Policy in Adaptive Financial Markets – The Use of Systemic Risk Early Warning Tools

Abstract

Adaptive macroprudential policy is a response to a financial system in continuous transformation. In order to reduce the likelihood of and impact from systemic instability, adaptive macroprudential policy depends on the availability and quality of information about the markets. This study examines to what extent early warning systems (EWSs) of systemic financial risk are driven by and respond to these information needs. The information value of EWSs is investigated with regard to the identification of conditions within the financial system, the analysis of these conditions and the projection of systemic conditions. Particularly, the ex-ante capacities of early warning for macroprudential policy are important in the context of adaptive markets. The study grounds on both general considerations for EWSs and examples from a specific EWS. While the EWS is found to be a suitable information tool for adaptive policy and to be flexibly adjustable to this policy, its usefulness depends on the conceptual model of systemic risk underlying the policy. A question that deserves further attention is to what extent an EWS based adaptive policy itself may cause additional dynamics.

JEL: G01; G18; G28; E32; E37

Keywords: Adaptive markets, adaptive policy, early warning system, information value, systemic risk
Contents

1. Introduction ........................................................................................................................... 1
2. Information context in adaptive financial markets ............................................................... 4  
   2.1. Adaptive macroprudential policy and information..................................................... 4  
   2.2. Information from an Early Warning System (EWS).................................................. 7  
3. Adaptive macroprudential policy and EWS impulses ....................................................... 11  
   3.1. A framework .............................................................................................................. 11  
   3.2. Disclosure policy and EWS stress identification...................................................... 13  
   3.3. Target policy and EWS stress analysis ...................................................................... 17  
   3.4. Preventive policy and EWS stress projections ......................................................... 22  
4. Conclusion .......................................................................................................................... 30  
References ............................................................................................................................... 32
1. Introduction

As a consequence from their dynamics and structural changes the financial markets are considered as an “adaptive system.”\(^1\) The adaptive nature manifests itself in distinct and multiple variations of the system patterns and the behavior of its economic agents. A growing body of interdisciplinary research reveals that the financial system is increasingly complex, heterogeneous, sensitive to initial conditions, nonlinear in its processes and therefore inherently unpredictable.\(^2\) Put differently, an integral aspect and an integral problem of an adaptive financial system is its continuous state of relative instability.\(^3\) This evidence is quite contrary to the former perception and modeling of financial markets as mostly linear, rational and stable systems.

The adaptive context of the financial system imposes challenges on the prudential supervision of the system. Higher instability necessitates higher efforts to maintain stability, while the system’s growing complexity puts further constraints to supervision. In addition to the regulation of individual institutions (microprudential approach), a specific focus on the system’s overall characteristics (macroprudential approach) is essential (Borio 2003, Nier 2011).

Furthermore, as the nature of the system is adaptive (see Fig. 1), the strategy of macroprudential supervision has to be adjusted to the higher sensitivity of the system as well as to keep up with the financial system’s transformation (adaptive macroprudential policy). Particularly, an adaptive

---


\(^3\) Nicolis and Prigogine (1977, p. 464) show that in adaptive systems relative instability is a continuous state feature of the system, and that the onset of an adaptive “process is dictated by the behavior of the fluctuations.”
macroprudential policy would act in a more flexible and discretionary way depending on the intensity and nature of systemic risk. Suggestions for a more dynamic macroprudential policy are made e.g. by the Bank of England (BoE 2011) and the IMF (Lim et al. 2011a). Although the new supervisory framework of Basel III addresses aspects of a more flexible and granular regulation, an adaptive macroprudential policy would provide a distinct conceptual and use enhancement of prudential tools.

**Fig. 1:** Assets of financial intermediaries in the US 1952-2012

Given the complexity and dynamics of today’s financial systems, a major challenge for adaptive macroprudential supervision is the availability of appropriate and timely information about the system (Flood et al. 2013). Judge (2012, p. 690) considers “information loss” from fragmented markets itself as a source of systemic risk. In addition to the increased quantity of data caused by a macroprudential approach, a new quality of information about the system’s behavioral characteristics is needed. The success of adaptive macroprudential policy is supposed to be existentially dependent on the availability of this specific information. Therefore, this study aims to shed light on the relationship between adaptive macroprudential policy and its information context. This topic becomes further relevant as the multiple information disclosures required from financial institutions (“micro information”), e.g. under the accounting standards and the Basel framework, so far provide only marginal transparency to detect and prevent the recent financial crises. From an information theory point of view it may be argued that the decentralization and specialization of information may have led to a “loss of organizational control” (Monu et al. 2013, p. 77). Alternatively, a macroprudential approach to information may

---

4 E.g. the application of countercyclical capital buffer and special capital and liquidity requirements for systemic institutions.
help to restore systemic control. A new wave of understanding leaves researchers cautiously optimistic in yielding encouraging “evidence that early warning indicators exist which signal costly asset price developments in ‘real time’ and with sufficient lead to react” (Alessi and Detken 2009, p. 8).

Multiple financial stress indices (FSIs) and early warning systems (EWSs) have been developed recently to measure and display risk inside financial markets. As most of these tools have been invented by supervisory institutions it is obvious to ask if these instruments may also provide an appropriate data basis for an adaptive macroprudential policy or can be further extended to deliver necessary information. Reciprocally, the research question is: To what extent an EWS responds to the information needs of an adaptive macroprudential policy?

To answer this question, first the information requirements from adaptive macroprudential policy are analyzed – referring both to adaptive financial markets and to the design of the policy itself – and a basic overview of EWSs is given (section 2). The comparative analysis between information required and information provided begins with comparing the conceptual approach of the adaptive policy and the EWS (section 3.1). The further analysis is referred to elements of the dual mitigating and preventive directions of adaptive macroprudential policy (sections 3.2 – 3.4). A major conclusion (section 4) is that from a more technical point of view EWSs are basically well suited to support adaptive policy, however, their value depends on the conceptual approach of the adaptive policy itself.

---

2. Information context in adaptive financial markets

2.1. Adaptive macroprudential policy and information

Adaptive macroprudential policy is a response to a financial system in continuous transformation. It can be considered a continuous and sensitive process of flexibly monitoring and managing systemic financial stability as a response to the specific time and structure related patterns of the financial system. Adaptive macroprudential policy is defined and continually adjusted from its objectives, through reconsideration of its functions, redesign of its forms, and through its methodological revaluation (see Fig. 2). In this concept, objectives refer to the fundamental conceptual goals of the policy,6 functions comprise the activities exercised within that policy,7 forms include the strategies used,8 and evaluation stands for the critical assessment and potential modification of the overall process.

Fig. 2: Elements of adaptive macroprudential policy

The overall objective of adaptive macroprudential policy – maintaining systemic financial stability – may be interpreted as limiting the probability and severity of systemic failure. Information requirements from “adaptive macro stability” and, correspondingly, the functions and forms to achieve this objective refer to the aggregate, systemic character of financial markets’ risk and predicate on the capacity to distinguish the level and type of excessive exposures. Systemic risk is not only an aggregation of individual institutions’ risk, but depends

---

6 The formation of systemic risk policy objectives is discussed through seminal contributions of Acharya (2001), Elsinger et al. (2002), Borio (2003), Rochet (2004, 2005), and Nier (2011). Principally these objectives include time and cross-sectional aspects.

7 Systemic policy functions are considered starting with the influential contributions of Gonzalez-Hermosillo (1996), De Bandt and Hartmann (2000), and Borio (2006).

8 In a series of IMF papers, Lim et al. (2011a, 2011b) survey the forms and global usage of macroprudential tools.
on the risk connectivity and risk sensitivity of institutions. It also means that while in the microprudential perspective, aggregate risk is exogenous (independent of behavior of individual institutions), in the macroprudential view, aggregate risk is endogenous (dependent on collective behavior of institutions).

This endogeneity leads to the fundamental challenge in the macroprudential policy to assess the process by which the risk aggregates in the system over time (dynamics) and across the systems’ participants (structure) (Borio 2006, Aikman et al. 2013, p. 13):

− Information needs in the time dimension are concerned with the aggregate risk profile over time relative to the financial cycle and the adverse amplification between financial system and the real economy (risk procyclicality). These information requirements refer to the overall level of aggregate risk – both its actual level and past evolution – and further to the comovements of risk in different subsections of the market (risk correlation). Here it is important to know about risk amplification, specifically the parallelism of risk issues and the immediate or delayed effects from risk spillovers. To assess and manage risk evolution over time it is useful to differentiate four phases of the systemic risk process: 1) ex-ante stability (fluctuations of stress within a historically normal range), 2) ex-ante escalation (dual increases in the level and rate of financial stress), 3) systemic stress (stress within moderate to significant range of historical stress values), and 4) ex-post (stress anywhere from normal to below normal range).

− Policy in the cross-sectional dimension is concerned with a complementary dual set of issues: information about common exposures (risk concentration) and information about connectivity among institutions (risk network), particularly through their contractual obligations (Flood et al. 2013, p. 33). Acharya (2001 and 2009, p. 227) proposes a prudential approach that
separately considers exposures to systematic and idiosyncratic risk factors. Elsinger et al. (2002, p. 2) consider correlated exposures (as a source of systematic risk) and interbank exposures (as a source of contagion) in assessing the financial stability of the Austrian banking system and “find that correlation in banks’ asset portfolios dominates contagion as the main source of systemic risk.” Recent theoretical studies specifically focus on the importance of common exposures as a source of systemic risk (Allen and Carletti 2011). Wagner (2010), Ibragimov et al. (2011), and Allen et al. (2012) explore the paradox between private optimality of diversification across asset classes and its systemic sub-optimality.

The important information needs first refer to appropriately identify and analyze the system’s present and past risk profile. Further, the use of adaptive macroprudential tools is also based on projections of the future path of stress providing the time to select and apply supervisory instruments. In a theoretical assessment of banking system fragility, Gonzalez-Hermosillo (1996) argues that a macroprudential measure of financial system’s stability must be forward-looking based on the probability that the banks will remain solvent following a destabilizing shock. In the late 1990s and early 2000s, several IMF studies emphasize conceptual development and implementation of the forward-looking capacity in macroprudential mandates (IMF 2000, pp. 26-28). The forward-looking capacity is consistently included in the macroprudential strategic sets developed by the central banks in Asia and Australia following the 1997 Asian crisis.9

Forms within the adaptive macroprudential framework may be conceived in two ways. In terms of instruments needed (internally) to prepare macroprudential actions, they refer to

---

9 E.g., in Hong Kong, the Monetary Authority adopts “a forward-looking stance in supervision, [so that the] risks inherent in the business activities of banks can be identified early and mechanisms to manage such risks will be set up to deal with them effectively as they arise” (Yue 2001, p. 237).
information tools, e.g. asset pricing models, single-institution risk models, and EWSs (Lim et al. 2011b, p. 10). In terms of macroprudential actions intended to impact markets (externally), they basically include disclosure of systemic risk information and targets for systemic imbalances (for return, risk, liquidity, and structure). As forward-looking capacity becomes more important for supervisors and the adaptive context demands a more anticipatory assessment of systemic risk, the preventive policy form becomes central (Lastra 2013). Preventive policy specifically focuses on actions based on the projection (e.g. alerts, signals) of future risk. It will also include disclosure and targets, however, in this case the actions have a specific ex-ante, pre-emptive character and the information they are based upon is uncertain. This may be supposed to be a major challenge for EWSs.

In general, macroprudential policies of disclosure and targets in the time dimension seek a set of remedial actions to “create built-in mechanisms that attenuate the impact of procyclical behavior” (Cukierman 2011, p. 30). In the cross-sectional dimension, macroprudential policy controls the build-up of large imbalances of the system (common exposures) and strengthens the resilience of risk networks to attenuate risk propagation. Adaptive macroprudential policy in the stability, ex-ante and ex-post phases is mainly supported by instruments of disclosures, communication, identification, time-varying exposure targets and limits. In the critical phase the management of increased risk is based principally on limits and targets (mitigation).

2.2. Information from an Early Warning System (EWS)

EWSs for systemic risk are tools to assess and model the relationship between macrofinancial stress and stress driving factors. EWS projections about upcoming stress support the user’s risk management strategies. The global financial crisis has propelled a wave of new research in early warning tools for systemic risk (Davis and Karim 2008, Melvin and Taylor

EWSs for systemic financial risk comprise three core elements (Gramlich et al. 2010, p. 201): a theory or functional relationship to explain the emergence of financial crises, a measure of systemic conditions of risk, and a set of factors that are supposed to impact this measure. New research shows that financial crises are mainly driven by imbalances (vulnerabilities) within the financial system and/or between financial system and real economy, and are propagated also from structural weaknesses of the financial system itself (Gramlich and Oet 2011). In the context of a financial system’s stability, the accumulation of imbalances characterizes the system’s transition from a stable to an unstable state, whether through an endogenous process or due to exogenous shocks (Schinasi 2004, pp. 8-10).

Financial imbalances are defined as deviations of financial variables from their mean, so they represent pressures in the financial system. The EWS explains financial stress in the markets as a build-up of aggregate imbalances of financial sectors and/or institutions (the agents). The imbalance theory was developed by Borio and Lowe (2002a, 2002b, 2004) to study the relationship between “banking distress” and aggregate macroeconomic imbalances such as imbalances in credit-to-GDP, property prices, and equity prices. The recent EWS research increasingly extends imbalance theory to data about individual institutions.

To assess the level of stress in a financial system, mostly a financial stress index (FSI) serves as a useful measure of systemic conditions by providing a continuous signal of financial stress and broad coverage of the areas that could indicate it (Kliesen et al. 2012, Manamperi 2013). A responsive FSI methodology uses daily public market data collected from different sectors of the financial markets and employs a specific aggregation method to capture the
changing relative importance of the different sectors. As stress is always present in the financial system, significant stress is identified by observations of extreme co-movements of stress components across all markets.

While the basic architecture is generally similar across the EWSs, there are differences in particular measures of systemic risk as a dependent variable and specific variables selected as the explanatory drivers of systemic risk. However, as this study aims to provide a more conceptual analysis of the information obtainable from EWS for adaptive macroprudential policy, a comparison between different types of systemic risk EWSs is not intended (these are compared by Davis and Karim (2008) and Bisias et al. (2012). In addition, EWSs may not be regarded as mechanical and fixed, rather they are flexible instruments that are continually adjusted to the theory of systemic risk, the evolution of markets, and the availability of information. Therefore, this analysis is further based on a selected EWS as representative for the entire class of EWSs. This allows to refer to the concrete setup of an EWS and give numerical examples for the information provided.

Here, the EWS selected is the SAFE early warning tool developed at the Federal Reserve Bank of Cleveland. SAFE is applied by the Bank’s Supervision and Regulation Department, data of its systemic risk measure is available from the Federal Reserve Bank of Cleveland’s website, and the EWS is also recognized in literature (Oet et al. 2013a, 2013b). The SAFE architecture relates a measure for systemic risk – the CFSI – to a set of imbalances historically shown to drive systemic risk (see Equation (1) and Table 1). The financial stress measure CFSI is based on the level of systemic conditions (mostly spreads) in six different

---

10 E.g. a simple addition of normalized variables is employed, while other authors use weights based on principal components and portfolio considerations.
11 SAFE stands for Systemic Assessment of the Financial Environment. SAFE is explained in more detail in Oet at al. (2013b).
12 CFSI stands for Cleveland Financial Stress Index. The CFSI is presented in Oet et al. (2012).
markets and their dynamic, weighted aggregation. The four classes of imbalances (I) assessed in SAFE to explain systemic risk are: risk, return, liquidity as institutional imbalances, and imbalance of the system’s structure. In each imbalance class, the EWS includes multiple exposures with significant statistical and Granger properties in explaining financial stress in the past. The EWS explains financial stress using both public and proprietary supervisory data from systemically important institutions, regressing the imbalances using an optimal lag (l) method. The institutional and structural imbalances are selected considering their optimal lag characteristics, based on the notion that shocks to various agent exposures take varying amount of time to precipitate to the conditions that materially change the agents’ market behavior—i.e. the conditions tied to the financial markets’ stress.

\begin{equation}
\text{CFSI}_t = \beta_0 + \sum_{n=1}^{4} \beta_n \cdot I_{n,t-l(n)} + \epsilon
\end{equation}

In SAFE, some imbalances are adverse: that is, the larger the deviation of such an imbalance, the greater is the potential shock. Therefore, systemic financial stress tends to increase with the rise in adverse imbalances. Other imbalances are defensive: systemic stress tends to decrease with the rise in defensive imbalances (e.g. capital). Across institutions, the EWS distinguishes excessive exposures for adverse imbalances and sufficient exposures for defensive imbalances based on the historical association of imbalances with stress.

\textbf{Table 1:} SAFE overview – risk measure, risk function, risk factor
3. Adaptive macroprudential policy and EWS impulses

3.1. A framework

As a permanent response to continuous transformation of financial markets, adaptive macroprudential policy is particularly depending on the availability and quality of information about the markets. Much more than in the traditional regulatory approach, the adaptive policy demands data that is at the same time aggregate and granular and also timely and forward-looking. Most notably, the systemic features of procyclicality, connectivity and common exposures have to be assessed and responded to adequately. Reciprocally, the efficacy of this policy is highly sensitive to the data input, and informatory deficits will have a higher negative impact than in the traditional approach. In addition, the information tool – here the EWS – is not to be conceived as a purely technical tool for provision of data. Rather, it is to be considered as an organic part of the overall macroprudential approach reflecting the policy’s conceptual design and displaying itself the ability to adjust flexibly both to the evolution of markets and the evolution of policy:

(2) adaptive monetary policy ↔ systemic risk model ↔ early warning system

(↔ means reciprocally dependent).

Recent research addresses the relationship between proposals for macroprudential policy and information from an EWS (Frait and Komářková 2011, Schoenmaker and Wierts 2011, Sinha 2011, BoE 2011, and Oet et al. 2013a). Basically, these studies refer to strategies in the time (mostly consistent) and cross-sectional dimension (distinct details for the pursuit of

---

13 Data availability and management as a challenge of macroprudential policy are analyzed from Alampalli (2013), Bholat (2013), Flood et al. ( 2013).
14 Similarly, Monu et al. (2013, p. 76) relate to the information problem from accounting reports for supervision, where “if records are incorrect, regulators will be unable to assess the appropriateness of a firms actions.”
imbalances and connectivity) with similar information demands. The intrinsic information functions mainly involve identification of systemic conditions, identification of systemic imbalances, differentiation of excessive exposures, forward-looking and forecasting capacities, and sensitivity to systemic risk posed. Categorizing and complementing these functions from the perspective of their information objective leads to these types of information needs:15

− identification of systemic risk conditions: level and evolution of stress in the overall market and submarkets, systemic risk phases, risk amplification/ procyclicality,

− analysis of systemic risk conditions: drivers of stress (imbalances), common exposures/ risk concentration/ risk correlation, risk connectivity; both from the overall market and submarket perspective,


Table 2 displays these information requirements in the context of adaptive financial markets and directions for adaptive macroprudential policy.

**Table 2:** Information requirements in the context of adaptive markets and policy

Lim et al. (2011b, pp. 4-5) refer to the underlying model of adaptive macroprudential policy as the usefulness of functions and forms to reduce procyclicality “is sensitive to the type of shock facing the financial sector.” They further suggest that macroprudential efficacy is increased when usage includes targeted tools with higher ability to differentiate among exposures, time-varying tools that can be adjusted through the range of financial conditions, and

15 Similarly, in an investigation of macroprudential tools Lim et al. (2011a, p. 31) distinguish “Risk identification”, “Risk assessment,” and “Resilience of the financial system” as information values.
dynamic tools accompanied by clear rule-based communication thus emphasizing the distinct information requirements from this type of policy.

As the basic need for EWSs to be consistent with the policy’s theory of systemic risk is concerned, EWSs should principally be able to meet this demand. Their modular architecture enables them to easily integrate further elements (mainly based on regressions), while their flexible aggregation methods and use of high-frequency data provide a suitable basis for earlier indications of systemic conditions. Notably, most EWSs can be conceived as naturally learning systems in the sense that reported exposures change as the financial system adapts over time. They considerably extend the information provided from traditional accounting systems as a basis for supervision. However, even if EWSs prove suitable for macroprudential policy from an architectural standpoint, they also depend on the underlying theory of systemic risk. That is, in order to be able to manage systemic risk via macroprudential policy, early warning has to be based on a definition of systemic risk as well as the determination of its measure. Furthermore, to assess connectivity and contagion as explanatory factors of systemic risk, early warning has to define the nodes and linkages in a financial system.\textsuperscript{16} Taking this into account, the following sections analyze what specific information may be provided by EWS for the different directions of macroprudential policy.

3.2. Disclosure policy and EWS stress identification

As the loss of information in an increasingly adaptive system is to be considered as a major source of systemic risk (Judge 2012, pp. 690, 697), the overall strategy of macroprudential disclosure is to stabilize the system by reducing its uncertainty (information opacity). Information about the system’s characteristics complements the knowledge of individual

\textsuperscript{16} E.g., institutions, instruments, or sectors could serve as nodes.
institutions about own risks and fills knowledge gaps about risks of counterparties and markets. This “additional conditioning information” (Flood et al. 2013, p. 28) is expected to strengthen the institutions’ individual risk management. Further, as Herring (1999, p. 77) points out, the release of systemic risk information “may exercise some constraining influence” thereby attenuating the build-up of concentrations and reducing procyclicality; even if disclosure fails to prevent this build-up, it may constrain the effects from eventual corrective shocks “by reducing the destructive uncertainty about which institutions have sustained damage.” More basically, investigating and communicating systemic risk information enhances the basis for supervisors upon which to take macroprudential decisions and helps the markets to better understand this policy.

Based on an appropriate measure of systemic risk, the EWS has to provide information for disclosure in two dimensions: The current level of risk and its historical evolution (time dimension) has to be reported and also the risk in the overall system and in its main subsections (cross-sectional dimension). While emphasizing the significant policy role of regulatory disclosure and communication, it is particularly to claim that the systemic EWS driving policy applications is able to differentiate stress aggregation across time and the various phases of a stress cycle. As a consequence, the systemic information released to the markets mainly involves the level of stress and its evolution both for the overall markets and its submarkets and further the relative position of current stress with regard to stress phases.

The CFSI as an integral part of the SAFE early warning tool measures systemic stress as an aggregated index of stress from six markets.17 Systemic conditions of these markets are

---

17 As shown in Table 1, these are credit, foreign exchange, equity, interbank, real estate, and securitization markets with sixteen origination factors. All of them have proved to be significant for financial crises in the past (see
assessed on the basis of normalized spreads (more precisely: the relative rank in cumulative
density function) and aggregated using credit weights (share of market) as a dynamic weighting
method (stress adjusted to variations in share). Using the daily observable market phenomena,
the CFSI is able to continually inform the policymakers and the public about the aggregate and
sector-specific level of financial stress. In addition, this financial stress measure provides stress
grades (zones of stress) to allow the interpretation of time pattern of significant systemic stress.
The stress grades are modeled as standardized distances (z-scores) and calibrated against
independent volatility benchmarks of distress in each of the financial sectors. The CFSI finds
based on probit regression that the pattern optimally corresponds to stress grades 1-4 matching
the four conceptual time phases (ex-ante stability, ex-ante escalation, crisis, ex-post) of a
systemic stress cycle (see Fig. 3).18

Fig. 3: Systemic stress and risk grades

As shown on the right-hand-side vertical axis of Fig. 3, the CFSI provides the
probabilities of a systemic stress episode, given the particular level of stress. Here, the
probabilities are obtained by calibrating the CFSI against a set of stress benchmarks (e.g. VIX,
VDAX) given that these benchmarks themselves are under stress. For example, the May 2012
FSI level is very close to zero, falls into the normal stress grade, and implies that the probability
of this stress being a part (e.g. being the “on-ramp”) of a systemic stress episode is no greater
than 8.7%. The vertical bars in the chart represent incidents of well-known stress episodes.19

---

Oet et al. 2012 for discussion of the CFSI and comparative discussion of other US financial stress measures. These
measures show alternative allocations of sectors and factors of the US financial system.

18 By comparison, Bordo et al. (2000) suggest a five-category differentiation of distress, with a refinement
of the below normal stress grade into two categories: “moderate expansion,” and “euphoria.”

19 Oet et al. (2012) find the index to be responsive to stress episodes and a reasonably good identifier of
systemic financial stress.
This is additional information useful for institutions to assess the systemic environment, adjust own policies and get prepared for possible macroprudential reactions. It is also evident that the policymakers’ choice of policy actions in the time dimension is assisted by establishing the decision rules defining the ranges and the thresholds of systemic stress. The decision rules then allow differentiation of stress phases among the volatile time patterns of stress.

As systemic stress often evolves from single sub-markets and their correlated behavior, information about the state of stress in the sub-sections of the system is particularly useful. The SAFE early warning tool enables disaggregated information for the six markets included in the stress measure. Knowledge about the components of stress permits much more detail in macroprudential communication and also for the design of the institutions’ risk management.

Fig. 4 displays the components of stress in the US financial markets 1991-2011. Basically, information about the factors causing stress may be released as well and provide guidance for macroprudential policy and individual risk management. This information is based on a more refined assessment (here: analysis) of systemic risk and reported in the following section.

Fig. 4: Components of US financial stress by market sector

The EWS basis in the interaction of institutional imbalances and financial stress also provides the quantitative basis for the corresponding transition matrices as an additional instrument for monitoring. A typical monitoring transition matrix describes the change of a particular aggregate imbalance or a class-based set of imbalances that is associated with transition of stress from one grade to another, all else held equal. A sample transition matrix for leverage is shown in Table 3. The monitoring transition matrices may be integrated into the assessment of overall level of stress, where transition of stress components may be observed, the
analysis of the contributions of individual stress components and institutional imbalances to overall stress, and the design of policy actions (whether any action is warranted, in what area of exposure, and how to act).

**Table 3**: Sample transition matrix (leverage)

In the stability, ex-ante, and ex-post phases, the principal responsibility of regulators will be to ensure existing stability and to prevent systemic stress increase. This is mainly supported from disclosure instruments. Thus, in this time phase the macroprudential actions focus particularly on instruments that enable careful monitoring and releasing levels of stress and imbalances. As far as disclosure of information is used in the critical phase, tactics emphasize disclosure of instruments that ameliorate existing stress (generally measures of solvency and hedging) and communication of adverse imbalance limits and defensive buffers. In the critical phase, following the mitigation strategy, the macroprudential actions focus on instruments that enable reduction of adverse stress impacts. Here, instruments comprise mainly limits and targets.

However, given the considerable variation in disclosure practices (Monu et al. 2013), the substantial burden of excessive disclosure, and its information overload, it may be particularly important to clarify which exposures should be disclosed in pursuit of macroprudential objectives.

**3.3. Target policy and EWS stress analysis**

While the release of information is intended to impact the risk taking of institutions conditional to systemic conditions, effects from information release are based on voluntary

---

20 With respect to the impact of disclosure on the 2007-2009 Subprime Crisis, Kohn (2011, p. 8) argues that “excessive complexity and information overload may be limiting factors on the effectiveness of disclosures.”
actions of the institutions and therefore may have limited effects. A more restrictive instrument to accompany disclosure is the set-up of limits and targets for institutions that depends on the risk profile of the system. These limits mainly address the risk, return and liquidity profile in the context of requirements from the overall system and submarkets. As systemic effects also stem from the connectivity of institutions, Kashyab et al. (2011) suggest that collateral may serve as a further limitation depending on the degree of connectivity. Basically, limits and targets for institutions are supposed to particularly apply in the critical phase. This policy builds on the capacity of an EWS to analyze systemic conditions of risk. However, its implementation calls for detailed information about the origins of stress and the nature of imbalances.

Limits in the sense of restrictions for the risk drivers of institutions (adverse balances) and targets as levels of variables that support risk resilience (defensive balances) can be applied differently. Considering what is regulated, limits and targets refer to types of imbalances (risk, return, liquidity, structure), the type of intermediation driving risk (e.g. lending, securitization), and finally are addressed to either a single institution or a set of institutions. As far as the nature of limits and targets is concerned, they may be directed to the time dimension or cross-sectional dimension, based upon short or long run perspectives and may have adverse or defensive effects. E.g., time-varying targets can include countercyclical buffers, time-varying provisioning, and time-varying reserve requirements (Frait and Komárková 2011). Long-term macroprudential EWS utilize instruments based on the long run institutional imbalances. Specifically, they could include several new instruments of recommended targets, e.g. for consumer lending, real estate lending secured by other real estate, securitizations, and asset liability mismatch. The supervisors would utilize macroprudential EWS analysis to establish pre-targeted minimums that institutions must maintain in systemic stress phases.
A macroprudential strategy with a capacity to limit severity of failure should in particular be able to subdue the imbalances that increase financial stress and result in excessive stress propagation (time dimension). In other words, the information tool needed should be able to differentiate imbalances that are associated with amplifications in systemic risk. Applications of a systemic risk EWS in the cross-sectional dimension reflect the macroprudential policy objectives of limiting failure across institutions and strengthening infrastructure resilience. The key features of a systemic EWS driving its tactical applications cross-sectionally are its capacities to distinguish imbalances across institutions. Additionally, it has to respond sensitively to systemic risk posed through the intricate interconnections of the financial system (risk connectivity, common exposure).

Alternatively, the information tool first should be able to identify uncorrelated behavior across institutions and provide regulators with tactical instruments to encourage uncorrelated behavior. Second, the tool should distinguish those exposures that consistently reduce financial stress for both prudential perspectives, that is for the institution and the system (defensive imbalances). A classic example of such a defensive exposure is capital. To an individual institution, accumulation of capital is a defensive mechanism to reduce vulnerability to failure. To the financial system, accumulation of capital acts as protective buffer against systemic stress. Other defensive exposures include liquidity buffers and leverage targets. The resilience tool should be able to identify several of these and provide regulators with tactical instruments to encourage defensive exposures.

The SAFE early warning tool is able to differentiate imbalances and their impact on systemic risk with respect to the type of imbalance, to a single or a set of institutions, to different market segments, and/or for a combination of these aspects. Depending on the information
targeted, CFSI regressions are run from different perspectives. Specifically, as the data is assessed on the risk, return and liquidity profiles of individual institutions, the early warning tool allows the institutions to be grouped first by distinct clusters, second by the type of imbalances across the institutions, and third by the institutions across the imbalances. As Fig. 5 shows, consideration of the top twenty-five US firms across time shows evidence of idiosyncratic contributions to stress up to 1998-1999. After this time, institutional contributions to stress begin to synchronize, where the top institutions become more correlated with one another, just as they seem to become individually more diversified.

**Fig. 5:** Individual contributions to systemic financial stress (CFSI)

Complementary, the focus in Fig. 6 is cross-sectional. The risk contributions from different segments of the financial markets are shown. The risk topography of the EWS allows the study of change in aggregate risk across various markets and across time. Furthermore, the EWS provides the analytical perspective that allows common exposure analysis for tactics to limit severity of systemic failure. In fact, Fig. 6 provides clear visual evidence of the structural break of 1998 that can also be observed through the structural monitoring capacity of the CFSI.

**Fig. 6:** Financial market concentrations of top twenty-five US Bank Holding Companies

In addition, a combined perspective of risk contributions from institutions and segments can be applied. Fig. 7 shows the contribution of two different banking groups (within top twenty-five US institutions) across different business segments to overall systemic stress. The red bars indicate contributions from all institutions to increasing stress and green bars the contributions to decreasing stress. In the upper part of the figure it is asked how much LISCC (Large Institution Supervision Coordination Committee) organizations contributed to overall stress. In the lower
part the risk contributions from LBOs (Large Banking Organizations) is displayed. The analysis suggests that the LISCC and LBO groups contribute to stress at different rates. There are clear differences, e.g. related to the contributions from equity buffers, securitization, concentration in FX markets and concentration in interbank markets.

**Fig. 7:** Tiered contributions to systemic financial stress (CFSI)

Regarding the SAFE early warning tool, it can be shown that the financial stress index exhibits important autoregressive properties and that different Granger property patterns of interaction exist between institutional imbalances and financial stress. These Granger causality association patterns are shown in Fig. 8 with the positive imbalance-to-stress-relationships above the horizontal axis and the negative relationships below the axis. The short-lag contributions indicate Granger causalities from 1-6 quarters, and the long-lag imbalances are those from 7-12 quarters. The patterns of association of institutional imbalances with financial markets’ stress allows the EWS to establish and utilize several basic monitoring models, including an FSI-based benchmark model, and some basic short and long run models based on publicly available data.

**Fig. 8:** Institutional imbalances’ Granger contributions to stress

In addition to recognizing the impact of imbalances at a given point in time, the instruments should recognize the varying weight of the imbalance’s contribution to overall predicted financial stress. Fig. 9 shows a 1Q 2012 example of that the actions of the financial agents result in varying sensitivities of the long-lag imbalances to financial stress. As this example illustrates, among the imbalances with consistent Granger properties to financial stress that enter the EWS models, recent evidence emphasizes those imbalances with particularly high
stress interaction sensitivities. Based on recent analysis, potential EWS based time-varying limits\textsuperscript{21} would include liquidity index, aggregate expected default frequency, interbank concentrations, and leverage. The time-varying limit instruments are also relevant in the cross-sectional dimension, as policymakers further attribute adverse imbalances to specific institutions and form detailed microprudential limits.

**Fig. 9:** Potential targets and limits through monitoring of imbalance contribution

Similarly, the defensive imbalances can also become the source of time-varying policy targets, where policymakers can target financial institutions to maintain certain defensive aggregate exposures at a certain level. For example, as Fig. 9 suggests, recent EWS analysis supports the beneficial effect of the post-crisis institutional deleveraging on financial stress. Across institutions, early warning improves identification of adverse common exposures.

### 3.4. Preventive policy and EWS stress projections

Although forward-looking capacity and outcome estimation are elements principally inherent to any policy, adaptive macroprudential policy demands a much more specific anticipation of future systemic conditions (Lastra 2013). In the context of adaptive financial markets, the capacity to learn and adjust to the prospective changes in system sensitivity is a basic need for policy. Anticipating the transformation of the system, estimating the markets’ reaction to policy actions (feedbacks), and self-adjusting accordingly are elementary. From the perspective of policymakers, the type, intensity and projected duration of the adaptive

\textsuperscript{21} There are different possibilities to construct these limits. One possibility for example could be to fix limits as one standard deviation from long-term mean. Another could be to refer to some level below the migration level to a higher stress grade.
macroprudential tool can be adjusted to the systemic risk projection with a larger time perspective. Particularly, when the forecast of concurrent stress is below a target action level, this approach supports a policymakers’ laissez-faire decision to let the markets’ self-resolve. When forecast of stress exceeds the target level of stress, this approach enables a policymakers’ risk management process to weigh the economic costs of regulatory action against economic costs of a shock. Consequently, in addition to the identification and analysis of the most recent and historic conditions on financial markets, an information tool applied from adaptive macroprudential policy has to provide projections of the system’s future state.

Forward-looking information about the system further enhances the institutions’ own forecast for risk management. Alerts about upcoming systemic risk may help to reduce uncertainty and attenuate the system’s adverse reactions. Further, timely information about intended actions from macroprudential policy itself can make the institutions more prepared and avoid precipitant reactions. This approach to include forward-looking information both into the design of own actions and as a tool for systemic orientation is referred here as preventive policy. It is supposed that – in addition to the assessment of current and historic stress – a higher quality of information and subsequently a higher quality of macroprudential policy arise from estimates of future stress. However, projections of stress are hypothesized scenarios, basically subject to uncertainty and may thus cause further dynamics.

Getting estimates for macroprudential policy may follow two directions, the first mainly based on the continuation of past and present conditions (extrapolation), and the second taking into account new scenarios on the markets and/or reactions of the markets as a consequence of
policy actions based on estimates (forecasting). In the extrapolation approach, patterns inherent in current and historic data are supposed to repeat or continue in the future and therefore provide guidance for forward-looking policy.

However, as has been argued, adaptive markets evolve along a path of structural transformation and dynamic sensitivity. A projection approach that is more in line with this would center on estimates of future scenarios and behavioral aspects of markets as a consequence of supervisory actions. Consequently, as Bernanke (2004) points out in the context of macroeconomic policy, a more forecast-based policy “must predict how the economy is likely to respond in the medium term—say, over the next six to eight quarters—to alternative plans for monetary policy.” The adaptive challenge of policymaking is addressed through three distinct features of regulatory policies: preemptive policymaking (forward-looking in the time dimension), ex-ante structural monitoring (assessment in the cross-sectional dimension), and risk-management approach. In particular, under the risk management approach to policymaking, a central bank must “project not only the most likely scenarios for the economy but also what amounts to a probability distribution of possible economic outcomes” (Bernanke 2004).

Similarly, in an important early study of “Prudential supervision to manage systemic vulnerability,” Guttentag and Herring (1988) consider policy options to counteract financial agents’ behavioral factors such as cognitive bias and Knightian uncertainty. They strongly advocate the use of systemic application of supervisory stress testing. Herring (1999, p. 77) emphasizes that by “specifying the kinds of shocks and magnitudes of shocks that banks should be prepared to sustain, the regulatory authorities can ensure that low-probability, high-severity

\[22\text{ In the context of macroeconomic policy Bernanke (2004) similarly refers to “feedback policy” (linked to a small number of variables that are observable) and “forecast-based policy” (linked to the best guess of how the economy is likely to evolve).}\]
hazards are not simply ignored.” Consequently, an EWS conducive to the forecasting approach has to provide functions enabling to easy modify the settings of data and behavior and further the analysis of outcome from this modification.

Basically, an EWS provides several features to respond to the demands of extrapolation and forecasting and may be flexibly adjusted to a forward-looking adaptive macroprudential policy:

− As has been shown, the SAFE architecture as a regression approach enables projections of systemic stress from extrapolating the underlying institutional and structural imbalances.

− SAFE distinguishes between two time perspectives, a short-lag and a long-lag model to adjust for different dynamics on the markets and to provide distinctive projections in the time horizon.

− The SAFE setting incorporates different features to be used within a scenario and/or stress testing approach: The underlying imbalances and indicators can be adjusted to assumptions about the future, changing the regression coefficients provides the ability to adjust for different risk sensitivities and for changes in the markets behavior, the approach is flexible to incorporate new drivers of risk and aggregate them to the existing ones. However, even if the EWS architecture is flexible from a technical point of view, the results depend fundamentally on the selected scenarios.

Specifically, as the time horizon of projections is concerned, the EWS considers short-lag models that historically have taken relatively short time (from one to six quarters) to precipitate into the financial system stress, and imbalances that take relatively longer (from seven to twelve quarters, long-lag models). The two modeling perspectives have distinctly different functions and lead to different models of macroprudential policy. Short-lag models function are
dynamically, seeking to explain stress in terms of recent observations of it and of institutional imbalances that tend to produce stress relatively quickly and with a short lead. They are predominant in times of ex-ante escalation and crisis for the mitigation of prospective stress. Long-lag models seek to explain the buildup of financial stress well in advance, in terms of institutional imbalances that tend to anticipate stress with a long lead. They are important for prevention strategies. For each of the two forecast horizons, the respective EWS forecast combination highlights the most persistent features of the institutional imbalance models in explaining and forecasting financial system stress.

Fig. 10: Out-of-sample forecast as of 2Q 2007

A first graphic output from the EWS out-of-sample forecast is shown in Fig. 10. The forecast is for the second quarter 2007 that is typically considered as the beginning of the most recent financial crisis (subprime crisis). The graph compares the actual realized stress index (solid line) against the two sets of EWS out-of-sample forecasts: near-term using short-lag imbalances (dashed lines) and medium term using long-lag imbalances (dotted line).

Projections of future systemic stress are enhanced by statistical properties of the systemic stress measure. In the case of the CFSI, it can be shown that the index exhibits important autoregressive properties and that different Granger property patterns of interaction exist between institutional imbalances and financial stress (see Table 4). The patterns of association of institutional imbalances with financial markets’ stress allow the EWS to establish and utilize several basic forecasting models. These include a CFSI-based benchmark model (autoregression) and some basic short and long run models based on publicly available data.

Table 4: Benchmark and base models out-of-sample static forecasts
In his seminal critique of econometric policy evaluation, Lucas (1976, p. 41) emphasized the point that the short-term success of econometric forecasting in capturing past change in the system had no policy value, since the system will change in the future in response to a policy change, resulting in “deviations between the prior ‘true’ structure and the ‘true’ structure prevailing afterwards.” To remedy this limitation, Lucas suggests the use of adaptive forecasting where policy must take into account the adaptive behavior of the economic agents. New research on the dynamics of feedbacks in financial systems poses additional challenges. The key problem is the greater understanding of the dynamic effects and the variety of the transmission mechanisms by which regulatory policies may feed back into financial systems and for which there is significant theoretical and empirical evidence (e.g. Bijlsma et al. 2010). This evidence shows that financial systems have a number of elements with procyclical response to various shocks. Under shocks, these elements can initiate a dynamic sequence from being shock absorbers into shock amplifiers.

Principally, it has to be admitted that feedbacks and non-linear reactions of the system deserve a particular class of modeling. This class is mainly based on behavioral considerations, individual scenarios, and based on simulations for a range of assumptions. Although an EWS may provide indications for the intensity and directions of stress impulses from changing variables, it has to be complemented by further modeling tools. For example, these tools may include approaches from system dynamics theory and agent-based modeling.

In the forward-looking, preemptive approach the concept of signals or alerts for upcoming stress is elementary. This addresses requirements for the early identification of changes of variables supposed to impact systemic risk. Alerts can be established on the basis of
changes in the financial stress series. Fig. 11 shows alerts for the CFSI series from 4Q 1991 to 4Q 2011. Here, the alerts are obtained from the CFSI’s one-period (FSI₁) and two-period (FSI₂) intertemporal change. Analysis of FSI trends would alert policymakers to the significant developing stress in the 3Q 1998 (the advent of LTCM crisis) and the 3Q 2007 (the advent of Subprime crisis). The two-period intertemporal rate of change FSI₂ at these points showed a movement of one standard deviation or more: 1.0 and 1.3 standard deviations respectively.

**Fig. 11:** FSI, FSI₁, and FSI₂ alerts

EWS based tactics of macroprudential policy to strengthen resilience in the event of shock to a particular exposure center on the principal defensive means to withstand the shock. These tactics implement two types of strategic emphasis: The first type consists of tactics that encourage idiosyncratic imbalances across significant institutions and the second referring to tactics that encourage defensive imbalances. In the stability and ex-ante phase of systemic stress these tactics include e.g. the building up of defensive exposures through time-varying risk weights (mainly for capital and liquidity), versions of short run and long run defensive targets, and also the progressive reduction in required minimum buffers and targets when institutions show certain idiosyncratic imbalances or exceed defensive targets. In the critical phase additional instruments are suggested to help reduce stress, e.g. stress-testing targets for institutional liquidity, stress-testing targets for fire-sale liquidity buffer, and leverage targets. Among these instruments, probably the most challenging set of instrument design issues is raised by the time-
varying risk weights. This instrument is not unique to the EWS tactics. In fact, it is common across several macroprudential mandates.23

Table 5: Impulse responses and preventive application of structural imbalances

To estimate the reaction of the system to (fast) changing variables, the EWS should be conducive for sensitivity analyses. As an illustration, the concept of impulse responses is applied to the SAFE early warning tool. Table 5 shows the results from testing the impact on CFSI when varying structural imbalances. As can be seen, higher leverage increases systemic stress with a maximum effect in the third quarter following the impulse. Alternatively, an increase in connectivity has an attenuating effect on systemic stress (highest impact in quarter 3), while consequences from varying FX concentration display mixed effects.

As a consequence from assessing impulse responses, the defensive imbalances can also become the source of forward-looking, time-varying policy targets. Policymakers can target financial institutions to maintain certain defensive aggregate exposures at a certain level. For example, the results from Table 5 support the beneficial effect of the post-crisis institutional deleveraging on financial stress. Current forecasts retain this defensive impact of deleveraging, assuming that the interaction sensitivity with financial stress is maintained at its present level. Based on further impulse responses, time-varying targets suggested from EWSs may also include capital buffer, consumer lending, real estate lending, securitizations, asset liability mismatch, stress-testing for fire-sale liquidity buffer, stress-testing for solvency distance to stress, connectivity, and change in FX currency concentration.

23 E.g., Acharya (2011) explains this instrument as implemented by the Reserve Bank of India.
4. Conclusion

To be conducive for macroprudential policy in adaptive financial markets, an information tool has to support the identification, analysis, and projection of systemic risk conditions. Specific information requirements in the context of financial markets arise from the behavioral and interconnected pattern of the system. In this study it has been argued that EWSs are able to meet these requirements. The finding is based on a discussion of the EWS´s conceptual design in general and the results from a specific, selected EWS.

As a result of their modular approach mostly based on regressions, EWSs are flexibly adjustable to the design of the underlying systemic risk policy. As they include multiple sets of high frequency data from markets and aggregated confidential data from institutions, they offer a much more comprehensive and timely information than either standard macroeconomic data usually employed for economic forecasts or institutional data usually employed for supervision. Particularly, measuring the level of stress in relation to its historical path allows determining risk grades, phases, and an indication of the cyclicality of systemic risk. Based on the inclusion of multiple granular data, EWSs offer analyses of systemic risk from very different perspectives. These comprise risk contributions from sectors, institutions, types of imbalances, and also, via the comparison of risk contributions, the indication of common exposures, risk concentrations, and risk correlations.

Estimations of future systemic stress and ex-ante actions adjusted to these estimations are a prerequisite for efficient adaptive macroprudential policy. Using optimal lags, Granger causality, and impulse responses, EWSs provide many opportunities to develop future risk trajectories in the short and long run (extrapolation). From a technical point of view, EWSs can easily be run for different scenarios. This adaptability helps policymakers test potential strategies.
by experimenting with models that are sensitive to the possible outcomes from own actions. However, while extrapolations are supported technically, EWSs have limited ability to invent assumptions on their own and do not generate future scenarios by themselves (forecasts). The value of forecasts from an EWS is therefore related to the quality of anticipations about changes in risk factors, risk sensitivity and risk connectivity defined from the EWS user.

Basically, although EWSs are found to be highly suitable for adaptive macroprudential policy from a conceptual and instrumental point of view, their information value essentially depends on the systemic risk model itself. Notably, policy has to determine up to what extent financial markets are considered to be relevant, what are the central elements (nodes) in this context and what type of relationship (connectivity) to consider. In addition to providing data for macroprudential policy the EWS may be used to test the underlying theory of systemic risk itself and – by a permanent comparison of conceptual theory and data output – constantly improve the macroprudential risk model. To this extent, the value of EWSs’ data may be complemented by integrating further techniques as e.g. network analysis and behavioral finance. In addition, as EWSs head for a new quality of systemic information, there is also the restriction to provide new data input into the early warning tool (Lim et al. 2011b, p. 11).

A basic problem related to the identification and analysis of systemic risk is that it may emerge from patterns “for which we have no precedent” (Judge 2012, p. 659). This is particularly relevant for adaptive markets. Alternatively, assessing systemic risk on the basis of own considerations and scenarios may lead to unrealistic assumptions. A particular challenge while applying EWSs’ projections for macroprudential policy is that the policy itself leads to feedbacks and an increase in dynamics. This further increase of the system’s adaptive response to macroprudential policy has to be considered as a major challenge of the adaptive policy itself.
A further question is therefore, up to what extent policy should restrict itself to ex-post response to the transformation of markets or direct itself ex-ante to control the sensitivity of system’s adaptation.

References


### Table 1: SAFE overview – risk measure, risk function, risk factor

<table>
<thead>
<tr>
<th>Systemic risk measure (CFSI subindices)</th>
<th>Systemic risk model (function)</th>
<th>Systemic risk factor (imbalance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreads including</td>
<td>Regressions based on</td>
<td>Institutional</td>
</tr>
<tr>
<td>– funding (financial beta, bank bonds, ...)</td>
<td>– type of imbalance</td>
<td>– return (equity, derivatives, currency, ...)</td>
</tr>
<tr>
<td>– foreign exchange (weighted currency crashes)</td>
<td>– type of institution</td>
<td>– risk (credit, interest rate, solvency, ...)</td>
</tr>
<tr>
<td>– credit (corporate bonds, treasuries, ...)</td>
<td>– type of subsector</td>
<td>– liquidity (asset-liability-gap, liquidity index)</td>
</tr>
<tr>
<td>– equity (stock market index crashes)</td>
<td>Optimal lags</td>
<td>Structural</td>
</tr>
<tr>
<td>– real estate (CRE, RRE)</td>
<td>– short-lag</td>
<td>– system (concentration, connectivity)</td>
</tr>
<tr>
<td>– securitization (ABS, CMBS, ...)</td>
<td>– long-lag</td>
<td></td>
</tr>
</tbody>
</table>

Information
- public data
- supervisory data

Optimal lags
- short-lag
- long-lag

Information
- public data
- supervisory data

### Table 2: Information requirements in the context of adaptive markets and policy

<table>
<thead>
<tr>
<th>Adaptive financial system</th>
<th>Dynamics</th>
<th>Structure</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- variation of dynamics</td>
<td>- varying</td>
<td>- complex</td>
<td>- systemic risk ≠ sum of single risks</td>
</tr>
<tr>
<td>- variation of structure</td>
<td>- sensitive</td>
<td>- fragmented</td>
<td>- almost non-predictable</td>
</tr>
<tr>
<td>Information requirement: systemic conditions</td>
<td>- non-linear</td>
<td>- connected</td>
<td></td>
</tr>
<tr>
<td>➔ EWS</td>
<td>- bounded rational</td>
<td>- correlated</td>
<td></td>
</tr>
</tbody>
</table>

Identification
- nature of risk
- level of risk
-- overall risk
-- sectional risk
-- evolution of risk
-- cyclicality
-- parallelism

Analysis
- model of the system
-- nodes
-- connectivity
- model of risk
-- imbalance
-- common exposure
-- driver (type) of risk

Projection
- extrapolation/forecast
- simulation
-- stress tests
-- scenarios
-- risk sensitivity

Adaptive macroprudential policy
- reduce probability and severity of systemic risk
- system sensitive to the time dimension
cross-sectional dimension

Disclosure
- exposure (systemic)
- connectivity
- concentration
- contribution

Target
- default
- liquidity
- leverage
- collateral

Prevention
- alert
- announcement
- design of policy
time dimension
cross-sectional dimension
Table 3: Sample transition matrix (leverage)

<table>
<thead>
<tr>
<th></th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>-</td>
<td>$X_{1,2} = 3.5$</td>
<td>$X_{1,3} = 7.2$</td>
<td>$X_{1,4} = 10.4$</td>
</tr>
<tr>
<td>Grade 2</td>
<td>$X_{2,1} = (3.5)$</td>
<td>-</td>
<td>$X_{2,3} = 3.7$</td>
<td>$X_{2,4} = 6.9$</td>
</tr>
<tr>
<td>Grade 3</td>
<td>$X_{3,1} = (7.2)$</td>
<td>$X_{3,2} = (3.7)$</td>
<td>-</td>
<td>$X_{3,4} = 3.2$</td>
</tr>
<tr>
<td>Grade 4</td>
<td>$X_{4,1} = (10.4)$</td>
<td>$X_{4,2} = (6.9)$</td>
<td>$X_{4,3} = (3.2)$</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: $X_{i,j}$ denotes the change in imbalance, measured in standard deviations, that is associated with transition of stress from grade $i$ to grade $j$. 

- 38 -
Table 4: Benchmark and base models out-of-sample static forecasts

<table>
<thead>
<tr>
<th>Panel A: Benchmark FSI model</th>
<th>$FSI = 7.85 + 0.60FSI_{-1} + 0.24FSI_{-4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>8.35</td>
</tr>
<tr>
<td>DF = 58</td>
<td>K = 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Candidate base model</th>
<th>$FSI = 36.58 + 0.35FSI_{-1} + 1.70GT.AL3_{-5} + 7.04GT.LEVN_{-9} + 2.34\Delta PMKTCP_{-5} - 12.62\Delta CRCAP.NV_{-11}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>11.70</td>
</tr>
<tr>
<td>DF = 61</td>
<td>K = 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C: Short-lag base model</th>
<th>$FSI = 38.77 + 0.40FSI_{-1} + 2.06\Delta HFX4_{-11} + 8.65\Delta HEQ5_{-11} + 8.15GT.LEVN_{-5} - 2.94\Delta EQLGDW3_{-7} - 4.55CR.EVSV_{-6}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>9.04</td>
</tr>
<tr>
<td>DF = 61</td>
<td>K = 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel D: Long-lag base model</th>
<th>$FSI = 37.85 - 9.88GT.ALG3_{-9} + 2.29 EDF_{-11} - 2.24 CR.EVNV_{-6} + 4.55 GT.HIB_{-6} + 11.20 GT.LEVN_{-7}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>15.14</td>
</tr>
<tr>
<td>DF = 57</td>
<td>K = 5</td>
</tr>
</tbody>
</table>
Table 5: Impulse responses and preventive application of structural imbalances

<table>
<thead>
<tr>
<th>Uses</th>
<th>Correlation with financial stress</th>
<th>Impulse response to positive innovation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Time-varying instrument</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>-Short-term time dimension instrument</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>-Long-term time dimension instrument</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>-Short term cross-sectional instrument</td>
<td>-0.75</td>
<td></td>
</tr>
<tr>
<td>-Long-term cross-sectional instrument</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

**Leverage † †**

![Graph](image)

**Connectivity Indicators – CoVaR at 5% †**

![Graph](image)

**Change in FX Currency Concentration † †**

![Graph](image)
Fig. 1: Assets of financial intermediaries in the US 1952-2012

Note: Vertical bars highlight episodes of change in relative ranking of financial sectors by total assets

Fig. 2: Elements of adaptive macroprudential policy

- **Objectives**
  - Managing systemic instability (systemic stability)
  - Sensitivity to risk profile (across time and sections)

- **Functions**
  - Systemic monitoring
  - Systemic projection

- **Information**
  - Early warning system
  - Single risk model
  - Asset pricing model

- **Evaluation**
  - Efficiency
  - Feedbacks

- **Forms**
  - Disclosure
  - Target
  - Prevention
Fig. 3: Systemic stress and risk grades

Fig. 4: Components of US financial stress by market sector
**Fig. 5:** Individual contribution to systemic financial stress (CFSI) of top twenty-five US Bank Holding Companies

**Fig. 6:** Financial market concentrations of top twenty-five US Bank Holding Companies
Fig. 7: Tiered contribution to systemic financial stress (CFSI) for the LISSC and LBO groups: 2Q 2007

Note: The red bars show stress escalation and green bars show stress reduction for each quarter, while the blue bars represent LISCC and LBO contributions to that total.

Fig. 8: Institutional imbalances’ Granger contributions to stress
Fig. 9: Potential targets and limits through monitoring of imbalance contribution to stress

Note: The figure describes sample long-lag contributions of a subset of the top twenty-five bank holding companies as of 1Q 2012.

Fig. 10: Out-of-sample SAFE EWS forecast as of 2Q 2007
Fig. 11: FSI, FSI₁, and FSI₂ alerts