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What Role for Financial Supervisors in Addressing Systemic Environmental Risks?

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What role for financial supervisors in addressing systemic environmental risks?¹

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Abstract

Since the global financial crisis, financial supervisors have developed a new macroprudential policy framework: mechanisms to identify systemic financial imbalances and instruments to address these. At the same time, a literature is rapidly developing on financial shocks that may originate from ecological imbalances, triggered by either intensified environmental policies to protect ecological boundaries or due to the economic costs of crossing these. However, financial supervisors have so far given little attention to this ecological dimension. This allows systemic financial imbalances resulting from ecological pressures to build up and concentrate in financial institutions and markets. This paper sketches the ecological dimension of the macroprudential policy framework and illustrates the working for the case of carbon emissions.

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1. Introduction

Since the financial crisis of 2007/2008, financial supervisors have developed new mechanisms to identify systemic financial imbalances and new macroprudential instruments to address these (Brunnermeier *et al*, 2009; Hanson, Kashyap and Stein, 2011; Galati and Moessner, 2013). In this same period, an increasing number of studies have been published on financial shocks that originate from ecological imbalances, triggered by either intensified policies to protect ecological boundaries or due to the costs of crossing these ecological boundaries (e.g. UNEP FI, 2011; Weyzig *et al*, 2014; New Climate Economy, 2014). However, financial supervisors² have so far given little attention to this rapidly growing literature. A notable exception is the Bank of England (2015), which has put the potential impact of ecological imbalances on financial stability on the research agenda

The lack of attention for ecological imbalances allows systemic financial imbalances to build up and concentrate in certain financial institutions and markets. Whereas many reports have documented that from a global macroeconomic perspective the costs of acting swiftly on climate change are much lower than letting the climate change or acting later (e.g. Stern, 2006; IPCC, 2014), the micro perspective is very different. Individual companies and financial institutions do often not have incentives to operate in a truly sustainable way. And when they do nevertheless want to make the transition towards a real sustainable handling of their operations, this may not be financially possible, as environmental externalities are not priced.

The existence of externalities as market failure is the ratio behind the new macroprudential policies of financial supervisors: to act on systemic risks that individual financial institutions have no incentive to act upon. This article applies the rationale of the (still developing) macroprudential supervisory framework towards the ecological imbalances to which the financial system is exposed.

This contribution of this article is twofold. Firstly, should macroprudential policies target the ecological risks that are building up outside the financial system itself? Some authors argue that macroprudential policies should aim to increase the resilience of the financial system against economic shocks (e.g. Borio, 2014b). The policy is then targeted at risks within the financial system (labelled first order risk) by building adequate buffers in good times. Others argue that macroprudential policies should also aim to prevent a misallocation of real resources (Gros and Alcidi, 2013). A case in point is the housing boom bust cycle, which is the heart of most financial crises (Reinhart and Rogoff, 2009). Housing is mostly debt financed, which intensifies the propagation of shocks. The severe impact of the resource misallocation on the financial system and the wider economy may warrant that this type of asset (labelled second order risk) is targeted by macroprudential policy. In the case of environmental risks, adjustments may also be severe and abrupt, leading to disorderly markets and substantial losses for financial institutions.

Second, how can macroprudential policies address ecological imbalances? We propose an outline of a policy framework for the ecological dimension of macroprudential supervision: the intermediate objectives and indicators for ecological imbalances (Galati and Moessner, 2013). We discuss the instruments to address these imbalances and the institutions best equipped for this task. Finally, the working of this macroprudential framework is illustrated in the case of carbon emissions.

In the next section, we discuss the macroprudential policy framework and develop criteria for including specific risks into this framework. Section 3 indicates that financial risks increasingly originate from ecological drivers. We analyse the specific case of carbon emissions. Section 4

² We use the broader term financial supervisor, which includes macro-prudential supervisors (often central banks) responsible for financial stability and micro-prudential supervisors responsible for individual financial institutions.

examines the specific role of central banks and financial supervisors, given their mandate, with regard to the ecologically driven financial risks. Section 5 describes which elements of the current macroprudential toolkit could be used for addressing these ecological driven financial risks and how this could be applied to the case of carbon emissions. Section 6 concludes.

2. Post crisis shifts in financial supervision

2.1 From micro- to macroprudential supervision

Before the global financial crisis, financial supervision was primarily directed at the supervision of individual financial institutions, focusing on risk weighted capital ratios. The underlying assumption of this approach was that the system as a whole can be made safe by making the individual financial institutions safe (Brunnermeier *et al*, 2009). It was assumed that identification of (macro) risks would automatically reduce them, as financial institutions would price these risks.

After the global financial crisis, it is widely recognised that the macro perspective was lacking. The 'fallacy of composition' (Brunnermeier *et al*, 2009) is the main rationale why the behaviour of individual financial firms may not be socially optimal. A first example is contagion through fire sales whereby it may be optimal for individual financial institutions to sell equities to reduce their exposure, while these fire sales may reduce equity prices further (Shleifer and Vishny, 2011). Another example is the credit crunch after a crisis (debt overhang), whereby individual banks that are capital constrained do not grant new credit. The individual behaviour of financial institutions can thus cause externalities to other financial institutions and the real economy (Hanson, Kashyap, Stein, 2011). Furthermore, the underpricing of risk, herding behaviour and moral hazard in the presence of implicit safety nets can lead to the build-up of financial imbalances over time. When imbalances unwind, shocks quickly propagate through the financial system due to its high degree of interconnectedness (Galati and Moessner, 2013).

The objective of macroprudential policy is to foster financial stability. Macroprudential policy reviews potential threats to the stability of the financial system, stemming from the real economy, financial institutions, financial markets or financial infrastructures. This should enable the relevant authorities to gain better insight into the development of imbalances, such as asset price bubbles or vulnerabilities stemming from financial innovation, as well as the degree to which the financial system itself is capable of absorbing such risks.

What is the main threat to the financial system? Goodhart (2014) argues that the threat is multifold. First, Goodhart (2014) considers the banking system as vulnerable due to the high leverage combined with massive maturity mismatch. Next, the banks' involvement with stock exchange financing was a source of instability during the interwar period in the US. Finally, housing and property loans in bank portfolios are a major source of systemic instability, leading to housing and construction booms and busts. Taking an empirical approach, Claessens *et al* (2011) find that financial cycles, especially those in the credit and housing markets, can be long and deep causing financial crises. While the most severe fluctuations take place in equity markets, they are not causing, or signalling the possibility of, financial crises. For example, the bursting of the dotcom bubble, which was mainly equity financed, did not cause a financial crisis, as the equity-holders were able to absorb the losses without propagating the initial shock.

The classical macroprudential approach to cycles is reactive. Borio (2014b) argues that the objective of macroprudential policy should be to increase the resilience of the financial system (reactive). It is sufficient to build-up buffers in good times for the financial system to withstand a bust. Borio (2014b) questions the effectiveness of a more proactive objective of constraining financial booms. By contrast, Gersbach and Rochet (2014) argue forcefully that stabilising credit cycles should be the objective. That would also improve accountability. Drawing a parallel with monetary policy, a clear numerical

objective (e.g. a 2 per cent inflation target or a stable credit cycle) is better to monitor for parliament than a vague objective (e.g. limiting the probability and cost of a hyper-inflation episode or a financial crisis).

The occurrence of financial crises is intimately linked to economic fundamentals (Allen and Gale, 1998). An important question is whether macroprudential policy should only focus on the banking (and wider financial) system (which we label first order risk), or also on imbalances building up in the real economy outside the financial system, such as housing and construction (labelled second order risk). There is strong empirical evidence that most financial crises, including the 2007-2008 financial crisis, find their roots in a housing boom bust (e.g. Reinhart and Rogoff, 2009; Claessens *et al*, 2011). Gros and Alcidi (2013) show that financial crises are longer lasting when there is an underlying construction boom with a misallocation of real resources.³ Adjustments take time as housing is a long-lived and capital-intensive asset (so new construction is subdued for a long time after the bursting of the housing and construction bubble) and human capital cannot easily be redeployed in the economy. Moreover, housing is mostly debt financed, which intensifies the propagation of shocks. The severe impact of the resource misallocation may warrant that the second order risk from this asset class is also targeted by macroprudential policy.

What criteria can we distil from this literature overview for including asset classes as financial crisis prone? The first is the maturity of an asset. An abrupt change in the services of an asset with a long maturity can lead to a major downward adjustment of its price, as future services become less worthwhile. The second criterion is the capital intensiveness of an asset. As the market value of an asset drops below its marginal cost price, the production of that asset will be halted leading to a realignment of resources in the real economy. The third criterion is the economic share of an asset class. What proportion of the economy is affected? The fourth and final criterion is the amount of debt financing of an asset. While equity can absorb financial shocks, failure on debt may propagate a financial shock. The four criteria are cumulative. So an asset class need to fulfil all criteria in order to be crisis prone.

To illustrate the working of these criteria, we apply these criteria to a few asset classes in Table 1. Housing and dotcom are already discussed above. In the aftermath of the global financial crisis, global trade collapsed causing a sharp drop in the value of cargo vessels and the production of new ones. While shipping shares many of the characteristics of housing, it is a very small economic sector (except for Greece). In the next section, we discuss whether (abrupt) changes to the ecological system could similarly affect certain assets classes (second order risk) causing a financial shock.

Table 1. Criteria for financial crisis sensitivity of asset classes

Criteria	Housing	Shipping	Dotcom
1. Long-lived	✓	✓	✗
2. Capital-intensive	✓	✓	✓
3. Economic share	✓	✗	✓
4. Debt-financed	✓	✓	✗
Crisis prone	Yes	No	No

³ In the case of Ireland and Spain, Gros and Alcidi (2013) provide evidence that the construction sector expanded from 15 per cent of GDP in 1999 to well over 20 per cent of GDP in 2006 (the top of the housing cycle).

2.2 The macroprudential policy framework

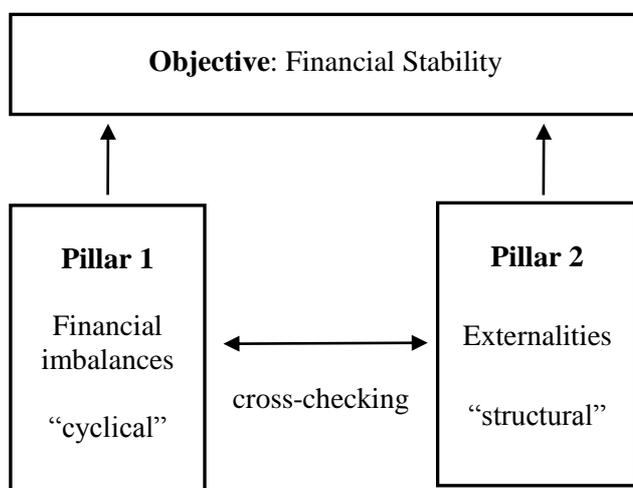
Prudential supervision is forward looking, both on the micro and the macro side. Its time horizon is rather limited, in practice between two to three years. The monitoring and analysis should in particular focus on (Borio, 2009):

- how aggregate risk evolves over time, i.e. the *time dimension*, and
- how risk is distributed in the financial system at a given point in time, i.e. the *cross-sectional dimension*.

Figure 1 illustrates the two-pillar strategy (Schoenmaker and Wiertz, 2011). The key issue in the time dimension is how system-wide risk can be amplified by interactions within the financial system as well as between the financial system and the real economy. In good times, agents tend to underestimate risk and, subsequently, overinvest. This overinvestment is fuelled by credit. The credit cycle is in its upward swing. In bad times, the reverse happens: agents become more risk averse and reluctant to invest. In the extreme, this may accumulate in a credit crunch, where banks are withholding credit for new investment.

The key issue in the cross-sectional dimension is how to deal with the structural features of systemic risk, i.e. the common exposures across financial institutions. These arise either because institutions are directly exposed to the same or similar asset classes (exposure concentration) or because of indirect exposures associated with linkages among them (e.g. counterparty relationships). Common exposures are critical because they explain why institutions can fail together.

Figure 1. Two-pillar strategy for macroprudential policy.



Source: Schoenmaker and Wiertz (2011)

While fostering financial stability is the ultimate objective, intermediate objectives need to be specified to make macroprudential policy operational (De Haan *et al*, 2015). The macroprudential strategy relates intermediate objectives to indicators and instruments. The European Systemic Risk Board (ESRB, 2014) has identified four intermediate objectives, which aim at mitigating systemic risks to financial stability that follow from:

- *Excessive credit growth and leverage*. Excessive credit growth has been identified as a key driver of asset price bubbles and subsequent financial crises, with leverage acting as an amplifying channel;

- *Excessive maturity mismatch and market illiquidity.* Reliance on short-term and unstable funding may lead to fire sales, market illiquidity and contagion when the financial cycle turns;
- *Direct and indirect exposure concentrations.* Exposure concentrations make a financial system (or part of it) vulnerable to common shocks, either directly through balance sheet exposures or indirectly through asset fire sales and contagion;
- *Misaligned incentives and moral hazard.* This includes risks associated with systemically important financial institutions and the role of implicit government guarantees.

Table 2 summarises indicators for each intermediate objective. Panel A shows the indicators and instruments under the cyclical pillar. The guiding principle is to calibrate policy tools so as to encourage the build-up of buffers in good times so that they can be drawn down as strains materialise. By allowing the system to absorb the shock better, this would help to limit the costs of incipient financial distress. Moreover, the build-up of the buffers, to the extent that it acted as a kind of dragging anchor or “soft” speed limit, could also help to restrain the build-up of risk-taking during the expansion phase (Borio, 2009). In the pro-active stance, stabilising the cycle would be the primary objective (Gersbach and Rochet, 2014).

Panel B shows indicators and instruments under the structural pillar. In the cross-sectional dimension, the guiding principle for the calibration of prudential tools is to tailor them to the individual institutions’ contribution to system-wide risk. Ideally, this would be done in a top-down way. One would start from a measure of system-wide tail risk, calculate the contribution of each institution to it and then adjust the tools (capital requirements, insurance premia, etc.) accordingly. This would imply having tighter standards for institutions whose contribution is larger, contrasting sharply with the microprudential approach, which would have common standards for all regulated institutions. In turn, that contribution will depend on features that are either specific to the institution itself (e.g., its size and probability of failure) or relevant for the system as a whole (its direct and indirect common exposures with other institutions).

Table 2. Mapping intermediate objectives, indicators and instruments

Panel A: Cyclical pillar

Intermediate target	Excessive credit growth and leverage		Excessive maturity mismatch and market illiquidity		
Indicators	Credit-to-GDP gap		Housing credit, housing prices	Structural funding ratio, short-term liquidity stress indicators	
Key instruments	Counter cyclical capital buffer	Capital instruments: -leverage ratio - by sector	LTV / LTI caps	Stable funding restrictions	Liquidity charges

Panel B: Structural pillar

Intermediate target	Exposure concentration		Misaligned incentives		
Indicators	Indicators for large exposures, interconnectedness, price contagion		Size, complexity, substitutability and interconnectedness of SIFIs		
Key instruments	Large exposures restrictions (by counter-party, sector, geographic)		SIFI capital surcharges	Systemic risk buffer	

Source: Adapted from ESRB (2014)

A particular challenge is how to organise the global cooperation, which is needed given the integration of (financial) markets (Haldane, 2014). There exist several platforms where macroprudential risks can be discussed, ranging from the Financial Stability Board (FSB), the Bank for International Settlements (BIS), the International Monetary Fund (IMF), the Group of Twenty (G20) to several UN-supported platforms. Among these international institutions, the BIS has taken the intellectual lead on macroprudential supervision. In the execution of macroprudential supervision, central banks are typically responsible with overarching committees such as the Financial Stability Oversight Council (FSOC) in the US and the European Systemic Risk Board (ESRB) in Europe for coordination.

3. Ecologically driven financial risks

3.1 Ecology, economy and finance

The health of the ecology and that of the economy of a region or country have always been intimately linked. In an early study, Jevons (1884) describes how sunspots caused drought and poor harvests and ecological shocks thus led to financial crises in the past. That is why current global ecological imbalances should also worry financiers. The overuse of the environment as a sink (CO₂, material trash) and over exploration of scarce resources (water, raw materials) result in climate change, depletion of natural resources and loss of biodiversity. These ecological imbalances develop partly linear and thus predictable, but partly (and the more so the greater the imbalance) also highly unpredictable, with sudden transitions due to tipping points and feedback loops (IPCC, 2014). Ecological risks share this feature with macroprudential risks, as highlighted in Section 2. In 2009, a group of 28 internationally renowned scientists identified and quantified a set of nine planetary boundaries within which humanity can continue to develop and thrive. However, they argue that three of them have already been broken: biodiversity, nitrogen cycle and climate change (Rockström *et al*, 2009).

Ecological imbalances affect the economy in a myriad of ways, many of which are of a global nature. The economic costs of environmental depletion are already significant and are set to increase. The average annual economic cost of human-induced environmental depletion was estimated at approximately \$6.6 trillion in 2008, equivalent to 11 per cent of global GDP (UNEP FI, 2011). If environmentally unsustainable activity continues at this scale, the annual costs for the global economy will reach nearly \$28.6 trillion by 2050, equivalent to 18 per cent of global GDP. Of this, greenhouse gas (GHG) emissions account for a large and growing share of environmental costs, rising from 69 to 73 per cent between 2008 and 2050.

The cost of environmental damage can also be calculated at company level. The United Nations Environment Program Finance Initiative study (UNEP FI, 2011) analyses the value of externalities from 2,439 companies in the MSCI All Country World Index. The proportion of company earnings that could be at risk from environmental costs in an equity portfolio weighted according to the MSCI All Country World Index is more than 50 per cent of pre-tax profits. Five sectors account for around 60 per cent of all externalities from the largest 3,000 listed companies. Reducing carbon emissions in the Electricity, Oil and Gas Producers, Industrial Metals and Mining, Food Producers, and Construction and Materials sectors would have the greatest effect on reducing carbon costs (see Section 3.2). Some sectors, such as food producers, would have no profits left if they had to pay the full cost of their negative environmental externalities. In the case of food producers, the main environmental costs comprise carbon emissions, air pollution and water abstraction. The transition to a sustainable economy poses risks to the laggards, but also opportunities for the companies that are frontrunners. Various studies done by McKinsey for the Ellen MacArthur Foundation (2012, 2013, 2014) illustrate the potential of the circular economy for companies. These studies find net materials cost savings up to \$630 billion per year and many new jobs created.

As the financial sector is the mirror image of the real economy, it cannot be shielded from these costs (and missed opportunities) in the medium to long term. Rising environmental costs contribute to economic and market risks, which could affect asset values and fund returns (UNEP FI, 2011). Fund owners are exposed to environmental costs through: 1) Reduced cash flows for companies held in portfolios, and lower dividends; 2) More uncertain, rapidly changing conditions in capital markets; 3) Depleted natural capital and reduced future cash flows to the economy; 4) Increased environmental costs for companies causing damage.

Next, the costs of externalities are increasingly internalised through regulation and standards, market dynamics and stakeholder actions. If environmental policies are strengthened, the price of assets that are relatively dependent on the use of these now unpriced environmental services will decrease. The financial risk in the medium term is the sudden pricing of externalities and thus loss of value of stranded assets (see below). These disruptions will have consequences for the financiers as well. Equity owners will be particularly hard hit (pension funds, insurance companies), but also lenders (banks) will suffer because the percentage of non-performing loans will rise (Weyzig *et al*, 2014). More generally, the disruptions may lead to disorderly markets (e.g. disorderly energy markets as discussed below).

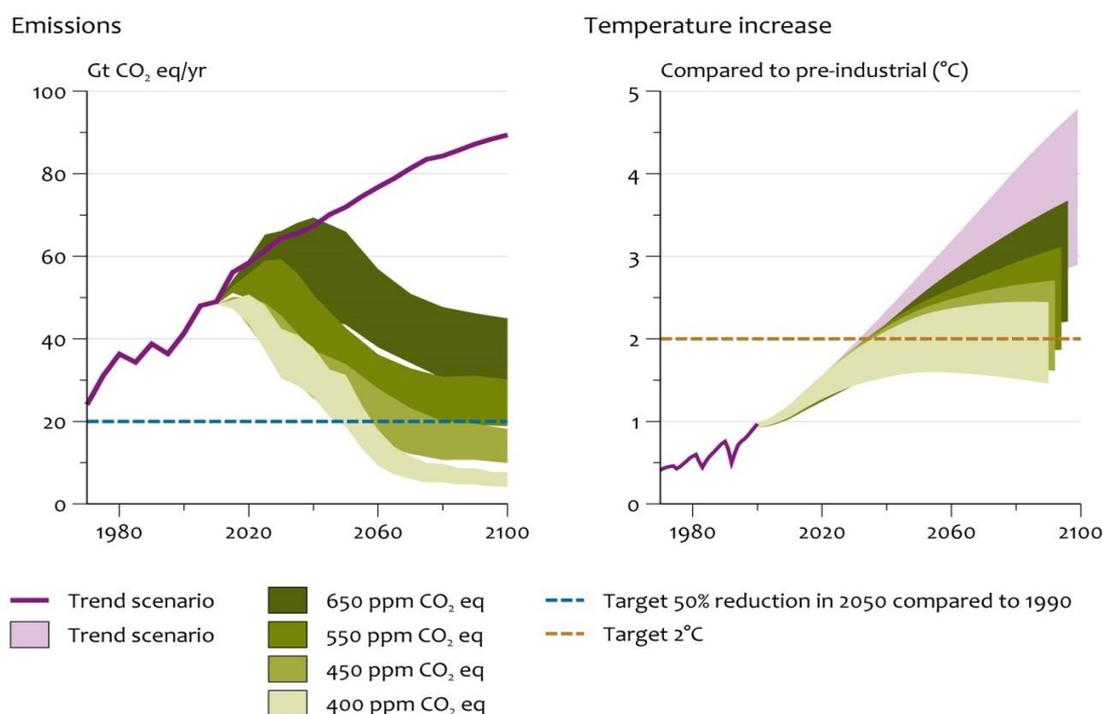
3.2 The financial shock of the 'carbon bubble' and climate change

One of the most studied risk to the financial system stemming from ecological imbalances is the so called 'carbon bubble'. This refers to the overvaluation of fossil fuel reserves and related assets should the world meet its stated objective of limiting climate change to 2°C compared to the pre-industrial age. Meeting this target puts a limit on future carbon dioxide (CO₂) emissions and hence on the amount of fossil fuels that can be burned, requiring a sharp bending of the current trend (see Figure 2).

The current global reserves of oil, gas and coal are several times larger than this limit, even if emissions are progressively reduced via carbon capture and storage. This means that the majority of fossil fuel reserves are stranded assets: they cannot be used if stated governmental objectives are respected. Stranded assets can also result from technological developments that quickly reduce the demand for fossil fuels. Private oil, gas and coal mining companies own about a quarter of fossil fuel reserves. If a large part of these reserves cannot be extracted or extraction becomes commercially unviable, the valuation of these companies and their ability to repay their debt is reduced.

Equity, bond and credit exposures of EU financial institutions to firms holding fossil fuel reserves and to fossil fuel commodities are substantial. Total estimated exposures are €463 billion for banks, €342 billion for insurance companies and €256 billion for EU pension funds (Weyzig *et al*, 2014). Such large numbers raise serious concerns about the potential consequences of these investments if a large part of the oil, gas and coal reserves ends up stranded. Table 2 indicates that the total exposure of €1,061 billion is for 38 per cent equity financed and for 62 per cent debt financed.

Figure 2. Current emission trend and reduction needed to reach 2°C target



Source: Vuuren and Faber (2009).

Table 2. Exposures of European financial institutions to fossil fuel firms (in € bn)

	Equity	Debt	Total	As % total assets
Banks	98	365 ^{a)}	463	1.4
Pension funds	196 ^{b)}	60	256	5.0
Insurance	109	233	342	4.0
Total				
- in € billion	403	658	1.061	
- in % of total	38%	62%	100%	

Notes: a) sum of bonds (62) and loans (303); b) sum of equities (118) and commodities (78).

Source: Weyzig *et al* (2014)

In a scenario study, Weyzig *et al* (2014) show that the impact on the carbon bubble on the European financial system will be severe. The “Low-Carbon Breakthrough” scenario consists of a quick and definite transition to a low-carbon economy. It assumes losses on exposures to fossil fuel firms ranging from 60 per cent on equity investments to 20 per cent on credit facilities. This scenario causes average losses on the order of 0.4 per cent of total assets for large banks, 2 per cent for insurance companies and 3 per cent for pension funds. The losses for all EU banks, insurance companies and pension funds combined would be €350-400 billion.

A second “Uncertain Transition” scenario assumes that emissions will eventually remain within the carbon budget, but with a transition path that is initially slow and highly uncertain. This increases the losses for financial institutions, because fossil fuel firms will continue to make large investments to develop new reserves, increasing the amount of stranded assets. Annual capital expenditures of large oil and gas firms are approximately €500 billion, which is high compared to, for example, the total market capitalisation of these firms which stands at roughly €3 trillion. In addition, significant

uncertainty about future developments could itself become a source of financial instability due to doubt regarding the valuation of high-carbon businesses and fears about hidden losses at financial institutions.

Whereas these are large numbers, on their own they will probably not cause a systemic crisis in a healthy economy and financial sector. However, the effect of the bursting of the carbon bubble will not be limited to the coal, oil and gas sectors alone. A sudden transition will be a shock to all sectors using fossil fuels as an input either in the production or in the use of their products and services. There will be strong adjustments between sectors (electricity powered high speed trains versus fossil fuel jet planes) and within sectors (car manufacturers that specialise in electric cars versus heavy car manufacturers). The financial impact will therefore be much greater than the numbers here indicate. So far, however, no research has been undertaken in this field.

Weyzig *et al* (2014) also consider a “Carbon Renaissance” scenario, characterised by quickly increasing demand for fossil fuels and ineffective climate policies. Existing studies indicate that this scenario causes the largest losses for financial institutions as it seriously harms the global economy and generates large claims for insurance companies. A relatively predictable effect of global warming is the rise in sea levels, which will increase flooding in coastal areas and river deltas, potentially affecting various large cities in the US and China. This may cause large losses for insurers covering damages in flooded areas, but also for financial institutions with exposures to affected property, infrastructure and businesses. Hurricane Katrina that came ashore in south Florida in August 2005 had an estimated total economic impact in Louisiana and Mississippi of over \$150 billion (Burton and Hicks, 2005).

More generally, floods in densely populated areas will negatively affect economic output. Global warming will also increase droughts and water shortages in some regions and floods in others, reducing agricultural productivity, while increasing crop yields in other regions (CIER, 2007; IPCC, 2007). Coping with climate change will involve large adaptation costs for businesses as well as governments and households. The Stern Review (Stern, 2006), a hallmark report on the effects of climate change, estimated that the overall costs of unmitigated climate change could reach five per cent of GDP per year.

Finally, we need to answer the question whether macroprudential policy should target these ecological imbalances directly. Using our criteria developed in section 2, we find that the carbon intensive industry is capital intensive and the assets (e.g. power stations or car plants) are long-lived. The bursting of the carbon bubble, or a substantial increase in the carbon price due to a carbon tax, can thus lead to a major downward adjustment of the value of these assets. On the third criterion, we have shown that the carbon bubble affects a large part of the economy. Finally, we find that exposures to fossil fuel firms are largely debt financed (at 62 per cent in Table 2). Electricity utilities are also to a large extent debt financed, typically between 50 to 80 per cent (Damodaran, 2014). So a large swing in asset prices can lead to substantial losses on debt.

These characteristics suggest that the carbon intensive industry is potentially a major source of second order risk, which could lead to a financial crisis. Further research is needed to assess the financial crisis implications of ecological imbalances more precisely.

4. The role of financial supervisors

4.1 Financial markets may be myopic for new and long-term risks

From a long-term and global perspective, sustainable development is the best business case (Stern, 2006; IPCC, 2014; New Climate Economy, 2014; Dietz and Stern, 2015). Financial professionals and institutions would include ecologically driven financial risks when they are material. But in reality there

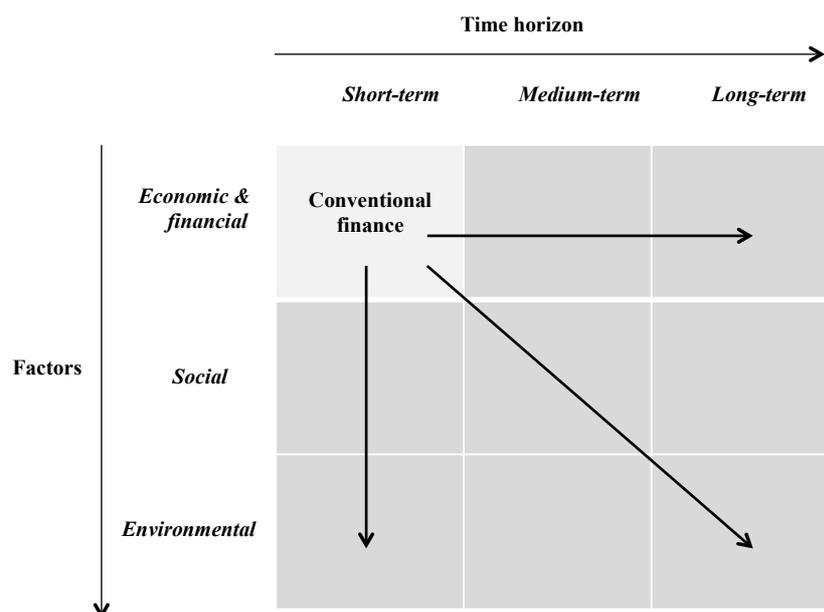
are several market failures causing risks to be underestimated grossly and for a long time. There is for instance evidence that financial markets induce myopic decision making within the economy. In a recent survey, Barton and Wisemann (2014) find that of 1,000 board members:

- 44 per cent said they use a time horizon of less than three years in setting strategy while 73 per cent said they should use a time horizon of more than three years;
- 86 per cent declared that using a longer time horizon to make business decisions would positively affect corporate performance in a number of ways, including strengthening financial returns and increasing innovation;
- 63 per cent of respondents said the pressure to generate strong short-term results had increased over the previous five years.

Barton and Wiseman (2014) conclude that the main source of the problem is the continuing pressure from financial markets to maximise short-term results. An earlier study by Graham *et al* (2005) amongst 400 US CFOs finds similar results, with short-term financial results being pursued at the expense of long-term value creation. The majority of managers would avoid initiating a positive NPV project if it means falling short of the current quarter’s consensus earnings. More than three-fourths of the surveyed executives would give up economic value in exchange for smooth earnings. Haldane and Davies (2011) provide further evidence of an undue short-term focus in business. They find excessively high discount rates for companies in the UK FTSE and US S&P index over the period 1980-2009.

The focus of conventional finance is on short-term economic and financial risks, as illustrated by Figure 3. Financial institutions may thus miss ecological driven financial risks as these risks are relatively new, non-linear and materialise in the medium to long term. But as explained in Section 3, the sudden pricing of these risks may lead to disorderly markets in the medium term. That would fall within the time-horizon of macroprudential authorities, which typically adopt a two to three year horizon.

Figure 3. Time horizon and factors in sustainable finance



Source: Sikken (2014).

One reason for missing ecological driven financial risks is the widespread use of models that hardly take the ecological dimension into account. Whereas an increasing number of (financial) companies formulate explicit strategies in the field of corporate social responsibility (CSR) and environmental, social and governance (ESG) issues, these policies are still often to a large extent image-driven. Leading them to focus on excluding activities that may lead to social arousal that could damage the brand. The mass media logic is driving the risk assessment rather than the financial materiality of the risk. When ecological risks are taken into account, this is often done using models calibrated on a past where no comparable transition has taken place as the one ahead. This may lead to an underestimation of the risk. Next, more complex and connected financial institutions have an incentive to take excessive risks as they have an implicit government guarantee arising from their too-big-to-fail (TBTF) status (Ueda and Weder di Mauro, 2013).

For individual financial institutions that are aware of ecological imbalances and the financial risks they pose, it may still not be possible to adequately act upon this. Firstly, regulations, and supervisors implementing these, often prescribe the use of the incomplete models described above and the use of credit ratings based on these models. As these models often do not, or inadequately, take into account risks resulting from ecological imbalances, they miss the benefits of strategies that reduce these risks. As this strategy may involve less liquid assets and/or more concentrated portfolios, it may be judged as riskier and thus discouraged or even forbidden. This can be seen with some of the regulatory reforms that have taken place after the crisis like Basel III for banks and Solvency II for insurers. These regulations put a premium on liquid assets and thus may hamper the often long-term investments that are needed for the economy to make the sustainability transition (CFA Institute, 2013). Also certain accounting rules that are meant to increase transparency and consistency in financial statements - such as fair value or mark-to-market accounting - can be hard to apply to illiquid investments with long holding periods (New Climate Economy, 2014).

Apart from these regulatory hurdles there is also a limit to what individual market participants can do when the market is moving in another direction. When the financial 'herd' moves in a certain direction, this will drive prices in that direction, even when a fundamental analysis points to another direction. This can happen for a long time and the price distortions can be substantial, as witnessed in recent history with the dotcom-shares pre-2000, and the subprime and CDO market pre-2008.

Whereas for individual institutions, it can be highly rewarding to move in the other direction (a contrarian strategy) this is costly and has its limits ('limits to arbitrage'). The so-called 'costly trade theory' (Shleifer and Vishny, 1990) predicts that due to the capital needs and risk of arbitrage, prices reflect much less long-term information. Therefore the mispricing of assets whose true value will only show in the longer run will be greater. Although such highly mispriced assets offer potential large returns through arbitrage, in practice investment managers may shy away from them out of fear that the potential gain will not materialise before they may lose the investment mandate (Shleifer and Vishny, 1997). Given the short-term on which investment managers are judged, it can be rational to go with the 'herd' instead of following one's own rational analysis. Investment managers will out of career concerns rather go with the 'herd', even when their fundamental analyses contradicts this (Scharfstein and Stein, 1990). Eventually this bubble will burst. However, it cannot be predicted when that happens, and this may take very long. In the case of the financing of ecologically unsustainable business practices, this imbalance has been building for a long time now.

What makes it even harder for individual financial institutions to conduct their business in an ecologically sustainable way is the path-dependency that is created as a result of the financing decisions that are being taken. Take as an example the case of the costs of energy production through fossil fuels (say coal) and clean tech (say sun-photovoltaic (pv)). If the market continues to finance coal rather than sun-pv, the sunk costs of coal plants will increase, making burning coal the

low marginal cost option for decades to come, while not allowing sun-pv to attain cost reductions that come with the large scale production and roll out.

Thus today's investments determine the costs and benefits for other market participants. No single company or financial institution can decide to operate sustainably when the herd is not moving, at least to a certain degree, in the same direction. So whereas stabilising the climate may be the option with the best cost-benefit for the economy and (thus) for the stability of the financial sector, it may financially not be viable to operate in a sustainable manner for any individual financial institution.

4.2 Need for supervisor to act on the ecological driven financial risk

So what could and should financial supervisors do in this specific case of ecological imbalances feeding into ever larger financial risks? A first best option would be that governments tackle ecological imbalances directly. Either by placing a price on the negative externalities that environmental degradation entail (e.g. a carbon tax), subsidising alternatives (e.g. renewable energy), creating a market through its procurement policies or using its power as regulator in standard setting. Information limitations could also be reduced with macro stress tests. A case in point would be a climate stress test. Whether employed primarily as tool to uncover vulnerabilities in tranquil times or to support crisis management and resolution, macro stress tests can also help to discipline and structure thinking about financial stability among the many parties involved (the "stakeholders"). Macro stress tests can help to inform and reconcile different perspectives (Borio, Drehmann and Tsatsaronis, 2014).

These instruments are currently not being used in an effective way. Financial supervisors have to take this as given. It is then the responsibility of supervisors, both macro- and microprudential, to deal with this situation as it is. The rational behaviour of individual financial institutions may deviate from what is socially optimal. But macroprudential supervision should take these externalities into account. In this case a two-step process can be followed:

1. Identifying the ecological imbalances that give rise to the most material financial risks;
2. Mapping the financial risks that originate from these ecological imbalances.

On the basis of this two-step process, the risks from a macroprudential point of view can be identified. These could be addressed by specific macroprudential instruments, or translated into microprudential requirements. Credible macroprudential policy in the field of ecological imbalances may thus help to reduce these ecological imbalances as expectations are fed into the pricing.

5. Instruments and institutions for addressing ecological risks

5.1 Green macroprudential policy

What elements of the 'standard' macroprudential approach can be used, and how, in addressing ecological risks to improve the stability of the financial system? The grey-shaded cells in Table 3 provide a long-list of possibilities. Firstly, in the cyclical pillar, the growth of credit into unsustainable business practices can be labelled as 'excessive' given the ecological imbalances that it feeds into. All three instruments in the macroprudential toolbox (countercyclical capital buffers, capital instruments (risk weights) and caps) can be used to counter this excessive credit growth. Secondly, in the structural pillar, the exposure concentration to unsustainable companies, sectors or investments can be identified. The macroprudential tool is to put limits to these exposures, the so-called large exposure restrictions. Finally, large financial institutions may have insufficient incentives to address ecological risks. The macroprudential tool is to increase the SIFI capital surcharge.

Table 3. Relevance of macroprudential framework for ecological risks

Panel A: Cyclical pillar

Intermediate target	Excessive credit growth and leverage		Excessive maturity mismatch and market illiquidity		
Indicators	Credit-to-GDP gap		Housing credit, housing prices	Structural funding ratio, short-term liquidity stress indicators	
Key instruments	Counter cyclical capital buffer	Capital instruments: -leverage ratio - by sector	LTV / LTI caps	Stable funding restrictions	Liquidity charges

Panel B: Structural pillar

Intermediate target	Exposure concentration		Misaligned incentives	
Indicators	Indicators for large exposures, interconnectedness, price contagion		Size, complexity, substitutability and interconnectedness of SIFIs	
Key instruments	Large exposures restrictions (by counter-party, sector, geographic)		SIFI capital surcharges	Systemic risk buffer

In the remainder of this section we give a first outline of a tentative framework for one specific ecological imbalance, carbon emissions.

5.2 A macroprudential framework for the financing of carbon emissions

Intermediate target and indicators

The risk with the financing of economic activities that (in)directly cause carbon emissions is that their value will depreciate. These could be assets whose value is directly dependent on the burning of fossil fuels (like fossil fuel reserves) or assets that have a more indirect link, but are still highly dependent on the burning of fossil fuels like car manufacturers. The crucial element here is to distinguish these companies and sectors.

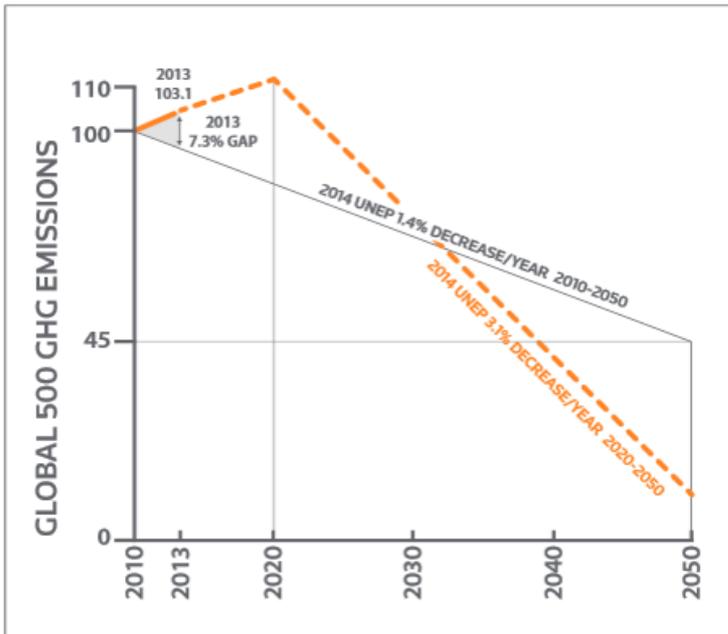
The intermediate target could be set as having a portfolio that is in line with a scenario where the goal is achieved of limiting climate change to 2°C. According to the UNEP Emissions Gap Report (UNEP, 2014), this intermediate target means that emissions need to shrink by 1.2-1.7 per cent annually. Starting from this macro carbon reduction target, all carbon emissions above this target are at risk of an intensification of climate policies to reach the agreed upon goal or a technological breakthrough in renewable energies. The next step is to translate the carbon emissions to the portfolios of individual financial institutions, whereby the average carbon intensity of current portfolios can be taken as a starting point. Thomson Reuters (2014) has calculated the average carbon intensity of the 500 largest publicly listed companies, which count for 13.8 per cent of total global carbon emissions. Rather than decreasing (the grey line in Figure 4), Thomson Reuters (2014) finds that carbon emissions of the 'global 500' have actually increased by 1 per cent a year over the period 2010-2013 (illustrated by the orange line in Figure 4).

Some financial institutions have already formulated goals along this line. A case in point is the Dutch pension fund for healthcare PFZW (with €200 billion assets under management), which has stated as part of its new investment strategy that it wants to reduce the carbon intensity of its equity portfolio by 50 per cent in 2020 (PFZW, 2014).

Cyclical instruments

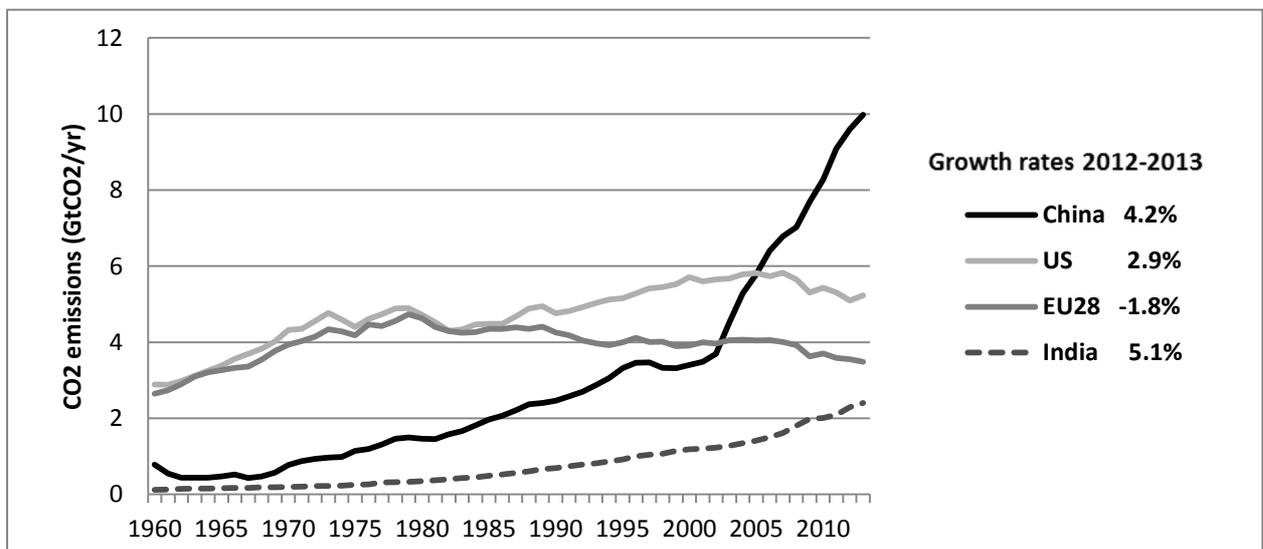
In the cyclical pillar, there are three instruments that can be used to mitigate excessive credit growth that fuels excessive levels of carbon emission. The countercyclical capital buffer is meant to dampen the financial cycle (measured by credit and house prices), as a counterweight against feedback loops that make the financial sector overshoot in both good and bad times (Borio, 2014a). The countercyclical capital buffer can also be used to dampen the carbon cycle that started with the Industrial Revolution (see Figure 2 above). It is not yet a cycle as the global carbon emission has only been going up. Figure 5, however, indicates that the growth rate in the EU and US is slowing down, with the EU recently even shrinking its annual carbon emission.

Figure 4. Greenhouse gas emissions of 500 largest global companies



Source: Thomson Reuters (2014)

Figure 5. Absolute carbon emissions and growth rates China, EU, India and US, 1960-2013



Source: Global Carbon Project (2014)

Like in the financial cycle, during this upward phase the risk of overshooting and hence an upcoming correction builds. A countercyclical carbon capital buffer has two advantages: a buffer is built to draw upon when the cycle turns, and it dampens the carbon cycle itself, thus reducing the imbalance itself. However, for this instrument to be used the impact of the excessive credit growth for carbon investments needs to have a system wide impact, like with housing that drives further credit growth through wealth effects. It remains to be seen whether this effect is big enough to warrant the use of this instrument.

Moving to capital instruments, specific carbon-intensive assets can be given a higher risk weight to account for the increased risk of these assets for policies to tackle climate change. Thus making them less attractive for financial institutions. Likewise, assets that are not dependent on carbon emissions can be given lower risk weights. As a first step higher (and lower) risk weights could be given to sectors, depending on their carbon intensity. With the quickly growing availability of data on carbon performance at the company level, these differences in risk weighing could be made more granular to the level of the firm. This seems a well-suited instrument as it allows for integrating the added 'carbon risk' to the overall risk-return assessment.

Lastly, caps can place an absolute limit on the financing of companies (and sectors) that exceed certain levels. This can be done by either:

1. Setting a cap on the deviation that companies are allowed to have in their carbon intensity with regard to the rest of the sector. Companies exceeding this threshold would effectively be placed on an exclusion list; or,
2. Setting a cap on the level of debt financing of companies exceeding a certain threshold. Here, the cap would be in the form of a maximum part of debt finance (and thus a minimum amount of equity finance) for carbon intensive firms.

The attractiveness of caps in macroprudential policies is that they set very clear uniform standards, as with a loan-to-value ratio in housing. As the instrument is very digital (on/off), the danger is that the threshold is rather arbitrary and does not influence the companies that are either far above or under it. Nevertheless, it can be effective, for example, to put a ban (i.e. a zero cap) on financing of coal-fired power stations, as these stations produce a relatively large amount of carbon.

Structural instruments

With the large exposures restrictions, the exposure to carbon-intensive and dependent assets could be limited. This would mean that a maximum limit is set for certain companies and/or sectors (e.g. max. X per cent of all loans can be made to coal companies). As the net exposure matters for the resilience of an institution, this maximum limit could be netted by subtracting assets that in case of a shock (i.e. the bursting of the carbon bubble) would increase in value (e.g. renewable energy companies). As with the caps discussed above the danger is that the limit set is rather arbitrary. However, this instrument allows for a more granular setting of restrictions (and the netting) leaving the financial institutions more leeway to comply with the regulation.

Systemically Important Financial Institutions (SIFIs) are selected on the basis of a range of indicators, which reflect their size, their interconnectedness, the lack of readily available substitutes for the services they provide, their global (cross-jurisdictional) activity and their complexity (Basel Committee, 2013). Carbon intensity can be added as an extra indicator. Next, the SIFI capital surcharge is calibrated on the expected economic impact of a SIFI failure, as well as TBTF subsidies.

Calibration of the instruments

Table 4 provides an overview of a possible macroprudential framework for carbon emissions. In order to calibrate the macroprudential instruments (i.e. determine how high cyclical buffers, risk weights and caps should be, what net exposures and capital surcharges are appropriate), different 'carbon bubble'

scenarios need to be developed and their effect on different asset classes estimated. These scenarios can be used in carbon stress tests that identify specific vulnerabilities of financial institutions.

Also the interaction between these instruments needs to be assessed. The next question is whether all instruments are needed or that one or more instruments are sufficient. Using the carbon stress test, a correlation matrix for assets can be calculated in the case of the bursting of the carbon bubble. It is expected that both direct carbon-intensive assets (e.g. fossil fuel firms) and indirect carbon-dependent assets (e.g. car manufacturers) will show high correlation in this scenario. The global financial crisis of 2008-2009 showed that correlations between assets can be far higher during a downturn.

Table 4. Instruments for the carbon dimension of macroprudential policy

Panel A: Cyclical pillar

Intermediate target	Excessive credit growth for carbon intensive and dependent economic activities		
Indicators	Carbon intensity and dependency credit		
Key instruments	Counter cyclical capital buffer	Capital instruments, higher risk weights for: - carbon intensive and dependent sectors (transport, mining, energy) - carbon intensive and dependent companies within these sectors	'Carbon cap' - exclusion list - maximum debt finance for carbon intensive/dependent sectors and companies

Panel B: Structural pillar

Intermediate target	Exposure concentration to carbon intensive and dependent assets	Misaligned incentives
Indicators	Net exposure	Carbon intensity and dependency of SIFIs
Key instruments	Large exposures restrictions	SIFI capital surcharge

5.3 Institutional design

Haldane (2014) calls for international coordination in the execution of macroprudential supervision. That seems in particular relevant for ecological imbalances, as these pose a global financial threat. Moreover, the building up of the imbalances varies across countries, as illustrated by Figure 5, which warrants a differentiated, albeit coordinated, approach. While the setting of intermediate targets and indicators and the use of macroprudential instruments are the responsibility of the macroprudential authorities (i.e. national central banks), international institutions, such as the FSB, the BIS, the IMF, the G20 and several UN-supported platforms, can provide for international coordination.

It is also important to judge the vulnerability of the financial sector. This can be done through the Financial Sector Assessment Program (FSAP) of the IMF. The FSAP, established in 1999, is a comprehensive and in-depth analysis of a country's financial sector. FSAP assessments are the joint responsibility of the IMF and World Bank in developing and emerging market countries and of the IMF alone in advanced economies. With ecological risks as an integral part of the financial stability assessment, a common standard can be set and guarded. The carbon stress test can thus become an integral component of the FSAP. Finally, the FSB conducts peer review assessments of the macroprudential policy framework of its members. As with the FSAP, the ecological dimension should be an integral part of this exercise.

6. Conclusion and further research

Since 2008 financial supervision has left its sole focus on microprudential policy, adding a macroprudential perspective. At the same time, ecologically driven financial risks have increased, and will increase further. Several financial market imperfections make that individual financial institutions are not willing or able to effectively reduce these risks. That is why macroprudential authorities have a role to play.

The first best option is for government to price these risks (e.g. carbon taxes, emission rights and caps). The earlier governments adopt climate policies, the better these risks can be contained. Nevertheless, as these policies currently are not sufficiently implemented, systemic financial imbalances resulting from ecological pressures are allowed to build up and concentrate in certain financial institutions and markets, thus threatening financial stability.

Financial shocks may originate from ecological imbalances, triggered by either intensified environmental policies, technological breakthroughs (e.g. cheap renewable energy), an expectation of this in financial markets or due to the economic costs of crossing these ecological boundaries (e.g. climate change disrupting economies). Applying several criteria, we find that ecological imbalances have the potential to create a financial crisis. We therefore propose to incorporate ecologically driven financial risks into the macroprudential framework. In particular, we explore how macroprudential tools can be designed to curb the carbon bubble. We identify capital instruments (adjusting risk weights), caps, large exposure restrictions and stress tests as the most promising instruments.

It is important to develop scenarios for the different sustainability challenges (carbon bubble, climate change, water and material shortage) that provide estimates of losses and gains for different financial instruments (equity and debt) over different economic sectors and the kind of companies within those sectors. This further research can clarify which sustainability themes are the most important from a financial stability perspective. This may also help in deciding which of the here described macroprudential instruments are best suited for this challenge. Lastly, in order to stimulate learning and identify potential weaknesses in the supervision of the globally connected financial system, we propose that both the IMF's FSAP and the FSB's assessment of macroprudential policies take this ecological dimension into account.

References

- Allen, F. and Gale, D. (1998). Optimal Financial Crises, *Journal of Finance*, 53, 1245-1284.
- Bank of England (2015). One Bank Research Agenda. Discussion Paper, London.
- Barton, D. and Wiseman, M. (2014). Focusing capital on the long term. *Harvard Business Review*, 92(1/2), 44-51.
- Basel Committee on Banking Supervision (2013). Global systemically important banks: updated assessment methodology and the higher loss absorbency requirement, Basel.
- Borio, C. (2009). Implementing the macroprudential approach to financial regulation and supervision. *Banque de France Financial Stability Review* No. 13, pp. 31-41.
- Borio, C. (2014a). The financial cycle and macroeconomics: What have we learnt? *Journal of Banking & Finance*, 45, 182–198.
- Borio, C. (2014b). Macroprudential frameworks: (Too) great expectations? in: D. Schoenmaker (ed.), *Macroprudentialism*. VoxEU eBook, CEPR, London, pp. 29-45.
- Borio, C., Drehmann, M. and Tsatsaronis, K. (2014). Stress-testing macro stress testing: Does it live up to expectations? *Journal of Financial Stability*, 12, 3-15.
- Burton, M. L. and Hicks, M. J. (2005). Hurricane Katrina: Preliminary Estimates of Commercial and Public Sector Damages. Center for Business and Economic Research, Marshall University.
- Brunnermeier, M., Crockett, A., Goodhart, C., Persaud, A. and Shin, H. (2009). The Fundamental Principles of Financial Regulation. Geneva Report on the World Economy 11, ICBM, Geneva, and CEPR, London.
- Center for Integrative Environmental Research (2007). The US Economic Impacts of Climate Change and the Costs of Inaction, University of Maryland, October.
- Claessens, S., Kose M.A. and Terrones M.E. (2011). Financial Cycles: What? How? When? In: R. Clarida and F. Giavazzi (eds), *NBER International Seminar in Macroeconomics 2010*, pp. 303-343.
- CFA Institute (2013). Long term financing; Investor Perspectives in Europe.
- Damodaran, A. (2014). *Applied Corporate Finance*. 4th Edition, New York: John Wiley and Sons.
- De Haan, J., Oosterloo, S. and Schoenmaker, D. (2015). *Financial Markets and Institutions: A European Perspective*. Third Edition, Cambridge University Press, Cambridge.
- Dietz, S. and Stern, N. (2015). Endogenous growth, convexity of damages and climate risk: how Nordhaus' framework supports deep cuts in carbon emissions, *Economic Journal*, forthcoming.
- Ellen MacArthur Foundation (2012). Towards the circular economy: Economic and business rationale for an accelerated transition, Cowes, UK.

- Ellen MacArthur Foundation (2013). Towards the circular economy: Opportunities for the consumer goods sector, Cowes, UK.
- Ellen MacArthur Foundation (2014). Towards the circular economy: Accelerating the scale-up across global supply chains, Cowes, UK.
- European Systemic Risk Board (2014). Flagship Report on Macro-prudential Policy in the Banking Sector, Frankfurt.
- Galati, G. and Moessner R. (2013). Macroprudential Policy: A Literature Review. *Journal of Economic Surveys*, 27, 846-878.
- Gersbach, H. and Rochet, J.-Ch. (2014). Capital regulation and credit fluctuations, in: D. Schoenmaker (ed.), *Macroprudentialism*. VoxEU eBook, CEPR, London, pp. 89-95.
- Global Carbon Project (2014). Global carbon budget 2014, September.
- Goodhart, C.A.E. (2014). The use of macroprudential instruments, in: D. Schoenmaker (ed.), *Macroprudentialism*. VoxEU eBook, CEPR, London, pp 11-17.
- Graham, J. R., Harvey, C. R. and Rajagopal, S. (2005). The Economic Implications of Corporate Financial Reporting. *Journal of Accounting and Economics*, 40, 3-73.
- Gros, D. and Alcidi, C. (2013). Country adjustment to a 'sudden stop': Does the euro make a difference?, European Economy Economic Papers No. 492, Brussels.
- Hanson, S. G., Kashyap, A. K. and Stein, J. C. (2011). A Macroprudential Approach to Financial Regulation. *Journal of Economic Perspectives*, 25(1), 3–28.
- Haldane, A.G. (2014). Managing global finance as a system. Bank of England, Speech at the Maxwell Fry Annual Global Finance Lecture, Birmingham University, 29 October.
- Haldane, A.G. and Davies, R. (2011). The Short Long. Bank of England, Speech at 29th SUERF Colloquium: New Paradigms in Money and Finance?, Brussels.
- Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Synthesis Report. New York.
- Intergovernmental Panel on Climate Change (2014). Fifth Assessment Synthesis Report. New York.
- Jevons, S. (1884). *Investigations in Currency and Finance*. Macmillan, London.
- New Climate Economy (2014). *Better Growth Better Climate*. London.
- PFZW (2014). *Beleggingsbeleid 2015-2020 (Investment Policy 2015-2020)*, December.
- Reinhart, C. and Rogoff, K. (2009). *This Time is Different: Eight Centuries of Financial Folly*. Princeton University Press, Princeton.
- Rockström, J. *et al* (2009). A safe operating space for humanity. *Nature*, 461, 472-475.

- Scharfstein, D.S. and Stein, J. C. (1990). Herd Behavior and Investment. *American Economic Review*, 80(3), 465-479.
- Schoenmaker, D. and Wierds, P. (2011). Macroprudential Policy: The Need for a Coherent Policy Framework, DSF policy paper, No. 13.
- Shleifer, A. and Vishny, R. W. (1990). Equilibrium short horizons of investors and firms. *American Economic Review Papers and Proceedings*, 80(2), 148-153.
- Shleifer A. and Vishny, R. W. (1997). The limits of arbitrage. *Journal of Finance*, 52, 35-55.
- Shleifer, A. and Vishny R.W. (2011). Fire Sales in Finance and Macroeconomics. *Journal of Economic Perspectives*, 25(1), 29-48.
- Sikken, B.J. (2014), Lecture Series Finance & Sustainability, Duisenberg School of finance, Amsterdam.
- Stern, N. (2006). The Stern Review: The economics of climate change.
- Thomson Reuters (2014). Global 500 Greenhouse Gases Performance 2010-2013: 2014 Report on Trends, New York, December.
- Ueda, K. and Weder di Mauro, B. (2013), Quantifying structural subsidy values for systemically important financial institutions, *Journal of Banking & Finance*, 37, 3830-3842.
- United Nations Environment Programme (2014). Emissions Gap Report, New York, November.
- United Nations Environment Programme Finance Initiative (UNEPFI) (2011). Universal Ownership: Why environmental externalities matter to institutional investors, New York.
- Vuuren, D.P van and Faber, A. (2009). Growing within Limits; A report to the Global Assembly 2009 of the Club of Rome. Netherlands Environmental Assessment Agency (PBL), Bilthoven, October.
- Weyzig, F., Kuepper, B., Gelder, J.W. van and Tilburg, R. van (2014). The price of doing too little too late; the impact of the carbon bubble on the European financial system. Green New Deal Series, Volume 11.