peltonen 2013, and Saldías 2013a), credit risk data (Schwaab et al. 2011) and surveys (Babecký et al. 2012 and 2013, and Louzis and Vouldis 2012). Some projects investigate whether aggregation across EU countries is supported by the data. For example, cluster analysis indicates that aggregation is possible (Babecký et al. 2011), while the possibility of pooling the EU data in a factor structure has also been examined (Schwaab et al. 2011).

Building on previously employed methods, other examples of how early warning indicators in WS2 papers are selected and assessed include Bayesian model selection criteria (Babecký et al. 2012 and 2013), the computation of optimal thresholds for policy action (Lo Duca and Peltonen 2013), a partly non-linear and non-Gaussian factor model (Schwaab et al. 2011) and non-parametric methods that can lead to simple conditional rules of thumb for a small set of indicators describing vulnerable situations (Alessi and Detken forthcoming, and Joy et al. forthcoming). Furthermore, WS2 research has drawn attention to the issue of time lags for early warning indicators. The preferred lag structure for the right-hand-side variables depends largely on the preference of the policy-maker as regards identifying future crises at an early or later stage. Naturally, this choice comes with a trade-off in terms of precision, as it is more difficult to predict crises in the more distant future. Another issue relates to the timing of crises. As predicting the actual moment at which a crisis starts is very difficult (not least owing to the idiosyncratic factors turning a vulnerable financial system into a crisis), several studies have applied early warning models to predict so-called periods or states of financial vulnerability, defined as a period before the onset of a crisis, rather than the actual onset of a crisis. This has been done by essentially lagging the left-hand-side variable (Behn et al. 2013, Lo Duca and Peltonen 2013, and Sarlin and Peltonen 2013). Other studies vary the lag structure to test the robustness of the model (Babecký et al. 2012, Joy et al. forthcoming and Schudel forthcoming) or propose testing the lag structure with systematic lag selection for each indicator by panel VAR (Babecký et al. 2013) or probVAR (Fornari and Lemke 2010).³⁴ Regulatory considerations can also affect the preferred lag structure (Behn et al. 2013).³⁵

WS2 papers have proposed several graphical tools that can be used when communicating with policy-makers and the public. As discussed above, one novel methodology presents the results with the help of “self-organising maps” (Sarlin and Peltonen 2013). Other examples include variable selection charts as part of Bayesian model averaging (Babecký et al. 2012 and 2013), the financial stability map pioneered by the IMF (Lo Duca and Peltonen 2013), fan charts (Rouabah et al. 2012), heat maps depicting significance (Schudel forthcoming) and binary classification trees (Alessi and Detken forthcoming, and Joy et al. forthcoming). 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 predictive power scores for each variable and time lag and sort alternatives from best to worst

³⁴ ProbVAR is a combined model based on vector autoregression with endogenised regressors and a probit approach.

³⁵ Behn et al. (2013) use an early warning model for setting counter-cyclical capital buffers. Given that the CRD IV regulation stipulates that financial institutions should have 12 months to implement buffer decisions by the macro-prudential authority, the authors focus on predicting a “state of vulnerability” lying 12 to 7 quarters before a banking crisis, so as to provide a signal that is early enough to fit the regulation.

performers. In the third case, the graph shows both determinants of systemic risk and their dynamics over time. In the fourth case, the forecast for 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. Finally, decision trees show how the crisis probability varies depending on which early warning indicators breach their respective thresholds.

As regards the testing of predictive power, various methods have been applied by WS2 projects, including: tests based on the noise-to-signal ratios and minimised policy loss functions (Alessi and Detken 2011, Andersen et al. 2012, Babecký et al. 2012, Behn et al. 2013, Csartos and Szalai 2014, Lo Duca and Peltonen 2013, Sarlin and Peltonen 2013, and Sarlin 2013), where missed crises (Type I errors) and the relative frequency of false alarms (Type II errors) depend on policy-makers' preferences; tests based on the in-sample fit (compared with a simple autoregressive function for the left-hand-side variable) or out-of-sample performance and the mean squared errors compared with naive models such as a random walk (Babecký et al. 2011, Fornari and Lemke 2010, and Lo Duca and Peltonen 2013); and tests based on the Area Under the Receiver Operating Characteristic (AUROC),³⁶ a common summary statistic for the goodness of a predictor in a binary classification task (Alessi and Detken forthcoming, and Alessi et al. forthcoming).

As part of their empirical findings, WS2 results suggest that the following indicators should be considered when constructing an early warning system:

- credit-related variables, including term and credit spreads (Andersen et al. 2012, and Fornari and Lemke 2010), credit-to-GDP ratios (Andersen et al. 2012, and Babecký et al. 2012 and 2013), intra-financial credit (Andersen et al. 2012), credit risk conditions when decoupled from macro-financial fundamentals (Schwaab et al. 2011), credit growth (Behn et al. 2013, Csartos and Szalai 2014, Lo Duca and Peltonen 2013, and Schudel 2013), credit lending standards (Neagu et al. 2014), loan growth and customer deposits (Altunbas et al. 2011 and 2012), and holdings of mortgage-backed securities (Antoniades forthcoming);
- asset price-related variables, including the house price gap (Andersen et al. 2012, and Babecký et al. 2012 and 2013), yield curves (Joy et al. forthcoming), house price growth and inflation (Behn et al. 2013 and Joy et al. forthcoming), equity valuations (Behn et al. 2013, Lo Duca and Peltonen 2013, Sarlin and Peltonen 2013, Saldías 2013a and Schudel forthcoming), stock returns (Fornari and Lemke 2010), real equity growth (Sarlin and Peltonen 2013), asset price misalignments owing to market sentiment (Dunne et al. 2012) and the dynamics of absolute excess returns as a herding measure for stock markets (Kurz and Kurz-Kim 2013);
- interest rate-related variables, including the slope of the yield curve (Joy et al. forthcoming);

³⁶ See, for example, Berge and Jordà (2011), Canelon et al. (2012), and Drehmann and Juselius (2013) for a discussion of this model evaluation metric.

- macroeconomic variables, including the terms of trade (Babecký et al. 2012), real exchange rates (Csortos and Szalai 2014), the current account deficit (Csortos and Szalai 2014, and Sarlin and Peltonen 2013) and country-specific macroeconomic imbalances (Betz et al. 2013);
- banking sector variables, including lower bank efficiency as approximated by the inefficiency score (Fiordelisi et al. 2011), banking sector profitability (Behn et al. 2013 and Joy et al. forthcoming), banking sector micro data (Neagu et al. 2014), bank contagion effects derived from network analysis (Betz et al. 2013) and banking sector leverage (Behn et al. 2013, and Sarlin and Peltonen 2013);
- global macroeconomic variables, such as global credit volumes, global GDP growth, global real credit growth, global leverage, global real equity growth, global equity valuations and commodity prices (Alessi and Detken 2011, Babecký et al. 2012 and 2013, Behn et al. 2013, Csortos and Szalai 2013, Lo Duca and Peltonen 2013, Sarlin and Peltonen 2013, and Schudel forthcoming).

Moreover, some of these variables (credit gaps) are also found to produce acceptable policy reactions for macro-prudential policy rules (Andersen et al. 2012). With regard to the relevant transformations of credit aggregates, Alessi and Detken (forthcoming) suggest that useful information is contained in gaps, ratios to GDP and rates of growth, once all of them are considered in a unified framework. It is worth noting that some approaches do not allow the identification of individual indicators owing to their composite nature (Guarda et al. 2012). Finally, there is evidence suggesting that (binary) early warning models can be improved by controlling for the temporal and spatial dependence of systemic banking crises (Alessi et al. forthcoming and Schudel forthcoming).

Despite improvements made by the above-mentioned early warning models, predicting the timing of crises remains an extremely difficult task. MaRs' models have therefore been designed to identify which variables should be monitored to detect vulnerabilities, rather than to predict the exact start date of the next crisis.

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, and Schularick and Taylor 2012), researchers have focused 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 (Alessi and Detken 2011, and Borgy et al. forthcoming) and banking crises (Alessi and Detken forthcoming, Behn et al. 2013 and Schudel forthcoming) or as dependent variables, if the credit boom itself is to be predicted. Both of these approaches should be considered an attempt to predict earlier stages of financial vulnerabilities, which often precede systemic financial crises.

WS2 has produced several studies that shed light on these issues. Using a multi-regime regression model, Serwa (2013a) identifies different economic states of the market for credit to households (e.g. a normal regime and a boom regime). Serwa (2013b) evaluates the distortion of the ratio of non-performing loans caused by rapid credit growth. Rubaszek and Serwa (2012) propose a structural approach 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 ratio³⁷) affect the equilibrium value of household credit. Preliminary results on the derivation of equilibrium credit growth using 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 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 countries, as the incurred error 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 central and eastern Europe on economic fundamentals and then applying the derived elasticities to central and eastern European countries. Kadlčáková et al. (2013) examine the potential for concurrence of departures from equilibrium in different financial markets, revealing a significant potential for joint occurrence of extreme events in these markets in central Europe. Alessi and Detken (forthcoming) and Behn et al. (2013) show how to extract useful information from other early warning indicators, to complement the total credit-to-GDP gap (“Basel gap”) as a guide to counter-cyclical capital buffer decisions.

Identifying asset price bubbles remains a very challenging field of research. The great reluctance to acknowledge the existence of asset price bubbles (see, for example, Garber 1990, or Martin and Ventura 2012) and use the term “bubble” is declining in the research community following the experience of the financial crisis. However, the empirical difficulties involved in identifying inaccurate pricing do of course remain, as, for example, evidence would be needed supporting the premise that expectations of future cash flows and discount rates were clearly unrealistic. Nevertheless, a few projects in WS2 aim to improve on simple statistical methods with a view to identifying asset price booms and bubbles. Alessi and Detken (2011) test the performance of a host of real and financial variables as early warning indicators for costly aggregate asset price boom/bust cycles, finding that global measures of liquidity (such as the global credit to GDP gap) are the best performing indicators and display forecasting records

³⁷ Changes in the replacement rate alter the uncertainty that individuals face with respect to their life-time resources. Higher replacement rate means that uncertain income from labor is exchanged for certain income from pensions and thereby the variability of the life-cycle income profile becomes lower. As a result, higher replacement rate means that the precautionary motive to accumulate savings is diminished, which leads to a decline in the stock of capital in the model.

which are informative for policy-makers. Borgy et al. (forthcoming) analyse factors driving house price booms relative to those driving stock price booms and find that money and credit supply affect the former, while real GDP influences the latter. Dunne, Forker and Stuart (2012) evaluate the contribution made by (non-linear and interactive) sentiment effects to the Eurostoxx 50 index 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 which can provide an early warning of asset price misalignments. Kurz-Kim (2012b) introduces a novel technique, producing an alarm index from a composite crash model for stock market crashes, while Kurz and Kurz-Kim (2013) quantify the dynamics of absolute excess returns on stock markets and show that the absolute excess return depends mostly on stock market volatility. Sousa and Sousa (2013) 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 (2012a) develops a model to compute equity price bubbles (i.e. predict crashes) and combines it with an estimation of the intensity of herding behaviour, with a view to also assessing the short-run dynamics of equity prices. Kurz-Kim and Scharnagl (2012) use a simple test based on the Welch statistic³⁸ to detect bubbles in stock markets.

3.2.3 The role of fiscal developments in financial instability

Early warning models of fiscal vulnerabilities can contribute to the standard toolkit for systemic risk analysis. This owes less to the observation that fiscal crises tend to follow banking crises (Reinhart and Rogoff 2009) than to the fact that concerns about fiscal sustainability can also trigger a banking crisis (capital losses, 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).³⁹ Afonso, Furceri and Gomes (2011) provide evidence of spillover effects from rating downgrades for fiscally weak countries to the bond yields and sovereign CDS spreads of fiscally strong countries. This is a relevant way of identifying sources of systemic risk that can be exacerbated through cross-country bond holdings (see also Section 4.3 on sovereign contagion). Afonso, Baxa and Slavík (2011) use a threshold VAR model to provide evidence 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. This approach can be used to identify implausible CDS spreads (given an estimate of the current deficit) or, conversely, determine the deficit that would correspond to the current

³⁸ Welch's (1947) t-test is an adaptation of Student's t-test intended for use with two samples having possibly unequal variances.

³⁹ See also the WS1 paper by Pierard, Rouabah and Tabarraei (2013) referred to in Section 2.2.1 for a theoretical characterisation of the sovereign-bank nexus and its macroeconomic implications (and the paper by Cooper and Nikolov 2013 produced under WS3).

CDS spread, assuming the latter reflects an appropriate assessment of the fiscal situation. Checherita-Westphal and Holm-Hadulla (2012) estimate a system of simulta

neous 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 is the case with simple calculations based on single-equation debt arithmetics, because pernicious feedback loops are at play when fiscal concerns arise. The model suggests that at high debt levels, fiscal consolidation has a more positive effect than is suggested by simple debt arithmetics, while this effect is reversed at low debt levels. Vuillemeij and Peltonen (2013) presents a stress test model for the CDS market, with a focus on the interplay between banks' bond and CDS holdings. The model enables the analysis of credit risk transfer mechanisms, includes features of market and liquidity risk, and allows for contagious propagation of counterparty failures. As an illustration, the model is calibrated using sovereign bond and CDS data for 65 major European banks. The model simulation shows that, in case of a sovereign credit event, banks' losses due to direct and correlated bond exposures are significantly higher than losses due to CDS exposures. The main risk for CDS sellers is found to be sudden increases in collateral requirements on multiple correlated CDS exposures. Close-out netting considerably reduces the extent to which contagion may occur.

All in all, WS2 researchers have produced a wealth of early warning models, applying different approaches, analysing different aspects or stages of financial vulnerabilities and including a comprehensive set of indicators. It is evident that determining a superior model or list of variables – as WS2 has sought to do in response to Questions (i) and (iii) – is nearly impossible, given the complexity of comparing these approaches without a common yardstick. One potential method of selecting a superior model is to compare different models using the same dependent variable, an exercise which has been organised by WS2 researchers and which is discussed in Section 3.2.5.

3.2.4 Aggregation of early warning indicators and models

One key issue as regards devising an early warning system for the EU is the question of the optimal aggregation of country results versus keeping the breadth of country/institutional coverage (Question (ii)). Owing to the low number of national crisis episodes, it is also difficult to derive reliable and efficiently estimated national early warning models. Some pooling of data across countries or across financial institutions is therefore reasonable. However, the acceptance of the warning signals by national policy-makers will depend on whether indicators and thresholds which are derived from a pool of countries/institutions are deemed to be representative for the country/institution under scrutiny. For example, WS2 researchers find that even one of the best performing early warning indicators, the credit-to-GDP gap, does not perform well for every EU country 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 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 (2013a and 2013b), and Betz, Sarlin and Peltonen (2013) pool data across individual EU banks. Alessi and Detken (forthcoming), and Behn et al. (2013) derive their early warning system for counter-cyclical capital buffers from macro and credit data for the EU27.

Some projects currently use a euro area sample that could be extended to EU level. For example, Checherita-Westphal and Holm-Hadulla's (2012) sovereign debt analysis focuses on the euro area, but their panel structure could, in principle, be generalised to cover the EU as a whole, subject to the availability of data. Holló, Kremer and Lo Duca (2012) already have a first preliminary version of an aggregated CISS including some non-euro area EU countries. The picture that emerges from this preliminary EU CISS does not differ substantially from that derived from the euro area CISS. For the euro area aggregate, Sarlin and Peltonen (2013) predict and visualise systemic risk using Self-Organising Financial Stability Map. The same methodology could be extended and applied to the EU country aggregate as well. Zhang, Schwaab and Lucas (2011) 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.

As regards 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. Although it has been planned, the aggregation has not yet been carried out. As for the financial vulnerability index for Luxembourg in Guarda, Rouabah 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 (2012a) early warning indicator could be aggregated at the EU level according to the composition of the Eurostoxx 50 index. Overall, the issue of aggregation deserves further attention.

3.2.5 A collective exercise in comparing early warning models

A central element of WS2 was a joint cross-country project, which comprised two steps. The first step was the development of a common database on various types of crisis in EU countries, notably banking, currency and sovereign debt crises (Babecký et al. 2012). It is described in greater detail in Box 2 below. The second step consisted of a comparative assessment ("horse race") of different early warning models for systemic banking crises, using the new database and applying a uniform evaluation method. The evaluation method was based on the AUROC curve, an assumption of indifference on the part of policy-makers regarding missing crises and false alarms (i.e. Type I and Type II errors) and an absolute usefulness measure based on preferences and error rates (see also Lo Duca and Peltonen 2013). Participants were asked to estimate their models so as to predict a state of vulnerability, defined as a period between 20 and 4 quarters prior to a systemic banking crisis. Moreover, two sub-periods were

defined, namely an “early period” (20-12 quarters before a crisis) and a “late period” (12-4 quarters before a crisis).

Box 2: AN EU-WIDE DATABASE OF CRISES

The main motivation for joining forces in the ESCB to establish a database of crises in EU countries was to provide a common basis for analysing the causes and effects of these crises and assessing the performance of early warning tools. This would serve both internal central bank staff and outside researchers, as the database is publicly available via the ECB’s website (www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1485-annexes.zip).

The database covers banking, currency and sovereign debt crises in the EU27 and other OECD countries from the first quarter of 1970 to the fourth quarter of 2010. The crises and their dates were derived by combining available literature and data sources with a survey of country experts (mostly from the respective national central banks) using the network of ESCB Heads of Research. The crisis index is binary, taking the value of 1 when a crisis occurred in a given quarter in a given country and the value of 0 otherwise. The decision to use a discrete indicator was made inter alia because the widely varying definitions of crises in the literature and other sources would have risked preventing the data entries from being comparable.⁴⁰

The literature considered included: Caprio and Klingebiel (2003); Detragiache and Spilimbergo (2001); Kaminsky (2006); Kaminsky and Reinhart (1999); Laeven and Valencia (2008, 2010 and 2012); Levy-Yeyati and Panizza (2011); and Reinhart and Rogoff (2009). While some studies identify crisis episodes with the help of a particular variable and its threshold value (e.g. Kaminsky and Reinhart 1999, and Kaminsky 2006), other studies (e.g. Caprio and Klingebiel 2003, and Laeven and Valencia 2008) also employ expert judgment or use systematic literature or media reviews. In many cases, there is also considerable disagreement about the timing of the end of crises, while it is easier to find uniform information about the timing of the onset of crises. Some studies do not cover all developed countries owing to their specific focus or various data limitations. Most existing studies offer only an annual data frequency. These limitations led to the adoption of the approach described above.

For the “horse race” involving the various early warning models, the identification and dating of banking crises was essential. In this regard, the national experts surveyed were asked to use a common definition, defining a banking crisis as significant signs of financial distress in the banking system as evidenced by (i) bank runs in relevant institutions or losses in the banking system (with non-performing loans above 20% or bank closures totalling at least 20% of banking system assets) or (ii) significant public intervention in response to losses – or to avoid the realisation of losses – in the banking system. In terms of the latter, an intervention is considered significant if at least one of the following applies: (a) extensive liquidity support (i.e. the ratio of central bank claims on the financial sector to deposits and foreign liabilities exceeds 5% and more than doubles relative to its pre-crisis level); (b) bank restructuring costs (i.e. the gross fiscal outlay directed towards restructuring the financial sector, excluding asset purchases

⁴⁰ For example, heterogeneities such as the following were present in previously available databases of financial crises. While definitions of currency crises commonly included references to episodes of massive exchange rate depreciation, the term “massive” covered declines in value ranging from 15% to more than 30% across different studies. In addition, the definition of banking crises involved judgment on size of the capital losses (e.g. small versus systemic banking crises), while the coding of sovereign debt crises implied judgment on the debt category (e.g. domestic or external default, debt restructuring, or a combination thereof).

and direct liquidity assistance from the treasury, is at least 3% of GDP in at least one fiscal year); (c) significant bank nationalisations (i.e. government takeovers of systemically important financial institutions, including cases where the government takes a majority stake in the capital of such financial institutions); (d) significant guarantees (i.e. either full protection of liabilities or guarantees extended to non-deposit liabilities of banks; actions that only raise the level of deposit insurance coverage are not deemed “significant”); (e) significant asset purchases (i.e. cumulated purchases totalling at least 5% of GDP by the treasury or the central bank); and (f) deposit freezes and bank holidays.

Overall, the exercise featured nine early warning models developed by seven participating NCBs (the Banco de Portugal, Česká národní banka, De Nederlandsche Bank, the Deutsche Bundesbank, the Bank of England, Suomen Pankki – Finlands Bank and the Oesterreichische Nationalbank) and the ECB, which demonstrated great variety in terms of the types of models used and in terms of the method of selecting variables. Several studies applied a logit or probit model approach, but these models still deviated considerably from one another. A more detailed discussion of the participating models can be found in Alessi et al. (2014).

Frost et al. (2013) include an interdependency index in their multivariate probit model, providing interesting empirical evidence for the notion that financial vulnerabilities are not restricted to individual countries. This index effectively depicts a spatially lagged dependent variable which captures estimated financial vulnerabilities in other countries, where the spatial lag is weighted by bilateral trade volumes. Bush et al. (2013) employ principal component analysis to guide the choice of right-hand-side variables, finding evidence suggesting that banking sector variables play an important role in predicting future crises. Antunes et al. (2013) estimate dynamic probit models and find that accounting for the temporal dependence of the dependent variable improves the models’ fit. Sigmund and Neudorfer (2013) estimate Bayesian random coefficient models, a novel approach which allows for country-specific coefficients in estimating a logit model, which improves model precision and addresses the above-mentioned criticism that pooled models do not fit individual countries well. Behn et al. (2013) estimate a logit model with the aim of developing an early warning tool that can be used for decisions on the activation of counter-cyclical capital buffers. They find not only that the inclusion of global (common to all) variables considerably improves the predictive power of the model, but also, in line with Bush et al. (2013), that the level of banking sector capitalisation and profitability significantly affects future crisis probabilities. Babecký et al. (2012) employ the Bayesian model averaging method to guide their selection of explanatory variables in a multivariate model. The analysis benefits from a very rich set of explanatory variables, which minimises the risk of omitting potentially important ones from the model. Eventually, they find evidence suggesting that global variables play an important role in predicting future crises, particularly at very early stages.

A different and fairly novel modelling approach, the binary classification tree, is used by Alessi and Detken (forthcoming) and Joy et al. (forthcoming). This non-parametric methodology permits the detection of key variables driving crisis outcomes, allowing for interaction between key variables while determining critical tipping points. This approach tries to provide a more organised selection of crisis triggers, starting from a relatively rich set of variables, and allows the identification of critical non-linearities. Joy et al. (forthcoming) find that a shallow yield curve coupled with high money market rates

and low bank profitability are the most reliable indicators of banking crises, while global variables (such as global GDP and credit) interact significantly with country-specific variables. Alessi and Detken (forthcoming) propose robustly selecting the key indicators by “growing” a “Random Forest” – i.e. by bootstrapping and aggregating a multitude of trees so as to improve the stability and accuracy of the predictions. They find that the bank credit aggregate in the form of trend deviations (“gaps”), the ratio to GDP and the growth rate features prominently in the benchmark tree “grown” for the key indicators.

Finally, there is evidence suggesting that (binary) early warning models can be improved by controlling for the temporal and spatial dependence of systemic banking crises (Alessi et al. forthcoming, Antunes et al. 2013 and Schudel forthcoming). Kauko’s (2013) contribution focuses on proposing a new signalling indicator, which essentially makes the effect of credit growth as a share of GDP conditional on the current account of a country by dividing the credit variable by a factor of 10 when the current account is not in deficit.

In order to select the best performing models, various decision rules were applied, assessing the performance of the respective models with regard to the four evaluation criteria across the three time horizons. The variation in model performance depending on the decision rule demonstrated the specific strengths and weaknesses of each approach. For example, some models performed very well in terms of their Type I errors, while other models issued very few false alarms.

If anything, the main conclusion to draw from the horse race exercise is that multivariate approaches, in their many variations, generate potentially very useful early warning results and offer considerable improvements over univariate signalling variables in terms of crisis prediction performance. Having said that, each multivariate approach has its strengths and weaknesses. For example, multivariate logit models tend to reduce both Type I and Type II errors (although admittedly less so than decision trees in the case of Type II errors) and enable researchers to easily gauge the marginal contribution of each individual variable. However, the reliability of their results tends to be sensitive to the model specification. In turn, decision trees tend to reduce Type II errors, as they allow to take into account the conditional relationships among variables, implying that a signal is released in very specific circumstances. Also, they are less restrictive regarding the inclusion of, for example, level information, as non-stationarity is not an issue for this type of approach. However, with the exception of an out-of-sample exercise carried out by Alessi and Detken (forthcoming), little is known as yet regarding the out-of-sample performance of decision trees.

In the context of applying these results to macro-prudential policy and taking the strengths and potential weaknesses of each approach into consideration, there is reason to argue that the use of a suite of multivariate models could be an advisable approach when developing empirical macro-prudential policy instruments. This argument is especially valid when assuming that policy-makers do not have strong ex ante preferences as regards minimising Type I or Type II errors. Moreover, as it seems logical for such preferences to vary between policy-makers in different jurisdictions and to evolve over time, a broad empirical approach based on several early warning methods seems warranted – all the more so as policy-makers are still learning about how new macro-prudential policy instruments affect financial stability and the real economy.

4. Assessing contagion risks

The 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 data⁴¹ and previous research on contagion risk within EU countries.⁴² Based on a vast academic literature,⁴³ 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 or fundamental factors and/or is of particular (i.e. “extreme”) strength.

Relevant research questions asked by the General Council are: (i) What is the relevance of different channels of contagion, and how are they affected by the structure of the interbank market? (ii) Are there feedback effects which amplify contagion? (iii) Are there spillovers across different countries, markets and types of financial intermediaries?

In order to complete and deepen this research agenda, at the end of 2012 a dedicated group of MaRs WS3 researchers were granted access to transaction-level data from the TARGET2 payment system, the Eurosystem settlement system for large-value payments in euro. These data on interbank payments enable us to gain particularly valuable insights into the functioning of money markets, which is so important for assessing contagion risks. As a consequence, the following issues were added to the research agenda: (iv) Construction of databases of money market transactions; (v) Application of network theory to characterise the structure of euro area interbank markets; (vi) study of the payment behaviour of cross-border banking groups.

WS3 has produced 46 individual research papers: 11 of which are based on TARGET2 data and 14 relate to the special initiative on sovereign contagion risk. Although the papers are at different stages of development, all available papers were used in writing this chapter. Section 4.1 summarises the results on the structure of the euro area interbank market based on the TARGET2 dataset, touching on various aspects of the above-mentioned deliverables and integrating them with other MaRs research papers. Section 4.2 discusses research on financial spillovers between aggregate sectors in the economy. Section 4.3 describes the results of the initiative on sovereign contagion.

⁴¹ See, for example, Hartmann, Straetmans and de Vries (2006) or Gropp, Lo Duca and Vesala (2009).

⁴² 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 (2011) for Italy. See Upper (2011) for a critical assessment of the counterfactual simulations to estimate the danger of contagion owing to exposures in the interbank loan market.

⁴³ 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).

4.1 Money market structures, interbank spillovers and contagion

This section first describes the evolving structure of the euro area money markets emerging from the analysis of the TARGET2 data. Second, it focuses on the phenomenon of interbank contagion, emphasising and documenting the empirical evidence of alternative potential channels.

4.1.1 Mapping the euro money markets and assessing fragmentation

Operational data derived from the TARGET2 system include any type of transaction among banks, but the interest of most research papers reviewed here lies in analysing interbank loans, which are not identified specifically in the dataset of raw transactions. Arciero et al. (2013) and De Frutos et al. (2013) have created two alternative datasets, by setting up an algorithm which extracts estimates of the interbank loan contracts from the rest of the transactions.⁴⁴ Both datasets rely on the implementation of the Furfine (1999) algorithm. This algorithm matches transactions between banks on a specific date with a reverse transaction at a later date, accrued by a plausible interest rate. The implementation relies on several assumptions about, inter alia, minimum loan values, plausible interest rates and the maximum reliable duration. One key difference between the two datasets is that De Frutos et al. (2013) focus exclusively on overnight transactions. This allows them to impose very mild ex ante restrictions on the plausible interest rates, a feature which is particularly appealing during periods of high stress (such as those witnessed during the Lehman bankruptcy or the euro area sovereign crisis). Arciero et al. (2013) also extract term loans up to a maturity of 12 months. The availability of longer maturity loans in the dataset provided by Arciero et al. (2013) makes it possible to analyse different maturity segments of the interbank market separately.

Both Arciero et al. (2013) and De Frutos et al. (2013) validate thoroughly the identified interbank loans, using the transaction-level data available for the Italian and Spanish MID platforms, as well as the individual EONIA panel contributions. There are two types of errors the algorithm can commit: Type I errors or false positives (i.e. transactions which are identified as a loan between the two banks but were in fact unrelated) and Type II errors or false negatives (i.e. the algorithm misses actual loan transactions which occurred between the two banks). For overnight transactions, they respectively find Type I errors of less than 1% and Type II errors of around 10%. Arciero et al. (2013) point out that the algorithm becomes less reliable in identifying interbank loans, as the maturity increases; the most reliable results are obtained for identified TARGET2 loans up to three months.

A first general description of the key characteristics of the euro overnight market has been published by Hartmann, Manna and Manzanares (2001). A broader description of all euro money market segments is given in Hartmann and Valla (2008). De Frutos et al. (2013), and Arciero et al. (2013) provide a first description of the functioning of the euro area overnight interbank loan market during the financial crisis on the basis of TARGET2 data. They find that cross-border transactions fell by a third following the Lehman bankruptcy. After a period of stabilisation in 2009, they picked up again in 2010, in spite of

⁴⁴ Massarenti et al. (2014) provide a first set of descriptive statistics on overall TARGET2 interbank payments.

tensions related to the emergence of problems in Greece and Ireland. A new decline, which began in the spring of 2011 with the acute phase of the sovereign debt crisis, brought cross-border transactions to their lowest value after the three-year long term refinancing operations and the cuts in the key ECB policy rates. By mid-2012, cross-border overnight volumes were around €30 billion, down from around €80 billion in mid-2008.

The network analysis in Garcia et al. (2013) reveals that, despite the significant drop in cross-border transactions after the Lehman default, network density – as measured by the number of actual links between banks relative to all possible links – remained relatively stable.⁴⁵ This is consistent with Gabrieli and Georg (2013) who document that, after the Lehman default, a large drop in market turnover and significant changes in structural network features only occurred in the term segments of the euro money market, especially for loans with maturities of more than one month. This suggests that, at least at the beginning of the crisis, banks continued to trade with each other, albeit with much smaller volumes and mostly at shorter maturities. It is only with the acute phase of the sovereign crisis and the ECB liquidity injections of the three-year refinancing operations that the network density started to drop significantly. The drop in the share of cross-border market volumes, after September 2008 and since mid-2011, can be interpreted as *prima facie* evidence of market fragmentation.

An alternative measure of fragmentation is proposed by Garcia et al. (2013). It relies on the idea of network community membership. For this purpose, the network is split into several “communities”, such that banks within a certain community are tightly linked to each other, i.e. exhibit above-average mutual trading volumes, whereas links across communities are weak. In a market with perfect cross-border integration, one should not expect community membership to be correlated with the geographic location of a bank. The authors find instead significant evidence that the major two communities are associated with a North/South separation in the first few years of the crisis. Tiering in the money market has not received that much attention in the literature so far.⁴⁶ Craig and von Peter (2010) use data on the German interbank market drawn from the Deutsche Bundesbank credit register. They 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 play a key role in the network, the paper argues that interconnectedness should be considered an important measure of systemic relevance, in addition to size.

Hoffmann et al. (2013) propose a third indicator of fragmentation. In a perfectly integrated market, banks should not charge different rates for loans to counterparties located in different countries, after controlling for counterparty risk. The authors regress the inferred overnight interbank loan rates onto a constant, a country dummy and a bank rating dummy, to control for idiosyncratic bank risk. Their measure of

⁴⁵ 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). They have been examined empirically by Cocco et al. (2009), using Portuguese data.

⁴⁶ 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.

interbank fragmentation is the regression coefficient associated with the country dummy, which in a situation of perfect integration should be zero. They identify significant phases of market fragmentation, all associated with different stages of the euro area sovereign crisis. Overall, one can conclude that cross-border fragmentation has varied substantially since 2008. Fragmentation peaked twice during episodes of intensified sovereign stress, but declined in the aftermath of policy interventions. This holds, in particular, for the three-year refinancing operations, which markedly reduced cross-border fragmentation despite the overall decline in market activity in this period.

Hoffmann et al. (2013) also estimate a bivariate vector autoregression (VAR) for the average borrowing rates paid by banks located in non-stressed and stressed countries. They estimate the VAR in two sub-periods, a relatively integrated period (i.e. June 2008 to April 2010) and a fragmented period (i.e. May 2010 to August 2013). The beginning of the fragmented period is identified with the methodology of Hoffmann et al. (2013) already discussed in the previous sub-section. The analysis of the generalised impulse-response functions associated with the VAR estimated in the two sub-periods reveal that, in integrated times, shocks to the interbank rates in stressed countries are evenly transmitted to those of the non-stressed countries, and vice versa. Things change in periods of market fragmentation, however. A shock in a non-stressed country continues to be transmitted to the interbank markets of all the other countries, albeit with reduced intensity. By contrast, a shock in a stressed country has a small and very short-lived effect, mainly contained to the banking systems of the group of stressed countries.

The intensity of the crisis and the subsequent ECB interventions appear to affect also banks' willingness to trade at rates below the ECB deposit rate and above the marginal lending facility rate. De Frutos et al. (2013) find that a significant number of overnight loans are exchanged at an interest rate above the ECB marginal lending facility. This evidence is unlikely to be on account of errors in the Furfine algorithm employed in the estimation, as the number increases sharply in periods of stress, reaching its peak right after the Lehman bankruptcy and at the height of the European sovereign debt crisis at the end of 2011. This suggests that the phenomenon is likely to have been driven by actual difficulties, for certain banks, in obtaining interbank funds. Abbassi and Schulze (2013) suggest that, after the three-year long-term refinancing operations (themselves a reaction to the situation of stress which led to interest rates above the ECB marginal lending rate), a significant fraction of interbank overnight trades took place at rates below the ECB deposit rate. The authors argue that this finding can be explained by market segmentation: when the central bank provides disproportionate amounts of liquidity, it shifts the bargaining power in favour of those banks with access to the ECB standing facilities.

Rünstler (2013) adopts a linear spatial model to gauge links between money market participants. Variables such as trading volumes and interest rates are regressed against those of corresponding entities of the individual banks' neighbours in the network. Neighbours are defined from the presence of trading relationships in the past. Rünstler finds that spillovers for net lending and lending-borrowing spreads are usually negative, consistent with the hypothesis that neighbours act as a buffer to partly absorb bank-specific liquidity shocks. The most interesting feature, however, is that most of the time the network structure does not seem to matter, but it grows in importance during periods of crisis or market

turbulence, such as the various episodes of sovereign debt stress in 2010 and 2011, and around the three-year liquidity operations.

4.1.3 Euro money market developments around the Lehman default

Turning to the core topic of WS3, one strategy for understanding the mechanics of contagion is to analyse banks' behaviour around specific events. The TARGET2 data sample contains the period around the Lehman default, which definitely represents an interesting case study. Several papers focus on this event.

Gabrieli and Georg (2013) find evidence that, after the Lehman bankruptcy, only the term segment of the market froze, as banks switched from longer maturities (1 to 12 months) to the shortest possible one (overnight). Like Rünstler (2013), they find that a bank's position within the interbank network before the Lehman event had a significant impact on how much liquidity the bank obtained afterwards, and at what price. Abbassi et al. (2013) confirm the perception that interbank relationships are an important factor in improving banks' access to interbank credit. They find that, during times of elevated credit risk, borrowers are able to obtain a larger amount of credit and pay a significantly lower interest rate to their relationship lenders, relative to the conditions obtained from non-relationship lenders.

Di Filippo (2013) suggests that, after the Lehman bankruptcy, banks were able to discriminate among their counterparties based on their creditworthiness, rationing and charging higher rates for banks with higher credit risk, as proxied by the share of non-performing loans. This discrimination effect persists after the ECB liquidity injections.

The macro-prudential implication of these findings points to a positive stabilising effect that interbank relationships have during crisis times. This positive effect needs to be weighed against the contagion risks which inherently arise in the presence of tightly interconnected networks. Interestingly in this context, the paper by Abildgren et al. (2013) in WS1 suggests that, during the financial crisis, in Denmark, non-financial firms that had retail lending relationships with a weakened bank exhibited a higher default probability than firms borrowing from banks less affected by the crisis.

4.1.4 Assessing bank contagion and spillovers using financial market data

A large number of papers analyse interbank instabilities using financial market data.

Bekaert et al. (2011) analyse the transmission of crises to country-industry equity portfolios in 55 countries during the 2007-09 financial crisis. Using an asset pricing framework with global and local factors, they find evidence of systematic contagion from US markets and from the global financial sector; but the effects are very small. By contrast, the co-movement of portfolios within a country increased systematically during the crisis, above and beyond what can be accounted for by underlying fundamentals, with its severity inversely related to the quality of countries' economic fundamentals and policies. The evidence is against the "globalisation" hypothesis (linking the transmission of the crisis to the extent of global exposure), confirming instead the old "wake-up call" hypothesis, with markets and investors focusing to a greater extent on idiosyncratic, country-specific characteristics during the crisis.

Other studies focus more specifically on bank equity market data. Degryse, Elahi and Penas (2013) study the fragility of banking systems between 1994 and 2008 from a multi-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 regional macro factors and a series of regional banking system characteristics, such as liquidity, capitalisation, competition, diversification, and the presence of foreign banks in a region. In general, 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. In the second part, the paper analyses the possibility of contagion across regions. 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 supplementary work, Degryse, Elahi and Penas (2013) study more directly the fragility of a set of European countries' banking systems. Their approach suggests that banking system indices of European countries experience jointly very low returns more often than in other countries over this sample period. Comparing banks of euro area countries with US banks between 1992 and 2004 with methods of extreme value analysis, Hartmann, Straetmans and De Vries (2006) reached different conclusions on this issue. They found that multivariate extreme spillover risk was higher among US banks than among euro area banks during their sample period, mainly as cross-border risks were still relatively mild in Europe. At the same time, on both sides of the Atlantic, systemic risk had increased during the 1990s. Interestingly, in Degryse et al. greater liquidity and capitalisation reduce the likelihood that some countries' banking stock indices experience very low returns but not the likelihood of many countries' banking indices being in the tail (consistent with other research results in MaRs WSs 1 and 3). Cross-regional contagion of all other regions on Europe is considerable but most pronounced from the United States. A greater reliance in Europe on wholesale funding and foreign banks increases the impact of cross-regional contagion from Latin America and Asia. Banking system characteristics in Europe do not influence cross-regional contagion from the United States.

With the highly connected worldwide financial structure, financial contagion naturally does not stop at borders. In the Czech Republic, where most participants are subsidiaries and branches of foreign banks, Geršl and Lešanovská (2013) suggest that developments in markets abroad have a strong potential (stronger than domestic factors) to generate cross-border contagion and to affect risk premia. Increased uncertainty about the solvency of the main western European banks during the global financial crisis, as captured by the CDS spread dispersion, increased the interbank market risk premium in the "host" country. Thus, risk premia in interbank markets may be affected not only by the traditional liquidity and counterparty risk factors, but also by the foreign influence via foreign ownership of market participants. Another potential channel of cross-border contagion is the parent-subsidiary relationships. Derviz and Raková (2012) undertake a theoretical and empirical analysis of how the condition of a parent bank may affect 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 significant in statistical terms, appears to be of subordinate economic importance, at least in the Czech banking sector in the pre-crisis period (i.e. before 2008).

Other papers which exploit advanced econometric techniques using market data are Idier (2011) and Saldias and Craig (2013). Idier (2011) proposes a Markov switching multifractal model with dynamic conditional correlations in order to assess market contagion over several horizons and disentangle, for example, short-term crisis contagion from long-term market integration. Saldias and Craig (2013) estimate data-driven correlation networks based on bank stock returns of international banks and conduct a comprehensive analysis of their topological properties.

4.1.5 Assessing bank contagion using interbank exposures

Many papers of WS3 study interconnectedness using information about interbank exposures.

Hałaj and Kok (2013 and 2014) study the characteristics of a network of interbank claims. As their dataset only contains aggregate exposures of large European banks, they resort to simulations replicating the matrix of all bilateral interbank claims. This approach has the advantage of allowing extreme events to be studied and, indeed, – in line with much of the previous literature on counterfactual simulations – it is found that the failure of one bank in the network only has a detrimental effect on other banks' solvency 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. The non-linearity is related to the inclusion of fire sales in the analysis. 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 partly explain the limited contagion risk that was often found in the past.

Another stream of research under WS3 analyses the nature of interbank lending structures for assessing interconnectedness among banks. Craig and Von Peter (2010), Memmel, Sachs and Stein (2012) and Memmel and Sachs (2013) use data on the German interbank market drawn from the Deutsche Bundesbank credit register. Simulations conducted taking the distributional feature of the loss given default (LGD) into account show that the interbank system is more fragile than appears to be the case when simulations fix LGD at the sample mean. Memmel, Sachs and Stein (2012) have actual data on interbank loan write-offs, which suggest that the distribution of the LGD is strongly bimodal (i.e. U-shaped). 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, which most likely reflects the presence of fully collateralised exposures (through repos) and totally uncollateralised exposures (through interbank deposits), stands in contrast to the 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. Memmel and Sachs (2013) explore the factors which determine the stability of the interbank market. They find that banks' capital, their lending within the system, the LGD and the degree of how equal banks spread their claims are important factors.

Brown et al. (forthcoming) resort to experimental data to investigate the mechanisms behind contagion. The authors find that panic-based deposit withdrawals can be strongly contagious across banks, but only if depositors know that the banks are economically related (in their experiment this is done through asset commonality). More specifically, under these information conditions a panic-based bank run at one bank makes the bank-run equilibrium more salient for depositors at another bank. The run at the observed bank leads to an update of subjective beliefs of depositors in the observing bank that their fellow depositors will withdraw. There is no evidence for a belief-update, and no subsequent contagion of deposit withdrawals between banks, when depositors know that the banks are economically unrelated.

The potential for contagion within the Czech banking system via interbank exposures of domestic banks over the period 2007-12 is also explored by Hausenblas, Kubicová and Lešánovská (2012), using network analysis. Their results point to several banks that are important for the stability of the network and whose failure could potentially have systemic consequences. The resilience of the system is assessed using a simulation approach where the initial shocks have the form of a credit, liquidity, or asset price shock.

Di Iasio et al. (2013) and Gabrieli et al. (2013) use information contained in TARGET2 data to assess contagion through interbank exposures, further developing the literature on counterfactual simulations referred to above. Starting from a common market shock on banks' capital and an exogenous bank default event, Gabrieli et al. (2013) assume that contagion propagates via a large number of probabilistic networks of long- and short-term interbank linkages. The probabilistic networks are constructed relying on bank balance sheet data and TARGET2 money market exposures. Their findings suggest that the risk of cross-border contagion through the European interbank market gradually abated between 2008 and the end of their sample. One driver of this trend has been the decline in the number of interbank transactions, also documented by other TARGET2-related WS3 studies. The results also highlight that contagion can be significantly enhanced when amplification effects, such as liquidity-hoarding by stressed counterparties, are taken into account. Furthermore, the overall contagion outcome depends to a significant extent on the evolving network structure of interbank linkages when running realistic contagion simulations: the number of defaults resulting from extreme market stress can be more than three times larger or smaller depending on the underlying structure of interbank linkages, pointing to a need to take into account the evolving interbank network structure when studying contagion.

Di Iasio et al. (2013) start from the observation that the standard default cascade exercise has a binary nature: the cascade only has the potential to get started if a bank defaults; otherwise, no contagion is observed. In reality, however, a shock reducing the capital base of a bank weakens its balance sheet and reduces its distance-to-default in a more gradual manner. This, in turn, erodes the market value of its liabilities, weakening via this channel the balance sheet of its counterparties even if no default occurs.⁴⁷ In other words, counterparty banks' balance sheet weakness (not just outright default) can also be a source

⁴⁷ Ota (2014) has a similar intuition of how "marginal" contagion can spread without the need for outright defaults. In the model a negative shock to a bank increases its default probability, devaluing the claims other banks have on it. This market mechanism causes capital losses at those other banks, which are again transmitted to banks that have claims on them and so on.

of contagion to their creditors. This idea is operationalised via the so-called DebtRank methodology developed by Battiston et al. (2012). They confirm previous literature by finding that, in the traditional default cascade model, only very few scenarios generate significant losses. Even in these few cases, the estimated equity losses are lower by a factor of three than those obtained with the DebtRank methodology. Furthermore, the banks identified as systemic by the DebtRank methodology tend to be the largest ones (in terms of total assets), but with two important qualifications. First, the relationship between size and systemic impact is highly nonlinear; many very large banks have an over-proportionally large systemic impact. At the same time, the systemic impact of very large banks is also widely dispersed; and certain highly-interconnected small banks may also sometimes have sizeable systemic importance. So, size by itself is not necessarily a sufficient statistic for identifying banks which pose systemic risks.

4.1.6 Further potential of the TARGET2 data

Some of the papers presented in the previous sub-sections exploit the interbank loan datasets derived from the TARGET2 data. Since the authorised researchers only have access to the data from the end of 2012, many research projects that would be valuable for macro-prudential purposes have not been tackled yet. Moreover, the data also lend themselves to addressing issues other than macro-prudential and financial stability issues, such as research on the functioning of payment systems, central bank market operations or even aspects of monetary policy transmission.

One particularly interesting example of a further potential use for these data is the study by Galan et al. (2013). It shows, inter alia, how individual payment data can be helpful for macroeconomic purposes. The authors start from the idea that the overall volume of interbank activity contained in TARGET2 data can be exploited to develop high-frequency measures of macroeconomic activity. They develop a daily measure of activity (which they call “daily GDP”) and show that there is a strong correlation between bank transactions and traditional GDP, which is only available on a quarterly basis. In other words, payment system data may be a very useful and timely source for measuring economic activity.

Box 3: USING TARGET2 PAYMENT SYSTEM DATA FOR MACRO-PRUDENTIAL ANALYSIS

In the context of the ESCB MaRs network, the Governing Council has granted 15 researchers from WS3 dedicated access to transaction-level data from the TARGET2 payment system. Cooperating with payment system experts, this group pursued a joint research agenda on the WS3 questions that could be answered best with these common data and by pooling expertise across the central banks that are connected via TARGET. This box briefly describes how these data can be put to work for macro-prudential analysis, in particular regarding interbank market developments and their implications for bank stability and contagion, and highlights some key results of the 11 papers produced in this coordinated effort, which started at the end of 2012. More extensive discussions of these papers, the methodologies they apply and their results are embedded in other parts of this chapter.

TARGET2 is the Eurosystem settlement system for large-value payments in euro.[§] Operational data derived from the system include all types of transaction among banks, the greatest interest from a macro-prudential perspective lies in analysing interbank loans, which are not identified specifically in the raw dataset of payment transactions. Payment system experts and researchers from several European central banks have joined forces to extract the interbank loan contracts from the raw data. Arciero et al. (2013) and De Frutos et al. (2013) have created two alternative datasets, which both rely on the implementation of the Furfine (1999) algorithm.^{§§} This algorithm matches transactions between banks on a specific date with a reverse transaction at a later date, accrued by a plausible interest rate. The result of this procedure is a detailed picture of individual interbank loans, their sizes, interest rates and counterparties. Both datasets have been validated by matching the identified interbank loans with the transaction-level data available for the Italian and Spanish MID platforms, as well as the individual EONIA panel contributions.^{§§§} The validation shows that the algorithm is very reliable for identifying TARGET2 interbank loans, especially for maturities up to three months. Given the confidentiality of the underlying data, high security requirements have been applied at every stage of the data and subsequent research work and only very aggregated information has been disseminated outside the group of dedicated researchers.

A first application of the resulting interbank lending data is to track the overall evolution of money markets over time from a financial stability perspective. For example, Garcia et al. (2013) find that, at the beginning of the crisis, many banks were still trading with each other, albeit at lower volumes. The density of the trading network only dropped significantly in the acute phase of the euro area sovereign debt crisis and after the three-year refinancing operations stabilising the system. Gabrieli and Georg (2013) find evidence that, after the Lehman bankruptcy, only the term segment of the market froze, as banks switched from longer maturities (1 to 12 months) to the shortest possible one (overnight). Moreover, Hoffmann et al. (2013) suggest that the interbank market continued to be integrated after the Lehman bankruptcy and throughout 2009, but that it showed strong signs of fragmentation at the peak of the sovereign debt crisis in the second half of 2011.

A second strand of work deals with interbank relationships and risk assessments. For example, Abassi et al. (2013) and Gabrieli and Georg (2013) provide evidence that, in periods of elevated credit risk, relationship borrowers benefit from larger loans and lower interest rates than banks borrowing from a counterparty with which they do not have a standing relationship. This is also consistent with the evidence of Rünstler (2013), who suggests that counterparties with past trading relationships tend to buffer their individual liquidity shocks. Di Filippo's (2013) analysis suggests that, even after the Lehman Brothers bankruptcy and later ECB liquidity injections, euro interbank market participants were able to differentiate among their counterparties according to their creditworthiness, providing lower volumes and charging higher interest rates in proportion to their non-performing loans.

A last body of work derives bilateral interbank exposures from the lending data and studies contagion effects directly via various forms of counterfactual simulations. Gabrieli et al. (2013) reckon that the evolving structure of interbank lending is of primary importance for assessing contagion risk, estimating that the number of defaulting banks under stressed market conditions can vary by a factor of five or six depending on the underlying network. Di Iasio et al. (2013) suggest that contagion effects can be enhanced through market-driven balance-sheet effects, irrespective of whether outright defaults occur. Taking this into account, they find that a bank's role as a potential spreader of contagion is highly non-linear in its size, even though some highly interconnected small banks can also become a source of material risk to the system.

All in all, this joint cross-country research effort highlighted the great value of actively using payment system data for macro-prudential analysis.

§	Payments are settled in TARGET2 via the central banks participating in the system (all euro area central banks plus five non-euro area ones). The system settles transactions between financial institutions, as well as those of many ancillary systems, such as the Italian e-MID and the Spanish MID, electronic money markets system for interbank loans. Although other payment systems are available (such as EURO1), the overwhelming majority of money market transactions are settled through TARGET2. See Kokkola (2010) for more details.
§§	Furfine's original method was applied to the US Fedwire payment data and, subsequently, has been implemented for many other payment systems around the world: Millard and Polenghi (2004) in the United Kingdom, Hendry and Kamhi (2007) in Canada, Akram and Christophersen (2010) in Norway, Heijmans et al. (2010) in the Netherlands, Guggenheim (2010) in Switzerland. Arciero et al. (2013) and De Frutos et al. (2013) are the first to apply the Furfine method to the euro area TARGET2 payment system.
§§§	Armantier and Copeland (2012) raise a major concern about the reliability of the Furfine algorithm applied to the US Fedwire payment system. Matching the filtered data with a dataset of bilateral transactions between two large US dealers, they find 81% of Type I errors and 23% of Type II errors. As explained before in this chapter, validation of the interbank loan data from TARGET2 – using a variety of alternative data sources – has detected only relatively small errors in the European context. But vigilance is certainly justified in verifying that this also remains so in the future.

4.2 Cross-sectoral spillovers using financial accounts

Two MaRs WS3 studies exploit financial accounts data at an aggregate level: one for the euro area as a whole, another for a small euro area economy. The advantage of this approach is that it makes it possible to study the aggregate interconnectedness and contagion among the various economic sectors (financial firms, nonfinancial firms, households, government etc.) and thereby link financial spillovers and contagion to the macroeconomy. Castrén and Rancan (2013) construct cross-sectoral networks of financial assets and liabilities for individual euro area countries, which are then connected across borders for the euro area as a whole. Simulations reveal that the contagious impact of negative credit shocks 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, including 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.

Silva (2010) uses financial accounts data to infer the level of interconnectedness among sectors of the Portuguese economy. The paper replicates the euro area approach adopted by Castrén and Kavonius (2009) at the national level. Silva (2010) finds 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 sectoral level, the methodology allows losses stemming from the market price of credit risk to be distinguished from other losses. The results suggest that the latter account for the vast majority of losses. However, the credit 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.

4.3 Special initiative on sovereign contagion risk

WS3 was originally meant to focus on interbank contagion. The European sovereign debt crisis that started from around the end of 2009, however, demonstrated the importance of sovereign debt exposures.

Indeed, the increases in sovereign bond spreads, which partly differed in their timing across countries but nevertheless were related to each other, suggest that it may not only be idiosyncratic factors (government debt levels) or exposures to common shocks (due to the financial crisis) that caused the rise in spreads, but also contagion.⁴⁸ Here, financial stress for one country's sovereign may spread both to other countries' sovereigns and to the financial sector.⁴⁹ In 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 that contributed to this initiative. The papers use a variety of data: sovereign CDS spreads (Broto and Perez-Quiros 2011, Calice et al. 2013, Kocsis 2013, Zhang et al. forthcoming), sovereign bond yield spreads (Barbosa and Costa 2010, Claeyns and Vašíček 2012, 2014, De Santis 2012, Conefrey and Cronin 2013), and bank equity returns (Mink and De Haan 2012). Some of these papers are also interesting from the perspective of WS2 on early warning systems and systemic risk indicators.⁵⁰

To investigate the extent of sovereign contagion, the WS3 authors use a wide range of econometric methodologies, ranging from dynamic factor models (Broto and Perez-Quiros 2011, Barbosa and Costa 2010), cointegration analysis and regressions (De Santis 2012), event study based on bank equity data (Mink and De Haan 2012), forecasting error variance decompositions from vector autoregressions (Claeyns and Vašíček 2012, 2014, Conefrey and Cronin 2013), Markov-switching unobserved component model and quasi-threshold VAR (Calice et al. 2013), to a dynamic copula for dependence (Zhang, Schwaab, and Lucas, forthcoming).

Most of these studies find that European sovereign credit spreads – measured as either 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 2013, and Zhang, Schwaab, and Lucas, forthcoming). 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 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 country-specific developments, consistent with investors “waking up” to different risk profiles across countries around 2009 (Broto and Perez-Quiros 2011).

Most authors in WS3 find evidence of sovereign contagion in the euro area since the onset of the 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 2011, De

⁴⁸ Constâncio (2012) discusses the early evidence on sovereign contagion in Europe.

⁴⁹ This initiative did not address particularly the sovereign-bank stability nexus (except the papers by Alter and Beyer 2013 and Cooper and Nikolov 2013), which is the subject of a paper in WS1 (Pierrard et al. 2013).

⁵⁰ For example, both Broto and Perez-Quiros (2011) and Zhang et al. (2012) contain risk measures that are interesting from a financial stability surveillance perspective.

Santis 2012, Kocsis 2013 and Zhang, Schwaab, and Lucas, forthcoming). However, Claeys and Vašíček (2014) argue that what often seems to be contagion is actually more of an abrupt break in interdependence (due to higher shocks), rather than genuine contagion (due to stronger transmission mechanism).

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

Broto and Perez-Quiros (2011) find some evidence that Greece was a source of sovereign risk contagion during most of 2010. Other countries, such as Italy and Spain, were 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.

Calice et al. (2013) employ the CDS term premium as a forward-looking measure of idiosyncratic sovereign default risk. They decompose it into two unobserved components of statistically different natures (i.e. stationary and non-stationary) and study determinants of their short-term dynamics in a vector autoregression with various observed financial market variables. They find that the strongest impact can be attributed to CDS market liquidity, local stock returns and overall risk aversion. On the contrary, the impact of shocks from the sovereign bond market is rather muted. Therefore, CDS market micro-structure effects and investor sentiment play the main role in sovereign risk evaluation in real time. Moreover, the results suggest that the response of CDS term premium to shocks in financial variables can be ten times stronger during periods of high volatility.

Claeys and Vašíček (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 permanently in magnitude since 2007. Moreover, they document significant spillovers from news about rating downgrades to the yields of other government bonds. Claeys and Vašíček (2014) extend this framework to test for contagion. Testing for structural breaks in their vector autoregressive framework, they find that the frequent surges in co-movement across bond markets are mainly driven by larger shocks rather than by an increase in the intensity of shock transmission, i.e. what often appears to be contagion may not be contagion.

Conefrey and Cronin (2013) also use a vector autoregressive framework to assess spillovers in euro area sovereign bond markets. They find changing spillover values over time, lending support to the view that the euro area sovereign bond crisis has moved from being driven initially by broadly-based systemic concerns to a later focus on country-specific developments. While Greece had a strong influence on euro area bond markets around the time of its first bailout, this had diminished by the time of its second bailout. After that event, it became relatively detached from other markets. There is evidence pointing to the re-establishment of spillover patterns that existed before the crisis with gross spillovers having fallen over time from 2009-10 levels and net spillovers again occurring from the core to the periphery.

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 can, together, explain most of the observed developments in sovereign spreads. He also reports 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 those most affected by them.

Zhang, Schwaab, and Lucas (forthcoming) 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 (2013) 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 a deterioration of public finances in several countries suffice to largely explain rising yields in euro area peripheral countries for the period from 2008 to early 2010. Hence, for this period, contagion is not “needed” as an additional factor to explain rising yields.

Using an event study approach, Mink and De Haan (2012) distinguish 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 or Government 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, whereas news about a Greek bailout does. The result holds true 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 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.⁵¹

⁵¹ These conclusions are exactly in line with the problems found in the empirical bank contagion literature (De Bandt and Hartmann 2000).

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Work stream 1

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De Frutos, J.C., C. Garcia, F. Heider and P. Papsdorf, “Stressed interbank markets: Evidence from the European financial and sovereign debt crisis”, mimeo, ECB, 2013.

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Annex 1: MaRs contributors					
	<i>Plenary members</i>	<i>NCB coordinators</i>	<i>Work stream 1</i>	<i>Work stream 2</i>	<i>Work stream 3</i>
			<i>Macro-financial models linking financial stability and the performance of the economy</i>	<i>Early warning systems and systemic risks indicators</i>	<i>Assessing contagion risks</i>
Work stream coordinators			Philipp Hartmann Laurent Clerc	Carsten Detken Kateřina Šmídková	Paolo Angelini Simone Manganelli
Consultants			Javier Suarez (CEMFI)	Hans Degryse (Katholieke Universiteit Leuven)	
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Bank of Greece	Heather D. Gibson	Eleni Angelopoulou Hiona Balfoussia Heather D. Gibson	Eleni Angelopoulou Hiona Balfoussia Heather D. Gibson Dimitris Louzis Angelos Vouldis	
Banco de España	Juan Jimeno			Gabriel Pérez-Quirós Sofia Galán
Banque de France	Laurent Clerc	Denis Beau Laurent Clerc Ramona Jimborean Jean-Stéphane Mésonnier	Vladimir Borgy Laurent Clerc Jean-Paul Renne	Valère Fourel Silvia Gabrieli Julien Idier Mario Di Filippo

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Bank Ċentrali ta' Malta (Central Bank of Malta)	Christine Balzan			-
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Oesterreichische Nationalbank	Martin Summer	Nicolas Albacete Martin Summer		

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		Sandra Gomes		Luciana Barbosa
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European System of Central Banks - non-euro area					
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Danmarks Nationalbank	Kim Abildgren Sean Hove		Kim Abildgren Brigitte Vølund Buchholst Jacob W. Ejsing Atef Qureshi Jonas Staghøj		
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Banca Națională a României	Ion Drăgulin	Adrian Costeiu Irina Mihai Florian Neagu Alina Tarta	Irina Mihai Luminita Tatarici Florian Neagu	Horatiu Lovin	
Sveriges Riksbank	Kasper Roszbach			Xin Zhang	
Bank of England	Benjamin Nelson Victoria Saporta	Paweł Zabczyk Benjamin Nelson	Marc Faraq Julia Giese	Marco Galbiati (seconded to ECB)	

Annex 2: MaRs conferences

First Conference of the Macro-Prudential Research Network (MaRs) of the European System of Central Banks hosted by the European Central Bank

5-6 October 2011, Frankfurt am Main

WEDNESDAY, 5 OCTOBER 2011

08.15 - 08.45 Registration

08.30 - 09.00 Welcome coffee

09.00 - 09.15 **OPENING REMARKS**

Jean-Claude Trichet (President, European Central Bank)

09.15 - 10.30 **SESSION 1: FINANCIAL INSTABILITY AND THE MACROECONOMY**

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)

Paper 2: “Financial Crises, Credit Booms and External Imbalances: 140 Years of Lessons” by Oscar Jordá (University of California, Davis), Moritz Schularick (Freie Universität Berlin) and Alan M. Taylor (Morgan Stanley)

Discussant: Jaume Ventura (Pompeu Fabra University and CREI)

General discussion

10.30 - 10.45 Coffee break

10.45 - 12.00 **SESSION 2: LEVERAGE CYCLES AND MACRO-FINANCIAL LINKAGES**

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)

Paper 2: “Leverage, Balance Sheet Size and Wholesale Funding” by H. Evren Damar, Césaire A. Meh and Yaz Terajima (Bank of Canada)

Discussant: Luc Laeven (International Monetary Fund)

General discussion

- 12.00 - 12.50 **POLICY KEYNOTE**
Vítor Constâncio (Vice-President, European Central Bank)
- 12.50 - 14.00 Lunch
- 14.00 - 15.50 **SESSION 3: MACRO-PRUDENTIAL POLICY**
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)
- Paper 2: “Macro-prudential Policy and the Conduct of Monetary Policy” by Denis Beau, Laurent Clerc and Benoît Mojon (Banque de France)
- 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)
- Discussant: David Aikman (Bank of England)
- General discussion
- 15.50 - 16.05 Coffee break
- 16.05 - 17.00 **RESEARCH KEYNOTE**
Markus Brunnermeier (Princeton University)
- 17.00 - 18.15 **SESSION 4: CONTAGION RISK**
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)
- Paper 2: “Funding Costs and Loan Pricing by Multinational Bank Affiliates” by Alexis Derviz and Marie Raková (Česká národní banka)
- Discussant: Morten Bech (Bank of International Settlements)
- General discussion
- 20.00 Dinner

THURSDAY, 6 OCTOBER 2011

08.30 - 09.00 Coffee

09.00 - 10.15 SESSION 5: FINANCIAL STABILITY INDICATORS

Chair: Kateřina Šmídková (Česká národní banka)

Paper 1: “A Financial Systemic Stress Index for Greece” by Dimitrios P. Louzis (Bank of Greece) and Angelos T. Vouldis (Bank of Greece)

Paper 2: “Mapping the State of Financial Stability” by Peter Sarlin (Åbo Akademi University) and Tuomas A. Peltonen (European Central Bank)

Discussant: John Theal (Banque centrale du Luxembourg)

General discussion

10.15 - 11.10 RESEARCH KEYNOTE

Jean-Charles Rochet (Universität Zürich)

11.10 - 11.25 Coffee break

11.25 - 13.15 SESSION 6: EARLY WARNING MODELS

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)

Paper 2: “Predicting Recession Probabilities with Financial Variables Over Multiple Horizons” by Fabio Fornari and Wolfgang Lemke (European Central Bank)

Paper 3: “Business Cycles, Monetary Transmission and Shocks to Financial Stability” by Kim Abildgren (Danmarks Nationalbank)

Discussant: Ray Barrell (Brunel University)

General discussion

13.15 - 13.20 Closing

13.20 - 14.30 Lunch

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

30-31 October 2012, Frankfurt am Main

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 Macro-prudential 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: FINANCIAL INSTABILITY AND THE MACROECONOMY

Chair: Heinz Herrmann (Deutsche Bundesbank)

Paper 1: “Booms and Systemic Banking Crises” by Frederic Boissay (European Central Bank), Fabrice Collard (University of Bern) and Frank Smets (European Central Bank)

Paper 2: “Stress-testing US Bank Holding Companies: A Dynamic Quantile Regression Approach” by Francisco Covas (Federal Reserve Board), Ben Rump (Federal Reserve Board) and Egon Zakrajsek (Federal Reserve Board)

Paper 3: “Bank Overleverage and Economic Fragility” by Ryo Kato (Bank of Japan) and Takayuki Tsuruga (Kyoto University)

Discussant: Xavier Freixas (Universitat Pompeu Fabra)

General discussion

SESSION 2: EARLY WARNING MODELS

Chair: Carsten Detken (European Central Bank)

Paper 1: “Predicting Bank Distress and Identifying Interdependencies amongst European Banks” by Frank Betz (European Central Bank), Silviu Oprica (European

Central Bank), Thomas Peltonen (European Central Bank) and Peter Sarlin (Abo Akademi University)

Paper 2: “Banking, Debt and Currency Crises: Early Warning Indicators for Developed Economies” by Jan Babecký, Tomáš Havránek, Jakub Matějů, Marek Rusnák, Kateřina Šmídková and Bořek Vašíček (Česká národní banka)

Paper 3: “Formal Identification of Sentiment Effects in Asset Markets” by 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)

Discussant: Philip Davis (National Institute of Economic and Social Research)

General discussion

13.10 - 14.20 Lunch

14.20 - 16.10 **PARALLEL SESSIONS**

SESSION 3: MACRO-PRUDENTIAL POLICY

Chair: Ignazio Angeloni (European Central Bank)

Paper 1: “A Macro-economic Model of Endogenous Systemic Risk-taking” by David Martinez-Miera (Carlos III) and Javier Suarez (CEMFI)

Paper 2: “An Integrated Framework for Analysing Multiple Financial Regulations” by Charles Goodhart (London School of Economics), Anil Kashyap (Chicago Booth), Dimitrios Tsomocos (Oxford University) and Alexandros Vardoulakis (European Central Bank)

Paper 3: “A Model for Assessing Macro-prudential Regulatory Policies” by Laurent Clerc (Banque de France), Alexis Derviz (Česká národní banka), Caterina Mendicino (Banco de Portugal), Livio Stracca (European Central Bank) and Alexandros Vardoulakis (European Central Bank)

Discussant: Michael Kumhof (International Monetary Fund)

General discussion

SESSION 4: CONTAGION IN FINANCIAL NETWORKS

Chair: John Fell (European Central Bank)

Paper 1: “Derivatives and Credit Contagion in Inter-Connected Networks” by Sebastian Heise (King’s College, London) and Reimer Kühn (King’s College, London)

Paper 2: “Size and Complexity in Model Financial Systems” by Nim Arinaminpathy (Princeton University), Sujit Kapadia (Bank of England) and Robert May (Oxford University)

Paper 3: “Bank Networks, Inter-bank Liquidity Runs and the Identification of Banks that are too Inter-Connected to Fail” by Alexei Karas (Roosevelt Academy) and Koen Schoors (Ghent University)

Discussant: Ester Faia (Goethe University Frankfurt)

General discussion

16.10 - 16.25 Coffee break

16.25 - 18.15 **PARALLEL SESSIONS**

SESSION 5: CROSS-BORDER BANK CONTAGION

Chair: Mauro Grande (European Central Bank)

Paper 1: “Determinants of Banking System Fragility: A Regional Perspective” by Hans Degryse (Tilburg University and KU Leuven), Mohamed Elahi (Center for Business and Economic Research) and Maria Penas (Tilburg University)

Paper 2: “Shocks Abroad, Pain at Home? Bank-Firm Level Evidence on Financial Contagion During the Recent Financial Crisis” by Steven Ongena (Tilburg University), José-Luis Peydró (Universitat Pompeu Fabra) and Neeltje van Horen (De Nederlandsche Bank)

Paper 3: “Vulnerable Banks” by Robin Greenwood (Harvard University), Augustin Landier (University of Toulouse) and David Thesmar (HEC Paris) Discussant: Robert de Young (University of Kansas)

General discussion

SESSION 6: 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” by Paolo Gelain (Norges Bank), Kevin Lansing (Federal Reserve Bank of San Francisco and Norges Bank) and Caterina Mendicino (Banco de Portugal)

Paper 2: “Bank Leverage Shocks and the Macro-economy: A New Look in a Data-rich Environment” by Jean-Stéphane Mésonnier (Banque de France) and Dalibor Stevanovic (Université du Québec à Montréal)

Discussant: Kim Abildgren (Danmarks Nationalbank)

General discussion

20.00 Dinner

DINNER REMARKS: “Insights into the Work of the ESRB”

Francesco Mazzaferro (Head, Secretariat of the European Systemic Risk Board)

WEDNESDAY, 31 OCTOBER 2012

08.30 - 09.00 Coffee

09.00 - 10.50 **SESSION 7: SOVEREIGN CONTAGION AND RUNS ON MONEY-MARKET FUNDS**

Chair: Cornelia Holthausen (European Central Bank)

Paper 1: “Conditional Probabilities for Euro-area Sovereign Default Risk” by André Lucas (University of Chicago), Bernd Schwaab (European Central Bank) and Xin Zhang (Sveriges Riksbank)

Paper 2: “Liquidity Shocks, Dollar Funding Costs and the Bank Lending Channel during European Sovereign Crisis” by Ricardo Correa (Federal Reserve Board), Horacio Saprizza (Federal Reserve Board), and Andrei Zlate (Federal Reserve Board)

Paper 3: “Runs on Money-market Mutual Funds” by Russ Wermers (University of Maryland)

Discussant: Sascha Steffen (European School of Management and Technology)

General discussion

10.50 - 11.05 Coffee break

11.05 - 12.55 **SESSION 8: FINANCIAL IMBALANCES AND POLICY RESPONSES**

Chair: Diego Rodriguez Palenzuela (European Central Bank)

Paper 1: “Macro-prudential Regulation Versus Mopping Up After the Crash” by Anton Korinek (University of Maryland) and Olivier Jeanne (Johns Hopkins University)

Paper 2: “Optimal Monetary and Prudential Policies” by Fabrice Collard (University of Bern), Harris Dellas (University of Bern), Behzad Diba (Georgetown University) and Olivier Loisel (ENSAE ParisTech)

Paper 3: “Prudential Policy for Peggers” by Stephanie Schmitt-Grohe (Columbia University) and Martin Uribe (Columbia University)

Discussant: Enrico Perotti (University of Amsterdam)

General discussion

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 Economic and Monetary Affairs, European Parliament)

Nathalie de Basaldua (Head, Financial Stability Unit of the Directorate General Internal Market and Services, European Commission)

Thomas Hoenig (Director, US Federal Deposit Insurance Corporation)

Erkki Liikanen (Governor, Suomen Pankki – Finlands Bank)

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

**Concluding Conference of the Macro-prudential Research Network (MaRs) of the
European System of Central Banks hosted by the European Central Bank**

23-24 June 2014, Frankfurt am Main

MONDAY, 23 JUNE 2014

08.15 – 08.45 Registration

08.45 - 09.00 Welcome coffee

09.00 - 10.00 **POLICY KEYNOTE**

Vítor Constâncio (Vice-President, European Central Bank)

10.00 - 11.00 **“Results of the ESCB Macro-prudential Research Network”**

Philipp Hartmann (European Central Bank and Chair of MaRs)

11.00 - 11.15 Coffee break

11.15 - 13.05 **PLENARY SESSION**

**SESSION 1: TOOLS FOR ASSESSING MACRO-PRUDENTIAL
REGULATORY INSTRUMENTS**

Chair: Anil Kashyap (University of Chicago Booth School of Business)

Paper 1: “Capital Regulation in a Macroeconomic Model with Three Layers of Default” by Laurent Clerc (Banque de France), Alexis Derviz (Česká národní banka), Caterina Mendicino (Banco de Portugal), Stéphane Moyen (European Central Bank), Kalin Nikolov (European Central Bank), Livio Stracca (European Central Bank), Javier Suarez (Center for Monetary and Financial Studies) and Alexandros Vardoulakis (Federal Reserve Board)

Paper 2: “Examples of Macro-prudential Policy Experiments in MAPMOD” by Jaromír Beneš (International Monetary Fund), Michael Kumhof (International Monetary Fund) and Douglas Laxton (International Monetary Fund)

Paper 3: “Bank Capital Requirements: A Quantitative Analysis” by Thiên Nguyen (University of Pennsylvania)

Discussant: Skander van den Heuvel (Federal Reserve Board)

General discussion

13.05 - 14.30 Lunch

14.30 - 16.20 **PARALLEL SESSIONS**

**SESSION 2: SYSTEMIC FINANCIAL INSTABILITY VERSUS FINANCIAL
CYCLES IN EMPIRICAL MACROECONOMICS**

Chair: George Tavlás (Bank of Greece)

Paper 1: “Melting Down: Systemic Financial Instability and the Macro-economy” by Philipp Hartmann (European Central Bank), Kirstin Hubrich (European Central Bank), Manfred Kremer (European Central Bank) and Robert Tetlow (Federal Reserve Board)

Paper 2: “Financial Conditions and Density Forecasts for US Output and Inflation” by Piergiorgio Alessandri (Banca d’Italia) and Haroon Mumtaz (Queen Mary University)

Paper 3: “Credit Risk in the Euro Area” by Simon Gilchrist (Boston University and National Bureau of Economic Research) and Benoît Mojon (Banque de France)

Discussant: Harald Uhlig (University of Chicago)

General discussion

SESSION 3: CONTAGION AND INTERBANK NETWORKS

Chair: Simone Manganelli (European Central Bank and MaRs WS3 coordinator)

Paper 1: “Marginal Contagion: A New Approach to Systemic Credit Risk” by Tomohiro Ota (Bank of England)

Paper 2: “Cross-border Interbank Contagion in the European Banking Sector” by Silvia Gabrieli (Banque de France), Dilyara Salakhova (Banque de France) and Guillaume Vuillemeys (Banque de France)

Paper 3: “Financial Firm Bankruptcy and Contagion” by Jean Helwege (University of South Carolina) and Gaiyan Zhang (University of Missouri - St. Louis)

Discussant: Hans Degryse (KU Leuven)

General discussion

16.20 - 16.35 Coffee break

16.35 - 18.25 **PARALLEL SESSIONS**

SESSION 4: REGULATORY POLICY INSTRUMENTS

Chair: Laurent Clerc (Banque de France and MaRs WS1 coordinator)

Paper 1: “Lending Pro-cyclicality and Macro-prudential Policy: Evidence from Japanese LTV Ratios” by Arito Ono (Mizuho Research Institute), Hirofumi Uchida (Kobe University), Gregory Udell (Indiana University) and Iichiro Uesugi (Hitotsubashi University)

Paper 2: “Bank Networks: Contagion, Systemic Risk and Prudential Policy” by Inaki Aldasoro (Goethe University Frankfurt), Domenico Delli Gatti (Catholic University of Milan) and Ester Faia (Goethe University Frankfurt)

Paper 3: “Centrality-based Capital Allocations and Bailout Funds” by Adrian Alter (International Monetary Fund), Ben Craig (Deutsche Bundesbank) and Peter Rauppach (Deutsche Bundesbank)

Discussant: Martin Summer (Oesterreichische Nationalbank)

General discussion

SESSION 5: EARLY WARNING MODELS

Chair: Kateřina Šmídková (Česká národní banka and MaRs WS2 coordinator) and Carsten Detken (European Central Bank and MaRs WS2 coordinator)

Paper 1: “Comparing Different Early Warning Systems: Results from a Horse Race Competition Among Members of the MaRs Network” by Bořek Vašíček (Česká národní banka) et al.

Paper 2: “News and Narratives in Financial Systems: Exploiting Big Data for Systemic Risk Assessment” by David Gregory (Bank of England), Sujit Kapadia (Bank of England), Rickard Nyman (University College London), Robert Smith (University College London) and David Tuckett (Bank of England)

Paper 3: “Identifying Excessive Credit Growth and Leverage” by Lucia Alessi (European Central Bank) and Carsten Detken (European Central Bank)

Discussant: Mathias Drehmann (Bank for International Settlements)

General discussion

20.00

Dinner

DINNER REMARKS: “Challenges for Policy-relevant Research”

Richard Portes (London Business School and President of the Centre for Economic Policy Research)

TUESDAY, 24 JUNE 2014

08.30 - 09.00 Coffee

09.00 - 10.50 **PARALLEL SESSIONS**

SESSION 6: INTERACTION OF MACRO-PRUDENTIAL AND MONETARY POLICIES

Chair: Carmelo Salleo (European Central Bank)

Paper 1: “Monetary Policy, Financial Regulations and Industry Growth” by Philippe Aghion (Harvard University) and Enisse Kharroubi (Bank for International Settlements)

Paper 2: “Optimal Monetary and Liquidity Policies: Gains and Pitfalls of a Macro-prudential Approach” by Michael Kiley (Federal Reserve Board) and Jae Sim (Federal Reserve Board)

Paper 3: “Liquidity Trap and Excessive Leverage” by Anton Korinek (Johns Hopkins University) and Alp Simsek (Massachusetts Institute of Technology)

Discussant: Panicos Demetriades (University of Leicester)

General discussion

SESSION 7: INTERNATIONAL SPILLOVERS AND CAPITAL FLOWS

Chair: Kamil Janáček (Česká národní banka)

Paper 1: “Global Liquidity and Drivers of Cross-border Bank Flows” by Eugenio Cerutti (International Monetary Fund), Stijn Claessens (International Monetary Fund) and Lev Ratnovski (International Monetary Fund)

Paper 2: “Crisis Transmission in the Global Banking Network” by Galina Hale (Federal Reserve Bank of San Francisco), Tümer Kapan (Fannie Mae) and Camelia Minoiu (International Monetary Fund)

Paper 3: “Macro-prudential Capital Controls and the Shadow Economy” by Julien Bengui (Université de Montréal) and Javier Bianchi (University of Wisconsin)

Discussant: Alessandro Rebucci (Johns Hopkins University)

General discussion

10.50 - 11.10 Coffee break

11.10 - 12.40 **KEYNOTE DISCUSSION:** “What Type of Economic Research can support Macro-prudential Policy?”

Chair: Frank Smets (European Central Bank)

John Geanakoplos (James Tobin Professor of Economics, Yale University)

Anil Kashyap (Edward Eagle Brown Professor of Economics and Finance, University of Chicago Booth School of Business)

General discussion

12.40 - 13.45 Lunch

13.45 - 15.35 **PLENARY SESSION**

SESSION 8: MEASURING SYSTEMIC RISK

Chair: Garry Schinasi (Independent Advisor, formerly International Monetary Fund)

Paper 1: “Structural GARCH: The Volatility-leverage Connection” by Robert Engle (New York University) and Emil Siriwardane (New York University)

Paper 2: “Syndication, Interconnectedness, and Systemic Risk” by Jian Cai (Fordham University), Anthony Saunders (New York University) and Sascha Steffen (European School of Management and Technology)

Paper 3: “Bank Size, Capital Requirement, and Systemic Risk: Some International Evidence” by Luc Laeven (International Monetary Fund), Lev Ratnovski (International Monetary Fund) and Hui Tong (International Monetary Fund)

Discussant: Christian Gourieroux (University of Toronto and Paris Graduate School of Economics, Statistics and Finance)

General discussion

15.35 - 15.50 Coffee break

15.50 - 17.50 **POLICY PANEL ON “RETHINKING ECONOMICS AFTER THE CRISIS”**

Chair: Benoît Cœuré (Member of the Executive Board, European Central Bank)

Speakers: Robert Engle (Michael Armellino Professor of Finance, New York University Stern School of Business)

John Geanakoplos (James Tobin Professor of Economics, Yale University)

Stefan Gerlach (Deputy Governor, Central Bank of Ireland)

17.50 End of conference