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Review

Macroprudential policy: A review☆

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ABSTRACT

The severity and longevity of the recession caused by the 2007 financial crisis has highlighted the lack of a reliable macro-based financial regulation framework. As a consequence, addressing the link between the stability of the financial system as a whole and the performance of the overall economy has become a mandate for policymakers and scholars. Many countries have adopted macroprudential tools as policy responses for safeguarding the financial system. This paper provides a literature review of macroprudential policies, its objectives and the challenges that a macro-based framework needs to overcome, such as financial stability, procyclicality, and systemic risk.

Contents

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1. Introduction

> *One of the causes of the recent crisis was that concerned parties in the United States and Europe had not sufficiently learned the lessons from the bubble and financial crisis in Japan and the Asian financial crisis, so Japanese financial institutions might face similar problems in the future if they fail to sufficiently learn the lessons from the recent financial crisis in the United State and Europe.*
> Masaaki Shirakawa, Governor of the Bank of Japan[1]

If one wants to draw a parallel between the overall economy and the human body, the financial system would be the cardiovascular system, the banks would be the veins and the vessels and the capital would be the blood. Banks, as "institutions whose current operations consist in granting loans and receiving deposits from the public"[2] play a crucial role in allocation of capital and financial intermediation in the economy (see Merton, 1993). Therefore, significant failures in the financial sector create a severe scarcity in the credit supply, and raise the cost of intermediation which consequently cause unpleasant economic fluctuations (see Friedman and Schwartz, 1963). For instance, Hoggarth et al. (2002) show that the cumulative output loss are 15–20% of the annual GDP during a banking failure crisis, Laeven and Valencia (2010) document that the median output loss of the recent financial crisis is 25%. Major economic fluctuations yield long-standing low growth rates (sometimes negative) and consequently a high unemployment rate and harsh austerity measures by the governments.[3]

The frequent occurrence of financial crises and their consequences has led many to suspect that the existing financial regulatory framework is not sufficient to insure the stability of the financial system *as a whole* (for instance, see Davis, 1999; Crockett, 2000; Borio, 2003; Knight, 2006). They argue that the existing regulatory framework has a pure micro-based nature which is aimed at protecting the individual financial institutions. The idea behind the current regulatory framework is that keeping individual banks safe ensures the safety of the system as a whole. However, academics and some regulators have argued for a while that by looking at individual institutions in isolation, risks are overlooked that are only visible at the system level. The 2007 global financial crisis highlighted some shortcomings of the current regulatory framework, specifically its inability to address the stability of the financial system as a whole. Macroprudential policy, as an attempt to address this concern, has become a focal point of interest for policymakers and central banks, from the Central Bank of Japan and Thailand to the US Federal Reserve and Bank of Canada.[4] Also securities regulators around the world have increased their efforts to safeguard market infrastructure.

The term "macroprudential" has become a popular term after the recent financial crisis (see Fig. 1). However, as noted by Clement (2010), the origin of the term "macroprudential" can be traced back to the late 70s. One of the major concerns at this time in the financial regulatory circles was the rapid growth of loans to developing counties and its potential negative impact on financial stability. In 1979, the term "macroprudential" was first introduced at a meeting in the Cooke Committee (the predecessor of the present Basel Committee on Banking Supervision, BCBS) to address the issue of international bank lending. Shortly after the meeting the term "macroprudential" was introduced in a document

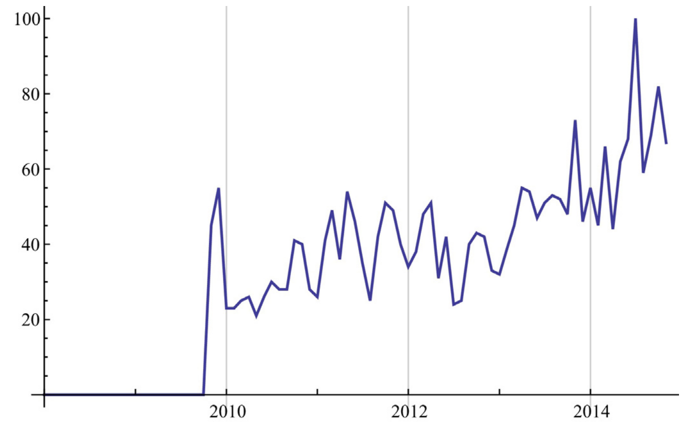

Fig. 1. Intensity of Google search for the term "macroprudential" over time. Note that the vertical axis does not represent the absolute number of Google searches over time. Each point on the graph is divided by the highest point and multiplied by 100.

prepared by the Bank of England (see Maes, 2009). The objective of the document was to investigate the use of prudential measures as one of the approaches to curb lending (Clement, 2010 provides a more in-depth review of the origins and evolution of the term "macroprudential").

This paper provides a brief survey to macroprudential policy and related challenges facing policymakers and scholars wishing to construct a reliable regulatory framework. This paper is organized as follows. Section 2 discusses the deficiencies of a pure microprudential approach to regulation. These deficiencies stem from ignoring the interconnectedness of the financial institutions and the effect of the collective behaviour of these institutions on financial stability. Section 3 provides the contemporary objectives of macroprudential policy and the related issues that need to be addressed in a comprehensive macroprudential framework such as financial stability, systemic risk, and the procyclicality of the financial sector. Section 4 surveys potential tools for implementing macroprudential policy. Section 5 summarizes where we are on implementing macroprudential measures and concludes.

2. What does the microprudential orientation miss?

> *[In 2006,] more than 99 percent of all insured institutions [in the US] met or exceeded the requirements of the highest regulatory capital standards.*
> Federal Deposit Insurance Corporation (2006)

As noted by the International Monetary Fund (2011), macroprudential policy is a complement to microprudential policy for safeguarding the financial stability. Therefore, the natural starting point for understanding macroprudential policy is to understand what a pure microprudential orientation misses. In 2006, 99% of the U.S. insured financial institutions met or exceeded the requirements of the highest regulatory capital standards yet the U.S. is widely seen as the epicentre of the recent global financial crisis. This section aims to illustrate some of the deficiencies of microprudential regulatory framework.

As argued by Crockett (2000) and Brunnermeier et al. (2009) the logic behind a pure microprudential orientation suffers from severe fallacies of composition.[5] Borio (2011a) argues, one of the underlying logics of the microprudential orientation is that "*financial stability is ensured as long as each and every institution*

[1] Shirakawa (2009).
[2] See Freixas and Rochet (1997).
[3] For instance, Reinhart and Rogoff (2009) observe that in financial crises unemployment rate increases by an average of 7 percentage points and lasts over four years.
[4] See Shirakawa (2009), Nijathaworn (2009), Bernanke (2011), Smaghi (2009), Gauthier et al. (2012) and Krznar and Morsink (2014).
[5] Samuelson (1955) defines a fallacy of composition as "a fallacy in which what is true of a part is, on that account alone, alleged to be also true on the whole."

Table 1
Differences between micro- and macro-prudential orientations.

	Macroprudential	Microprudential
Proximate objective	Limit financial system-wide distress	Limit distress of individual institutions
Ultimate objective	Avoid output (GDP) costs	Consumer (investor/depositor) protection
Characterization of risk	Seen as dependent on collective behaviour "endogenous"	Seen as independent of individual agent's behaviour "exogenous"
Correlations and common exposures across institutions	Important	Irrelevant
Calibration of prudential controls	In terms of system-wide risk: top-down	In terms of risks of individual institutions: bottom-up

Source: Borio (2003).

is sound".[6] As noted by Hellwig (1995), due to the interconnection of financial institutions, what may look stable at the individual level can be fragile and unstable at the macro level[7] (see also Hellwig, 1994). Moreover, as noted by Crockett (2000), assuring the soundness of each individual institution may provide excessive protection which harms market efficiency and discipline. Schinasi (2005) argues that irregular financial failures at the micro level yield a more vigorous financial system. Therefore, excessive protection of individual financial institutions deprives the financial system of "creative destruction" which is the most fundamental feature of a healthy capitalism.

As noted by Crockett (2000) and Morris and Shin (2008), another fallacy of composition that macroprudential policy suffers from is that actions and decisions that make sense for individual institutions in isolation, always yield desirable aggregate outcomes.[8] In the following section some practical illustrations of this fallacy of composition are discussed in the context of aggregate risk. Table 1 provides a brief review of the differences between microprudential and macroprudential orientations.

2.1. Endogenous versus exogenous risk

As noted in Table 1, microprudential orientation assumes that the risk is given by the market and does not depend on the decisions that are made by the individual financial institutions and the movement of asset prices is exogenous. In contrast, a macroprudential orientation treats the aggregate risk as an endogenous variable that depends on the collective behaviour of financial institutions. A brief look at the financial crises that had significant macroeconomic impacts illustrates this point. As observed by Gourinchas and Obstfeld (2012) this phase is characterized by rapid accumulation of leverage, domestic credit growth, and appreciation of real currency.[9] The ravenousness of the economic boom is fed by an extensive credit expansion and over-optimism regarding asset prices produces high levels of leverage (see Geanakoplos, 2010; Schularick and Taylor, 2012). The expansion and optimism in the economy increases and covers the over-extension in balance sheets. In this phase it makes sense (i.e. is profitable) for individual financial institutions to increase their leverage levels and provide excessive and cheap credit. However, as noted by Brunnermeier et al. (2011), if they all make this decision concurrently, the result is an extensive build-up of financial imbalances and latent risk which consequently sows the seeds of a financial crisis.[10]

In 2007, Chuck Prince, the former CEO of Citigroup said "when the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you have got to get up and dance. We are still dancing." The second phase, as the reverse of the first phase, starts when the "music of liquidity" stops. This phase starts with an unpredictable trigger. As noted by Borio (2003), it can happen either in the financial system or in the real economy. As noted by Tirole (2011a), this phase is characterized by substantial illiquidity, shortage of capital, and high levels of volatility in asset prices. In this phase it makes perfect sense for an individual financial institution to cut lending and sell assets. However, if they all make this decision simultaneously (because of the shortage of capital or regulatory requirements), it creates a high level of scarcity in the loan market (i.e. a credit crunch).[11] As noted by Bernanke et al. (1991), this yields a leftward shift in the supply curve for bank loans. In this situation consumers and entrepreneurs find credit substantially more expensive which causes a substantial output loss.[12]

During a recession there is an extensive shortage of liquidity in the financial sector. As argued by Squam Lake Working Group on Financial Regulation (2010) it is reasonable to force a troubled financial institution to sell some of its assets to provide liquidity and reduce the risk in its portfolio. However, if a significant portion of the financial sector sells their assets concurrently, a *fire sale* (see Shleifer and Vishny, 1992) occurs and a large shift in the supply curve of these assets causes a dramatic fall in the price of those assets.[13] The drop of prices may harm solvent institutions holding those assets and create a cascade of fire sales (see Shleifer and Vishny, 2011 for a contemporary review and discussion of fire sales). Fire sales exacerbate the fragility of the financial sector if they occur on a large scale.[14]

To illustrate the endogenous nature of systemic risk, Acharya (2009) examines a model in which financial institutions can invest

[6] For instance, the United States Federal reserve, in Glossary of Federal Reserve Terms, defines banks supervision as the "concern of financial regulators with the safety and soundness of individual banks, involving the general and continuous oversight of the activities of this industry to ensure that banks are operated prudently and in accordance with applicable statutes and regulations."

[7] He gives an example where a large number of equally sized banks $n = 1, \ldots, N$ each perform maturity transformation from month n to $n + 1$. While each bank only has small maturity transformation risk, the aggregate risk is immense.

[8] Bianchi and Mendoza (2010) propose a dynamic stochastic general equilibrium model to address two of the main concerns in the macroprudential literature: can over-borrowing cause significant macroeconomic problems (e.g. financial crises), and can macroprudential framework, which is adopted as response to the recent financial crisis, be effective in taming over-borrowing. The model shows that over-borrowing can be tamed with state-contingent schedules of taxes on debt and dividends. Moreover, the model indicates that the frequency and severity of financial crises are substantially higher in the competitive equilibrium than the equilibrium achieved by the regulator. See also Bianchi and Mendoza (2013) and Bianchi et al. (2012).

[9] Jorda et al. (2011) also observe that rapid credit expansions is the best predictor of financial instability.

[10] Dell'Ariccia et al. (2012) provide an evidence for bank's low denial rates when providing loans in the U.S. subprime mortgage boom. Their findings are consistent with the view that is discussed in this section (i.e. during an economic boom financial institutions become aggressive risk-takers and provide excessive and cheap loans).

[11] Bernanke et al. (1991) define a credit crunch as "a decline in the supply of credit that is abnormally large for a given stage of the business cycle."

[12] See Brunnermeier (2009) and Mizen (2008) for a comprehensive discussion of the 2007–2008 credit crunch.

[13] Cifuentes et al. (2005) provide a model that in a system of interconnected financial institutions regulatory solvency constraints depress the market prices of the assets owned by these institutions.

[14] See Shleifer and Vishny (2010) and Diamond and Rajan (2011) for other mechanisms through which fire sales harm the financial system.

in safe and risky assets in different industries. The correlation between the institutions' portfolios (i.e. systemic risk) stems from the choice of the industry. In this model when a financial institution goes bankrupt, there are two contradictory consequences for the surviving institutions. First, a spillover from the failed institution. Second, the positive gain from attracting the depositors of the failed institution. If the negative effect of spillover outweighs the positive gain, one optimal choice for institutions is to increase the probability of surviving (and also failing) together by investing in similar industries.

2.2. Moral hazard and deposit insurance

> *The general underlying thought behind the use of the word "guarantee" with respect to bank deposits is that you guarantee bad banks as well as good banks. . .. We do not wish to make the United States Government liable for the mistakes and errors of individual banks, and put a premium on unsound banking in the future.*
>
> 32nd President of the United States, Franklin Roosevelt (1933)

One approach to explaining financial crises is to interpret them as pure self-fulfilling prophecies caused by widespread panics (see Diamond and Dybvig, 1983).[15] In this approach depositors panic and withdraw their money, causing a banking crisis. Banking panics, as argued by Mishkin (1991) and Bernanke (1983), were one of the causes of the Great Depression. In order to restore the confidence of depositors and mitigate the risk of widespread bank panics, governments introduced deposit insurance.[16] In the presence of deposit insurance the depositors are not concerned about losing their deposits in the event of a banking failure and do not run the bank. Thus began the long tradition of adopting deposit insurance as a tool to assure the stability of financial institutions and consequently the stability of the financial system.[17] However, deposit insurance, similar to any insurance contract, can pose the threat of moral hazard. As noted by Mishkin (2001), deposit insurance guarantees that if a bank fails, depositors would not suffer from the losses. Therefore, depositors do not have the incentive to monitor banks' behaviour and discipline them when banks engage in risky activities (for instance by withdrawing their deposits). Moreover, as noted by Keeley (1990), since potential losses are covered by a third party and the banks' shareholders have limited liability, banks have an incentive to become excessive risk-takers.[18] Anginer et al. (2014) and Le (2013) provide evidence that the adoption of deposit insurance increases the risk taking of individual banks and the systemic fragility of the financial system. See Allen et al. (2011), for a recent and comprehensive discussion of the efficiency of deposit insurance and its effect on the risk-taking behaviour.

3. The objectives of macroprudential policies

Policymakers and academics have not yet achieved universal consensus on the objectives of macroprudential policy. Schoenmaker and Wierts (2011) and Galati and Moessner (2013) also provide reviews of the objectives of macroprudential policy.

The dominant theme of macroprudential policy is mitigating systemic risk and its aggregate cost for the real economy. The International Monetary Fund (2013) and the Financial Stability Board (2011) argue that macroprudential policy is introduced to mitigate systemic risk.[19] Borio (2003), in one of the earliest attempts to build a macroprudential framework, argues that the proximate objective of macroprudential policy is to curb the risk of episodes of system-wide financial distress and its ultimate goal is to limit output costs (GDP loss) in the event of such episodes.[20] Securities regulators are also concerned about systemic risk (see e.g. IOSCO, 2011), the resiliency of markets, and market efficiency.[21]

As noted by Borio (2011b) and Caruana (2009, 2010a) the aggregate risk in the financial system should be addressed with respect to two crucial dimensions: first, the time dimension, the dynamic of aggregate accumulation of risk in the financial system over time. Second, the cross-sectional dimension, the distribution of the risk across financial institutions at a point in time. Caruana (2010a) argues that macroprudential policy should address the common exposures and inter-linkage between financial institutions to reduce the systemic risk in the cross-section dimension and the procyclicality of the financial system to reduce systemic risk in the time dimension. We want to follow this classification and analyze the cross-sectional dimension in Section 3.2 and procyclicality in Section 3.3.

As can be seen in the above examples, the objective of macroprudential policy is still nebulous. However, three growing crucial concerns should be addressed through macroprudential policies: financial stability, systemic risk, and procyclicality of the financial sector. The rest of this section explains and provides contemporary views on these three concepts. It is important to note that

[15] This view is discussed in details in the financial stability section.

[16] In 1933 the United States federal government introduced deposit insurance as a response to the Great Depression (see Federal Deposit Insurance Corporation, 1998 for the history of deposit insurance in the United States).

[17] See Garcia (1999) for a survey of deposit insurance practices in different countries.

[18] Kane (1989) documents this phenomenon in the Saving and Loan Crisis.

[19] As noted by the International Monetary Fund (2011), macroprudential instruments are designed for (i) curbing the accumulation of financial imbalances; (ii) building defence mechanisms against severe financial distress; and (iii) addressing the systemic risk channels such as correlated and common exposures to risk, financial contagion, and excessive connectivity of financial institutions. The Bank of England (2009) notes that macroprudential policy, in general terms, should guarantee the resiliency of the financial as a whole, so that there will not be extensive interruptions in providing financial intermediation services. They argue that systemic risk, as the main threat to global financial stability, is one of the key elements in defining the objectives of macroprudential policy (Bank of England, 2011). They also note that some asset bubbles, for example "dotcom" bubble, do not cause a severe shift in aggregate supply of credit (Bank of England, 2009). Therefore, preventing asset bubbles is an unrealistic objective for macroprudential policy. As opposed to Bank of England's approach, Landau, the former Deputy Governor of Bank of France, notes that avoiding bubbles is a possible hypothetical objective for macroprudential policy. However, the problem is that bubbles can only be identified after they burst (see e.g. Landau, 2009). Moreover, he argues macroprudential policy addresses the financial system as a whole and its interaction with the overall economy, whereas systemic risk is about the internal interactions of the institutions inside the financial sector. Bean (2015) provides interesting insights by comparing the financial stability objective with that of price stability. He argues that policymakers should first focus on 'protecting banks from the cycle' as opposed to 'protecting the economy from the cycle', which will be harder to achieve.

[20] Shin (2010) argues that the interconnectedness of financial institutions (and consequently systemic risk) increases with excessive growth in assets held by financial institutions. Therefore, excessive growth rate is an essential issue that an effective macroprudential policy must address. Perotti and Suarez (2010) argue that macroprudential policy must discourage financial institutions from making decisions that significantly contribute to systemic risk. Perotti and Suarez (2009) propose that institutions pay a mandatory liquidity charge (liquidity risk premium) to central banks and governments in good times to be used as a liquidity insurance in the event of a systemic crisis. In a practical approach, Hanson et al. (2011) argue macroprudential policy should minimize the social cost of balance sheet shrinkage of financial institutions when a common shock hits a significant portion of the system. The social cost of this shrinkage mainly stems from credit crunches and fire sales. As noted by Kashyap et al. (2011), macroprudential policy should address three sources of instability: defaults, credit crunches, and fire sales. They argue that fire sales were one of the major issues in the recent crisis, therefore, a comprehensive macroprudential framework should limit the risk of fire sales.

[21] The international Organization of Securities Commissions in IOSCO (2014) defines systemic risk as follows: "systemic risk refers to the potential that an event, action, or series of events or actions will have a widespread adverse effect on the financial system and, in consequence, on the economy." See also IOSCO (2010, 2013).

systemic risk has different definitions. For instance, in central banking and policymaker circles the procyclicality of the financial sector is considered as time-varying systemic risk. In this paper the cross-sectional dimension of systemic risk is discussed in the systemic risk section and the time-varying dimension of systemic risk is discussed the procyclicality of the financial system section.

3.1. Financial stability

The most significant economic event of the era since World War II is something that has not happened: there has not been a deep and long-lasting depression.

Minsky (1982)

Allen and Wood (2006) note that the term "financial stability" (as an independent objective from price stability) was first used in 1994 by the Bank of England. Although the term is fairly new, the concept is an old one. Volcker (1984) notes that "the principal reason for the founding of the Federal Reserve [in 1913] is to assure stable and smoothly functioning financial and payments systems". Padoa-Schioppa (2003) provides a brief review of the history of central banks and financial stability. There have been extensive efforts by scholars and policymakers to define financial stability and assign an indicator for its measurement. However, there is still no widely accepted definition or measurement in the literature. From a practical perspective, as noted by Goodhart (2006), assessing financial stability of the banking sector is an intractable task. He argues this is mainly because of cross-border spillovers, lack of a clear demarcation line between banks and shadow banks,[22] and the financial vulnerabilities in the sectors that are connected to the banking sector.[23] One way of defining financial stability is to define its absence, i.e. financial instability and financial crises (see Mishkin, 1999). Another way is to define financial stability through the primary functions of the financial system: efficient allocation of capital, enabling individuals to smooth consumption across time or across states of nature and sustainable intermediation (see Haldane et al., 2004; Bundesbank, 2003). Schinasi (2005) argues these three elements should be considered in defining financial stability: first, efficient allocation of capital. Second, a forward-looking approach to assess financial risk. Third, the ability to absorb financial and real economic shocks.[24]

As noted by Borio and Drehmann (2009), in order to provide a framework for addressing financial (in)stability, three analytical dimensions should be considered: (i) are the financial crises self-fulfilling prophecies[25] or driven by fundamentals? Diamond and Dybvig (1983), as one of the most influential approaches to explaining financial crises, provide a model with multiple equilibria. In this setting, an equilibrium exists wherein all the depositors panic and withdraw their deposits from the banks, causing a widespread banking crisis. In their model the shift to the widespread bank run equilibrium does not necessarily stem from fundamentals governing banks' conditions (i.e. it can be caused by random events). In this setting, banking crises emerge only because of the depositors belief about their emergence (see also Bryant, 1980). On the other hand, the fundamental-based approach assumes that financial crises emerge only when there is a change in fundamentals. One of the most influential documentations of the link between financial crises and fundamentals was provided by Gorton (1988). He shows that crises are caused by the systematic response of depositors to increasing risk (see Allen and Gale, 1998; Jacklin and Bhattacharya, 1988; Goldstein and Pauzner, 2005 for fundamental-based models).[26]

(ii) Are financial crises caused by endogenous cycles or exogenous shocks? The endogenous-cycle view was originally developed by Minsky and Kindleberger (see Minsky, 1992; Kindleberger and Aliber, 2011). This view has become very popular since the recent financial crisis. For instance, the sub-prime mortgage market crisis, in August 2007, is called the "Minsky moment". According to this view, during prosperous periods in the economy, financial institutions engage in riskier investments and build up financial imbalances. Therefore, it is mainly the financial system that makes the economic system fragile.[27] This concern and the approaches to address it, are discussed in Section 3.3. On the other hand, exogenous-shock models assume that a financial crisis occurs because of extensive financial distress caused by an exogenous shock. As noted by Goodhart (2006), these shocks can stem from oil prices, productivity, labour militancy, a shift in (equity) risk aversion and a shift in exchange rate preferences. Hannoun (2010) mentions that considering the endogenous-cycle view is one of the key elements in designing a global financial stability framework.

(iii) Do shocks propagate in the financial system through systemic risk channels or idiosyncratic spillovers? In one approach to systemic risk (direct systemic risk) the financial distress, caused by the failure of some institutions, propagates in the whole financial system through a domino effect. In this approach, the shock transmissions mechanism can stem from different sources such as claims between financial institutions (Allen and Gale, 2000), credit restrictions (Kiyotaki and Moore, 1997), and interbank payment systems (Rochet and Tirole, 1996b). In another approach to systemic risk (indirect systemic risk), shocks simultaneously spread in the system. The indirect systemic risk stems from various reasons such as banks holding similar, correlated assets (Lehar, 2005; Allen and Gale, 2004; Acharya, 2009). In recent years systemic risk has become an indispensable element in assessing and achieving financial stability.[28] For instance, Bernanke (2009) states that financial institutions with high systemic risk contribution should receive special supervisory oversight and be subject to higher capital requirements. Moreover, as noted by Caruana (2010b), the "macroprudential overlay" in Basel III aims at mitigating systemic risk. For a recent discussion of systemic risk and global financial stability see Ellis et al. (2014). The next section provides the prevailing definitions and approaches for measuring systemic risk.

3.2. Systemic risk and systemic crises

We asked the Central Banks whether they have an official definition of financial stability and/or systemic risk, and if so, what definition. Only the Bank of Canada could provide an official definition of systemic risk.

Oosterloo and de Haan (2004)

Systemic risk as one of the main factors in assessing financial stability is a fairly new concept in the central banks and policy-makers' circles. However, the attempt to define and evaluate systemic

[22] See Gorton (2010) for an introduction to shadow banking system and its role in the recent financial crisis.

[23] Moreover, Schinasi (2004) notes it is unlikely to define and assess financial stability by a single target value. See Gadanecz and Jayaram (2009) for a review of measures for assessing financial stability.

[24] Padoa-Schioppa (2003) and Gonzalez-Paramo (2007) define financial stability in a similar fashion.

[25] Merton (1948) notes that "the self-fulfilling prophecy is, in the beginning, a false definition of the situation evoking a new behaviour which makes the original false conception come true."

[26] This debate also exists in the currency crisis literature (see the debate between Krugman, 1979; Obstfeld, 1996).

[27] See Palley (2010) for an introduction and discussion of Minsky's financial instability hypothesis. Bhattacharya et al. (2015) provide evidence for Minsky's financial instability hypothesis using leverage cycles.

[28] Oosterloo and de Haan (2003) argue that systemic risk is the most fundamental concept in understanding financial stability.

risk in the financial system can be traced back to mid 90s (see Kaufman, 1995). This section explores the prevailing definitions and approaches for measuring systemic risk.

Some of the early definitions of systemic risk focus on a substantial disruption of confidence and information in the banking sector and consequently in the financial sector. For instance, Mishkin (1995) argues that "systemic risk is the likelihood of a sudden, usually unexpected, event that disrupts information in financial markets, making them unable to effectively channel funds to those parties with the most productive investment opportunities."[29] Bartholomew and Whalen (1995) define systemic risk as "the likelihood of a sudden, usually unexpected, collapse of confidence in a significant portion of the banking or financial system with a potentially large real economic effect."[30] Some of the definitions focus on the propagation of distress and loss from one institution to another (also known as contagion phenomenon). For instance, Rochet and Tirole (1996a) argue that systemic risk "refers to the propagation of an agent's economics distress to other agents linked to that agent through financial transaction". The most recent approaches define systemic risk as the risk of a correlated and simultaneous failure of a significant portion of the banking sector. For instance, Lehar (2005) defines systemic crisis as "an event in which a considerable number of financial institutions default simultaneously." Acharya (2009) argues that "a financial crisis is systemic in nature if many banks fail together, or if one bank's failure propagates as a contagion causing the failure of many banks."[31] There are two main ways of measuring systemic risk: a micro based approach based on modelling the interbank network and a macro approach based on stock price data, which will be discussed in more detail in the following two subsections.[32]

3.2.1. Network based modelling

This stream of literature models in detail the interbank network as a contagion channel. When some banks are not able to honour their promises in the interbank market they might push other banks into insolvency which might again lead to further knock-on defaults. Most of this work is based on Eisenberg and Noe (2001) who define a clearing payment process for interbank networks considering all possible contagion effects. In their setting no dead weight losses occur when a bank defaults so their clearing mechanism is redistributing the existing assets in the banking system without any economic loss. Elsinger et al. (2006) include bankruptcy costs in their simulation of the Austrian banking system and show that the system is able to absorb shocks well for small bankruptcy costs while large dead weight losses can wipe out the banking system. Rogers and Veraart (2013) formally model clearing in interbank networks with bankruptcy costs.[33]

Financial networks are "robust-yet-fragile" (Haldane, 2013; Gai and Kapadia, 2010, and more formally Acemoglu et al., 2015, or Glasserman and Young, 2015), which means that they are capable to absorb smaller shocks to the system but might show contagion and cascade defaults once exposed to a large enough shock.[34] The specification of shocks for individual banks within the network is thus a key component of a network model of systemic risk. Once the shock proves to be sufficiently high to trigger the default of at least one bank within the network contagion can potentially spread and systemic risk can be analyzed. Much of the current literature examines idiosyncratic shocks, often assuming the exogenous default of a single bank leaving the financial position of other banks unchanged. Such an analysis is particularly appropriate as a way to examine the consequences of default due to operational risk, fraud, or excessive exposure to one particular risk by a single bank. These studies are systematically surveyed in Upper (2011).[35]

To examine the consequences of macroeconomic shocks on banking networks one has to consider that banks have correlated asset portfolios. Thus, upon a bank default, when the threat of contagion looms, other banks might be in a weak position as well, making them more susceptible to contagion. Gauthier et al. (2012) model loan losses of banks using detailed information on banks' loan books and common industry exposures, Elsinger et al. (2006) use loan registry data to model common shocks to loan books and banks' foreign exchange and stock market exposures to model shocks from financial markets. Caccioli et al. (2015) study common shocks emanating from overlapping securities portfolios. Frisell et al. (2007) use detailed Swedish data to model common shocks.

Another approach to simulate loss scenarios for banks within a network is to back out information on banks' assets from stock market information. Following Merton (1973) who interprets equity as a call option on the firms assets, asset values, asset volatilities, and correlations can be backed out of stock prices. The joint distribution of asset values is then used to create scenarios for all the banks in the system. Elsinger et al. (2006) follow that approach.

Most studies rely on simulations of bank losses and contagion effects to quantify systemic risk. So far there is limited direct empirical evidence on contagion in networks. Iyer and Peydro (2011) document that the failure (due to fraud) of an Indian cooperative bank triggered higher deposit withdrawals in banks that had higher exposure to the failed bank. Schnabl (2012) examines how shocks caused by the 1998 Russian default impact the Peruvian banking system by comparing subsidiaries of international banks that relied on funding from their parent company with independent banks borrowing from the international money market. He finds the latter to experience severe funding problems resulting in reduced lending to domestic firms. Morrison et al. (2016) derive a network of exposures from bilateral CDS contracts between UK banks. They document increasing CDS spreads for banks which are exposed to counter-parties that suffer losses from CDS trading.

In most practical applications only partial information on the interbank network is available, for example the total amount of interbank lending and borrowing by a specific bank to all other banks or to a group of other banks, e.g. to domestic banks or to credit unions. To estimate the network given the partial information on the link structure many researchers use entropy maximization as described in Blien and Graef (1997) which assumes that interbank exposures are as diversified as possible. One rate exception is Mistrulli (2011) who utilizes actual network data for the Italian banking system.

An emerging literature examines rationale for banks to form networks, which would help us to better understand the sources of systemic risk. In Leitner (2005) banks form network to share endowment risk. The investment technology is defined such that projects of all banks in the network will fail if one bank fails to invest, which creates the incentive for banks to bail each other out when they are in distress. The paper derives the optimal size of such networks. David and Lehar (2016) extend the Eisenberg-Noe

[29] See also Mishkin (2007).

[30] See also Billio et al. (2012).

[31] See also Kaufman and Scott (2003).

[32] Frank et al. (2012) analyze systemic risk from a complex adaptive systems analysis perspective.

[33] Müller (2006) includes lines of credit in interbank clearing using a sample of Swiss banks. Elsinger et al. (2013) provide an overview of network models in systemic risk assessment.

[34] Similarly Elliott et al. (2014) examine the occurrence of default cascades a network model with cross holdings and financial distress costs.

[35] They include Amundsen and Arndt (2011), Martin and Nimander (2002), Degryse and Nguyen (2007), Furfine (2003), Gueroo-Gómez and Lopez-Gallo (2004), Lublóy (2005), Mistrulli (2011), Müller (2006), Sheldon and Maurer (1998), Toivanen (2009), Upper and Worms (2004), Lelyveld and Liedorp (2006), and Wells (2004).

framework by allowing banks to renegotiate payments to avoid costly default. They find that interbank networks that seem fragile under the clearing process can be very robust if ex-post renegotiation of interbank links is allowed. In their model banks optimally form highly connected networks to facilitate ex-post renegotiations.

Empirically most financial networks have a core-periphery structure in which a few very highly connected banks (in the core) have connections to sparsely connected periphery banks.[36] In Farboodi (2016) banks form networks of credit lines through which money has to be allocated to banks which receive an investment opportunity. Banks balance the opportunity to obtain intermediation spreads with the costs of financial distress leading to excessive overall risk for the system and the formation of core-periphery networks. In Chang and Zhang (2016) traders with high trading needs optimally match with traders that have low trading needs. The latter then have the highest trading volume and form the core of the network. Neklyudov and Sambalaibat (2016) analyze a model in which dealers endogenously specialize to cater to clients with either high or low liquidity needs. Heterogeneity in clients leads to heterogeneity in dealers and the emergence of a core periphery network.[37]

3.2.2. Stock market based modelling

To avoid having to rely on detailed interbank link data, several risk measures have been proposed recently that can be derived from stock returns. The idea is that financial markets incorporate all information on linkages between banks as well as correlated exposures across banks in the stock price. One of the early approaches employed to measure systemic risk using stock market information is Lehar (2005). He considers equity as a call option on a bank's assets and proposes a measure for systemic risk through contingent claims analysis. He studies 149 international banks over a twelve year horizon. His results indicate an inverse relation between capitalization of banks and systemic risk.

The two major methods of measuring risk of an individual institution are Value at Risk (*VaR*) and Expected Shortfall (*ES*). VaR_β is the maximum possible loss that a firm experiences with probability β, ES_β measures the average of the worst losses that occur with probability $1-\beta$. Most systemic risk measures are conditional risk measures, i.e., they capture risk conditional on an adverse scenario. The first group of measures estimates the risk of a bank conditional on a bad realization of the market, examining how the risk of a bank changes when the market experiences a downturn. The second approach is to examine how much the risk of the market changes when one particular bank is in distress. Below we discuss these approaches in more detail.

Acharya et al. (2010) define Systemic Expected Shortfall (*SES*) for measuring systemic risk. *SES* measures the average return of a bank stock conditional on the worst stock returns of the market. Intuitively the measure estimates the level by which a financial institution is undercapitalized when the whole financial system suffers from an aggregate shortage of capital. Acharya et al. (2012) and Brownlees and Engle (2012) define *SRISK* for measuring systemic risk. *SRISK* follows a similar logic and is defined using a simulation approach or future stock returns using an assymmetric *GARCH* volatility process. One of the advantages of *SRISK* is the ability to rank the financial institutions based on their systemic importance which allows these measures to be used to construct practical tools for regulating Systemically Important Financial Institutions (SIFIs).[38]

Adrian and Brunnermeier (2016) propose *CoVaR* as a measure for systemic risk. They define *CoVaR* as the *VaR* of the financial system as a whole conditional on an institution experiencing a financial distress. In this setting, they define a new variable $\Delta CoVaR$ as an (non-causal) index for measuring the contribution of a financial institution to systemic risk. $\Delta CoVaR$ of an institution is the difference between *CoVaR* when that institution is in the "distress" state and *CoVaR* when the institution is in the "normal" state. $\Delta CoVaR$ has some interesting properties. For instance, there is no direct connection between *VaR* of an institution and its $\Delta CoVaR$. This property confirms that using *VaR*, as one of the major tools for microprudential stress testing is not sufficient for assessing financial stability. Another interesting property of *CoVaR* is the ability to capture the endogenous nature of risk. For a technical introduction and comparison of *SES*, *MES*, *SRISK* and *CoVaR* see Benoit et al. (2013).

In another approach, Billio et al. (2012) measure systemic risk based on the interconnectedness of the institutions in the financial system. In order to capture the connectedness they use two econometric tools: Granger-causality tests and principal components analysis. They study the monthly returns of brokers (and dealers), hedge funds, insurance companies, and publicly traded banks. Their results show that over the past decade these four sectors have become extensively interconnected. High levels of interconnection between the financial institutions provide substantial channels for shocks to propagate within the financial system. Brunnermeier et al. (2009) provide a comprehensive introduction to systemic risk and possible regulations to prevent a systemic crisis. Bisias et al. (2012) provide an all-encompassing survey of systemic risk. The survey provides 31 prevailing quantitative approaches for measuring systemic risk (for more surveys of systemic risk see Bandt and Hartmann, 2000; Oosterloo and de Haan, 2003).

3.3. Procyclicality of the financial sector

The worst loans are made at the top of business cycle.
Alan Greenspan (2001)[39]

Addressing the evolution of risk over time in the financial sector and its procyclical behaviour has become a crucial concern for academics and policy-makers (see Repullo and Saurina, 2011; Repullo et al., 2010). The Bank for International Settlements, in its 2009 annual report, defines procyclicality as "the fact that, over time, the dynamics of the financial system and of the real economy reinforce each other, increasing the amplitude of booms and busts and undermining stability in both the financial sector and the real economy."[40] Banks tend to engage in riskier investments and provide excessive loans in good times due to underestimation of risk in the market. By contrast, in bad times they tend to

[36] See e.g. Boss et al. (2004), Craig and Von Peter (2014), or in 't Veld and van Lelyveld (2014).

[37] Other papers in this stream of research include Navarro et al. (2016), who analyze network formation when banks face moral hazard and van der Leij et al. (2016) who rely on a costs to form connections and imperfect competition for connections.

[38] In a similar approach, Huang et al. (2012b) propose a new indicator, Distress Insurance Premium (*DIP*), for measuring systemic risk. *DIP* is the contribution of a bank to aggregate losses given that aggregate losses in the financial sector are above a given threshold and can be interpreted as the insurance premium needed to cover the losses when a banking sector is under distress. They apply this method to the 19 largest financial institutions in the U.S. from January 2004 to December 2009 (in 2009, the Federal Reserve System considered these banks as "too big to fail" and designed a program to investigate the sufficiency of their capital buffers. This program was called Supervisory Capital Assessment Program (SCAP)). Their results indicate that the systemic risk escalated from the summer of 2007 and reached its maximum level in March 2009 (from $ 50 billion to $ 1.1 trillion). Moreover, they argue that there is a linear relationship between the contribution of a financial institution to systemic risk and its probability of default.

[39] Speech delivered at the Chicago Bank Structure Conference, May 10, 2001.

[40] See Bank for International Settlements (2009).

shrink lending due to overestimation of risk.[41] Therefore, the financial sector can amplify fluctuations in business cycles, crippling the efficient allocation of capital in the economy and causing financial instability. The literature has provided strong empirical evidence for the procyclical behaviour of the banking sector. For instance, Asea and Blomberg (1998) show that banks' lending standards alter from curtailment to excessive relaxation through the business cycle. Their findings suggest that excessive relaxation during the upturns has a substantial undesirable impact on aggregate fluctuations. Bikker and Metzemakers (2005) provide strong evidence that when GDP growth decreases, the banking sector considerably increases provisions for its credit risk. Saurina and Jimenez (2006) provide empirical evidence that during expansion phases the financial sector is lenient in monitoring borrowers. Moreover, they provide robust evidence that during expansion phases, riskier investors have more access to bank loans, while loan collateral requirements decrease.

The literature has highlighted several underlying causes for the procyclical behaviour of the financial sector. Borio et al. (2001) note that the procyclical behaviour stems from misperception of risk and inappropriate responses to it. They argue that disaster myopia,[42] cognitive dissonance,[43] herd behaviour,[44] shortcomings from contractual arrangements, and the inappropriate decisions of agents in the market which are caused by incomplete information are the reasons behind the procyclical behaviour of the financial sector. Berger and Udell (2004) and Bouvatiera and Lepetit (2008) note that the institutional memory hypothesis[45] is one of the main underlying causes of procyclicality. Drumond (2009) and the European Central Bank (2005) argue that asymmetric information in the financial sector is the main source of the procyclical behaviour. Athanasogloua et al. (2014) argue that procyclicality stems from deviations from the efficient market hypothesis. One of the sources of deviation from the efficient market hypothesis is the well-known principal-agent problem.[46] Moreover, they argue that regulatory safety nets such as government bailouts and deposit insurance are other sources of procyclical behaviour of the financial sector.[47]

Recent contributions in work on credit cycles based on early papers by e.g. Kiyotaki and Moore (1997), Bernanke et al. (1999), Carlstrom and Fuerst (1997), Fostel and Geanakoplos (2008), and Lorenzoni (2008) also contribute to our understanding of procyclicality. Brunnermeier and Sannikov (2014) model an economy with impatient 'experts' and 'households' in which the former are impatient but also more productive and would manage all capital without frictions. When experts are assumed to be restricted to positive consumption and equity claims because of agency problems risk amplification occurs. Near the steady state small shocks cause no disturbance while large shocks can cause huge movements in prices. See also Gertler and Kiyotaki (2010) for an in-depth introduction to this literature and Borio (2014) for an excellent survey.[48]

Panetta et al. (2009) and Bank for International Settlements (2008) argue that procyclical behaviour of the financial sector does not materialize if banks reserve sufficient countercyclical capital buffers through the business cycle. As noted by Bank for International Settlements (2010) and Basel Committee on Banking Supervision (2010a,b), the most effective way of constructing the countercyclical buffers is to build them during good times and employ them to absorb financial shocks and losses in bad times (see Gordy, 2009; Gordy and Howells, 2006; Drehmann et al., 2010).[49] Drehmann et al. (2011) argue in favour of an immediate release of the countercyclical capital buffer in times of distress to increase the effectiveness of the buffer.

Designing efficient countercyclical capital buffers requires an indicator (or a set of indicators) to measure the accumulation of vulnerabilities and imbalances in the financial sector before the crisis materializes. As noted by Borio and Lowe (2002, 2004) and Arnold et al. (2012), a brief look at the history of financial crises suggest that asset prices and the gap between (private sector) credit-to-GDP ratio and its long-term trend, can be reliable indicators (see Shin, 2013; Behn et al., 2013; Bank of England, 2013 for other proposals of early warning indicators). Drehmann and Gambacorta (2012) employ the credit-to-GDP gap as an early warning indicator to construct countercyclical capital buffers and investigate the effect of the buffers on the supply of credit. Their findings suggest that the buffers alleviate the credit growth and mitigate the risk of credit crunch. Giese et al. (2014) show that the credit-to-GDP gap serves as a reliable early warning indicator for the recent UK crisis.[50] For a comprehensive introduction to credit-to-GDP and countercyclical capital buffers in Basel III, see Drehmann and Tsatsaronis (2014).

4. Macroprudential instruments

As noted before, the main objective of macroprudential policy is mitigating systemic risk. Therefore, macroprudential instruments need to address systemic risk in its both forms; cross-sectional and time dimension. The literature proposes many macroprudential

[41] The concept of procyclicality is intimately tied to financial cycles. See Borio (2013) for a contemporary introduction to financial cycles.

[42] Disaster myopia refers to the tendency of the market participants to underestimate the possibility of extensive financial losses with low probability (see Guttentag and Herring, 1984, 1986). Haldane (2009) and Herring (2008) note that disaster myopia is one of the most important underlying causes the 2007 financial crisis. Cornand and Gimet (2012) provide an empirical evidence for the existence of disaster myopia in the recent financial crisis. Hott (2011) constructs a theoretical model to show the effect of disaster myopia on real estate prices fluctuations.

[43] In economics and finance literature, cognitive dissonance refers to biased interpretation of information by the market participants, so that causes reinforcing the prevailing (dominant prior) beliefs (the theory was originally developed in psychology by Festinger, 1957). Antoniou et al. (2013) argue that cognitive dissonance occurs when there is a contradiction between the news (information) and the market participants' sentiment (optimism or pessimism).

[44] Herd behaviour occurs when market participants confirm and justify their behaviour only based on their peers' behaviour and this confirmation is a first-order effect. Rajan (2006) notes that herd behaviour is one of the main reasons that the movement of asset prices deviate from their fundamentals. However, herd behaviour does not always yield undesirable outcomes (see Rajan, 1994). The literature on the evidence of herd behaviour is very rich. For instance, Chiang and Zheng (2010) find evidence of herding activity from 1988 to 2009 in advanced stock markets except Asian markets and US. Grinblatt et al. (1995) find evidence of herd behaviour in mutual funds. Lakonishok et al. (1992) find small herding activity among pension managers in trading small stocks. Kremer and Nautz (2013) show that short-term herd behaviour among institutional investors in German stock market happens daily. Hirshleifer and Teoh (2003) provide a comprehensive review of the herd behaviour in capital markets. Devenow and Welch (1996) provide a brief review of rational herd behaviour in finance and economics.

[45] Institutional memory hypothesis refers to the eventual decline of bank loan officers' ability to identify bad loans (see Berger and Udell, 2004 for the original discussion).

[46] In the finance literature principal agent problem refers to when managers (the agents) make decisions on behalf of shareholders (the principals) which sometimes might cause a conflict interest between them.

[47] Another factor that contributes to the procylicality of the financial sector is the choice of the rating regimes by banks. Using a general equilibrium model, Catarineu-Rabell et al. (2005) show that banks do not choose stable ratings through the business cycles. They find it is more profitable to use countercyclical ratings. However, if the use of countercyclical ratings are not allowed by the regulators they adopt procyclical ratings. Using procyclical ratings may amplify the boom and cause a severe a credit crunch in downturns.

[48] Other interesting papers in this stream of research include Adrian and Boyarchenko (2013) who combine a procyclical banking sector with an anti-cyclical fund sector in a macroeconomic model and Christiano et al. (2014) who relate credit cycles to monetary policy.

[49] Note that the objective of the countercyclical capital buffers is not managing or undermining the business cycle (see Landau, 2009).

[50] See Edge and Meisenzahl (2011) for a criticism of using credit-to-GDP gap for constructing countercyclical capital buffers.

Table 2
Macroprudential instruments.

Tools	Risk dimensions	
	Time dimension	Cross-sectional dimension
Category I. Instruments developed specifically to mitigate systemic risk		
	• Countercyclical capital buffers	• Systemic capital surcharges
	• Through-the-cycle valuation of margins or haircuts for repos.	• Systemic liquidity surcharges
	• Levy on non-core liabilities	• Levy on non-core liabilities
	• Countercyclical change in risk weights for exposure to certain sectors	• Higher capital chares for trades not cleared through CCPs
	• Time-varying systemic liquidity surcharges	
Category II. Recalibrated instruments		
	• Time-varying LTV, Debt-To-Income (DTI) and Loan-To-Income (LTI) caps	• Power to break up financial firms on systemic risk concerns
	• Time-varying limits in currency mismatch or exposure (e.g. real estate)	• Capital charge on derivative payables
	• Dynamic provisioning	• Deposit insurance risk premiums sensitive to systemic risk
	• Time-varying limits on loan-to-deposit ratio	• Restrictions on permissible activities (e.g. ban on proprietary trading for systemically important banks)
	• Time-varying caps and limits on credit or credit growth	
	• Stressed VaR to build additional capital buffer against market risk during a boom.	
	• Rescaling risk-weights by incorporating recessionary conditions in the probability of default assumption (PDs)	

instruments (for a detailed discussion of available macroprudential instruments see Elliott, 2011; International Monetary Fund, 2011; Bank of England, 2011). This section explores the main available instruments and different countries' experience with these instruments. Table 2 provides a list of available macroprudential instruments. *Source*: International Monetary Fund (2011).

4.1. Tools addressing the time dimension

As discussed in the previous section, the main objective of countercyclical capital buffers is to mitigate procyclical behaviour of the financial sector. In an economic downturn they can be released to provide liquidity and avoid a credit crunch. Moreover, countercyclical capital buffers reduce the magnitude of a credit boom (see Tirole, 2011b). The required countercyclical capital requirement is an increasing function of the amount of credit lent by financial institutions. Therefore, in order to satisfy the requirements, financial institutions might find it optimal to cut excessive lending or charge the borrowers higher loan rates. Aiyar et al. (2014) document that banks cut lending as a consequence of higher capital requirements but also show limitations of macroprudential regulations as unregulated banks increase lending as a response to the restraints put on the regulated banks.[51]

Another valuable macroprudential instrument to mitigate the procyclicality of the financial sector is dynamic provisioning. Historically, as shown by Cavallo and Majnoni (2002), banks' voluntary provisioning follows a countercyclical pattern (i.e. banks' provisioning has a negative correlation with GDP, see also Pain, 2003). Banks have a tendency to underestimate the risk in good times and provide too few provisions and experience losses larger than they expected in economic downturns. Therefore, the cyclical behaviour of provisioning exacerbates the severity of economic downturns for the banks. With dynamic provisioning banks would put aside more provisions when their income is high. Examining a sample of 240 banks in 12 Asian countries, Packer and Zhu (2012) show that dynamic provisioning (countercyclical provisioning) has dominated throughout Asian emerging economies since the Asian financial crisis in the late 90s. Fernandez de Lis and Garcia-Herrero (2012) provide an overview on the Spanish experience with countercyclical provisioning, which was first introduced in 2000. Countercyclical provisioning coincided with a period of slower loan growth in the Spanish banking system, although it is hard to isolate the impact of the new regulation. Jiménez et al. (2017) show that the countercyclical dynamic provisioning smooths cycles in the supply of credit and in bad times upholds firm financing and performance. They also present some evidence that increased provisioning in good times might lead to more risk taking by banks.

Another macroprudential tool to curb excessive banks' lending during good times is lowering the caps on loan-to-value (LTV) ratios. Restrictions on LTV ratios can vary across industries. Prior to the recent financial crisis they were mainly used in Asian couturiers to tame rapid growth in the housing market. For instance, in 1991 banks in Hong Kong voluntarily reduced the maximum LTV ratio from 90% to 70%. Moreover, in 1997 the Hong Kong Monetary Authority imposed a 60%-LTV policy for "luxury" properties.[52] More countries adopted restrictions on LTV ratios after the recent crisis.[53] The evidence for the effect of LTV policies on financial stability are substantially mixed. Using panel data of 13 economies (including Canada and Hong Kong), Wong et al. (2011) show that caps on LTV ratios mitigate the systemic risk caused by boom-and-bust cycles of property markets. Using the data of Canadian banks, Krznar and Morsink (2014) show reducing the cap on LTV ratios by one percent reduces the annual mortgage credit growth by about 0.25–0.5 percentage points.[54] However, using data for business loans in Japan, from 1975 to 2009, results from Ono et al. (2013) imply that simple LTV ratio caps may not be effective in taming loan volumes. Lim et al. (2011) provide an excellent survey of macroprudential tools applied in different countries including some more detailed case studies such as Spain's experience with dynamic provisioning. In the context of a general equilibrium model with shadow

[51] In their study unregulated banks are branches which are in the EU regulated by their home country regulator and thus not subject to UK regulation.

[52] A property with a value of more than HK$ 12 million.

[53] For instance, shortly after the recent financial crisis, Hungary, Sweden, and Norway announced adoption of LTV ratio policies. In August 2013 the Reserve Bank of New Zealand announced the restrictions on LTV ratios in the housing sector (see Rogers, 2014).

[54] For a concise and detailed discussion of LTV ratios in Canada see Christensen (2011).

banking Goodhart et al. (2013) analyze complex interactions that arise when combinations of policy tools are implemented.

In addition to the tools mentioned above, Basel III has introduced two complementary instruments to reduce the short-term liquidity risk and longer time horizon funding risk. Liquidity Coverage Ratio (LCR) is defined as the amount of high quality asset of a bank divided by its net cash outflows for 30 calendar days. Higher levels of LCR increases the bank's resiliency to short-term liquidity shocks.[55] Net Stable Funding Ratio (NSFR) is defined as the amount of available stable funding divided by required stable funding. In a theoretical apparatus, Diamond and Kashyap (2016), based on a modification of Diamond and Dybvig (1983), show that the LCR and NSFR reduce the probability of bank runs by changing the bank's incentives. Implementing LCR would encourage a substitution from long-term illiquid assets to short-term liquid ones, which consequently deters bank runs. Under NFSR the bank needs to finance the illiquid assets with long-term deposits. Therefore, NFSR can alter the bank's incentive to use less runnable deposits.

4.2. Tools addressing the cross-section

The logical next step after measuring the risk of the financial system as a whole is to identify each bank's contribution to that systemic risk. Some of the measures outlined in Section 3.2, notably ones based on stock prices, directly identify a bank's contribution to systemic risk.

Other approaches to allocate risk have been developed in the financial risk management literature (see e.g. Jorion, 2007 and include marginal VaR and incremental VaR. The former is the product of the marginal impact of a bank on VaR (i.e. how much would VaR increase for a small increase of a bank's assets) times its size. The latter is the difference of the system's VaR with and without an individual bank. Many papers surveyed in Section 3.2.2 derive systemic risk measures on a bank level directly from stock prices. Huang et al. (2012a) derive systemic risk allocations based on a hypothetical distress insurance premium derived from CDS prices.

Another approach of risk allocation the Shapley value, is advocated by Tarashev et al. (2009, 2010) in the context of banking systems. The Shapley value can be seen as efficient outcome of multi-player allocation problems in which each player holds resources that can be combined with others to create value. The Shapley value then allocates a fair amount to each player based on the average marginal value that the player's resource contributes to the total.[56] In a bank regulation context, one can argue that a certain level of capital has to be provided by all banks as a buffer for the banking system and that Shapley values determine how much capital each bank should provide according to its relative contribution to overall risk.[57]

All of these papers derive risk contributions, measuring how much an individual bank contributes to the risk of the financial system in its present state. It is tempting to use these risk attributions for regulation, e.g. for minimum capital requirements or for capital surcharges. The problem with that approach, however, is that once capital levels at banks are changed, banks' default probabilities, their default correlations, and thus the risk of the whole system as well as the risk attributions change. The risk contribution of each bank therefore must be seen as a function of all the banks' capital levels including its own.

Gauthier et al. (2012) follow an iterative procedure in which they compute each bank's risk contribution, adjust the bank's capital level to that risk contribution and then recompute both systemic risk and each bank's risk contribution. They repeat this procedure until they get convergence and define macroprudential capital requirements as a fixed point where each bank's capital equals its risk contribution under that level of capital. Using a variety of risk allocation mechanisms they apply the fixed point procedure to a sample of Canadian banks. They find that the fixed point procedure, i.e., the simultaneous solution for all market participants, is far more important than the choice of risk allocation mechanism. Using simple risk allocation can lead to capital requirements that are substantially different from using the fixed point algorithm. For a variety of risk allocation mechanisms they found that macroprudential capital requirements can reduce the default probabilities of individual banks as well as the probability of a systemic crisis by about 25%.

While capital requirements are the primary mechanism employed in bank regulation, there are other ways to regulate banks according to their contribution of systemic risk. One way is to identify them as SIFIs. Another, developed by Acharya et al. (2010) determine deposit insurance premiums in the presence of systemic risk.

Goodhart et al. (2012) provide a general equilibrium model of a banking system and a less risk averse shadow banking system which agents in the economy can use for financing their projects. This theoretical framework can be used to asses the effects of five different macroprudential instruments: capital requirements, LTV, dynamic loan loss provisioning, LCR, and margin requirements on repurchase, agreements used by shadow banks on credit crunches, fire sales, and defaults. The model also provides an intuitive understanding of the interactions of these tools. Clerc et al. (2015) specify a dynamic stochastic general equilibrium framework that can be used for positive and normative assessment of macroprudential instruments and policies. The main source of bankers' fund are the inside equity and savings of the households. Bankers as intermediaries allocate the funds through mortgage lending to the households and corporate lending to the firms. The model is augmented by a non-trivial default risk in all the borrowing sectors. The default risk can be caused by both aggregate and idiosyncratic risks. The results of this model indicate that the high levels of idiosyncratic bank risk and low levels of capital requirement considerably increases the propagation and amplification of the shocks. The paper proposes 10.5% as the capital buffer ratio. The model is suitable for welfare analysis of macroprudential policies and tools that are designed to tame high levels of leverage such as, caps on LTV ratios, and countercyclical capital charges.

4.3. Institutional changes

In the aftermath of the financial crisis many regulators blamed the interconnectedness between banks and especially the market for OTC derivatives for creating systemic risk.[58] Great efforts have been made since to implement central counter-party clearing for derivatives. The idea is that trading partners would not contract directly but rather have a clearing house between them. The clearing house would guarantee the contract in case that the counter-party defaults and in turn manage its credit risk by

[55] The minimum required level of LCR will reach 100% by January 2019.

[56] While Shapley values were originally developed as a concept of cooperative game theory, they are also equilibrium outcomes of non-cooperative multi-party bargaining problems.

[57] Shapley values are commonly used in the literature on risk allocation. Denault (2001) reviews some of the risk allocation mechanisms used in this paper, including the Shapley value. See also Kalkbrener (2005). Drehmann and Tarashev (2013) examine how risk can be measured for subsystems within the existing banking system. Replacing risky interbank loans to banks outside the subsystem with safe claims will underestimate the subsystem's risk making risk measurements of subsystems a non-trivial task.

[58] The market for OTC derivatives and clearing houses is in many jurisdictions, such as in Canada, overseen by securities regulators and not by bank supervisors.

requiring counter-parties to provide adequate collateral. Having a central counter party would also allow for better netting, i.e., the cancellation of offsetting claims, since each bank has only one aggregate position with the clearing house instead of multiple positions with many banks. Off-setting trades can then be netted with the clearing house reducing the overall requirement for collateral and limiting the exposures within the financial network.

While these fixes in the “plumbing” of the financial system seem plausible, it is not clear they will always reduce systemic risk. First, the benefits of central counter-party clearing only materialize when very few clearing houses handle all financial transactions. In practice, however, clearing houses are limited to countries or regions because national regulators do not want to give up control or are limited to certain types of transactions (see e.g. Duffie and Zhu, 2011). Second, to avoid repeating the same mistake that microprudential regulation created for the banking system clearinghouses should set margins for clearing house members based on their contribution to systemic risk. At the moment margins are set according to fixed rules that consider each clearing house member separately. Correlations in exposures and interlinkages between members through other financial instruments are neglected leading potentially to the same problems that caused policymakers to call for more macroprudential regulation in the first place. Third, the guarantee of the clearing house to cover any losses from counterparty default levels the playing field in an undesirable way. Market participants do not have to be concerned about the risk of their counterparty any more, eliminating the market discipline that would have banned riskier market participants from the market in the past. Finally, clearinghouses are certainly too big to fail entities. Instead of bailing out big banks in the case of a crisis the government will be pressed to bail out clearinghouses in the case of default. The creation of clearing houses largely shifts the debate on government bailouts and proper regulation to a different level. It is not yet clear under what conditions overall systemic risk will be reduced.

5. Conclusion

Through academic research and policy debate we now understand more about financial stability than before the financial crisis. Regulators across the world have taken considerable steps in implementing policies that aim to enhance the resilience of the financial system.

Measuring systemic risk: Several central banks have implemented measurement and early warning systems on systemic risk. One of the first banks to establish a system for monitoring of systemic risk was the Austrian National Bank (OeNB) with their Systemic Risk Monitor (see Boss et al., 2006 for details). The Bank of England uses a systemic risk monitoring tool named RAMSI (see Burrows et al., 2012). While similar models are most likely used by other central banks many regulators are not transparent about the tools they use for macroprudential monitoring and systemic risk measurement.

Countercyclical regulation: Several countries as mentioned in Section 4.1 have implemented some measures to address the time dimension of systemic risk. Banks are forced to set aside funds or hold more capital in good times as a buffer against losses in downturns. In Canada several measures were implemented to improve loan origination standards like caps in amortization time and LTV and debt service ratios (see Crawford et al., 2013).

Institutional changes: Central counter-party clearing has been established for a wide range of derivatives in many jurisdictions. Yet, competing clearing houses have emerged reducing in part the benefit of netting. Regulators are still working on the tools to properly supervise and regulate them.

Macroprudential capital requirements: The main obstacle for a true implementation of macroprudential capital requirements is that each bank's capital requirement would in part be driven by the actions of other banks. A bank could therefore not exercise full control over its own capital requirements. Therefore we are not aware of any jurisdiction in which full macroprudential capital requirements have been implemented. In part regulators charge banks that are identified as system relevant a surcharge on their capital requirements.

Macroprudential regulation is the correct approach to ensure the long run stability of the financial system. Instead of focusing only on the individual bank as a standalone entity regulators must see the system as a whole and limit threats to financial stability. While we now know substantially more about systemic risk than just 10 years ago, many questions remain to be addressed.

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